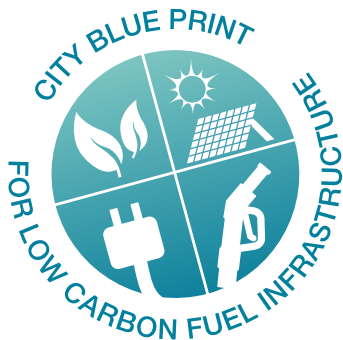


A CITY BLUE PRINT FOR LOW CARBON FUEL REFUELLING INFRASTRUCTURE

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A CITY BLUE PRINT FOR LOW CARBON FUEL REFUELLING INFRASTRUCTURE

REPORT FOR



www.makingbirminghamgreener.com/blueprint

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FOREWORD

From Councillor Lisa Trickett

Transport is a major contributor to carbon emissions and poor air quality across the world's cities. With transport emissions accounting for 25% of Birmingham's controllable CO₂ emissions, we already recognise that diesel vehicles are also a main source of Nitrogen Oxides (NO_x) and Particulate Matter emissions, with heavier vehicles such as trucks, buses, taxis and vans as the major contributors, besides diesel cars. A key challenge for Birmingham, therefore, is to specifically target the reduction of CO₂, NO_x and Particulate Matter emissions for the reduction of carbon and the improvement of air quality by enabling the take-up of ultra low emission vehicles, from small cars and vans to the HGVs, buses and refuse trucks.

In 2014 Birmingham's Green Commission outlined the ambition to build a leading green city and reduce our total carbon emissions by 60% by 2027. One of the decisive factors in achieving this ambition will be our ability to build an efficient, effective and low carbon transport system.

The recently launched 'Birmingham Connected' 20 year Transport Strategy for the city, provides the programme of action that sets out the strategic actions of implementing Green Travel Districts, integrated public transport, rapid transit network of cross city electric tram and sprint buses, road space allocation prioritising cyclists and pedestrians, all planning ahead to adapt to the needs of residents and businesses within Birmingham, as a green, smart and sustainable City.

Underpinning this strategic implementation programme and enabling the significant take-up of ultra-low emission vehicles is the need for understanding what low/zero carbon re-fuelling infrastructure is required for new vehicle technologies using electricity, hydrogen, gas, biofuels and liquid air.

The 'Birmingham Blueprint', as a mapping study, funded through the EU project Climate KIC Transition Cities Innovation Programme, sets out an innovative approach in tackling the challenge of refuelling infrastructure deployment across Birmingham by identifying the key priorities and opportunities for low carbon fuel infrastructure.

I am pleased that the results show Birmingham has access to alternative fuels to the extent that low carbon vehicles, including local renewable electricity production as well as local bio-methane production could save up to 260,000 tonnes of CO₂ a year by 2035.

The completion of this study has required strong engagement and contribution from local fleets and stakeholders from public and private sector organisations based in Birmingham. Fleet managers should be commended for the great enthusiasm they have shown developing a refuelling infrastructure which aligns with their own aspirations for reducing their carbon footprint as part of their social responsibility priorities and to increase business profitability.

Birmingham's Green Commission, the City Council and the Local Enterprise Partnership are looking to building on the support of our public and private sector fleet managers, their organisations, local stakeholders and the developing low/zero carbon re-fuelling industry, to implement this Blueprint vision to ensure the city, its residents and its businesses all benefit from the multiple opportunities of the transition to a greener Birmingham.

Councillor Lisa Trickett



EXECUTIVE SUMMARY

Birmingham's Green Commission has committed the city to achieving ambitious carbon reduction targets in the coming decades, as part of a programme of work that aims to make Birmingham a leading green city



EXECUTIVE SUMMARY

BACKGROUND AND APPROACH

Birmingham's Green Commission has committed the city to achieving ambitious carbon reduction targets in the coming decades, as part of a programme of work that aims to make Birmingham a leading green city. The Carbon Roadmap, launched by the Commission in November 2013, aims to reduce CO₂ emissions by 60% compared to 1990 levels by 2027. Road transport within the city is a priority area for reducing greenhouse gas emissions as well as improving local air quality.

Alternative fuel vehicles such as electric, gas and hydrogen vehicles have lower emissions than conventional fossil fuel vehicles, in terms of CO₂ and other pollutants. Their uptake will be essential to achieve the Commission's emissions targets. However, their adoption



Birmingham in context with the wider Midlands region

depends, amongst other enabling factors, on the provision of refuelling infrastructure. In this context, the Council commissioned Element Energy to develop a Blueprint for low carbon vehicle refuelling infrastructure deployment within the Birmingham region (including the 10 districts) over the next 20 years.

The role of the Blueprint is to provide recommendations on infrastructure roll-out in Birmingham to inform activities and investments within the sector, and advice for the Council on actions to be taken to support the delivery of the infrastructure plan. The focus is on the needs of fleet vehicles: taxis, fleet cars, vans, buses and trucks. Fleets are more accessible in terms of local government influence (compared to private vehicle users),

and are often subject to internal carbon reduction policies, mandated either by Government or by corporate environmental strategies. However, the Blueprint explores the ways in which infrastructure provided for fleets could also support private vehicles, supplementing other options such as home charging for electric vehicles.

The Blueprint will also be a relevant input to the national policy framework for the deployment for alternative fuels infrastructure that the UK has to submit by November 2016 to comply with Directive 2014/94/EU.

Element Energy has developed the infrastructure Blueprint through extensive consultation with a range of key stakeholders and user groups, including the Council itself. Projections of demand for vehicles and infrastructure are underpinned by input from fleet operators, and insights from fuel and infrastructure suppliers have informed assessments of supply constraints and opportunities in Birmingham. Overall, stakeholder engagement has been fundamental to the development of the analysis and recommendations in this report.

The Blueprint brings together key themes relating to the development of infrastructure:

- **The demand for low carbon fleet vehicles in the Birmingham area, based on operational needs, costs and market availability;**
- **The supply of local low carbon fuels.**

These aspects have informed the assessment of the **refuelling and recharging infrastructure** required to meet the needs of the expected vehicles.

UPTAKE OF LOW CARBON VEHICLES AND POTENTIAL CO₂ SAVINGS

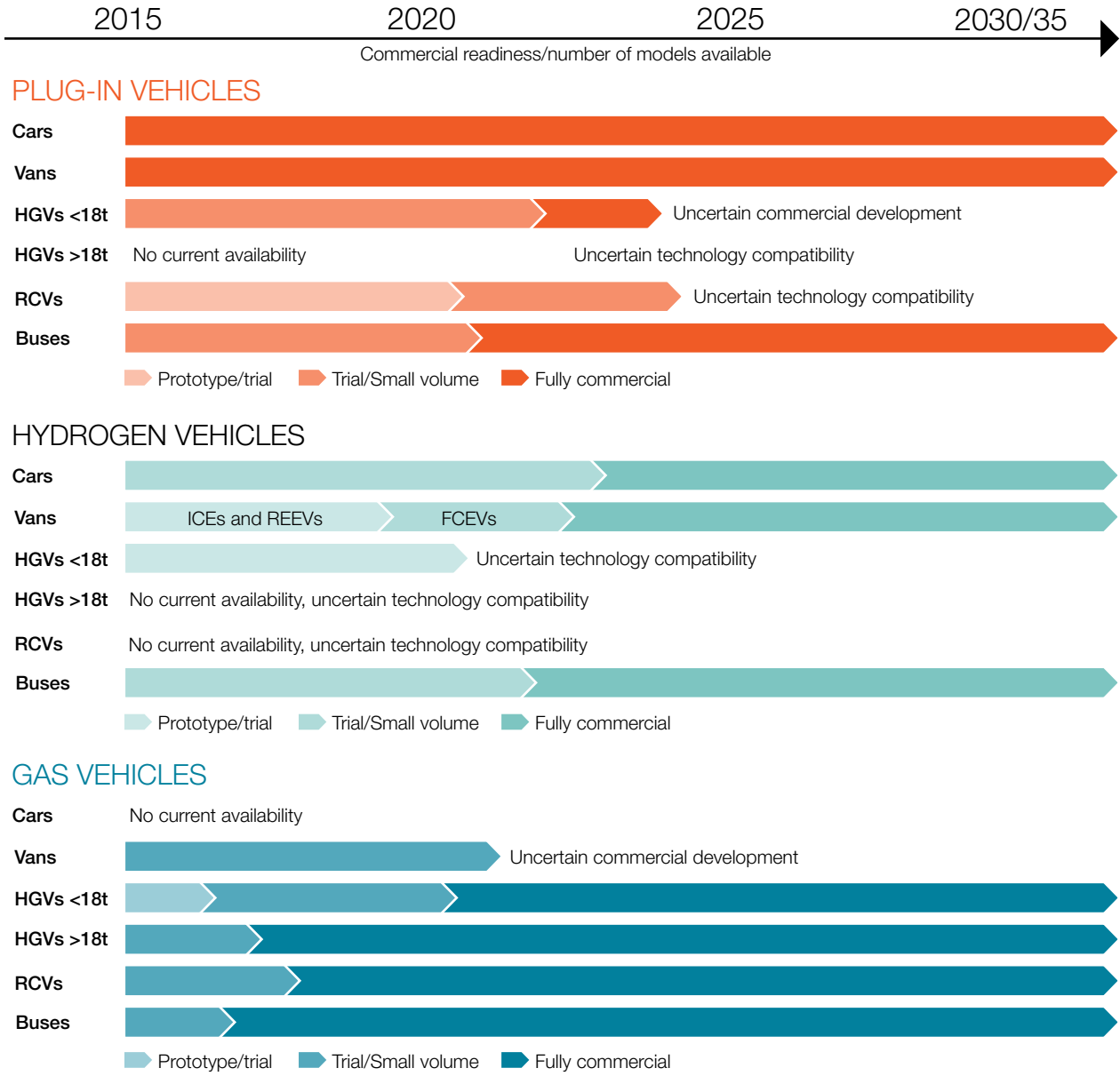
This report considers the potential uptake and impacts of four vehicle technologies: plug-in electric vehicles, hydrogen vehicles, gas vehicles (methane or biomethane) and liquid air cooling technology (primarily for refrigerated vehicles)¹. Liquefied Petroleum Gas is also considered for the case of taxis.

Each of these technologies has different compatibilities for the fleet segments under consideration. Determining factors include the typical duty cycles and refuelling patterns of these fleets, as well as the likely costs and market availability of each low carbon technology. For example, only fleets with sufficient time windows between operations for vehicle charging would have the potential to adopt plug-in vehicles, while the overall projected uptake of hydrogen vehicles is lower than that of plug-in vehicles over the time period considered, due to the lower level of maturity of the hydrogen vehicle market.

Figure 1 (next page) summarises the expected commercial readiness of the main low carbon vehicles under consideration, based on current policy measures and vehicle manufacturers' announcements.

¹ Other alternatives are not included because they do not require dedicated infrastructure (hybrid vehicles, low blend biofuels) or their uptake among fleet is not expected to require an infrastructure beyond a depot-based tank (high blend biodiesel, used cooking oil)

Availability and market projections of low carbon vehicles in the UK



FCEV: Fuel Cell Electric Vehicle **HGV:** Heavy Goods Vehicles **ICE:** Internal Combustion Engine
RCV: Refuse Collection Vehicle **RE-EV:** Range Extended EV

NB: Timings are Indicative. Extent of commercialisation and availability will depend on demand, fuel prices and policy measures

Figure 1
 Availability and market projections of low carbon vehicles in the UK

Feedback from fleet operators covering a wide range of business sectors and fleet characteristics was collected to inform the analysis in this report. This included information on typical driving cycles as well as experiences and lessons learnt from use of low carbon vehicles. This input was combined with vehicle market research and emissions data to inform projections of the use and impacts of low carbon fleet vehicles in Birmingham up to 2035. Table 1 presents an upper bound scenario for uptake and provides estimates of the potential impacts. In total the adoption of low carbon vehicles could save over 260,000 tonnes of CO₂ a year by 2035, representing a c. 17% cut in emissions compared to a baseline case without plug-in, gas and hydrogen vehicles.

Table 1. Uptake and impacts of low carbon vehicle fleets in Birmingham in 2030-2035

	Potential fleet uptake (average across fleets)	WTW GHG savings (tonnes CO ₂ e/year)	Percentage WTW savings for Birmingham road transport emissions ¹
Plug-in vehicles	20% (Taxis, vans, private cars, buses and small trucks)	190,000 tonnes (based on 100% renewable electricity)	12%
Hydrogen vehicles	3% (Taxis, vans, private cars and buses)	48,000 (based on carbon neutral electrolysis)	3%
Gas vehicles	7% (Buses, heavy goods vehicles, Refuse collection vehicles)	26,000 tonnes (based on injected biomethane)	2%
Liquid air refrigerated vehicles	45% (Refrigerated heavy goods vehicles)	Dependent on applications / duty cycles	Dependent on applications / duty cycles

Table 1. Uptake and impacts of low carbon vehicle fleets in Birmingham in 2030-2035

1 - Compared to a baseline case without low carbon vehicles

The potential fleet uptake is given as the average percentage of low carbon vehicles across applicable fleets, as listed above. Overall, plug-in and hydrogen vehicles are likely to be adopted by lighter vehicles including cars and vans, whereas gas vehicles are more suited to heavy vehicle applications. All three technologies have the potential to be adopted (to varying extents) by bus fleets.

While the future uptake of liquid air technology is highly uncertain (the technology currently being in early trials), its application in refrigerated trucks and trailers has been identified by the Council as complementary to the vision for future heavy vehicle transport in the city. In this vision, articulated in the Birmingham Connected White Paper, freight is diverted to consolidation centres located a few miles outside the city. By replacing diesel in refrigeration units, liquid air would enable clean ‘last mile’ deliveries to the city.

LOW CARBON FUEL PRODUCTION OPPORTUNITIES IN THE BIRMINGHAM AREA

Potential emissions savings depend heavily on the fuel production pathways for all technologies; Table 1 indicates the maximum savings from the projected vehicle uptake on a Well-to-Wheel basis, based on renewable production routes for electricity, hydrogen and gas².

In terms of renewable fuel supply, the current renewable electricity production in the West Midlands is more than 5 times the level required to meet demand from plug-in vehicles and hydrogen vehicles (assuming that all hydrogen is produced by electrolysis), and there are several further opportunities for renewable generation in the area (including the use of Birmingham City Council’s own waste).

In the UK most biomethane is compressed and injected into the gas grid, for use as renewable heat or used on site to produce heat and power (both activities being supported by national incentives). Injected compressed biomethane can however be purchased for use in transport, via the Green Gas Certificate system, that tracks and links injected gas to end user. Locally, Severn Trent expects to inject 5,000 tonnes of biomethane at its Minworth facility in 2015. With an estimated demand of 6,000 tonnes/year in 2030-2035 from gas vehicles in Birmingham, supply constraints for compressed biomethane are unlikely.

Fuel demand from low carbon vehicle fleets in 2030-2035 in Birmingham & current renewable fuel production

	Potential annual demand from vehicles in 2030-35	Current local production of renewable fuel
Electricity	138 GWh (including 66 GWh to make 1,600 tonnes of hydrogen) <i>represents <1.% of total current West Midlands electricity demand</i>	c. 1,000 GWh renewable electricity produced in the West Midlands in 2012, with more production units planned
Gas	6,000 tonnes	5,000 tonnes biomethane to be injected in Minworth (2015); opportunities for more compressed and liquid biomethane production
Liquid air	40,000 tonnes <i>High quantities of Liquid Air required to provide cooling needs</i>	Can make use of existing liquid nitrogen production facilities, until volumes justify a new production unit from renewable electricity

Table 2. Fuel demand from low carbon vehicle fleets in 2030-2035 in Birmingham & current renewable fuel production

² Estimates for non-renewable pathways are included in the full report (see Uptake scenario and impacts, within chapters 2-4)

Supply of liquid biomethane for transport is currently limited nationally, due to incentives in place for renewable heat and power, which may impose limits on the emissions savings that can be achieved by use of liquefied natural gas vehicles.

REFUELLING AND RECHARGING INFRASTRUCTURE PLAN

Consultation with fleet operators identified several distinct refuelling strategies for conventional and alternative vehicles, which depend to some extent on the type of fleet. Three main refuelling modes can be applied to low carbon infrastructure, with consequences for siting and scale. These modes are summarised in **Table 3**, with indicative requirements for infrastructure in 2030-2035, and details of the fleet segments that are expected to use each mode³.

Indicative long term infrastructure demand for low carbon vehicles in Birmingham, 2030-2035

Infrastructure demand	Public Open to all compatible fleets	In-depot Fleets use their own facilities – locations depend on routes and site costs	Shared access Several fleets share one site – not for public use
Charge points (light vehicles will use mainly overnight residential charging)	150-200 charging points Taxis, fleet cars, vans	5-10 depots Buses, heavy goods vehicles, some vans (up to 50 per depot)	20-30 charging points Taxis, light fleet vehicles
Hydrogen stations	5-10 stations Taxis, cars, vans	10-15 depots Buses	>5 stations Vans, light trucks
Gas stations	2-4 stations Long-haul HGVs	5-20 depots (Some shared access) Buses, heavy goods and refuse collection vehicles	
Liquid air stations		5-10 depots / 1-2 consolidation centres Refrigerated HGVs, Heat hybrid HGVs	

In-depot refuelling requires on-site installations which are not necessarily cost effective when fleets only have a small number of low carbon vehicles, but shared access refuelling stations could offer a good solution, particularly for gas, hydrogen and liquid air fleets that are too small to warrant dedicated in-depot refuelling. Conventional vehicles do not typically use shared access refuelling, but there are parallels with the consolidation centre

Table 3. Indicative long term infrastructure demand for low carbon vehicles in Birmingham, 2030-2035

³ Estimated infrastructure numbers relate directly to the projections for vehicle uptake in Table 1

approach (whereby delivery vehicles use a shared site outside a city to optimise the number of trips into the city). Consolidation centre refuelling could be an effective solution, with opportunities dependent on uptake of low carbon vehicles within relevant fleets. By 2035, it is likely that fewer shared access sites will be required than in the initial stages of hydrogen and gas vehicle uptake, and fleets are more likely to have dedicated facilities. The proportion of in-depot and shared access facilities will depend strongly on the rate of uptake within fleets.

In addition to the three refuelling modes outlined in the table, it should be noted that for light plug-in vehicles (taxis, cars and vans) the main charging mode is likely to be residential charging, which requires charging facilities to be installed at the driver's home. Depending on the duty cycle for these vehicles, use of public chargers may be required for "top-up" charging during the day.

The following specific locations have been identified within Birmingham:

• CHARGE POINTS

As indicated in **Table 3**, many plug-in fleets will be compatible with in-depot (or home) charging and will not require public infrastructure. However, a need for semi-dedicated rapid charging points for taxis near popular ranks has been identified, with the city centre as a priority zone (popular ranks in the centre are shown in **Figure 2**, there are typically close to the main train stations). These charging points will be in public locations, but priority will be given to taxis over private drivers to enable “top-up” charging during the day.

Popular taxi ranks in the centre of Birmingham

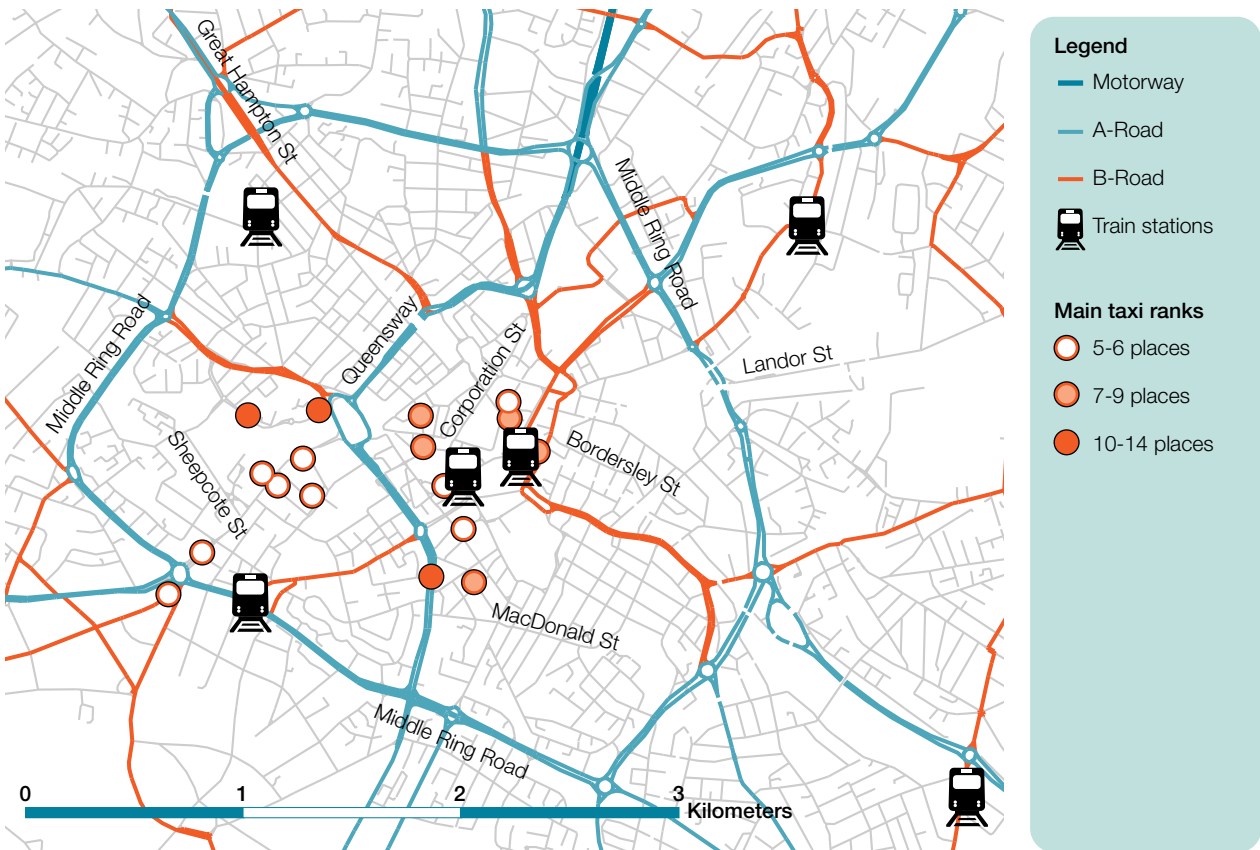


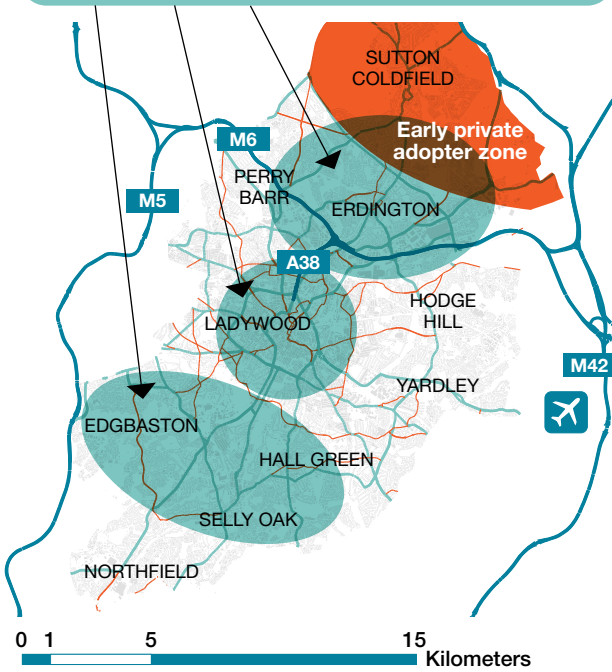
Figure 2. Popular taxi ranks in the centre of Birmingham

• HYDROGEN STATIONS

Public hydrogen stations will be shared with private drivers and therefore the likely locations of private early adopters should be considered in siting; the identified area is highlighted in **Figure 3**, alongside zones identified by taxi operators as “core zones” that constitute the minimum areas to be covered by at least one hydrogen station to support uptake of vehicles. **Figure 3** describes the criteria for station siting within these zones in more detail.

Illustrative zones for initial deployment of public HRS

Fleet operators think at least 1 public hydrogen station in each of these zones will be required for adoption of hydrogen light duty vehicles (taxis, fleet cars & vans)



SITING CRITERIA

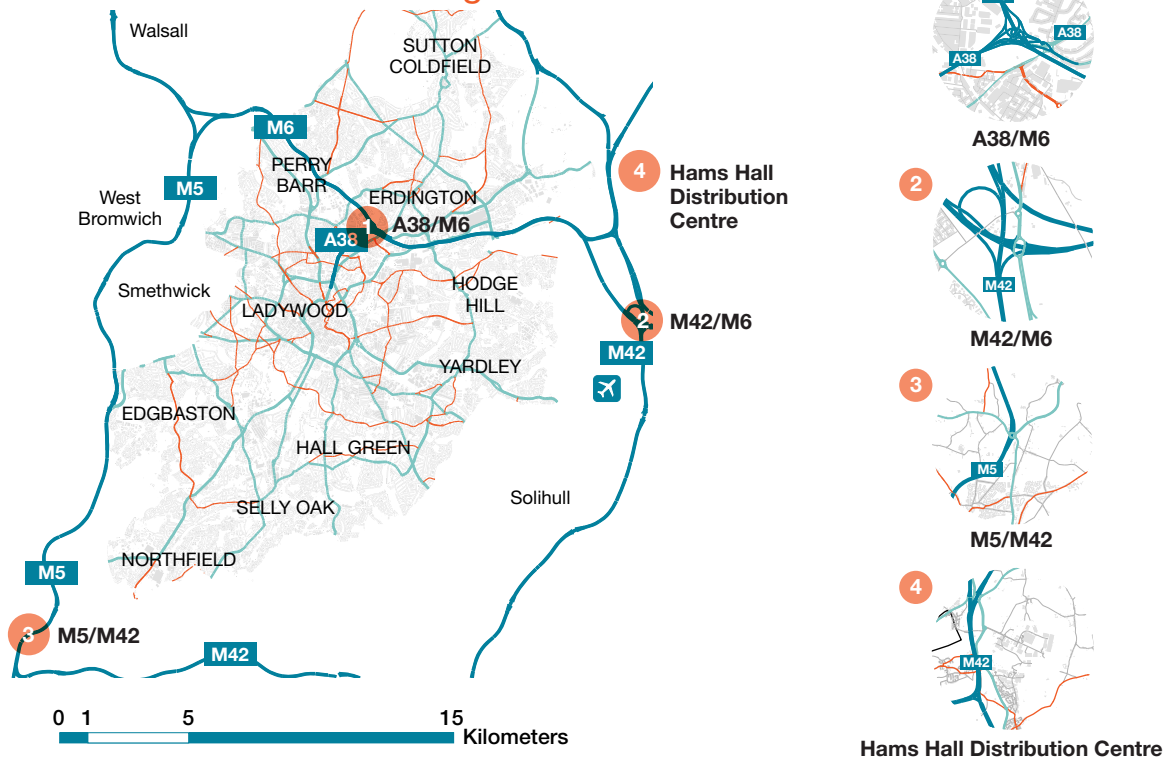
- Key is to avoid crossing the city to refuel; i.e. minimum of three stations: North, South and city centre
- Close to main roads/strategic corridors
- Away from heavily congested areas
- Siting of public stations should also consider locations of private early adopters of FCEVs to maximise station loading; Loughborough University study of early adopter demographics in Birmingham¹ suggests Northern wards (orange zone)

Figure 3. Illustrative zones for deployment of public HRS

• GAS STATIONS

For gas HGVs, the Freight Transport Association has signalled an interest from the industry for a Birmingham based station as early as 2012. Locations for public gas station(s) to supplement the existing regional network have been identified in several zones near key trunk routes (see **Figure 4**). These locations would enable more local fleet operators to adopt gas vehicles and provide opportunities to connect to the local gas grid.

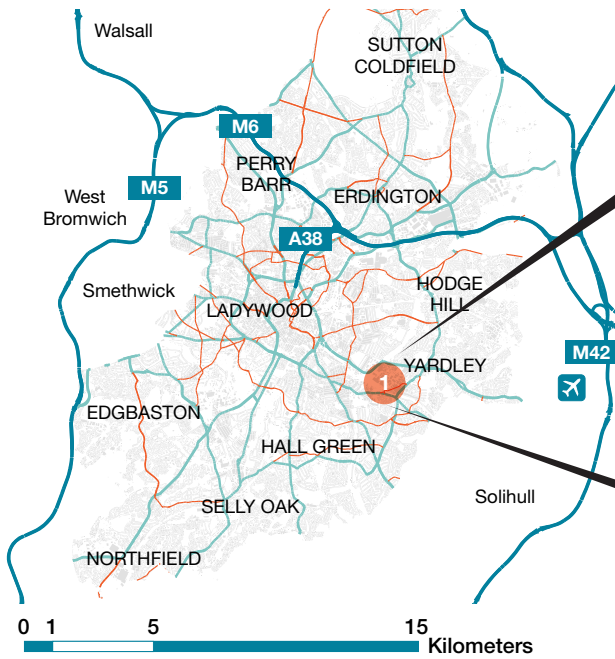
Opportunities for public gas stations on trunk routes near Birmingham



In addition, opportunities for shared access sites in the city have been identified, where there are clusters of potential demand from different fleets with associated depots. One of these sites is Hams Hall Distribution Centre, shown in **Figure 4**. **Figure 5** (next page) indicates another possible site in the Tyseley Environmental Enterprise district, which also benefits from close access to the gas grid and where Refuse Collection Vehicles deliver waste to incinerators.

Figure 4. Opportunities for public gas stations on trunk routes near Birmingham

Birmingham districts



CNG station opportunities

1 Tyseley Environmental Enterprise District

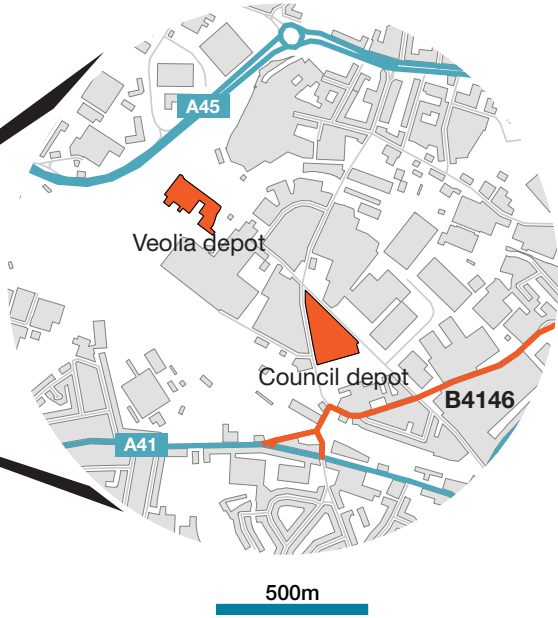


Figure 5. Opportunities for shared-access gas stations in Birmingham

RECOMMENDATIONS TO ADDRESS BARRIERS TO INFRASTRUCTURE DEPLOYMENT AND HARNESS LOW CARBON FUEL SUPPLY OPPORTUNITIES

To achieve the identified potential reductions in CO2 from road transport (estimated at 260,000 tonnes by 2035), Birmingham City Council can take a number of direct actions in relation to the development of refuelling infrastructure. Recommendations have been developed for each energy vector and are summarised below:

<p>Encourage and contribute to the uptake of low carbon vehicles</p>	<p>Consider where additional local incentives, e.g. parking/permit charges, taxi licence costs, could be used to improve the total cost of ownership of low carbon vehicles, complementing national incentives provided by OLEV.</p> <p>Adopt low carbon vehicles for Council fleets where suitable. Procurement of low carbon vehicles within Council owned fleets will contribute to market expansion and infrastructure utilisation. In addition, council-led installations could bring useful case studies and identify strategies to minimise costs (e.g. of electricity network upgrades and gas connections) and optimise planning processes, to be used as guidance for future installations.</p>
<p>Use planning guidance to deliver the infrastructure plan findings</p>	<p>Encourage infrastructure providers to meet various customer needs by producing planning policy and/or guidance in relation to siting requirements, accessibility, availability, Well-to-Tank fuel emissions etc. For example, for gas vehicles the fuel production and supply pathway can have a significant impact on the overall GHG emissions; biomethane in liquid or compressed form results in much lower emissions than methane on a Well-to-Wheel basis. As such, gas station planning applications should include evidence of a biomethane supply strategy and of station design that maximises GHG emission savings. In the case of charging infrastructure, for which no planning permission is required, only guidance can be provided to installers.</p>
<p>Work closely with private fleets on demonstration and deployment activities for low carbon vehicles</p>	<p>The Council should encourage formation of stakeholder forums bringing together fleet operators, infrastructure providers and fuel suppliers to deploy vehicles and infrastructure. These groups should consider working with other UK and European cities on joint procurement of low carbon vehicles (e.g. hydrogen or electric buses) to secure economies of scale; participation in demonstration projects and trials, via such groups, would provide support for the less mature technologies and contribute to commercialisation. In addition, such groups should foster links between infrastructure providers and renewable fuel suppliers; for example, Severn Trent’s biomethane injection at Minworth could be linked to the deployment of a new gas station.</p> <p>Stakeholder forums will also provide opportunities to share experiences regarding logistics and costs of infrastructure installation.</p>

<p>Make land available for infrastructure providers</p>	<p>The scarcity and high cost of land is a barrier to public infrastructure deployment that the Council could help address. Council-owned land that is compatible with the footprint and siting needs of refuelling infrastructure should be identified and could be used in demonstration projects, or leased to providers of refuelling infrastructure.</p>
<p>Streamline planning processes for renewable fuel production and infrastructure</p>	<p>Streamlining of planning processes for infrastructure could open more opportunities for potential sites; current uncertainty around safety requirements for hydrogen in particular can present a barrier to new stations. The Council should engage with the Government in the development of relevant safety guidelines to ensure that decisions can be made quickly and clearly for future infrastructure.</p>
<p>Include low carbon fuels for transport into the development of energy system strategies</p>	<p>The energy system, from heat and electricity networks to energy storage and production, is set to change under the City’s ambitious CO₂ reduction targets. When developing strategies around these themes, the benefits and integration with the transport system must be considered. For example, the upcoming review of the waste strategy presents the opportunity to use waste to produce biomethane (and thus address shortfall in liquid biomethane) and/or electricity. The economic viability of such a scheme and its role in meeting the local transport demand should be considered by the Council.</p>

NEXT STEPS FOR IMPLEMENTATION OF THE REFUELLING INFRASTRUCTURE PLAN

The recommendations made above are intended to be implemented over the next two decades, and should take account of changes in national policy and changes in vehicle technology.

As an immediate action, the Council should also **engage with Council teams** to ensure that recommendations are integrated into Council fleet procurement policy, and aligned and integrated with policy frameworks such as the Birmingham Connected transport strategy, the Carbon Roadmap and the Future Waste Strategy. The Council should also develop the planning requirements that assist infrastructure developments to enable the opportunities for CO₂ reductions identified in this study.

The Council can also **begin the near term deployments** where it has a leading role. For instance, the case of taxis (conversions to LPG for older vehicles and supporting adoption of new electric taxis) was identified as an early opportunity to impact on the area with the most severe air quality issues. Further action could also include the identification and deployment of trial fleets.

To support these near term deployments, the Council must **identify sources of funding** (national or European). Funding could also help to address high installation costs which often present a barrier to infrastructure deployment. The Council should also encourage the **establishment of the supply chains** needed to support the implementation of low carbon fleets (from conversions or manufacturing of vehicles and infrastructure to maintenance and installation) by determining the **opportunities for the development of local businesses**, and engaging with vehicle OEMs and other partners along the value chain.

Access to economies of scale could be gained through joint vehicle procurement as part of national or European consortia. **Strategic partnerships/consortia** for interested parties for low carbon infrastructure can be set up to that effect. Stakeholders could include utilities, fuel chain supply companies, infrastructure providers, fleet operators and local vehicle manufacturers, as well as other cities.

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ABBREVIATIONS

ACT	Advanced conversion technologies	LEP	Local enterprise partnership
AD	Anaerobic digestion	LIN	Liquid nitrogen
BCC	Birmingham City Council	LNG	Liquefied natural gas
BEV	Battery electric vehicle	LPG	Liquefied petroleum gas
BIS	Department for Business, Innovation & Skills	LTS	Local transmission system
CBM	Compressed biomethane	MPAN	Metering point administration number
CCCM	Common connection charging methodology	MSW	Municipal Solid Waste
CHP	Combined heat and power	N2	Nitrogen
CNG	Compressed natural gas	NTS	National transmission system
CO2	Carbon dioxide	OEM	Original Equipment Manufacturer
COMAH	Control of Major Accident Hazard	OLEV	Office of Low Emissions Vehicles
CP	Charge Point	PHEV	Plug-in hybrid electric vehicle
DECC	Department of Energy and Climate Change	PM	Particulate Matter
DfT	Department for Transport	RCV	Refuse collection vehicle
DNO	Distribution Network Operator	RE-EV	Range Extended Electric Vehicle
EBRI	European Bioenergy Research Institute	RHI	Renewable Heat Incentive
ETI	Energy Technologies Institute	RTFC	Renewable Transport Fuel Certificate
EV	Electric vehicle	RTFO	Renewable Transport Fuel Obligation
FC	Fuel Cell	SMR	Steam methane reformation
FCEV	Fuel cell electric vehicles	TCO	Total cost of ownership
FIT	Feed-In Tariffs	TEN-T	Trans-European Transport Network
FTA	Freight Transport Association	TfL	Transport for London
GGCT	Greenhouse Gas Certificate Trading	TRU	Trailer refrigeration unit
GHG	Greenhouse gas	TSB	Technology Strategy Board
GVW	Gross vehicle weight	TTW	Tank to wheel
GWP	Global Warming Potential	UCO	Used cooking oil
H2	Hydrogen	WPD	Western Power Distribution
HC	Hackney Carriage	WTT	Well to tank
HGV	Heavy goods vehicle	WTW	Well to wheel
HRS	Hydrogen Refuelling Station		
ICE	Internal combustion engine		
IGEM	Institution of Gas Managers and Engineers		
LAIR	Liquid air		
LBM	Liquefied biomethane		
LCNG	Liquid and compressed natural gas station		
LCV	Light commercial vehicle		

INTRODUCTION

The UK Government has committed to achieving an 80% reduction in greenhouse gas emissions by 2050, compared to 1990 levels. The transport sector currently contributes about 25% of all CO₂ emissions



1

INTRODUCTION

1.1 BACKGROUND

The UK Government has committed to achieving an 80% reduction in greenhouse gas emissions by 2050, compared to 1990 levels. The transport sector currently contributes about 25% of all CO₂ emissions, and dramatic reductions in this sector will be necessary if national targets are to be reached.

Local Governments will play a critical role in meeting these emission reductions, and to this end Birmingham City has developed the Birmingham Carbon Roadmap, setting out key initiatives that will contribute to achieving a 60% reduction in CO₂ emissions by 2027. One of the aims of the Carbon Roadmap is to implement more sustainable travel options, which will bring improved air quality as well as reducing CO₂ emissions in the city. Due to high volumes of road traffic in the city, Birmingham is currently one of the areas in the UK with NO₂ levels exceeding EC mandated limits, and consequently, improving air quality via reduction of NO₂ emissions is a priority for the Council.

Alternative fuel vehicles such as plug-in vehicles, gas vehicles and hydrogen vehicles have lower emissions than conventional fossil fuel vehicles, in terms of CO₂, NO_x and other pollutants. While increased adoption of these vehicles will be essential to achieve the Council's objectives for carbon reduction and air quality improvement, their adoption depends, amongst other enabling factors, on the provision of refuelling infrastructure.

While the need for a low carbon refuelling infrastructure strategy is recognised at European level (through the recent Directive on the deployment of alternative fuels infrastructure⁴), integrated plans for infrastructure deployment do not yet exist at a national or local level. Such plans are required to co-ordinate the rollout of current and future infrastructure, ensuring maximum benefits to private and fleet customers while minimising investment costs.

1.2 OBJECTIVES

The Council commissioned Element Energy to develop a 'blueprint' for future deployment of low carbon refuelling infrastructure in the city, to support uptake of low carbon vehicles that require a dedicated refuelling infrastructure.

The overall aim is to inform and advise the development of refuelling infrastructure for low-carbon vehicles in Birmingham through the following elements:

- A clear infrastructure plan for each low carbon fuel that recognises the needs of vehicle users (in terms of siting, fuel specification and vehicle operations) as well as fuel distribution constraints

⁴ Directive 2014/94/EU, adopted by the EU parliament in April 2014 and by the Council in October 2014, requires Member States to draw up a national infrastructure plan for low carbon fuels (electricity, hydrogen, gas) by November 2016.
<http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0094&from=EN>

- The provision of information and recommendations to steer activities and investments in low-carbon refuelling infrastructure; including the quantification of potential CO₂ emission reductions brought by low carbon vehicles
- Recommendations and next steps for the Council to support the delivery of the infrastructure plan

1.3 SCOPE

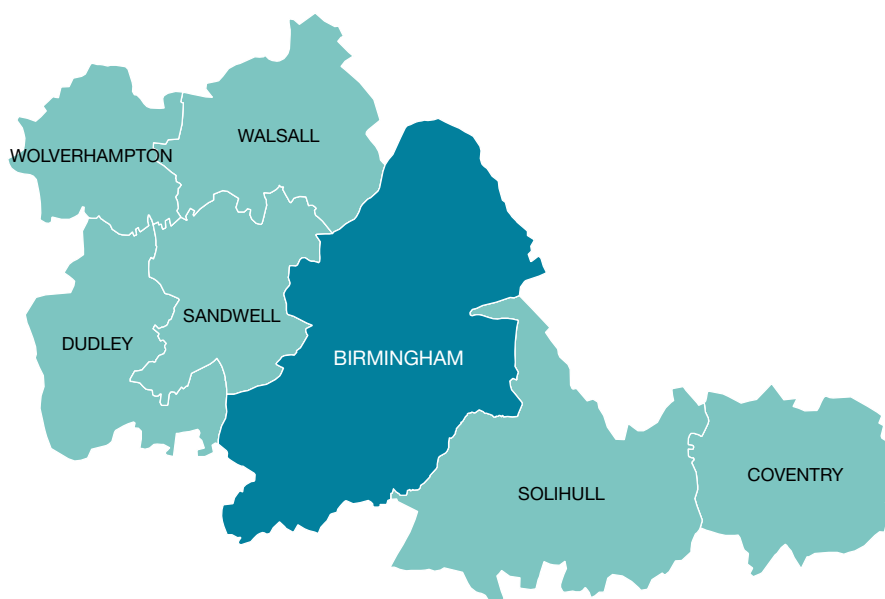
VEHICLE SEGMENTS INCLUDED IN STUDY

This report focuses on identifying infrastructure needs for fleet vehicles, including taxis, fleet cars, Light Commercial Vehicles (LCVs), Heavy Goods Vehicles (HGVs) and buses. Fleet vehicles offer good opportunities for uptake of low carbon vehicles: their duty cycles and refuelling patterns are generally more predictable and well understood, and they are likely to be subject to corporate emissions targets. In addition, the Council is better placed to engage with and influence fleet operators, compared to private car owners.

While the refuelling infrastructure plan focuses on fleet vehicles, the private car market is also taken into consideration, in particular when there are opportunities to deploy infrastructure that support both the fleet and private markets.

GEOGRAPHICAL SCOPE OF THE STUDY

Birmingham City is the area under consideration, in terms of fleet needs and infrastructure siting. The time period under consideration is the next two decades, i.e. from 2014 to 2035, in accordance with the Birmingham Connected transport strategy, the Council's long term vision for transport in the city. Birmingham is part of the wider Greater Birmingham and Solihull Local Enterprise Partnership area (**see Appendix 7.4 for map**).



Birmingham districts

Birmingham centre

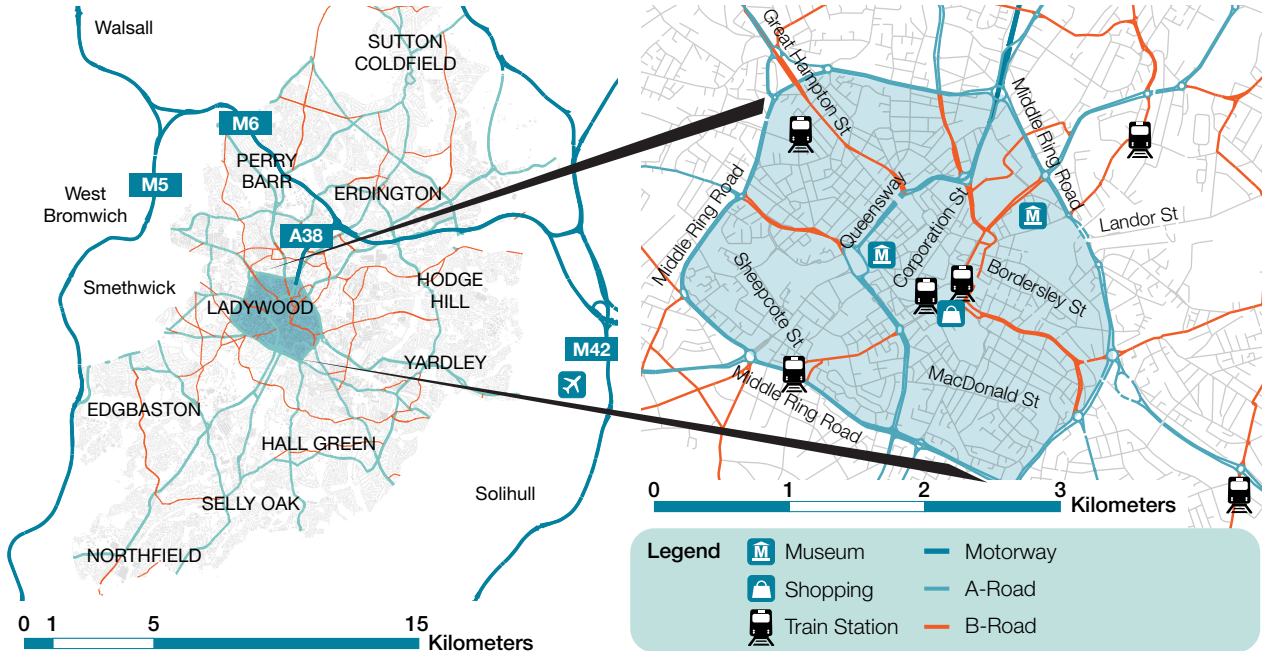


Figure 6. Birmingham region and city centre

VEHICLE TECHNOLOGIES UNDER CONSIDERATION

The technologies considered in this study are plug-in vehicles, hydrogen vehicles, gas (methane or biomethane, Liquefied Petroleum Gas) vehicles and liquid air vehicles. For the first three, the low carbon fuel under consideration is the primary vehicle fuel, whereas liquid air is considered mainly as an alternative to red diesel in vehicle refrigeration systems.

There are a range of other vehicle technologies currently available to reduce emissions. They have not been considered in this study either because they do not require a dedicated infrastructure (hybrid electric vehicles) or their uptake among fleet is not expected to require an infrastructure beyond a depot-based tank (high blend biodiesel, used cooking oil).

1.4 APPROACH

The different stages of the project are described below and summarised in **Figure 7**.

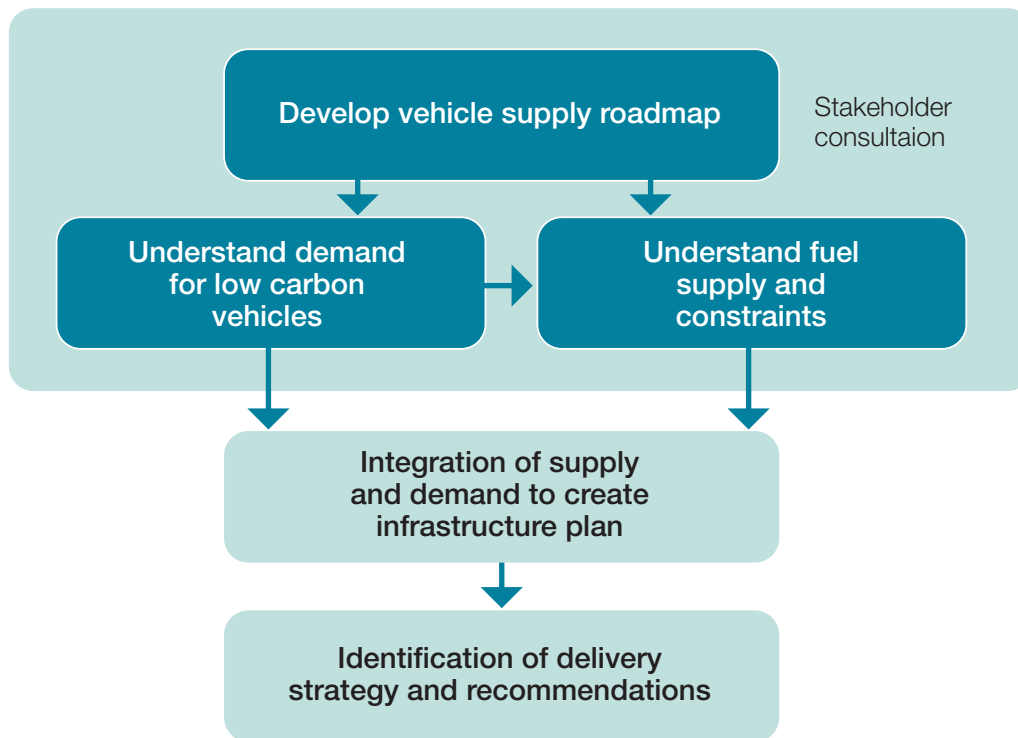


Figure 7. Strategy for development of Birmingham infrastructure plan

DEVELOP VEHICLE SUPPLY ROADMAP

A vehicle supply roadmap was developed for each energy vector. The current availability of low carbon vehicles was used as a starting point, with future introduction dates for new models and technologies based on OEM announcements and observed policy trends.

UNDERSTAND THE DEMAND FOR LOW CARBON VEHICLES

A series of workshops and bilateral discussions were conducted with fleet operators in different vehicle segments, to assess:

- The potential compatibility and demand for the vehicle technologies under consideration, within different fleets
- Refuelling patterns and infrastructure requirements

Using workshop results and our own databases, future costs, challenges and feasibility of vehicle adoption by different fleets were assessed to build a vehicle uptake scenario for each technology.

UNDERSTAND FUEL SUPPLY OPPORTUNITIES AND CONSTRAINTS

The potential supply options and constraints for provision of low carbon fuels in Birmingham was assessed, via bilateral discussions with project developers, infrastructure suppliers, gas and electricity grid operators and research organisations. The following were assessed specifically:

- Supply opportunities from current or planned infrastructure and local resources
- Constraints with the potential to influence fuel infrastructure locations
- Locations with high suitability for refuelling infrastructure due to e.g. proximity to fuel production sites

INTEGRATION OF SUPPLY AND DEMAND

Based on the understanding of user needs, vehicle demand and supply opportunities, an integrated infrastructure plan for Birmingham was developed. This plan is a combination of phased maps for roll-out of infrastructure over time, technology choice considerations, and a series of identified market trigger points that will be strong determinants for vehicle uptake and the level of infrastructure required. The infrastructure plan also provides an indication of the potential carbon savings that could be achieved if this level of uptake is achieved.

IDENTIFICATION OF DELIVERY STRATEGY AND RECOMMENDATIONS

A series of recommendations for implementation of the infrastructure plan were developed. These recommendations are designed to bring the necessary enabling factors and fuel supply that will maximise the achievable CO₂ savings from low carbon vehicle uptake. Interventions that may be required by Birmingham City Council, in order to ensure that low carbon vehicle infrastructure is aligned with user needs, were identified.

1.5 STAKEHOLDER CONSULTATION

A wide range of stakeholders including vehicle suppliers, end users, utilities, fuel suppliers and infrastructure providers were consulted throughout the project, to ensure that project outcomes accurately reflect the current landscape for vehicles and infrastructure, and the needs of vehicle fleets now and in the future.

Fleet operators consulted

Light vehicle fleets	Heavy vehicle fleets
A2Z	Arriva
AMEY	Asda
Birmingham and Solihull Taxi Alliance	Birmingham City Council - Fleet & Waste
Birmingham City Council - Adults & Communities	BRIT European
British Gas/ Centrica	Centro
Carillion	Coca Cola
Commercial Group	Freight Transport Association
Heart of England NHS Foundation Trust	Howard Tenens
Network Rail	John Lewis Partnership
nPower	Marks and Spencer
Royal Mail	National Express
Star Cabs	Sainsbury's
University of Birmingham	UPS
West Midlands Police	Veolia

Other key stakeholders consulted
Birmingham City Council - Planning and Regeneration Team
BRC (GB) Limited
Cenex
Dearman Engine Company
EBRI – Aston University Business School
Gas Bus Alliance
Gasrec
Severn Trent
Transport for London
Western Power Distribution

1.6 STRUCTURE OF THE REPORT

Sections 2, 3, 4 and 5 relate to, respectively, plug-in vehicles, hydrogen vehicles, gas vehicles and liquid air technologies. They all follow an identical structure:

- **Vehicle roadmap and fleet operator feedback** – this provides an overview of the powertrain technologies available, the level of commercial maturity and current refuelling network. The findings of the consultation with fleet operators are summarised, by vehicle segments.
- **Infrastructure plan** – this sub-section lays out the technology options and the areas identified as priority for deployment. Specific siting opportunities are then described, along with the fuel/energy vector supply options. Finally the potential uptake of alternative vehicles in Birmingham is projected, and the associated benefits and infrastructure requirements of this potential uptake are discussed;
- **Recommendations for delivery** – this sub-section provides specific recommendations for deployment of refuelling infrastructure over the next 20 years.

Section 6 describes the current and potential barriers to infrastructure deployment, and summarises the priority zones for future deployment of public refuelling infrastructure. Final recommendations for Birmingham City Council are provided, as well as proposed next steps to support the realisation of low carbon vehicle infrastructure.

Supporting information, including detailed assumptions for uptake projections, has been placed in the Appendix.

PLUG-IN VEHICLES

Increased uptake of electric vehicles is seen as essential to achieving national carbon reduction targets



2

PLUG-IN VEHICLES

2.1 VEHICLE ROADMAP AND FLEET OPERATOR FEEDBACK

2.1.1 OVERVIEW

Increased uptake of electric vehicles is seen as essential to achieving national carbon reduction targets. According to the Carbon Plan⁵, electric vehicles must account for 60% of car and van sales by 2030 to achieve emissions targets for 2050, and a number of policy measures are in place to support this. The main current grants and funding are summarised in **Table 4**.

MAIN GRANTS AND FUNDING FOR PLUG-IN VEHICLES

- £5,000 / £8,000 grant on purchase of plug-in cars and vans (until 2017)
- EVs are exempt from the Vehicle Excise Duty; electric goods vehicles are exempt from MOT
- £32 million fund for installation of charging infrastructure across the country
- Government grants for 75% of costs of home charging systems (£900 max)

Table 4.
Main grants and funding for plug-in vehicles

Electric vehicles are available in a range of fleet vehicle segments, including light commercial vehicles (vans), heavy goods vehicles (HGVs) and buses. There are two different powertrain options for plug-in electric vehicles:

- Battery Electric Vehicles (BEVs) run solely on electricity and do not have a fuel tank; typical driving ranges are 80-160 miles (c.100-250km) on a fully charged battery⁶. BEVs produce zero “tail-pipe” emissions, and they are virtually silent.
- Plug-in Hybrid Electric Vehicles (PHEVs) have a conventional fuel tank and engine, as well as a battery and electric motor. They can typically be driven in electric mode for between 20km to 80km.

Both types of vehicle can be recharged by connection to the electricity grid, using either private or publicly owned infrastructure.

⁵ The Carbon Plan outlines the UK Government’s plans to deliver the emissions savings it has committed to achieving by 2050. Full details can be found at: <https://www.gov.uk/government/publications/the-carbon-plan-reducing-greenhouse-gas-emissions--2>

⁶ For example, the driving range, based on New European Driving Cycle, of the Nissan Leaf, VW e-Up!, BMWi3, and Renault Zoe are respectively 140km, 150km, 190km, and 210 km.
Source: www.nextgreencar.com/

Availability and market projections of plug-in vehicles

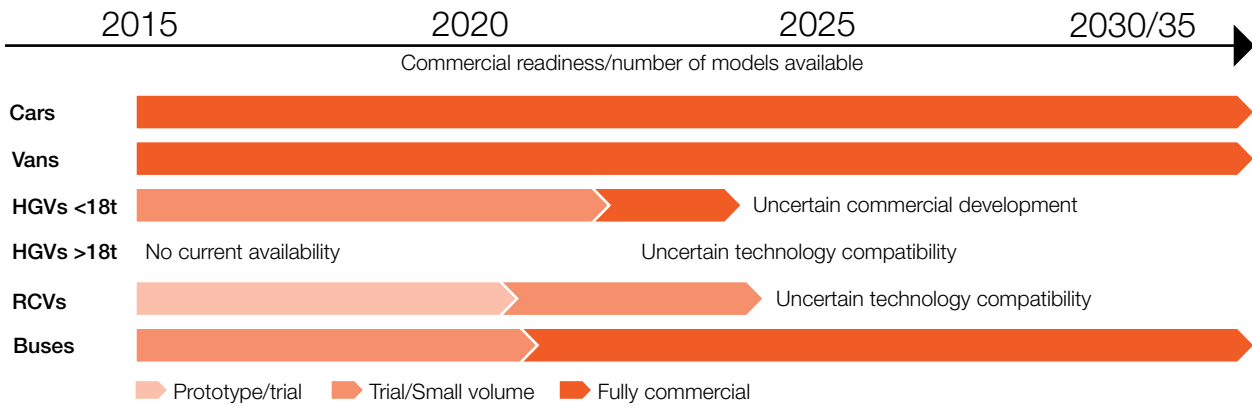


Figure 8 shows the projected development of the plug-in vehicle market over the next 20 years. The greatest availability for plug-in vehicles lies in the car and van market; numerous car manufacturers now have electric vehicles available in a range of sizes. Model availability is expected to increase as the technology matures and the cost of production decreases.

Figure 8. Availability and market projections of plug-in vehicles⁷

While the highest number of models is likely to be in for light vehicles, electric buses and small trucks have been deployed in small numbers in UK fleets, and the market is expanding. The bus market in particular is moving from the conversion of existing platforms towards dedicated vehicles produced by vehicle manufacturers, and the range of models available is becoming more diverse. Plug-in refuse collection vehicles (RCV) have also been trialled, but the technology compatibility is uncertain due to the loss of payload caused by the large batteries required.

CURRENT INFRASTRUCTURE IN BIRMINGHAM

Most vehicles that return to drivers’ homes overnight would be compatible with residential charging, which is usually the cheapest and most convenient charging mode. The majority of electric cars and vans registered in Birmingham (c. 200 vehicles) currently charge overnight at driver homes, with a small percentage recharging at depots or offices.

Public charging points can be effective in reducing “range anxiety” in potential adopters of plug-in vehicles, and will support vehicle uptake. The existing public charging infrastructure within the Birmingham area consists of 85 charging points (see map in appendix for locations); for comparison, there are 107 petrol stations. Of the 85 CPs, 16 are slow chargers (3kW), 68 are fast chargers (32-40kW) and one is rapid (40kW+)⁸. There are also two superchargers for Tesla vehicles (120kW), and a number of rapid charging points are due to be installed in 5 sites on the M6 outside Birmingham, as part of the national Rapid Charge Network project, which is co-financed by the EU. Birmingham City Council has also received OLEV funding for an additional 8 rapid charging points within the city, to be deployed in 2015.

⁷ Based on announced OEM roadmaps, technology compatibility considerations and policy support in place

⁸ Source: Zap-Map.com. A typical battery electric vehicle (c. 25kWh battery) would recharge completely in 7-8h at 3kW, in 3-4h at 7kW and would recharge to 80% in 20 to 30 min at 50kW

2.1.2 TAXIS AND LCV FLEETS

VEHICLE AVAILABILITY

Plug-in cars and vans are now available from a number of different vehicle manufacturers. Currently, there are no existing PHEV vans on the market but there a number of BEV options, as indicated in **Table 5**.







Taxis in Birmingham, as in other UK cities, are divided into Hackney Carriages and Private Hire Vehicles. Hackney Carriages are allowed to pick up passengers without a booking under the terms of the licences issued by the City Council. These vehicles must be recognisable and wheelchair accessible, and therefore adoption of plug-in vehicles within this segment relies on the availability of BEVs or PHEVs that meet these requirements. The Nissan e-NV200 will soon be available in a HC-compatible format, and it is likely that other electric van manufacturers will offer alternatives in the next few years.

Non-HC taxis, known as private hire vehicles, and other LCV fleets are not restricted in the same way and therefore have a range of options for EV uptake.






Availability of plug-in cars and vans

Suitable vehicles are available in a range of sizes; ~10 BEV and ~10 PHEV models in the short term

Hackney
Carriage
ready

 BEV	 BEV	 BEV	 BEV	 PHEV	 PHEV
Nissan e-NV200	BYD e-6	Nissan LEAF	Renault Zoe	Toyota Prius Plug-in	Volvo V60

BEV vans are available in a range of configurations, with 7 models currently eligible for the £8k grant

 Renault Kangoo ZE	 Peugeot Partner	 Nissan e-NV200	 BD Otomotive eTraffic	 Smith Edison
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Lease options are available

COSTS AND FUNDING

Vehicle cost premiums for plug-in LCVs range from 0 to 200% over equivalent diesel versions, although the higher end of the spectrum applies only to converted vehicles. Until 2017, £5k and £8k grants will be available for purchase of plug-in cars and vans respectively, with £20 million available from OLEV specifically to support uptake of plug-in taxis over 2015-2020. Most plug-in vehicles still retain a significant cost premium after grants. However, significant running cost savings can be achieved: fuel costs can

Table 5.
Availability of
plug-in cars
and vans

be as little as 20% of diesel vehicles on a per km basis⁹, and fleet operators report that maintenance costs for BEVs are typically half that of conventional vehicles¹⁰.

BARRIERS TO UPTAKE

Cost premiums and uncertain economics are the main barriers to uptake of plug-in taxis and LCVs, with taxi unions in particular stating that for most drivers, purchase of a more expensive vehicle would rely on grants to achieve purchase cost parity. In addition to the higher cost of purchase, a resale market for EVs does not yet exist and several fleet operators indicated that this has a detrimental effect on the business case for plug-in vehicle uptake. Currently, fleets likely to adopt plug-in vehicles include large organisations with strong corporate targets for reduction of fleet emissions, and those with compatible business interests, such as charging point technologies.

FLEET COMPATIBILITY AND CHARGING NEEDS

In spite of the barriers, the characteristics of Birmingham taxi operations imply significant opportunities for uptake of plug-in vehicles, particularly within the Hackney Carriage segment. These vehicles typically drive less than 100 miles per day and return to drivers' homes at night for a minimum of 6 hours, making them highly compatible with BEV ranges and charging requirements. Private Hire Vehicles tend to drive further each day (up to 200 miles) and drivers expressed a preference towards PHEVs, which provide the option of using the fuel tank when the electric range is exceeded.

Around 70% of drivers asked stated that they park "in close proximity to an electricity socket when off duty", and therefore it can be assumed that residential charging would be the main mode for electric taxis. However, feedback from taxi operators and drivers suggested that uptake would be more likely if rapid charging facilities providing guaranteed access to taxis existed, e.g. on sites adjacent to popular taxi ranks.

LCV fleets other than taxis can be separated broadly into two categories, with different compatibilities for plug-in vehicles:

- Fleets providing non-delivery services (e.g. utility companies doing home visits) and/or with low daily mileages (e.g. hospital delivery fleets)
 - o Daily mileages can be under 100 miles and charging during breaks in operation may be possible
 - o BEV compatible (several utility fleets interviewed already include BEVs)
- Logistics and delivery fleets (shorter stops during operation)
 - o Daily mileages may exceed BEV ranges and operations not suited to public recharging
 - o More suited to PHEV adoption
 - o BEV use reported on specific, compatible routes

⁹ Based on 10p/kWh, and £112p/l and vehicle use of 12.4L/km and 5kWh/km

¹⁰ Fleet operators interviews

Fleet vehicles are based at a mixture of drivers' homes, depots and offices, where overnight charging is likely to be feasible in most cases. Similarly to taxi operators, LCV operators indicated that uptake potential could be increased by the provision of rapid charging infrastructure within the city. Although specific locations were not identified, the emphasis was on provision of secure, reliable charging points (CPs) in visible locations. An additional requirement is interoperability, due to the range of charging connectors and networks available.

2.1.3 LIGHT TRUCKS AND REFUSE COLLECTION VEHICLES

VEHICLE AVAILABILITY

Light plug-in trucks (up to 12t GVW) are mainly available as BEV conversions of existing platforms, and >100 vehicles have been used in UK fleets (e.g. in delivery operations). BEV tractors (up to 18t GVW) are in trial stages. To date, plug-in options for RCVs have been very limited, although a PHEV model (Geesink Norba) has been trialled in London.

Examples of plug-in trucks available in GVWs 3.5-12t, with some trials of tractors (7.5-18t) and RCVs

Smith Edison/Newton	Renault Maxity (3.5t)	EMOSS - conversions	Trucks: <ul style="list-style-type: none"> • Payloads 0.8-7.5t • Ranges <100miles Tractors: <ul style="list-style-type: none"> • Payloads 4.5-12t • Ranges up to 120miles
			

Although gross vehicle weight over 18t might be achieved through the use of dynamic inductive charging or through conductive electrical transmission through overhead lines, this is currently at an early testing stage (e.g. Scania is testing both technologies¹¹).

Table 6. Example of plug-in trucks available in GVWs of 3.5t-12t, with some trials of tractors (7.5-18t) and RCVs

COSTS AND FUNDING

Vehicle cost premiums for plug-in HGVs range from 50% to 200% over equivalent diesel versions; converted vehicles are the most expensive. There are currently no grants available at a national level (although electric goods vehicles are exempt from MOT). Match funding is available at a European level, e.g. £8million funding was awarded for the FREVUE project, which trials electric trucks in urban logistics.

Payback periods depend on vehicle mileages, but fuel costs are typically only 30-50% of diesel equivalents and maintenance costs are also reduced¹².

¹¹ <http://newsroom.scania.com/en-group/2014/03/13/scania-tests-next-generation-electric-vehicles/>
¹² For example, energy consumption figures of 0.2l/km for diesel truck and 0.8kWh for electric truck, at £1/l and £0.1/kWh gives a 40% fuel cost reduction in favour of the electric truck. Energy use figures based on Daimler, Strategies to reduce CO2 emissions from commercial vehicles 2011 and Netherlands Enterprise Agency, Hybrid and Electric Driving Demonstration Projects, 2013

FLEET COMPATIBILITY AND CHARGING NEEDS

As well as vehicle cost premiums, reduced payloads and ranges for BEV trucks present barriers to uptake. The economics and integrity of most HGV operations are directly impacted by one or both of these factors, which can be limited by the low energy density of batteries, and as such BEVs are generally only compatible with specific, predictable duty cycles that match the constraints of the available vehicles.

Fleet operator feedback indicates that experiences of converted vehicles have been mixed, and uptake will be more likely when a range of BEV and PHEV options becomes available from vehicle manufacturers. Although PHEVs will be applicable to longer daily mileages, it is likely that they will be used for similarly predictable, back-to-base operations as BEVs.

The main option for charging plug-in fleets will be in-depot CPs of at least 40kW (to enable full re-charging of large batteries). This will place further restrictions on fleet compatibility, due to the potential requirements for upgrades to electrical connections within depots.

2.1.4 BUSES

VEHICLE AVAILABILITY

There are currently numerous trials of electric buses in the UK (around 60 electric buses in total), and the market is maturing: until recently, converted, single-decker buses have been the main option, but over the next two years a number of OEM options are expected, including several double-decker models. Choice is expected to increase for both BEV and PHEV buses.

Availability of plug-in buses in the UK

Table 7.
Availability of plug-in buses in the UK

Magtec BEV conversions e.g. Optare Versa (12m)



- Trials in Nottingham, York, Hounslow & Scotland
- Now includes double decker conversions

WrightBus StreetLite (BEV midibus)



- 8 in Milton Keynes
- Induction charging enabled

OEM options from e.g. Volvo and BYD



- Volvo plug-in hybrid to be available soon



- BYD have a range of single decker buses available
- Double decker models expected by 2016

COSTS AND FUNDING

Plug-in buses are typically twice the price of diesel versions. However, a £30 million OLEV fund is available for low emission buses in 2015-2020, after which point prices can be expected to be considerably lower. EC funding is also available for trials. As with other plug-in vehicles, fuel costs can be as low as 30% of diesel buses, and maintenance costs can be reduced by 50%, for fully electric operations¹³.

FLEET COMPATIBILITY AND CHARGING NEEDS

The BEV range and payload limitations that impact HGV operations also apply to buses. Currently, BEV buses can only be used for specific routes and therefore fleet uptake is somewhat constrained.

The majority of bus services in Birmingham are provided by two large operators, for which refuelling takes place in-depot. This pattern may also limit uptake due to availability of space and network capacity; charging more than e.g. 20 vehicles simultaneously at 50kW+ is likely to require some local network reinforcement. In addition to the large operators (namely National Express and Arriva), there are numerous small bus operators in Birmingham that are unlikely to adopt electric buses, for economic as well as practical reasons.

Wireless charging is now being tested in real world trials, and could address these constraints through provision of wireless charging at bus route start/end points (to increase range), and in depots (to ease space constraints). Policy support and grant availability is also likely to accelerate uptake, and the potential introduction of Ultra Low Emission Zones in cities will enhance this effect.

¹³ For example, energy consumption figures of 0.4l/km for diesel bus and 1.1kWh/km for electric bus, at £1/l and £0.1/kWh gives a 40% fuel cost reduction in favour of the electric bus. Energy use figures based on TfL London Electric Vehicle Partnership, Electric Buses, 2014 and FCH JU, Urban Buses: alternative powertrains for Europe, 2012.

2.2 RECHARGING INFRASTRUCTURE PLAN

2.2.1 TECHNOLOGY OPTIONS

Compatible charging modes and technologies vary across the different fleet segments, according to duty cycle, vehicle size and vehicle charging hardware. The charging rates and modes required for each segment are summarised in **Table 8**.

Indicative charging rates and modes

Charging modes	Home/office/depot charging points		Public charging points	
	3kW-7kW	40kW+	7-50kW	7-50kW+ Wireless
Compatible fleets	Taxis LCVs	Buses HGVs RCVs	Taxis LCVs	Taxis Buses
Fleet requirements	Enable payment tracking	Charge rate compatible with size of battery and available charging time	Booking systems to guarantee access	Initially dedicated to fleets, potential to be made public

Table 8. Indicative charging rates and modes

In general, higher charging rates will be required for larger vehicles, due to their greater daily energy consumption, but charge rates should also account for available time windows for charging; e.g. depot-based LCV vehicles with less than 8 hours between daily operations are likely to charge at 7kW rather than 3kW. The same principle is applied to public vs. home/depot charging: when charging mid-route, fleets prefer rapid charging points, to minimise operational disruption and maximise CP availability.

Technology choices for CPs should account also for the following criteria:

- Potential need for booking systems: guaranteed access at public/shared CPs at certain times will be essential to support BEV fleet operations in some sectors (e.g. taxis). Logging the usage data would also prove useful to optimise future fees/siting/systems.
- Potential for sharing with private EV users: multi-rate posts with several connection points should be considered, as there are a variety of rates in use among cars (e.g. PHEVs are currently typically limited to 3kW and BEVs do not all have the same rapid charging socket)
- Payment modes and billing processes might require vehicle identification systems, e.g. for CPs shared across several fleets/drivers and for chargers installed at employees' homes, use for fleet and private EVs may need to be differentiated.

In the long term, infrastructure requirements will depend on developments in battery and charging technologies. In terms of public charging point specifications, vehicle compatibility with numerous charging rates may increase (e.g. via the introduction of regulations); wireless charging may also become widely compatible. In addition, battery technology developments may lead to a reduced need for charging outside of homes and depots.

In terms of the type of socket outlets (or connectors type for DC tethered charging points), the 'Type 2' socket is the standard agreed at EU level ('Combo 2' for DC points)¹⁴.

2.2.2 PRIORITY ZONES FOR SITING

DRIVER RESIDENCES, OFFICES AND DEPOTS

As previously discussed, vehicle charging will make use of the available time windows between vehicle operations, and the majority of charging points will be sited where vehicles are kept overnight.

For most taxis and LCV service vehicles, this means driver residences, and therefore access to off-street parking will be a key determinant of EV uptake. Company pool cars were identified as a strong potential segment for uptake of plug-in vehicles, and chargers are likely to be installed within office car parks to support this.

Buses, trucks and many LCV fleets are depot-based and the majority of charging needs will need to be met in-depot. Some taxi fleets may also install charging facilities at depots/ car parks.

PUBLIC CHARGING AND BOOKABLE/SECURE ACCESS CHARGING

Provision of high power public infrastructure could enable a greater number of taxi and LCV operations to become viable; the option of rapid charging during short breaks in operation would extend the maximum daily range of EVs and reduce range anxiety amongst fleet operators. General siting requirements identified by fleet operators were visibility, accessibility and reliability. Access to a charging point should be possible with minimal route diversion. Key locations could include:

1. City centre, near taxi ranks for Hackney Carriages
2. Delivery hubs/distribution centres and/or retail parks for van fleets: emphasis on visible and accessible locations

These boundaries provide the focus for **Figure 9**, which shows indicative zones for public charging points in the next 20 years.

¹⁴ See Appendix for full standard references

Public charging infrastructure plan for fleet vehicles

Figure 9.
Public charging infrastructure plan for fleet vehicles

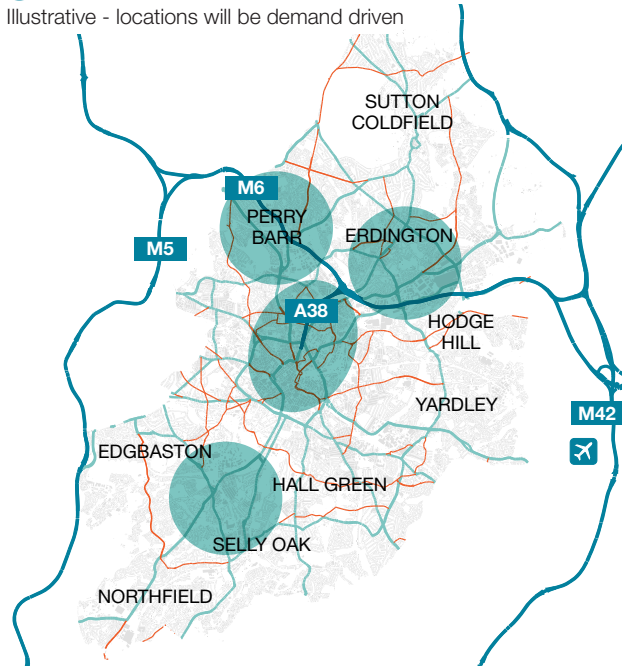
1 Short term (2015-2020)

Illustrative - locations will be demand driven



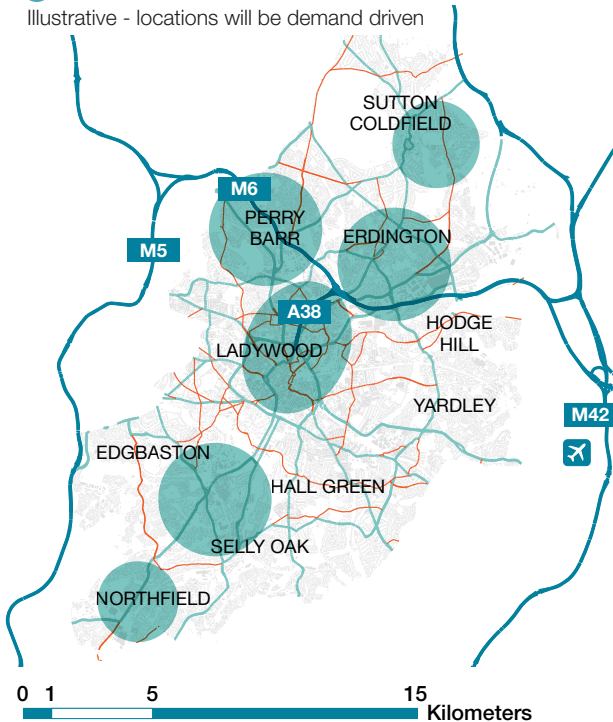
2 Medium term (2020-2025)

Illustrative - locations will be demand driven



3 Long term (2025-2035)

Illustrative - locations will be demand driven



- 1**
- Focus on fleets with compatible mileage such as Hackney Carriages taxis, with possible sharing with other fleets
 - High battery charging rates (40kW+)

- 2 3**
- Siting to ensure utility to fleets (zones of car/LCV fleet operations e.g. high Private Hire Vehicle traffic, at delivery/logistical hubs for LCVs) with ability to share across fleets to maximise usage levels
 - Specifications will depend on technology development (e.g. kW rate, wireless)

Legend

- Motorway
- A-Road
- B-Road
- Fleet charging point deployment zones

2.2.3 SITING OPPORTUNITIES FOR CHARGING INFRASTRUCTURE

Specific siting opportunities for charging points will depend on where demand from fleet vehicles emerges, and CP investors should engage directly with fleet operators to identify ideal locations. However, rapid chargers dedicated to taxis in the city centre could be an early opportunity to encourage Hackney Carriages uptake of BEVs, and could be used to support other fleet or private plug-in vehicles in the future (as described in **Figure 11**).

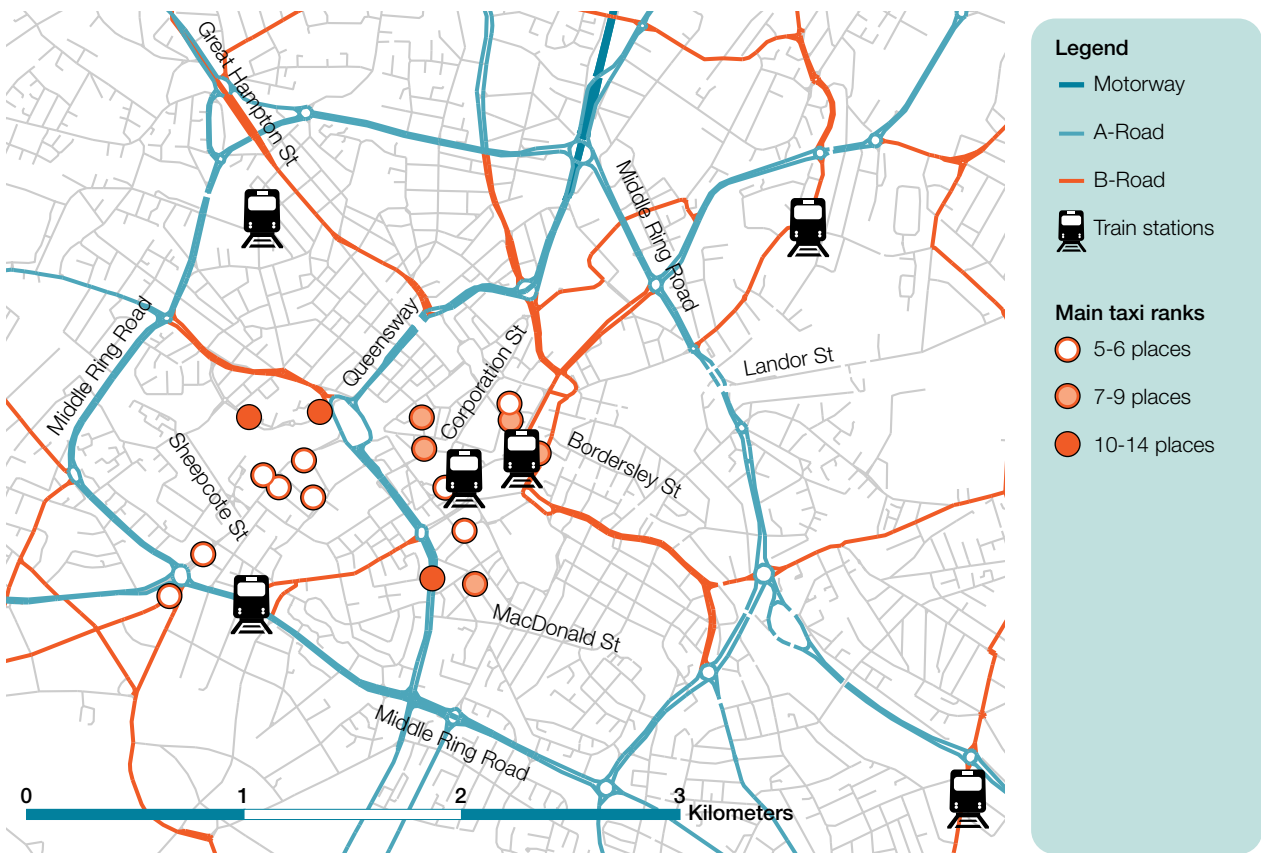


Figure 10.
Taxi ranks in the city centre

Some key opportunities and benefits of charging points in the city centre for HCs:

- The city centre (within the A4540 ring road) is an area of very poor air quality
- It concentrates a high density of Hackney Carriage usage (with 50% of total rank spaces and 30% of passengers taken from the Navigation Street Rank alone)
- The High Voltage network is very dense, which facilitates the installation of rapid chargers

Ideal sites would be within the ring road, or easily accessible from inside the ring road.

Access to plug-in Charge Points

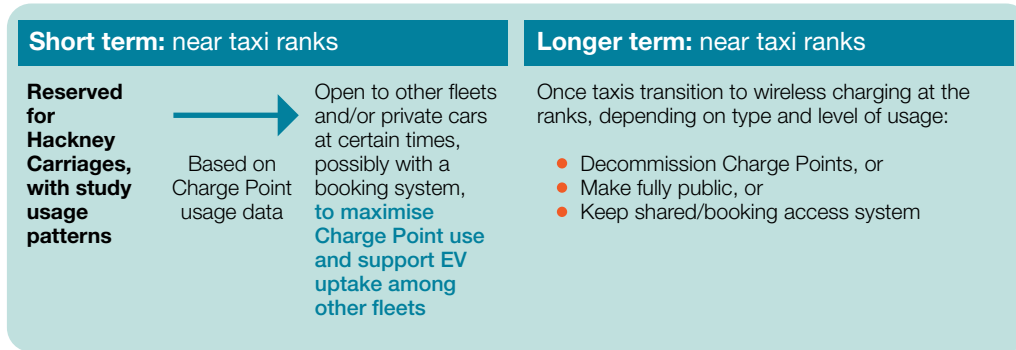


Figure 11. Illustrative roll-out of infrastructure for taxis

IDENTIFYING GRID OPPORTUNITIES AND CONSTRAINTS

A key consideration for fleet operators evaluating the possibilities of charging plug-in vehicles at a particular depot must be the available capacity in their Connection Agreement, and the potential to increase the demand on the local distribution network.

Low Voltage network

Depots who are connected to the LV network (<1kV), with no option for a High Voltage connection, will be limited to a capacity of 150kW. While this limit rules out simultaneous charging of several heavy vehicles (such as buses that would typically recharge at 40kW or over), it is sufficient for fleets of light vehicles that can recharge at lower rates (c. 40 vehicles at 3kW or c.20 vehicles at 7kW).

Fleets are unlikely to adopt 20 plug-in vehicles without having trialed the vehicles with a smaller sample first. For fleets who have the ambition of eventually needing the full 150kW allowance, it might be worth requesting a new connection that is compatible with 150kW (i.e. having 150kW 3-phase cables installed) even if the Connection Agreement is initially increased by only 50kW. This has the potential to save money on civils work and cable installation cost (installing a 3-phase cable is roughly the same cost than installing a one-phase cable¹⁵). There is however a risk that the installed spare capacity is taken up by other customers.

Fleet operators considering adopting plug-in vehicles must engage with the local Distributor Operator (Western Power Distribution) to understand the costs (and associated risks) of upgrading strategies, as these will be site specific.

¹⁵ Indicative costs are £105/m for 150kW cable vs. £100/m for 50kW cable. These are indicative only, and can vary widely due to street works, points of connection location and working periods. Source: Western Power Distribution

High Voltage network

Sites connected to the High Voltage network (11kV) can be more easily upgraded, with no upper kW limits. A rough guide to connection is as follow¹⁶:

- For a load increase of under 250kW, no major reinforcement is expected
- For a load increase of 250 kW to 1MW (e.g. 20 buses charging simultaneously at 50kW), a substation upgrade might be necessary and a new 1MW substation costs c. £50,000
- For loads over 1MW, the upgrade costs would be considerably over £50,000 and very site specific

As for depots connected to the LV network, fleet operators are advised to consult with WPD regarding their specific capacity upgrade opportunities.

2.2.4 FUEL SOURCE AND EMISSIONS ACCOUNTING

Uptake of BEVs and PHEVs could achieve significant CO₂ reductions for Birmingham on the basis of tail-pipe emissions (see next section). However, to maximise the CO₂ reductions from plug-in vehicle uptake, in keeping with the Birmingham Carbon Roadmap¹⁷, the source of the electricity should also be considered. Green electricity can be “allocated” to end users, guaranteeing a low carbon supply: domestic and other small consumers can access green tariffs from their supplier, and large users can enter Power Purchase Agreements for renewable electricity, directly with the generator¹⁸.

Table 9 summarises the current renewable electricity supply in Birmingham. With a **total generation of around 1TWh, around 330,000 electric cars could be powered on clean electricity**¹⁹, a number well above the projected uptake of electric vehicles (detailed next). Furthermore, the production of renewable electricity is projected to increase, with wind and solar installations of a total of 156MW being under construction or under planning consideration as of July 2014²⁰.

Renewable electricity production in West Midlands in 2012²¹

Biomass co-firing	482 GWh
Landfill gas and sewage gas	441 GWh
Solar	76 GWh
Wind and hydro	7.5 GWh
Total	1,006 GWh
	c. 4% total use electricity used in W. Midlands

Table 9. Renewable electricity production in West Midlands in 2012

¹⁶ Based on conversations with WPD. This is provided as an indication; upgrade needs will be site dependent. The cost of HV cable installation is typically c. £150/m

¹⁷ Birmingham City Council established the Green Commission to identify environmental priorities for the city. The Green Commission developed the Carbon Roadmap, a strategy to make Birmingham a leading Green City and achieve 60% carbon reductions by 2050, compared to 1990 levels. Source: http://greencity.birmingham.gov.uk/wp-content/uploads/2013/11/Final-Carbon-Roadmap_Interactive_Spreads_LR.pdf

¹⁸ PPA still requires an electricity supplier to act as intermediary but the user effectively enters in a contract with a generator, benefitting from an identifiable supply source and potential price reductions

¹⁹ Approximation based on cars travelling 15,000km per year and using 0.2kWh/km

²⁰ Source : <https://restats.decc.gov.uk/cms/planning-database/>

²¹ Source: <https://restats.decc.gov.uk/cms/regional-renewable-statistics>

2.2.4 UPTAKE SCENARIO AND IMPACTS

UPTAKE SCENARIO

In order to provide an estimate of charging infrastructure need and quantify the electricity need (and corresponding emission savings), an indicative plug-in vehicle uptake scenario has been developed. The uptake scenario to 2035 is based on published sales projections²² and feedback from fleet operators, and takes into account the vehicle replacement rate.

In the short term, uptake will be supported by the OLEV package (£500 million over 2015-2019) and, from 2020, uptake will depend on the costs of plug-in vehicles becoming competitive – along with other market enablers, identified in **Figure 12**. Figures for cars and vans include privately owned passenger vehicles, as provision of public infrastructure should account for potential sharing with these segments.

Overall the number of plug-in vehicles in Birmingham could be in the order of 10,000 by 2020 (mostly cars) and 150,000 by the 2030s, still with a prominence of light vehicles (cars, taxis, vans).

²² Notably Element Energy, Pathways for high penetration of EVs, 2013 for light duty vehicles

Illustrative uptake of light duty plug-in electric vehicles (includes private cars)

		Short term	2020	Medium term	2025	Long term	2030/35
Vehicles	Fleet vehicles	Number of vehicles on the road [% of all vehicles registered in Birmingham]					
	Cars & small vans	100s	10-12,000 [1%] (Mix of BEVs and PHEVs)	60-70,000 [10%]	100-150,000 [20%]		
	Taxis HC	<20 (mostly BEV)	30-50 [2%]	50-100 [7%]	200-300 [15%]		
	Private Hire	<50 (mostly PHEV)	70-100 [2%]	400-500 [7%]	700-1,000 [15%]		
Infrastructure needs	Charging points for fleets		~60 rapid CPs 5-10 for taxis & depot/office charging 10-20 EVs per depot	100-150 rapid CPs 10-20 for taxis & depot/office charging Up to 30 EVs per depot	150-200 rapid CPs, including 20-30 for taxis & depot/office charging Up to 50 EVs per depot		
Triggers / enablers		<ul style="list-style-type: none"> Release of electric Hackney Carriage (HC) models Continued increase in choice of e-car and e-van models Funding for home and depot chargers Charging technologies allowing for item billing Fast/rapid charging in city centre for HCs 	<ul style="list-style-type: none"> Continued increase in model availability and increase in driving range Increase in charging stations along highways nationwide Fleets given ability to book/guarantee access to public or shared stations Local incentives for EVs 	<ul style="list-style-type: none"> Continued increase in model availability and in performance (driving range, charging rate) Possible city centre access policy that favours plug-in vehicles 			

Figure 12. Illustrative uptake of plug-in vehicles and infrastructure

Illustrative uptake of heavy duty plug-in electric vehicles

		Short term	2020	Medium term	2025	Long term	2030/35
Vehicles	Vans 2-8t GVW	Number of vehicles on the road [% of all vehicles registered in Birmingham]					
	>8t HGVs	<10	10s [$<1\%$] (Mix of BEVs and PHEVs)	10s [1%]	50-100 [2%]		
	Buses 12m and over	<10	10s [$<1\%$]	10s [$<1\%$]	50-100 [1%]		
Infrastructure needs	Charging points		2-3 depots with charge points 5-20 EVs per depot	3-5 depots with charge points 10-30 EVs per depot	5-10 depots with charge points 10-30 EVs per depot		
Triggers / enablers		<ul style="list-style-type: none"> Release of electric vans and trucks models Continued increase in e-bus model availability CP at depots for fleets, cost/opportunity site-specific 	<ul style="list-style-type: none"> Continued increase in model availability and increase in driving range Introduction of charging technologies allowing less disruption to bus refuelling, e.g. wireless CPs at depots for fleets, cost/opportunity site-specific; reinforcement of distribution network where required 	<ul style="list-style-type: none"> Continued increase in model availability and increase in driving range Possible city centre access policy that favours plug-in vehicles Commercial arrangements and hardware that allows for better management of electric load, allowing increased use of power for vehicles 			

IMPACTS

Table 10 presents the CO₂ reductions that could be achieved under the uptake scenario previously described. The adoption of plug-in vehicles in Birmingham could save over 150,000 tonnes of tailpipe CO₂/year by the 2030s, which is a reduction of 12% compared to a baseline case without alternative fuel vehicles. On a WTW (well-to-wheel) basis, CO₂ savings amount to over 190,000 tonnes/year²³.

Impacts of plug-in vehicle uptake

	2020	2025	2030/2035	Comments
Vehicles on road [%fleet of cars, vans, buses and small trucks]	13,250 [2%]	62,000 [9%]	127,700 [20%]	See appendix for detailed assumptions
km travelled (millions)	138	594	1,290	Based on annual mileage as per workshop data and DfT data
CO ₂ TTW emissions saved compared to diesel (tonnes)	20,500	76,700	155,600	Assumes 71gCO₂/MJ for diesel, 0 for electricity
CO ₂ WTW emissions saved compared to diesel (tonnes)	20,500 -24,000	83,700 -93,100	186,000 -190,000	Upper range: based on 0g/kWh (renewable electricity) Lower range: based on DECC projection for UK grid
GWh needed	20	72	138	Equates to 0.6% of total annual demand in the West Midlands

Table 10.
Impacts of plug-in vehicle uptake

Modelling outputs indicate that the annual electricity demand from an average plug-in fleet uptake of 128,000 vehicles²⁴ in 2035 is 138 GWh. This is lower than the current level of renewable generation in the West Midlands (c. 1,000 GWh), and represents an increase of 0.6% to the total electricity demand of the West Midlands (24,000 GWh) and an increase of c.3% to the electricity demand in Birmingham. However, this demand could create local supply constraints, especially in the case of depots of large fleets.

While DNOs and Ofgem are working in collaboration with suppliers on solutions to cost-efficiently accommodate the increased demands on the distribution network from domestic charging²⁵, there is less research on the case of depots requiring a significant new load. This lack of research is a reflection of the state of the nascent market for electric heavy vehicles²⁶. This means the feasibility and cost of accommodating large new loads (>150kW) is uncertain and local fleets will have to work closely with Western Power Distribution to assess their particular site.

²³ For detailed assumptions, please refer to the appendix

²⁴ Representing 20% uptake across cars, LCVs, buses and small trucks

²⁵ The Ofgem's Low Carbon Network Fund is supporting many DNO-led projects trialling technical solutions as well researching commercial arrangements that will help accommodate new loads, such as Demand Side Response

²⁶ This topic is however under study as part of the EC funded electric truck demonstration project FREVUE(Freight Electric Vehicle in Urban Europe), 2013-2018 <http://frevue.eu/>

2.3 RECOMMENDATIONS FOR DELIVERY

Charging infrastructure should be deployed in careful consideration of the needs of current and future fleet adopters. While the deployment of charging points in private garages and in depots are beyond the Council’s remit, the Council can all the same support a recharging infrastructure for fleets through the following actions:

<p>Support installation of public charge points</p>	<ul style="list-style-type: none"> • Include the developed guidance (regarding opportunity to share with private vehicle users, power rate choices, booking systems for fleets etc., detailed in 2.2) in procurement clauses for infrastructure commissioned by the Council, or in recommendation guidance for chargers installed by private landowners (e.g. retails, restaurants) • Set aside parking spaces for rapid CPs by popular taxi ranks (within ring road) and put in place an assessment of level of use to allow usage by other fleets, if the data reveals it is appropriate • Maximise the utility/usage level of charging posts by setting a booking system and siting posts where several fleets operate. A practical example of how to identify fleet operational zones and specific travel patterns is provided by Transport for London, which has commissioned a study using telematics to track LCV routes²⁷
<p>Encourage and contribute to the uptake of plug-in vehicles</p>	<ul style="list-style-type: none"> • Consider the adoption of EVs in the Council’s fleet • Consider the implementation of local incentives for EVs, which could be supported by the OLEV ‘flagship cities scheme’²⁸ • Advertise the available funding opportunities to fleet operators, e.g. grants for taxis to taxi operators through the Licensing team, and the Green Bus Fund to bus operators through Centro
<p>Support installation of domestic and depot/workplace charge points</p>	<ul style="list-style-type: none"> • Help address the knowledge gap in depot connection upgrade cost and process by making the Council’s own depot(s) a case study, in collaboration with WPD • Encourage the sharing of best practices, e.g. for the practicalities of installing chargers at employee homes, monitoring and reimbursement of electricity, connection process for in-depot CPs • Planning policy/guidance could require all parking spaces in new builds (and some retrofits) to be socket ready, e.g. as successfully implemented by Westminster borough in London
<p>Ensure consistency with the Carbon Roadmap by securing access to low-carbon electricity</p>	<ul style="list-style-type: none"> • While the analysis shows an abundant supply of renewable electricity at West Midlands level in terms of transport demand, electricity is set to decarbonise other sectors too (e.g. heat). As such, streamlining the planning permission process for new renewable generation would be beneficial

²⁷ <https://www.zap-map.com/electric-van-fleets-supported-tfl-rapid-charge-point-project/>

²⁸ OLEV announced in April 2014 a £35 million cities scheme to support up to 4 flagship cities in introducing innovative local incentives, such as free parking, access to bus lanes and ULEV car clubs.

HYDROGEN VEHICLES

Hydrogen transport is currently supported at a European level, through funding for research and demonstration projects that support the commercialisation of vehicles and refuelling infrastructure



3

HYDROGEN VEHICLES

3.1 VEHICLE ROADMAP

3.1.1 OVERVIEW

Hydrogen transport is currently supported at a European level, through funding for research and demonstration projects that support the commercialisation of vehicles and refuelling infrastructure. UK stakeholders across industry, government and academia have been involved in such projects for over 10 years. At a national level, an £11m support package for hydrogen infrastructure and public sector vehicles was announced in Autumn 2014²⁹.

Uptake of hydrogen vehicles over the next 20 years will depend on the maturation of the vehicle market, which is at currently at the early stage of commercial deployment. Hydrogen vehicles are available in three configurations, as indicated in **Figure 13**.

	ICE (conversions)	Fuel cell range extended EV (conversion)	Fuel cell electric vehicles
Fuel (hydrogen typically dispensed at 350 or 700 bar)	Hydrogen and diesel (energy split 80:20)	Battery+fuel cell and small hydrogen tank	Hydrogen
Tailpipe emissions	Euro 6 compliant	Zero	Zero
Current vehicle segments	Vans	Vans	Cars, buses

FC: Fuel Cell **FC-REEV:** FC Range Extended Electric Vehicle

Figure 13. Available configurations of hydrogen

Hydrogen ICE van conversions have been available since 2009, but deployment has been limited to trials of about 20 vehicles. They have a low efficiency compared to FCEVs, and are often considered a ‘transition’ model, likely to be used mainly in niche applications before the development of a national H2 refuelling infrastructure and lower cost fuel cell powertrains.

The FCEV market is expected to expand to become the most widely used option for hydrogen vehicles, due to the efficiency and emissions benefits. However, fuel cell production is currently expensive and FC-REEVs, by using a smaller fuel cell and 350bar tanks, currently offer a capital cost benefit over FCEVs. FC-REEVs are currently available as converted versions of existing BEVs.

²⁹ <https://www.gov.uk/government/news/multi-million-pound-fund-to-get-hydrogen-cars-moving>

As indicated in **Figure 14**, the first vehicles to become widely available will be cars and LCVs, with several OEMs bringing fuel cell cars to the UK market in 2014-2017. In addition, small numbers of buses are currently being trialled in London and Aberdeen.

There is currently no availability for hydrogen HGVs, but some OEMs are developing FCEV models. In 2013, E-trucks Europe fitted an electric truck in Belgium with a fuel cell range extender. Long term prospects for HGVs over 18t GVW are uncertain, as the space required for fuel cells and hydrogen tanks may not be compatible with the payload needs of delivery and logistics vehicles.

Availability and market projections of hydrogen vehicles

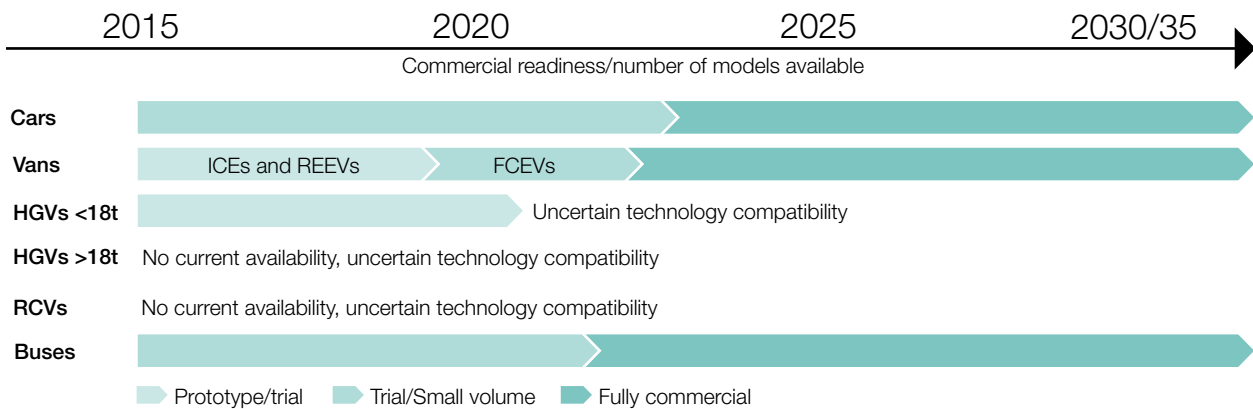


Figure 14. Availability and market projections of hydrogen vehicles³⁰

CURRENT INFRASTRUCTURE IN BIRMINGHAM

There are currently no public hydrogen stations in Birmingham, although the University of Birmingham has a small facility which has been used to refuel a number of hydrogen cars, owned by the University.

National infrastructure for hydrogen vehicles currently consists of c.15 stations, with 4 located in or close to London.

UK H₂Mobility, a consortium of stakeholders across the hydrogen transport sector that includes representatives from DfT, BIS and DECC, has published a report recommending the roll-out of around 60 new stations by 2020. The analysis, based on consumer research, found this number would initiate the hydrogen vehicle market, by enabling uptake in a number of cities in the UK, and provide a basic national driving infrastructure³¹.

London is likely to be the preferred zone for initial development of the UK hydrogen market, following a number of demonstration stations in the city and various trials with

³⁰ Based on announced OEM roadmaps, technology compatibility considerations and policy support in place
³¹ UK H₂Mobility, Phase 1 report, 2013; available at <http://www.ukh2mobility.co.uk/wp-content/uploads/2013/08/UKH2-Mobility-Phase-1-Results-April-2013.pdf>

buses and taxis, with Birmingham to be included in a number of potential cities that may see one or two public stations on this timescale.

3.1.2 TAXIS AND LIGHT COMMERCIAL VEHICLES FLEETS

VEHICLE AVAILABILITY

Small numbers of hydrogen cars and vans have been deployed in the UK through various demonstration projects. **Table 11** provides a list of the options available currently, and over the next year. As well as the options in **Table 11**, Honda is planning to release a model for the general public by 2015³². For the two FCEVs, availability will be limited over at least the next year, with vehicles being brought to the UK in small volumes.





It is unclear as yet whether these models will be adaptable for wheelchair access (and thus compatible with Hackney Carriage operations) but vehicle specifications indicate that all four options could potentially replace equivalent vehicles within private hire vehicle or LCV fleet applications. A few HC style FCEVs have been trialled in London, as part of the HYTEC project (Hydrogen Transport in European Cities). However, the technology

provider (Intelligent Energy) has not yet announced the launch date for a commercial version.

Future uptake of these vehicles will depend on continuing improvements in costs and infrastructure availability.

Table 11.
Availability of hydrogen cars and vans

Availability of hydrogen cars and vans

Vehicle	Description	Date available (UK)
Hyundai ix35 SUV 	Fuel cell vehicle Range: ~500km Refueling: 700bar	Currently available in limited numbers as 4 year lease (left hand drive only)
Toyota Mirai 	Fuel cell vehicle Range: ~700km Refueling: 700bar	2015-2016
Symbio FCell HyKangoo - converted Renault Kangoo ZE 	Fuel cell vehicle Range: ~300km Refueling: 350bar	Right hand drive version to be launched in 2015 (currently deployed in France)
ULEMCo - converted Ford Transit 	Fuel cell vehicle Hydrogen range: ~200km Refueling: 350bar	Currently available

³² http://www.thecarconnection.com/news/1091099_honda-toyota-will-launch-hydrogen-fuel-cell-vehicles-by-2015-but-they-wont-be-cheap

COSTS AND FUNDING

Currently, costs for fuel cell vehicles on release are around £40,000-50,000, which is representative of the low production volumes; these figures will decline as demand increases and are expected to drop to between £15,000 and £20,000 by the 2020s³³.

In line with the support package currently in place for plug-in vehicles, it is expected that OLEV will provide some support for hydrogen mobility, which could be support for FCEV purchase or/and for refuelling infrastructure.

Fuel costs are still uncertain, but are expected to be equivalent or lower than diesel costs. It is possible that vehicle manufacturers will offer vehicle and fuel purchase/lease packages in the early stages of uptake, to provide certainty for users while the H₂ market develops.

FLEET COMPATIBILITY AND INFRASTRUCTURE NEEDS

The fleet operators interviewed did not express strong positive or negative views on the adoption of hydrogen vehicles, and in general, awareness of the technology was considerably lower than for plug-in or gas vehicles.

Due to the costs and limited availability of vehicles, fleet uptake of H₂ taxis and LCVs in the immediate future is likely to be limited to vehicle placement within demonstration projects. As the market matures, increased uptake will depend on reduced costs and crucially, on the potential for savings on a total cost of ownership basis. Taxi drivers in particular indicated that they would not consider buying a H₂ vehicle unless they would see cost savings within a few years of purchase. Some LCV fleets, e.g. those with corporate CO₂ reduction targets, would consider vehicle uptake without seeing significant cost savings, but in all cases there was a limited willingness to pay for emissions savings alone.

Taxi operators and most LCV fleets indicated that a minimum of three public hydrogen stations in Birmingham would be required for even a very low level of uptake, with stations ideally sited at or close to existing forecourts, and distributed in the centre, North and South of the city, to avoid the need to cross the city centre in order to refuel. For wider uptake, users of public infrastructure would require a HRS network that is comparable to existing forecourts in terms of density and distribution.

For depot-based fleets, the preference was for dedicated refuelling facilities, but operators were open to the idea of sharing facilities with other fleets with compatible refuelling times and locations. For example, one option suggested was a refuelling facility within a shared distribution centre.

³³ Based on figure of 10 million Yen, quoted in March 2014. http://www.thecarconnection.com/news/1091099_honda-toyota-will-launch-hydrogen-fuel-cell-vehicles-by-2015-but-they-wont-be-cheap. Conversion factor used: 0.0056 GBP to 1 Yen. European pricing has not yet been announced

3.1.3 LIGHT TRUCKS

While there is no current availability for hydrogen HGVs, several OEMs are planning to develop demonstration vehicles (e.g. Renault, Nissan), and models may become available over the next 20 years. Uptake of these vehicles may come from, e.g. urban delivery fleets that are looking to reduce emissions and require a longer driving range than that offered by BEV trucks. Motivation for uptake may also come from a European level: the EC Transport 2050 Strategy calls for zero tailpipe emissions in cities for urban deliveries from 2030 in order to improve air quality in cities.

HGV fleets typically refuel at depots, but vehicle availability (and therefore demand) for FCEV trucks is likely to be low in the timescale of this project and it is unlikely that the economics of in-depot hydrogen refuelling will be viable. It is therefore more likely that these vehicles will refuel at either public or shared-access refuelling stations.

3.1.4 BUSES

VEHICLE AVAILABILITY

A number of bus manufacturers are currently developing single decker fuel cell buses in both 12m and articulated 18m configurations, and buses from WrightBus and Van Hool are currently being trialled in London and Aberdeen as part of European-funded projects. New models from a range of manufacturers (e.g. Daimler) are due to become available in the next five years, but at this stage procurement is on a project by project basis rather than through sales of a standard vehicle.

Hydrogen buses in the UK as of October 2014

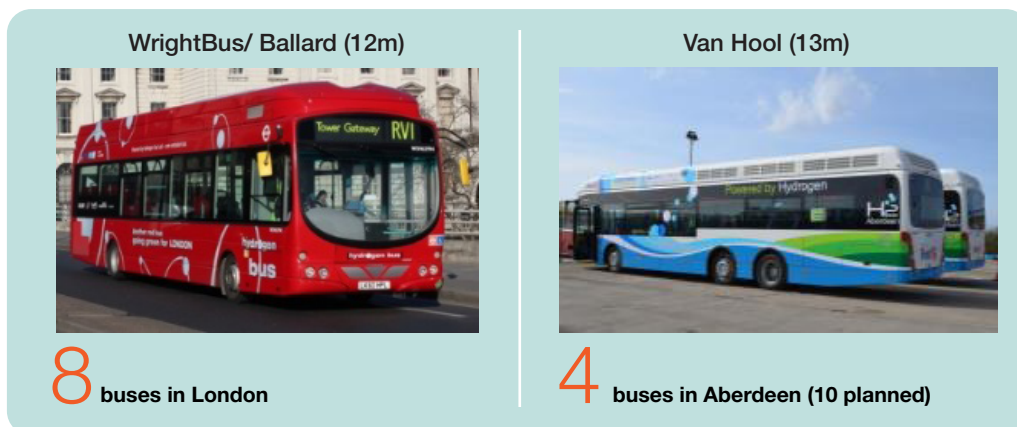


Table 12. Hydrogen buses in the UK as of October 2014

COSTS AND FUNDING

Vehicle costs are currently very high (>£700,000 vs. c. £150,000 for a diesel bus³⁴) and to date, deployment has been supported by European funds. However, the next stage

³⁴ Element Energy, Hydrogen Fuel Cell Bus Technology State of the Art Review, 2010

of bus trials is likely to involve large scale procurement, with involvement from multiple cities across Europe, which could bring costs down to around £500,000 per vehicle. Bus operators will still require support from other public sources to meet these costs, but the lessons learnt from such wide scale deployment could significantly accelerate the commercialisation of H₂ buses.

FLEET COMPATIBILITY AND INFRASTRUCTURE NEEDS

As with LCV fleets, bus deployment in the near term will be limited to demonstration projects, and infrastructure will be installed as required for these projects. The two large bus operators in Birmingham (National Express and Arriva) usually use dedicated in-depot refuelling facilities, and in the long term this is likely to be the case for hydrogen buses. To increase station loading and improve the economics in the short term, operators may open their facilities to other compatible vehicles, or consider the use of a shared-access refuelling station in the context of a small deployment/trial. Smaller operators may use shared access facilities, but are less likely to adopt hydrogen buses, due to lower capacity to absorb the additional costs.

3.2 HYDROGEN REFUELLING INFRASTRUCTURE PLAN

3.2.1 TECHNOLOGY OPTIONS

Currently, hydrogen vehicles on the market vary in their refuelling specifications: some vehicle segments must refuel at 35MPa, whereas others refuel at 70MPa. Some existing hydrogen refuelling stations (HRS) have the capacity to dispense hydrogen at both pressures, but for stations designed for fleet refuelling, the business case for a station is more viable if the dispensing pressure is tailored to the needs of the specific fleet. **Table 13** summarises the appropriate station refuelling options for various vehicle segments and site choices.

For example, depot-based stations solely dedicated to back to base fleet vehicles could opt for dedicated low pressure stations to minimise costs. 35MPa is currently the standard refuelling pressure for FC buses (and trucks in the future), as well as RE-FCEVs.

Any stations designed for car/van fleets not refuelling in depots should consider the opportunity to support the private FC car market, for which the emerging standard is 70MPa. Being open to both fleet and private vehicles will also improve the usage level of the station and hence the economics for the provider.

Like private drivers, FC taxis will require a refuelling time comparable to diesel cars, and as such will refuel at 70MPa. Refuelling station siting for taxi fleets therefore offers the best opportunity for provision of a 70MPa station that would also support the uptake of private FC cars.

Matching vehicle segment and station siting to refuelling pressure

Vehicle type \ Station type	35MPa	35MPa + 70MPa compatible	70MPa	Dual pressure 35/70 MPa
FC buses	Shaded	Shaded	Shaded	Shaded
RE-FCEVs (cars, vans, trucks)	Shaded	Shaded	Shaded	Shaded
FC cars & taxis	Shaded	Refills only to 60%	Shaded	Shaded
FC vans	No example on market yet	Shaded	No example on market yet	Shaded
FC trucks	Shaded	Shaded	Shaded	Shaded
HRS site	Industrial zone/ area not attractive to private drivers; Depot of 35MPa vehicles	Area attractive to both fleet and private drivers/taxis, with demand initiated by 35MPa users	Site attractive only for private drivers/taxis	Site attractive to both fleet and private drivers/taxis

■ Indicates HRS can be used

Table 13. Matching vehicle segment and station siting to refuelling pressure

3.2.2 PRIORITY ZONES FOR SITING

PUBLIC HYDROGEN STATIONS

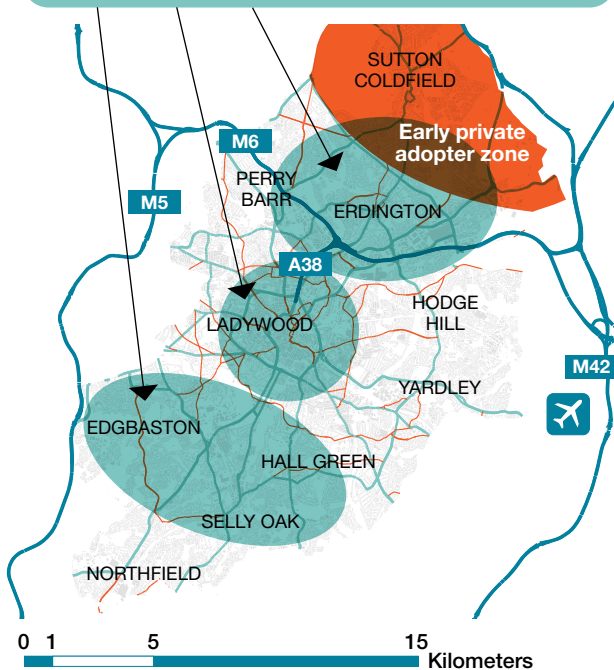
According to feedback from fleet operators, initial uptake by taxi and LCV fleets will depend on a minimum level of public infrastructure. Figure 15 shows the illustrative minimum zones identified and some criteria for siting.

It is likely that the initial roll-out of hydrogen vehicles and infrastructure will be strongly linked in the first stages of market development, with a significant proportion of uptake from fleets. It follows that the first public HRS are likely to be small (<100kg/day capacity³⁵) and based on containerised solutions since the number of vehicles refuelling will be too small to make a large station profitable. Over time, the size of new hydrogen stations will increase, along with integration of HRS with existing forecourts as regulatory standards and planning guidance are finalised (see Section 3.2.3 – Planning and safety requirements).

³⁵ As an indication, 100kg would be enough to refuel 20 FCEV passenger cars at 5kg each

Illustrative zones for initial deployment of public HRS

Fleet operators think at least 1 public hydrogen station in each of these zones will be required for adoption of hydrogen light duty vehicles (taxis, fleet cars & vans)



SITING CRITERIA

- Key is to avoid crossing the city to refuel; i.e. minimum of three stations: North, South and city centre
- Close to main roads/strategic corridors
- Away from heavily congested areas
- Siting of public stations should also consider locations of private early adopters of FCEVs to maximise station loading; Loughborough University study of early adopter demographics in Birmingham1 suggests Northern wards (orange zone)

DEDICATED REFUELLING FOR BACK TO BASE FLEETS

For fleet-dedicated HRS, the station capacity can be tailored to the demand relatively easily to achieve high loading levels and bring down the average cost of refuelling. Shared access stations used by several fleets could be a solution to optimise HRS business models, particularly for LCV and (potentially) HGV fleets. For these fleets, HRS siting will be based on operational zones for compatible fleets, with easy access from fleet routes and/or depots.

Hydrogen bus fleets may generate sufficient demand to justify dedicated refuelling facilities, depending on the scale of trials, and are less likely to use shared-access sites. Some operators may consider opening their refuelling facilities to third parties. In either case, HRS for buses will be located within appropriately sized depots, or very nearby.

Figure 15. Illustrative zones for initial deployment of public HRS

3.2.3 SITING OPPORTUNITIES FOR HYDROGEN REFUELLING STATIONS

To maximise demand for individual HRS, and optimise the economics, siting for the first public hydrogen stations should account for locations of private early adopters of FCEVs, as identified in **Figure 15**. Illustrative zones for initial deployment of public HRS Research at the University of Loughborough³⁶ identified the Northern wards as the most likely area for adoption of alternative vehicles (according to factors including levels of car ownership, age and socio-economic status), and the arterial roads connecting this area to the city centre (A453 and A5127) were identified as potential zones for HRS, due to their use for commuting purposes and access to motorways. This zone is shown in the first map of **Figure 16**.

The city centre is another potential zone for initial HRS deployment, given that it is an air quality hotspot and a region of high traffic flow. Alongside the North and South of the city, this is one of the minimum zones for HRS deployment, and the density of stations should gradually increase in these zones to support uptake of LCVs over the next 20 years.

³⁵ Campbell et al. (2012) *Identifying the early adopters of alternative fuel vehicles: A case study of Birmingham, United Kingdom*

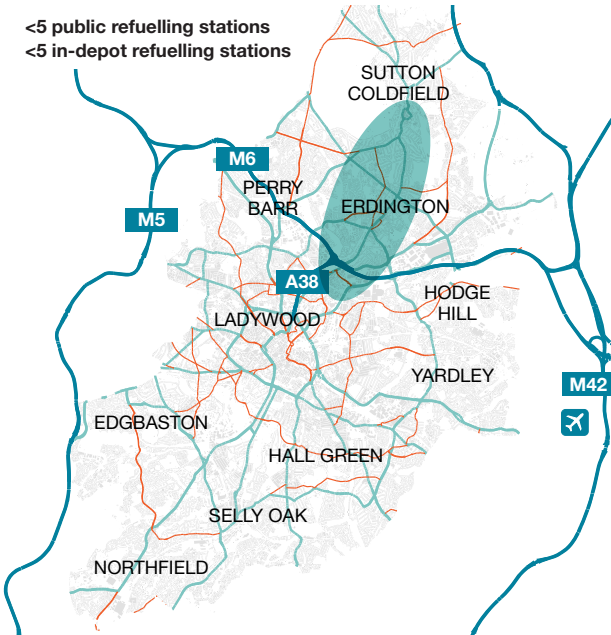
Siting opportunities for HRS up to 2035

Figure 16.
Siting opportunities
for HRS up to 2035

1 Short term (2015-2020)

Illustrative - locations will be demand driven

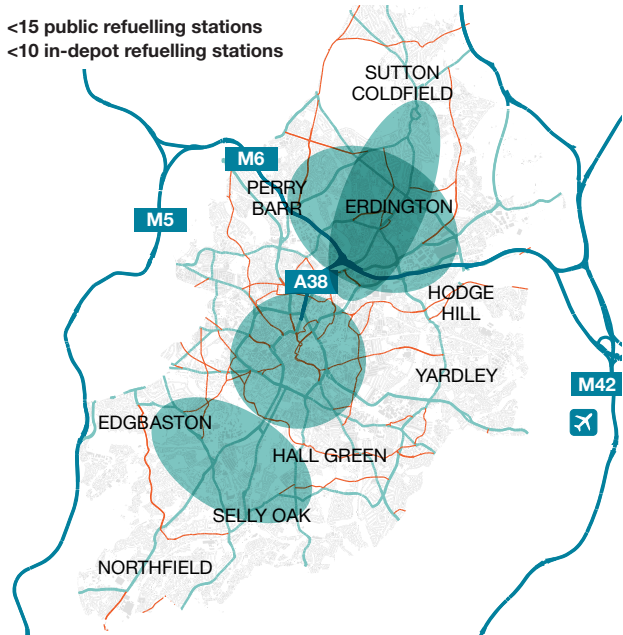
<5 public refuelling stations
<5 in-depot refuelling stations



2 Medium term (2020-2025)

Illustrative - locations will be demand driven

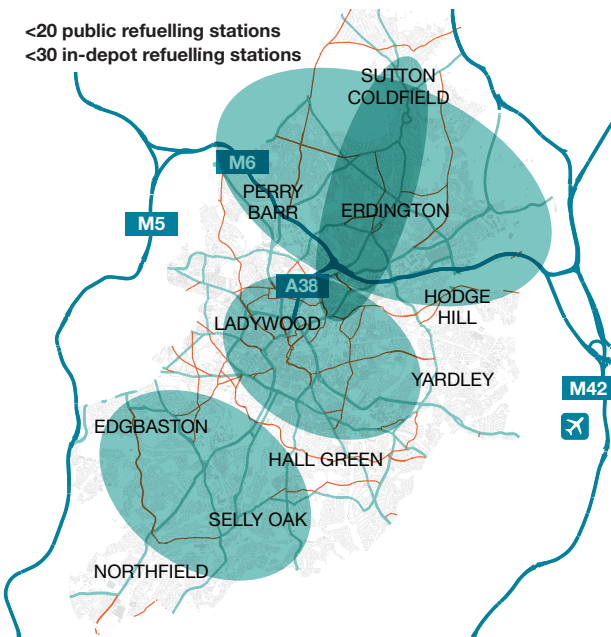
<15 public refuelling stations
<10 in-depot refuelling stations



3 Long term (2025-2035)

Illustrative - locations will be demand driven

<20 public refuelling stations
<30 in-depot refuelling stations



0 1 5 15 Kilometers

1

- Initial sites for public refuelling in private early adopter areas
- Supporting low level adoption by e.g. taxis and LCV fleets

2

- Development of three zones of public HRS (at least 1 station each) + motorway sites
- A few depot or shared fleet HRS

3

- Increased station density (public and depot/shared access)
- Network extends outside of "minimum zones"

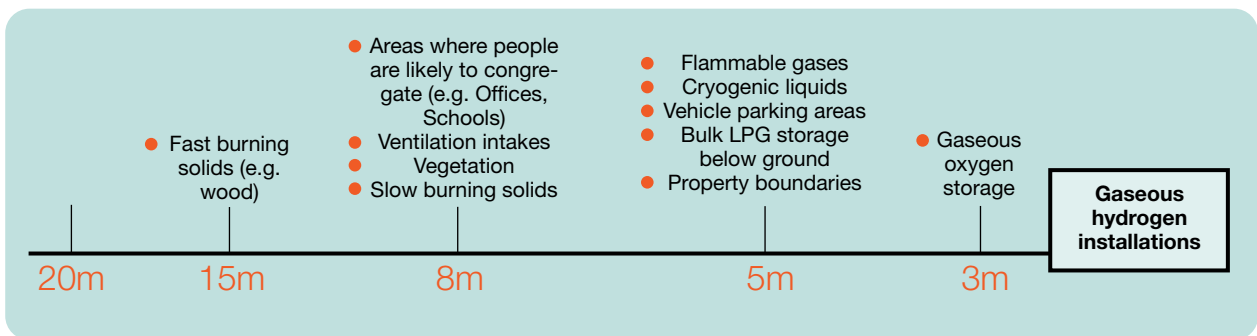
Legend

- Motorway
- A-Road
- B-Road
- Public HRS priority deployment zones

PLANNING AND SAFETY REQUIREMENTS

National regulations for hydrogen fuel storage are currently being developed, but currently the only safety guidelines for HRS siting come from industry best practices such as these safety distances.

Industry best practice: Minimum safety distances



Planning bodies tend to adopt highly conservative attitude to separation distances in the absence of formal guidance (of the type that exists for conventional forecourts), which can lengthen the planning process for station operators. In addition, the scarcity and cost of land in populated areas can create challenges in identifying suitable sites in convenient locations for HRS deployment.

Figure 17. Industry best practices: minimum safety distances (Air Products)

The effect of these combined factors is that site identification and the planning process can cause significant delays to station installation. Standardised guidance, once released, should help to alleviate some of the planning process uncertainties, but it is likely that raising awareness of hydrogen transport and the associated technologies, within the council and planning organisations, will be necessary to minimise future obstacles in planning and siting.

3.2.4 FUEL SOURCE AND EMISSIONS ACCOUNTING

Although hydrogen vehicles have zero tail-pipe emissions, production of hydrogen can produce different levels of emissions depending on the energy source. Total hydrogen production in the UK is around 200kt per year, which would be sufficient to fuel about 1.5 million cars, and therefore vehicle uptake in Birmingham is unlikely to be constrained by hydrogen supply. However, the main UK production route is currently steam methane reformation (SMR), which produces CO₂, and most hydrogen used in transport is currently imported (and produced from SMR or a by-product from chemical industry). Reformation of biomethane offers a lower emission pathway, but scope is limited due to the low availability of biomethane and competition with its direct use in gas vehicles and other energy applications.

Water electrolysis, which produces hydrogen from splitting water molecules, is likely to be a significant source of hydrogen for transport in the future. Advantages include the

possibility of using locally produced renewable electricity, and the option of onsite production, eliminating the need to transport hydrogen. From end 2014/early 2015, the buses in Aberdeen will be run on hydrogen produced on-site by an electrolyser run on renewable electricity³⁷.

The renewable energy production capacity for the West Midlands has been assessed in regard to the potential demand from plug-in vehicles (see Section 2.2.5), and given that the potential uptake of hydrogen vehicles will be significantly lower than this in the 2035 horizon (reflecting the relative maturity of the two markets) it is unlikely that the renewable electricity supply for electrolysis will be constrained.

Economics are currently the main barrier to electrolysis. Equipment costs and electricity tariffs are high relative to equivalent costs for steam reformed hydrogen, and the business case for electrolyser hydrogen for transport has yet to be proven. Some key information on economics and practicalities is presented in **Table 14**.

ELECTROLYSER ECONOMICS

- Capital investment ~£1m for a 100kg/day station (i.e. enough for 20 vehicles refuelling with 5kg, which corresponds to c. 500km driving range on a car)
- Hydrogen production costs are driven by the electricity tariff and load factor
- Potential for provision of grid services, such as frequency regulation and Short Term Operating Reserve

Table 14.
Electrolyser
economics³⁸

Hydrogen can be stored and as such, electrolysers are inherently much more flexible than charging points in terms of their demand on the grid, and can be switched on or off in accordance with peak demand. As such, electrolyser economics could be improved through access to the demand response market, and revenues for grid services. As well as providing additional revenues to electrolyser operators, this could help to reduce the negative grid impacts of increased intermittent renewable electricity production.

For most fleet operators, general awareness of hydrogen vehicles was low therefore there were no clear preferences for different hydrogen production method and consideration of onsite production of hydrogen was at best hypothetical. Some operators indicated that they would be open to the inclusion of onsite electrolysis in the long term, and those with strong carbon reduction targets in particular were keen to see this as a future option. However, it should be noted that on-site electrolysis will place further constraints on HRS siting as the total footprint of the station is increased³⁹.

³⁷ <http://aberdeeninvestiveisit.co.uk; http://press.edf.com/press-releases/all-press-releases/2012/edf-energy-awarded-contract-to-supply-scotlandys-public-sector-90890.html>

³⁸ E4Tech and Element Energy, Development of Water Electrolysis in the European Union, 2014

³⁹ Space footprint varies with technology and capacity (c. 30m² for 120kg/day capacity, excluding storage and compressors). Furthermore a connection to the high voltage network might be necessary for large installations for technical reasons or to access lower electricity prices

3.2.5 UPTAKE SCENARIO AND IMPACTS

UPTAKE SCENARIO

Figure 18 presents a roadmap for deployment of hydrogen fleet vehicles up to 2035, and provides indicative numbers for the corresponding infrastructure demand. Overall the number of hydrogen vehicles in Birmingham could reach 1,000 in the 2020s and grow to 20,000 by the 2030s. This level of uptake would require 5 to 10 public hydrogen refuelling stations (HRS), and 10 to 15 smaller depot based HRS for buses and light trucks. This uptake scenario, which will be strongly dependent on the realisation of numerous enabling factors and trigger points, is based on published data for cars and vans⁴⁰, and projections from fleet operators' inputs for heavy duty vehicles.

Figure 18. Illustrative uptake of hydrogen vehicles and infrastructure

Illustrative uptake of hydrogen vehicles and infrastructure

		Short term	2020	Medium term	2025	Long term	2030/35
Vehicles	Fleet vehicles	Number of vehicles on the road [% of all vehicles registered in Birmingham]					
	Cars & small vans	0	10s [$<0.1\%$] Mix of ICE and FCEVs	1,000 - 3,000 [0.5%] RE-FCEVs and FCEVs		20,000 - 25,000 [3%] Mainly FCEVs	
	Taxis HC/Private hire	0	10s [$<1\%$] Higher uptake among PHVs as most HC duty cycles compatible with driving range of BEVs	100 - 150 [2%]		600 - 800 [10%]	
	HGVs/Vans 2-8t GVW	0	20 - 50 [2%]	100 - 200 [5%]		100 - 500 [15%]	
	>8t	0	demo/trial	10 - 20 [$<1\%$]		30 - 50 [5%]	
Buses 12m & over	demo/trial	10s [$<1\%$]	50 - 100 [1%]		200 - 300 [5%]		
Infrastructure needs	H ₂ refuelling		1 public HRS (<50 kg/day) 1-2 in-depot HRS (<50 kg/day)	3-5 public HRS (100-200 kg/day) 5-10 in-depot HRS (<50 kg/day)		5-10 public HRS (<1,000 kg/day) 10-15 in-depot HRS (50-200 kg/day)	
Triggers / enablers			<ul style="list-style-type: none"> Release of FCEV vans and trucks, greater availability and reduced cost of cars and buses Funding and grants for H₂ vehicles and stations Planning process for H₂ stations streamlined / safety standards for HRS finalised Dispensing practicalities settled (Quality Assurance, measurement accuracy) 	<ul style="list-style-type: none"> Increased model availability and higher production volumes leading to lower vehicle capital costs Expansion of the nationwide infrastructure Hydrogen market maturing: e.g. electrolyzers offering storage and grid balancing services 		<ul style="list-style-type: none"> Increased model availability, with more vehicles at mass production reaching TCO parity with diesel vehicles National infrastructure providing GB coverage Possible city centre access policy that favours zero-emission vehicles 	

⁴⁰ UK H₂Mobility, Phase 1 report, 2013

IMPACTS

Table 15 presents the CO₂ reductions that could be achieved under the uptake scenario presented in **Figure 18**. The adoption of hydrogen vehicles in Birmingham could save over 39,000 tonnes of tailpipe CO₂/year by the 2030s. On a WTW basis, CO₂ savings could amount to around 50,000 tonnes/year⁴¹.

Impacts of hydrogen vehicle uptake

	2020	2025	2030/35	Comments
Vehicles on road [% fleet of cars, LCVs and buses]	140 [$<0.5\%$]	3,500 [0.5%]	21,000 [3%]	See Appendix for detailed assumptions
km travelled (millions)	4	44	256	Based on annual mileage as per workshop data
CO ₂ TTW emissions saved compared to diesel (tonnes)	700	7,500	39,500	Assumes 71gCO₂/MJ for diesel, 0 for FCEVs
CO ₂ WTW emissions saved compared to diesel (tonnes)	500-800	7,000-9,000	46,000-48,000	Upper range: based on 0g/kWh (renewable electricity) Lower range: based on DECC projection for UK grid 87g/CO₂/MJ for diesel
H ₂ needed (tonnes) [GWh]	28 [1]	310 [10]	1,600 [53]	
Electricity demand if all produced from electrolyser (GWh) [plus demand from plug-in vehicles]	1.4 [21]	15 [87]	76 [214]	Assumes electrolyser efficiency 65% in 2020 - 70% in 2035 (FCHJU study, 2014) Equates to <1% of demand in West Midlands

Assuming that by the 2030s, 100% of hydrogen will be produced by electrolysis, the annual electricity demand from an average fleet uptake of 3% (across cars, vans, taxis and buses, including private vehicles) is 76 GWh. Even when added to the demand from a 20% uptake of plug-in vehicles (see Table 10 in Section 2.2.5) this is lower than the current level of renewable generation in the West Midlands (c. 1,000 GWh), and represents a negligible increase to the total electricity demand of the West Midlands (24,000 GWh). In addition, electrolysers have the potential to be part of Active Network Management systems, in order to minimise the supply constraints on the local grid.

Table 15. Impacts of hydrogen vehicle uptake

⁴¹ For detailed assumptions, please refer to the appendix

3.3 RECOMMENDATIONS FOR DELIVERY

Funding for HRS is expected to come from an EU level (e.g. through the Fuel Cell Hydrogen Joint Undertaking) and a national level (OLEV funding to be announced in Autumn 2014). Birmingham City Council can support the deployment of hydrogen vehicles and stations through the following actions:

<p>Support the development and installation of an hydrogen refuelling infrastructure</p>	<ul style="list-style-type: none"> • Engage with Government to develop a streamlined planning permission process, for both public and depot-based HRS • Assess available public land for compatibility with HRS; suitable sites could be earmarked to facilitate siting and planning processes • Participate in consortia for hydrogen transport projects, showing the city’s commitment when applying for funding, and providing practical assistance where appropriate (e.g. land search for siting) • Engage with UKH₂Mobility coalition⁴² to highlight Birmingham as a potential early deployment city for hydrogen, and ensure consistency with identified customer needs • Engage with other regions to ensure that a linked “hydrogen highway” is created
<p>Ensure the hydrogen infrastructure meets customer needs</p>	<ul style="list-style-type: none"> • The Council, e.g. through planning policy or guidance, should encourage HRS to follow the guidance developed in this study (section 3.2), namely: <ul style="list-style-type: none"> o to be semi or fully publically accessible to encourage sharing of fleet and private vehicles, where justified by siting and refuelling compatibility o to be sited on strategic corridors and in zones identified by fleet operators o to follow industry standards and best practices for specifications such as nozzle type, refuelling time, fuel quality and station design
<p>Encourage and contribute to the uptake of hydrogen vehicles</p>	<ul style="list-style-type: none"> • Contribute to the FCEVs uptake (and loading of HRS) by considering H₂ vehicles in the procurement of the Council fleet • Consider the implementation of local incentives for FCEVs, which could be supported by the OLEV ‘flagship cities scheme’⁴³ • Advertise the available EU and national funding opportunities to fleet operators and other stakeholders • Support interested parties by introducing them to potential partners for joint funding applications, and providing political support and buy-in to funding applications
<p>Ensure consistency with the Carbon Roadmap by securing access to low-carbon electricity</p>	<ul style="list-style-type: none"> • While the H₂ used in transport might initially be imported, in the longer term, use/production of green H₂ must be encouraged and supported: <ul style="list-style-type: none"> o Study the planning process for on-site production by sharing of best practice with other councils, in order to offer a streamlined process when on-site production is proposed. o Investigate options for grid balancing services by engaging with electrolyser providers, WPD and aggregators o Engage with electricity suppliers to identify alternative options for low-cost grid-connected electricity supply

⁴² UK H₂ Mobility is a consortium of industry and government stakeholders across the hydrogen transport sector - <http://www.ukh2mobility.co.uk/>
⁴³ OLEV announced in April 2014 a £35 million cities scheme to support up to 4 flagship cities in introducing innovative local incentives, such as free parking, access to bus lanes and ULEV car clubs.

GAS VEHICLES

The natural gas vehicle market has grown strongly in Europe over the last 10 years, with a total fleet of over a million vehicles in 2014



4

GAS VEHICLES

4.1 VEHICLE ROADMAP

4.1.1 OVERVIEW

The **natural gas vehicle** market has grown strongly in Europe over the last 10 years, with a total fleet of over a million vehicles in 2014⁴⁴. Gas vehicle deployment is more limited in the UK (c. 100 buses, under 1,000 trucks as of 2014), but numbers are expected to grow, with a range of policy measures now in place to support the development of infrastructure and vehicle uptake. These measures are outlined in **Table 16**.

MEASURES TO SUPPORT DEVELOPMENT OF THE GAS VEHICLE MARKET

- Fuel duty differential: announced in December 2013, to be maintained to 2024 (25p/kg for gas; 58p/l for diesel, translating into a difference of 12p/km⁴⁵)
- Additional fuel rebate for biomethane buses; buses receive the rebate through the Bus Service Operators Grant (BSOG) for the proportion of km travelled using biomethane (minimum 50%)
- £4m OLEV fund to support infrastructure for gas HGVs
- Low Carbon Truck trial: £11.3m from OLEV and TSB to support vehicle procurement and infrastructure. This will include the installation of 17 new gas stations

Table 16.
Policy support for
gas vehicles

The market for **LPG vehicles**⁴⁶ is larger, with over 10 million vehicles in Europe and an estimated 150,000 in the UK, but limited to cars and vans⁴⁷. LPG vehicles benefit from a reduced fuel duty rate, as well as small reduction in Vehicle Excise Duty (£10).

Gas vehicles are currently available in three different configurations, which can use either gaseous or liquid methane. Dual fuel vehicles use a mix of gas and diesel burnt together in a diesel engine. Bi-fuel vehicles (typically cars and small vans) have a spark-ignition engine and can use either natural gas or petrol. For buses and refuse trucks, there is a spark ignition engine that only runs on natural gas, with no petrol back up, these are known as dedicated gas vehicles. Currently, most vehicles available in the UK are either dual fuel converted vehicles or dedicated gas vehicles, with some availability of bi-fuel vans. As described in **Figure 19**, the carbon and air quality benefits vary across different vehicle types, with the greatest benefits available from dedicated gas vehicles. It should be noted that while NO₂ and particulate matter emissions are reduced in gas vehicles,

⁴⁴ With Italy, Germany and Sweden as the lead markets. <http://www.ngvaeurope.eu/european-ngv-statistics>

⁴⁵ Based on fuel consumption figures for HGVs



⁴⁶ Liquefied Petroleum Gas is mostly composed of propane and butane; it is a by-product of oil refining or natural gas production process. Natural gas is mostly made of methane

⁴⁷ <http://www.aegpl.eu/> and UKLPG

the hydrocarbon emissions may increase if there is not a methane catalyst fitted. However, hydrocarbons are not part of the key pollutants for which a link between emission and health impacts has been made⁴⁸.

Biomethane can be used as an alternative to natural gas (methane), bringing higher emission savings on a Well to Wheel basis.

Typical characteristics of gas vehicles

	Dedicated	Dual fuel	Bi-fuel
Fuel [Storage – gaseous: 200 bar; liquid: -170°C, <10 bar]	Gas only (gaseous or liquid)	Mix of diesel and gas (gaseous or liquid)	Switchable petrol and gas
Typical tailpipe CO₂ emissions reductions compared to diesel vehicles	c. 10% reduction	Up to 10% reduction (varies with mix ratio)	<5% reduction
Typical impact on air quality compared to diesel vehicles HCs: hydrocarbons	PM ₁₀ : -90% NO _x : -60% CO: -80% HCs: increase	PM ₁₀ : -40% to -50% NO _x : -30% to -40% CO: increase HCs: increase	PM ₁₀ : -40% NO _x : -60% to -70% CO: increase HCs: increase
Applicable vehicle segments	LCVs, HGVs and buses	 HGVs	 LCVs

Currently, gas trucks, buses and vans are available from a small number of manufacturers, with a number of options for truck conversions to dual fuel. The prospective vehicle market is summarised in **Figure 20**; the best long term prospects are for trucks and buses. Future availability of light commercial vehicles (LCVs) is uncertain due to the very limited offer⁵⁰ and a policy focus on electric powertrains.

Figure 19. Typical characteristics of gas vehicles⁴⁹

LPG vehicles are all **bi-fuel configurations**. LPG vans are more widely deployed than natural gas vans in the UK, and they offer greater air quality benefits⁵¹, but LPG retrofit is limited to existing petrol vans and the market for new petrol vans is limited to vans with a payload under 1.2t. However, diesel vehicles can also be converted to LPG (where the compression ignition engine is replaced by a spark-ignition engine). The conversion of diesel taxis to LPG is an emerging way to improve air quality in cities. In September 2014, BCC was awarded £500,000 from the DfT Clean Vehicle Technology Fund to convert 80 older diesel Hackney Carriages to LPG, to address NO_x and Particulate Matter (PM) emissions in the city centre.

⁴⁸ Hitchcock G. et al., Air Quality and Road Transport. Impacts and solutions, 2014
⁴⁹ (CO₂ emissions) Ricardo-AEA for the DfT, Waste and Gaseous Fuels in Transport - Final Report, 2014; Ricardo-AEA, A review of the efficiency and cost assumptions for road transport vehicles to 2050, for the Committee on Climate Change, 2012; (Air quality) NGVA Europe, Position Paper: Dual Fuel, 2010; Ecolane, Life Cycle Assessment of Vehicle Fuels and Technologies, 2006; Frailey et al., An evaluation of natural gas versus diesel in medium-duty buses, SAE Technical Paper Series, 2000.
⁵⁰ There are only a small van (VW Caddy) and two panel vans (MB Sprinter NGT and Iveco Daily) on the UK market
⁵¹ Ecolane, Life Cycle Assessment of Vehicle Fuels and Technologies, 2006

Availability and market projections of gas vehicles

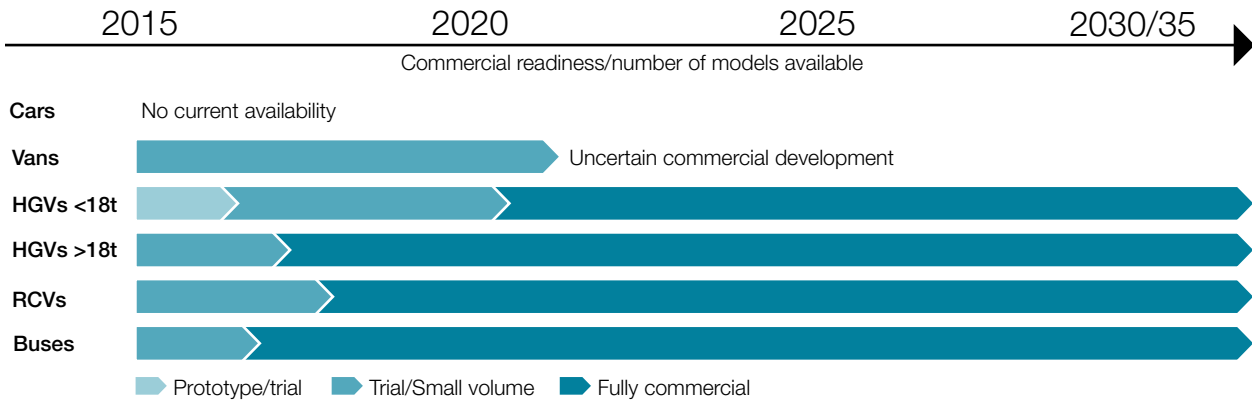


Figure 20. Availability and market projections of gas vehicles⁵²

The current availability of gas vehicles is reflected in fleet operator experiences: uptake is highest for heavy vehicles, i.e. buses and trucks, and several operators interviewed were either expanding their gas fleets or considering their adoption. In contrast, the few operators with experience of using light vehicles (i.e. vans) had no plans to extend their operations or increase uptake.

CURRENT INFRASTRUCTURE

There are currently approximately 30 gas stations in the UK, eight of which are located near major roads around Birmingham, shown in **Figure 21**. However, some are not accessible to third parties (i.e. in-depot stations), and none of the eight stations in the vicinity of Birmingham are easily accessible from within the city boundaries. In addition, there are several trunk routes into the city that are not covered by this infrastructure.

Directive 2014/14/EU on the deployment of alternative fuels infrastructure calls for “an appropriate number of” gas refuelling stations to be installed on the TEN-T Core Network (represented by the black dashed line in **Figure 21**) by 2025⁵³. The TEN-T Core Network is selected for priority deployment as it covers the main traffic flows. Birmingham is a key location on the Core Network, being the midpoint between London and Manchester and the connecting point for the network branch starting at Felixstowe.

⁵² Based on announced OEM roadmaps, technology compatibility considerations and policy support in place

⁵³ TEN-T: Trans-European Transport Network (see map in Appendix). The Directive suggests a distance of 400km between liquid gas stations and 150km for compressed gas stations.

UK Gas stations

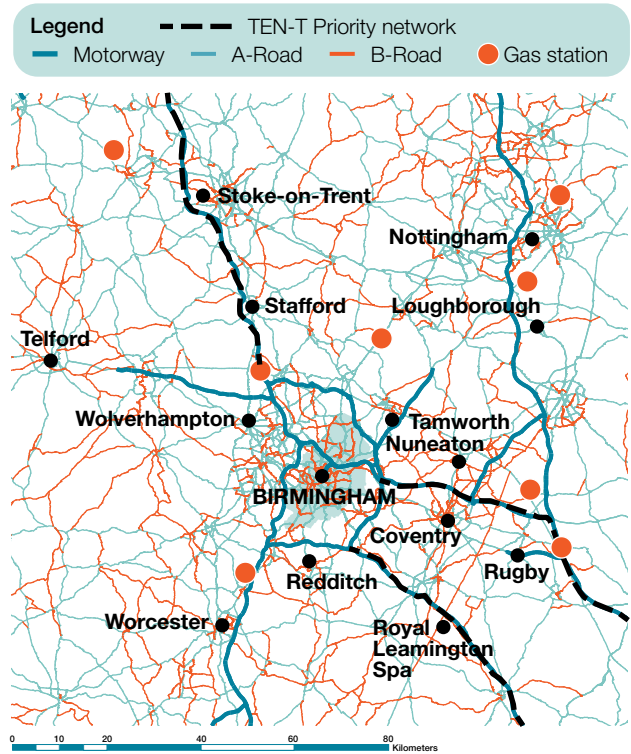


Figure 21. Gas stations in the UK and around Birmingham⁵⁴

4.1.2 DEDICATED AND DUAL FUEL TRUCKS

CURRENT MARKET

The gas HGV market currently consists mainly of dual fuel converted articulated trucks over 18t GVW, as reflected in the statistics for the Low Carbon Truck trial (see **Figure 22**) and list of available models (**Table 17**).

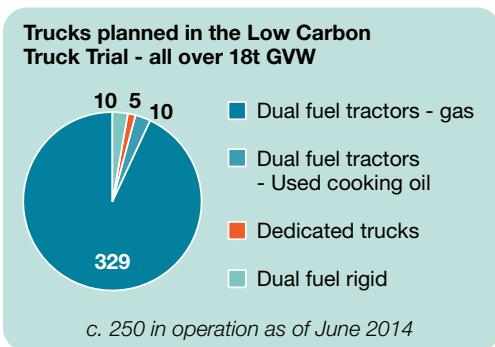


Figure 22. Trucks planned in the Low Carbon Truck trial (all over 18t GVW)

⁵⁴ www.gasvehiclehub.org, www.cngeurope.com, GasRec, CNG Services

Availability of gas HGVs

Vehicle segment	Rigid trucks (18-26t)	Tractors (26-44t)	Refuse collection vehicles
Converted vehicles - dual fuel		Hardstaff: MB Axor tractors (26-44t) Prins: DAF, MAN and MB tractors (26-44t) – now including EURO 6 G-Volution: DAF, MAN tractors (26-44t) Clean Air Power: Volvo FM/FH13, Renault Magnum (26-44t)	
OEM vehicles – dedicated gas Existing models Expected new models	Iveco Stralis (18-26t), Scania (202kW, 220 kW)	Scania (2015, 340bhp, CNG & LNG, 36t, 350km range); Volvo 2015 – details unknown; MB Econic (2015+, 18t)	Volvo FE CNG Renault Premium CNG Trucks (19-26t, 2014-15), Scania Euro 6 (2015), MB Econic (2015+)

Table 17. Availability of gas HGVs in the UK as of end 2014

Dual fuel vehicles are available with either liquefied gas (LNG) or compressed gas (CNG) fuel tanks, but some long-haul operators prefer LNG due to the increased tank capacity, and thus the greater distances that can be covered without using diesel. The ability to use diesel when required means that, despite the limited national coverage (see **Figure 21**) operators do not suffer from range anxiety. The Scania 340 bhp dedicated CNG/LNG being launched in 2015 is the first dedicated truck since 2002 (year when ERF ceased manufacture of their 340 bhp model). This is seen as ideal for regional gas distribution, where trucks make several back to depot trips per day, and therefore range is not an issue.

However, the introduction of EURO 6 emissions regulations (Jan 2014 for HGVs, Sept 2015 for LCVs) is currently affecting the availability of dual fuel models. Dual fuel systems that are compatible with EURO 6 diesel engines, and that can meet tighter hydrocarbon limits⁵⁵ must be developed. The first EURO 6 dual fuel truck, converted by Howard Tenens and Prins Autogas, was delivered to the UK in November 2014, and other converters are developing solutions and expecting to resume conversions in 2015. One outcome could be a lower gas mix for dual fuel vehicles, e.g. a diesel substitution ratio of 15% or less to meet exhaust emissions limits. This would reduce the CO₂ savings and running cost benefits of using gas vehicles (cost savings are discussed in the following section). In addition, by further reducing gas consumption, this would exacerbate filling station financing difficulties.

Another likely outcome for the gas HGV market is a shift towards dedicated vehicles, offering automatic EURO 6 compatibility, greater CO₂ savings, and the potential for rapidly increasing availability of OEM vehicles (as opposed to conversions) due to the existence of more mature markets in Europe and the US. This has already begun to some extent:

⁵⁵ Although there are no homologation test for converted vehicles, converters expect the VCA (authority in charge of Vehicle Type Approval) to request tighter emission thresholds

Scania, for example, has scheduled CNG and LNG dedicated trucks for release in the UK in Q4 2014.

As the market expands it is likely that gas vehicles below 18t GVW will also be released in the UK. This will open the possibility for gas vehicles within local delivery fleets, which tend to be lighter than long-haul trucks. According to fleet operators, dedicated vehicles are well suited to back-to-base, local operations in cities (due, in part, to the fact that such operations do not require a national infrastructure and can rely on a single refuelling station). Dedicated gas vehicles also offer noise reductions of around 50% compared to diesel vehicles.

Some operators are likely to be reluctant to use dedicated vehicles for long-haul operations, as fuel consumption is higher overall than for dual fuel trucks. However, as engineering for gas vehicles becomes more specialised, the difference in efficiency compared to diesel and dual fuel trucks is likely to become less significant.

COSTS AND FUNDING

Vehicle premiums range between £15,000 to £36,000 over diesel versions (a premium of c. 40%)⁵⁶, but fuel savings enable payback periods of 2-4 years⁵⁷; typical savings are in the region of 40% on a £/km basis, including the fuel duty differential. With the introduction of EURO 6 regulations, diesel truck costs will increase in order to meet the specifications, and this will close the cost gap and reduce payback periods.

One area of uncertainty regarding the dual fuel to dedicated market shift is concerned with the conversion of diesel trucks to dual fuel. Currently, converted vehicles can be “recovered” i.e. converted back to diesel, after their fleet lifetime has expired. The vehicles can then be sold on, and this forms a key part of the operator business model. With dedicated gas vehicles, the resale market is much more uncertain, and this is currently one of the barriers to uptake.

BARRIERS TO UPTAKE AND INFRASTRUCTURE NEED

While uptake of gas vehicles is likely to increase with greater model availability and choice, the main barrier to uptake is currently a lack of infrastructure, combined with historic experiences of poor station availability/accessibility by some operators. For dedicated trucks in particular, the lack of a national gas station network is a potential barrier (though not for the depot based fleet). The situation is improving through the Low Carbon Trucks Trial, with another 17 stations set to be installed in the UK. The company GasRec is also planning to install 4 new gas stations in 2015, supported by EC funding.

The majority of HGV fleets currently refuel at depots or distribution centres, and uptake of gas vehicles would require dedicated refuelling facilities, in addition to public gas stations. Some operators were open to the idea of sharing facilities with other fleets, if compatible sites and refuelling times could be identified.

⁵⁶ Dft, Low Emission HGV Task Force Recommendations on the use of methane and biomethane in HGVs, 2014

⁵⁷ Indicative range quoted by fleet operators; payback is highly depend on vehicle cost premium, fuel costs and annual mileage.

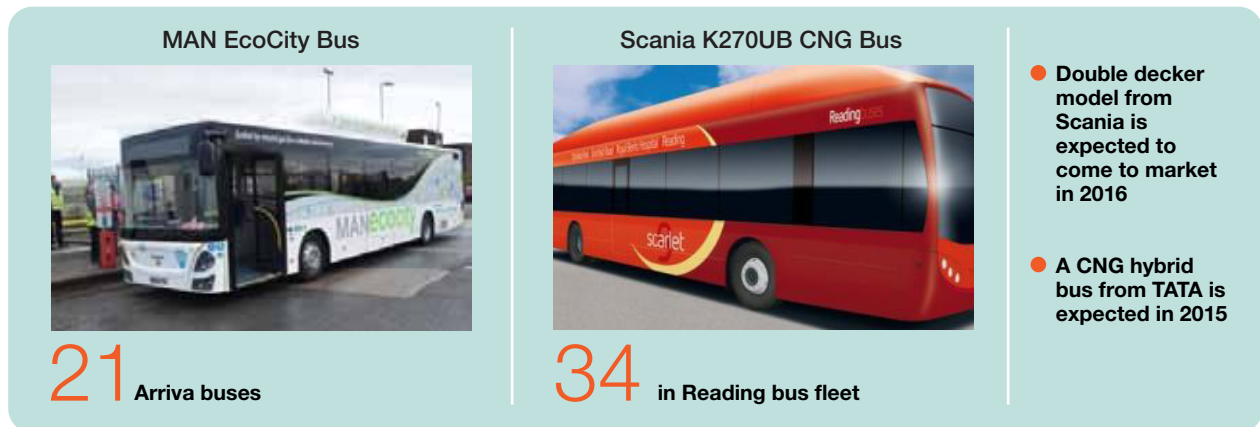
Some fleets prefer to refuel at stations with high proportions of liquid biomethane, to ensure that the WTW emissions benefits of gas vehicle uptake are both maximised, and fully accountable. However, supply of liquid biomethane for transport is constrained due to preferential incentives for biomethane injection in the gas grid or for power generation⁵⁸, and this may be a limiting factor, particularly for expansion of existing gas fleets.

4.1.3 BUSES

VEHICLE AVAILABILITY

Gas buses are currently available in dedicated CNG models (see Figure 23), with ranges and engines that are fully compatible with bus operations (and EURO 6 compliant). The market for gas vehicles is more mature outside of the UK, meaning that as demand increases, vehicle availability will increase quickly.

Availability of gas buses



COSTS AND FUNDING

Premiums for gas buses are around £25,000 (over diesel bus costs of c.150,000)⁵⁹. This is currently the cheapest “low emission” option, with premiums significantly lower than those for plug-in or hydrogen buses. Gas buses are expected to be eligible for grants under the £30 million low emission bus fund, which will be accessible to bus operators in 2015-2020.

Figure 23. Availability of gas buses

⁵⁸ The Renewable Heat Incentive rewards injection of biomethane in the gas grid and the Feed-in Tariff supports the use in Combined Heat and Power Systems. This is explained in more detail in Section 4.2.4

⁵⁹ Element Energy, Hydrogen Fuel Cell Bus Technology State of the Art Review, 2010 and R-AEA for the CCC, 2012

Fuel costs for gas buses are typically 40-50% below those of diesel buses⁶⁰, with cost and emission savings for operators currently maximised by the Bus Service Operators Grant Low Carbon Emission Bus incentive, which pays bus operators 6p/km for kilometres run on biomethane⁶¹.

Fuel cost benefits, along with policy support means that relatively high uptake is possible and as costs come down with increased production, support from the Green Bus Fund may no longer be required. However, vehicle cost premiums and resale market uncertainty are currently still a barrier to uptake, especially for small operators.

INFRASTRUCTURE NEEDS

Buses rely on in-depot refuelling, and are likely to require dedicated, in-depot gas stations. Station installations to date have had mixed success, with some difficulties in the planning process, and in some cases, station costs have been higher than expected. Some depots have insufficient space for gas refuelling, and operators may be open to the possibility of shared-access stations, which could also provide the option to increase station utilisation, and reduce costs. In addition, most station providers offer the option of leasing the station, which removes the cost risk to the operator.

4.1.4 REFUSE COLLECTION VEHICLES

Gas RCVs have been deployed across Europe and the US, while only one model (the MB Eonic) has been trialled in the UK. Over the next two years, a number of other models will become available: Mercedes Benz Eonic, Renault Premium (19-26t) and Scania have all scheduled dedicated gas RCVs for UK release by 2015.

Vehicle premiums and fuel cost savings are likely to be similar to those for trucks and buses, and funding to support vehicle purchase may become available. As with bus fleets, in-depot refuelling will be the preferred option, but shared access could be feasible, depending on compatibility with other fleets. One key opportunity for vehicle uptake is Birmingham City Council's own fleet of 147 RCVs, which are responsible for c. 70% of emissions from the Council's fleet (despite representing only 15% of vehicles). Introducing 40 gas RCVs could bring fuel savings in the order of £20,000 per annum⁶².

⁶⁰ Operating costs of CNG buses quoted as 13p/mile, compared to 26p/mile for equivalent Euro VI diesel bus. Reading Buses, CNG – future transport technology, today, NGV Day September 2014

⁶¹ <http://assets.dft.gov.uk/publications/certification-of-dedicated-gas-buses/guidance.pdf>

⁶² The Green Fleet Review (to be published by Spring 2015); based on observed RCV fuel consumption in Birmingham. Fuel cost assumptions: CNG - £0.75/kg, Diesel - £1.00/kg

4.1.5 TAXIS AND THE CASE OF LPG

A MARKET ALREADY IN PLACE FOR PRIVATE HIRE VEHICLES

There is no central record of the number of taxis already converted to LPG in the Birmingham area⁶³ but sales of LPG systems to local workshops and sales of autogas⁶⁴ at the pump suggest a significant share of the 4,800 mini-cabs registered in Birmingham now run on LPG⁶⁵. A refuelling network is already in place, with 6 forecourts selling LPG within the city boundaries, and additional 5 non-forecourt based LPG stations.

THE POTENTIAL FOR HACKNEY CARRIAGES

The use of LPG is now opening to Hackney Carriages which, despite being fitted with a diesel engine, can be converted to LPG (the compression ignition engine is refurbished to become a spark-ignition engine). This process has been shown to decrease PM and NOx emissions of EURO 2 or EURO 3 vehicles by over 90%⁶⁶. As around 60% of the 1,330 Hackney Carriages registered in Birmingham are EURO 2 or EURO 3 and operate mostly in the city centre where air quality issues are highest, a diesel-to-LPG conversion would bring significant air quality benefits.

When consulted on the option to have their vehicle converted to LPG (under the Clean Vehicle Technology Fund program), Hackney Carriages owners overwhelming expressed an interest.

ENABLING BENEFITS OF LPG

For Birmingham City to harness the air quality benefits of older hackney carriages conversion to LPG, the local supply chain to provide the diesel-to-LPG conversion must be developed. There are several approved UKLPG installers in the Birmingham area, but they have so far retrofitted petrol vehicles only.

The Council's procurement of conversion under the aforementioned taxi conversion program to be undertaken in winter 2014-15⁶⁷ will start the supply chain development. This funded conversion program and its results should be advertised widely to encourage further conversion beyond the funding period.

The local network of LPG refuelling stations is expected to increase in the short term, in answer to the increased demand for autogas. LPG can be dispensed in existing petrol forecourts or supplied in dedicated stations, which cost around £30,000⁶⁸. There are no strong siting constraints⁶⁹ but available land being scarce, the Council could consider leasing Council-owned land for this purpose. A station located close to the taxi operations in the City Centre would support the adoption of LPG by Hackney Carriages and reduce travel-to-refuel journeys.

⁶³ Records are poor for private cars too. As the LPG system is retrofitted, records rely on vehicle owners declaring the retrofit to the DVLA.

⁶⁴ Common name of LPG when used as road fuel

⁶⁵ Birmingham Autogas have two LPG refuelling sites that are reportedly visited by 200 mini-cabs a day and sell a daily average of 9,500 litres of LPG.

⁶⁶ The conversion brings the engine to EURO5a level; based on Millbrook test data, provided by Battersea Autogas (garage approved for diesel-to-LPG conversion in London).

⁶⁷ Birmingham City Council was awarded £500,000 by the Department of Transport in September 2014 under the Clean Vehicle Technology Fund, to retrofit 80 diesel Hackney Carriages to LPG.

⁶⁸ Industry quote for an unmanned autogas dispenser with pin car payment system, excluding ground work and installation costs.

4.2 GAS REFUELLING INFRASTRUCTURE PLAN

4.2.1 TECHNOLOGY OPTIONS

The existing gas infrastructure consists of a mix of LNG (liquefied natural gas) and CNG (compressed natural gas) stations. LNG (stored in cryogenic tanks at c.-170°C, <10bar) is trucked in to refuelling sites in tube trailers, whereas CNG can be compressed to 200 or 250 bar onsite, with gas imported from a connection to the gas grid. Trucked in LNG can also be pumped to 250 bar and then vaporised onsite, enabling stations to dispense both forms of gas (LCNG stations).

Table 18 compares the options for provision of stations in Birmingham, for the different fleet segments. Although most long haul operators using gas have opted for LNG tanks, some operators can carry sufficient CNG tanks on their tractors to enable long distance operations. For example, Howard Tenens can carry up to 120kg of CNG on its tractors, giving a range of up to 900 km⁷⁰. The lower emission footprint of CNG (discussed in more detail in the next section) and its lower cost, relative to LNG, strongly influence fleet manager decisions⁷¹.

CNG and LNG stations have roughly the same physical footprint requirement, and can both be designed with growth in mind; this means that the civil works and connection to utilities can be done for a target future station size, but the number of components (dispensers, compressors, etc.) starts low, and is increased with demand over time. This staged approach brings savings in civil works and connection costs. Both technologies are subject to safety separation distances, with added regulations for LNG related to storage of liquid gas.

Trends for CNG / LNG use across vehicle types

Technology options		CNG	LNG	Comments
Trucks	Long haul multi-stop	(✓)	✓	Wide availability of both tank types LNG preferred for long-haul and CNG preferred for shorter/start-stop journeys – but long haul CNG possible (and observed already)
	Buses	✓		Most available models are CNG
RCVs		✓	✓	Both types of vehicle available

Table 18. Trends for CNG / LNG use across vehicle types

⁶⁹ LPG is subject to separation distances from sources of ignition (typically 5m for a 2t system and 10m over 2t) but a station has a small footprint (e.g. c. 60m² for 2x1t system that can serve c. 60 vehicles a day). A skid mounted unit does not need planning permission.
⁷⁰ Interview with Howard Tenens, and DfT, Annex to the Low Emission HGV Task Force recommendations on the use of natural gas and biomethane in HGVs, March 2014
⁷¹ "In 2013, the cost of CNG from public access third party sites ranged from 75p/kg to £1.06/kg. LNG from third party access sites ranges from £1.05/kg to £1.08/kg." DfT, Executive Summary - Low Carbon Truck Trial, June 2014

COMPRESSED NATURAL GAS

CNG is likely to be the first choice for locally based fleets, as a CNG station is likely to offer higher compatibility with the expected vehicle market: most dedicated vehicles coming to market will use CNG, and it is currently the only option for buses. In addition, CNG offers stronger GHG benefits than LNG, for several reasons:

- Access to compressed biomethane is less restricted than liquid biomethane (most biomethane produced in the UK is injected into the gas grid, which is supported by the Renewable Heat Incentive)
- Lower risk of methane slip and no venting of cold methane, which has a very high global warming potential
- Lower energy footprint (no liquefaction or trucking)

Station costs are very site dependent, due to the need to connect to the gas grid, and the planning process can be more complex due to the civil works required. Therefore, a CNG station may not be ideal for operators with limited flexibility around station siting, although feasibility will be determined on a site-by-site basis. Siting and grid connection constraints are discussed in more detail in Section 4.2.3. Indicatively, the CNG station installed at the Reading bus depot cost c. £1million in total and refills 34 buses at night⁷². The key cost components, beyond the connection costs, come from the compressor, storage tanks and dispensers.

As dedicated gas vehicles entirely depend on availability of gas, CNG stations must be highly reliable, i.e. they must have a mitigation solution if the compressor fails. Tanks of compressed gas that can be delivered by truck and connected to the dispenser are the usual back-up solution; several CNG stations have their own tube trailer to enable quick delivery.

LIQUEFIED NATURAL GAS

Siting is more flexible for LNG stations, as no gas grid connection is needed and therefore for fleets looking for in-depot facilities, LNG is likely to be more feasible in some cases. LNG is the preferred choice for long-haul fleets, at least in the short term, as its energy density is greater and in the absence of a national infrastructure, this enables longer routes. However, for fleets looking to achieve significant CO₂ savings on a WTW basis, LNG is becoming an unlikely choice due to the restricted supply of liquid biomethane for transport (see section 4.2.4 for details)⁷³. Feedback received through the FTA indicates investment costs of £500k for a LNG station that can serve a fleet of 70 trucks. The key cost components are the dispensers, storage tanks and the land.

LNG stations can be converted to dispense compressed and liquefied gas at a cost premium of c. 30% (although the premium is reduced to 10-15% if the station is designed as LCNG from the start)⁷⁴. LNG/LCNG stations would be a likely choice for public stations on motorway routes, meeting the needs of long-haul LNG fleets, whilst providing the option of refuelling for any CNG vehicles.

⁷³ Recent studies indicate, that depending on the supply pathway, dual fuel LNG brings no or very low WTW GHG emission savings compared to diesel, while dual fuel liquid biomethane brings at least 30% WTW savings. Ricardo-AEA for the DfT, Waste and Gaseous Fuels in Transport - Final Report, 2014

⁷⁴ Estimates provided by infrastructure providers

4.2.2 PRIORITY ZONES FOR SITING

CITY-BASED FLEET OPERATIONS

As indicated in **Figure 24**, there are currently no public gas stations in Birmingham itself. Installation of refuelling facilities within the city will be essential for uptake of gas RCVs, buses, and locally operating HGVs (mainly <18t GVW).

Public/3rd party accessible gas stations near Birmingham

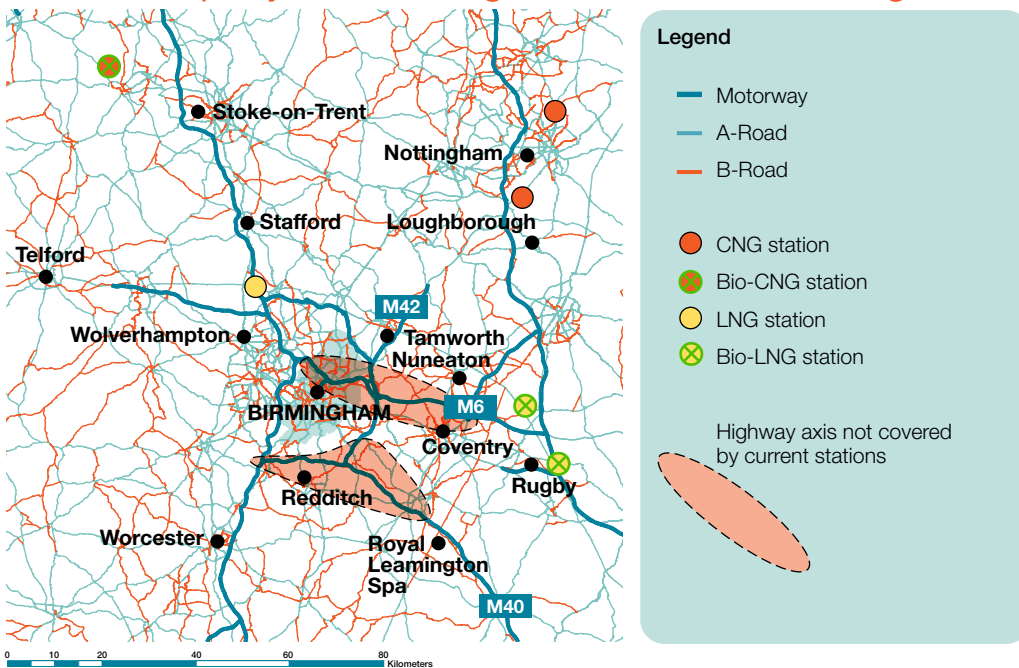


Figure 24. Public/3rd party accessible stations near Birmingham

Although most of these fleets have a preference for depot refuelling facilities, station installation costs can be high for low numbers of vehicles, and some operators with depots in Birmingham are open to the possibility of shared access stations in easily accessible locations, to make the business case for short-term gas vehicle adoption more feasible.

By identifying clusters of compatible fleet depots within a small radius, suitable sites could be determined through consultation with interested fleet operators. Some opportunities for shared stations have been identified and are presented in section 4.2.3.

MOTORWAY ZONES FOR FREIGHT OPERATORS

For long-haul HGV operations (mainly trucks >18t), demand has been identified for motorway stations near key junctions to support the wider uptake of gas trucks. Birmingham has been identified by members of the Freight Transport Association (FTA) as a key location for enabling use of gas vehicles in freight operations⁷⁵. Several operators

⁷⁵ FTA member survey, 2012

interviewed for this study indicated they would be likely to include gas vehicles in routes via Birmingham, given infrastructure provision along key routes. As shown in **Figure 24**, there are LNG/LCNG gas stations located on most of the motorways outside Birmingham, but fleet operators indicated a need for additional stations on the M6 and M42/M40 axis or the M6/A38 junction (highlighted in pink on the map), with a preference for sites on major junctions that will be easily accessible to the city. This would also provide the opportunity to serve operations in and around the city.

FTA: “In 2012, FTA and a group of member operators identified 20 potential sites for gas refuelling infrastructure across the country... Birmingham was identified as a key site. Since then, a number of UK companies have worked closely with commercial operators to set up infrastructure ...but the pace of expansion is slow. The opportunity to expand public infrastructure particularly in cities such as Birmingham is therefore welcome.”

4.2.3 SITING OPPORTUNITIES FOR GAS STATIONS

CNG SITING

One of the constraints when identifying CNG station sites is the need to connect to the gas grid. The gas distribution network consists of four overlapping pressure systems, as represented in Figure 25. If it is accessible, the **Local Transmission System (LTS)** provides the best solution to access gas for transport applications and inject bio-methane into the system, due to several factors:

- Cheaper running costs than with lower pressures, as less compression is needed to reach the required pressure (200/250 bar).
- Improved emissions performance relative to connections at lower pressures: no methane leakage from LTS grid and lower energy footprint (up to 80% less compression energy)
- Cheaper than connecting at the National Transmission System level: c. £250k to connect to the LTS vs. >£1million to connect to the NTS (furthermore, taking gas from the NTS would require adding an odorant, for detection/safety reasons)

The Intermediate and Medium pressure networks are the second best choice as they are commonly used on industrial sites. In general, higher pressure connections are more expensive to connect to, but lead to lower variable opex and higher maximum station capacities and therefore should always be considered where possible over a connection to the low pressure (LP) gas grid. For example, for a compressor of 500m³/hour, increasing the pressure from 1 to 5 bar (medium to intermediate) will reduce the energy requirements by a factor of 30%.

There are approximately 25km of LTS in Birmingham, with much of this network running adjacent to the M6 across Birmingham, along the M5 on the west side and along the M42 on the east side⁷⁶.

⁷⁶ FTA member survey, 2012

A representation of the gas distribution network

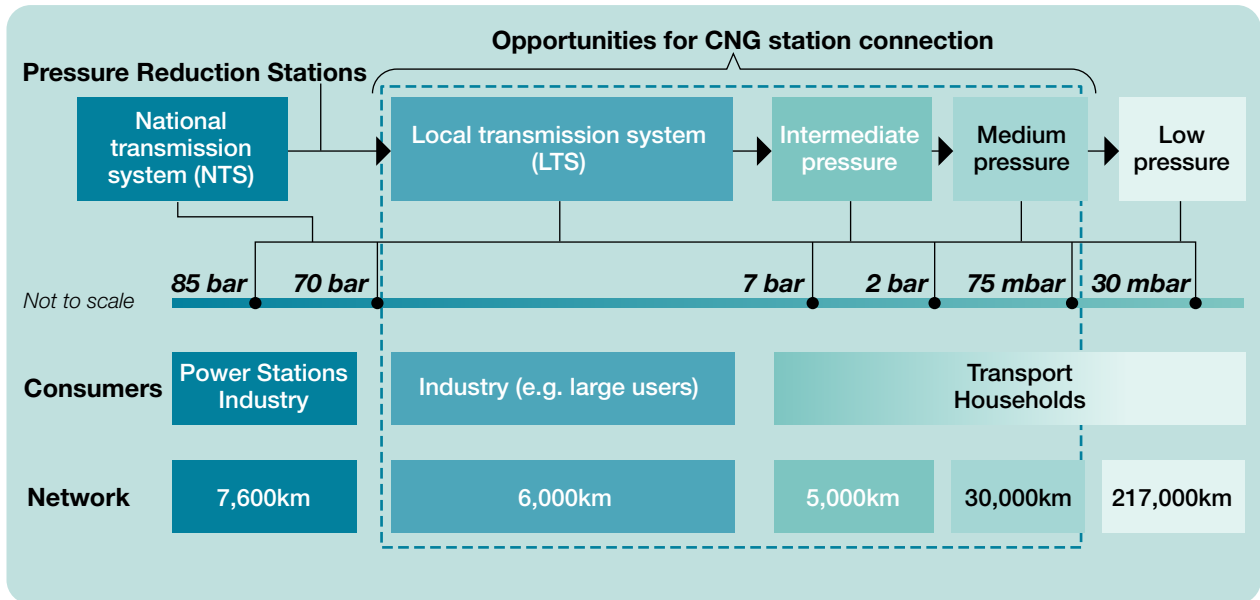


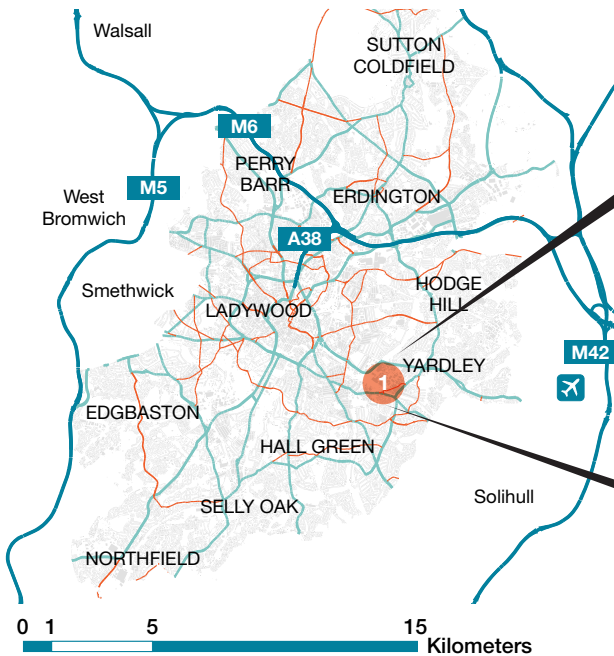
Figure 25.
A representation of the gas distribution network

A prospective site has been identified in the Tyseley Environmental Enterprise District, not far from the city centre, As indicated in Figure 26, this area includes two depots with fleets with potential gas vehicle uptake: the Council depot and the Veolia depot together account for around 80 RCVs, and another 40 Council RCVs will be relocated to the area as a result of High Speed 2 development elsewhere in the city. Overall there are c. 350 heavy vehicles coming to the site⁷⁷. In addition, the area is very close to the Intermediate Pressure network; depending on the specific location, the connection distance is between 20 and 200m.

The feasibility of this site is subject to further analysis of civil requirements, traffic and road conditions, and would also depend on vehicle uptake within the identified fleets, and the willingness of the depot owners to provide access to third parties. There are also opportunities to share across vehicle types within a fleet; for example, a gas station within a Council depot could be used by both RCVs and vans across the Council fleet⁷⁸.

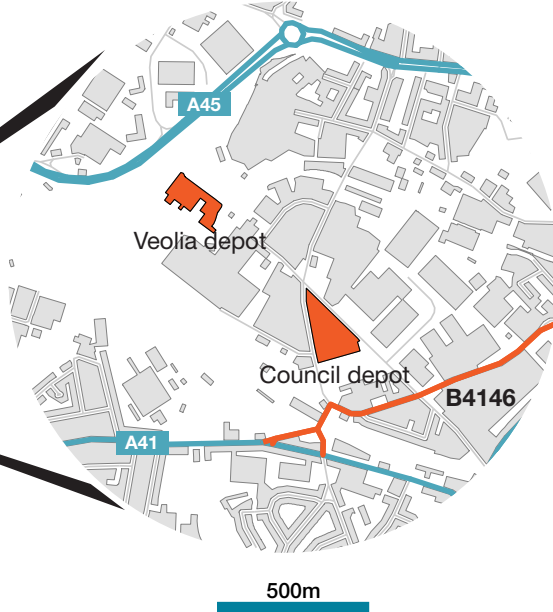
⁷⁷ In addition to RCVs based in Tyseley, the remaining vehicles in the council waste fleet also make regular journeys to the area to deposit waste for incineration. Trucks are also due to deliver waste to the upcoming new wood incinerator.
⁷⁸ The Green Fleet Review (to be published by Spring 2015) has shown that adopting both gas van and gas refuse collection vehicles could bring up to £340,000 in total ownership cost savings.

Birmingham districts



CNG station opportunities

1 Tyseley Environmental Enterprise District

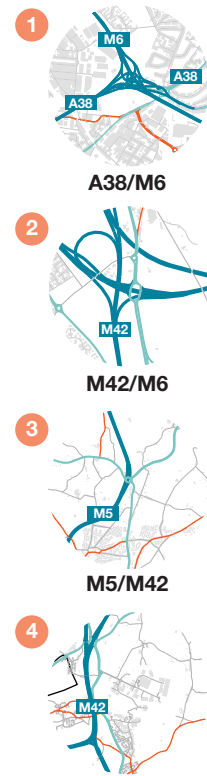
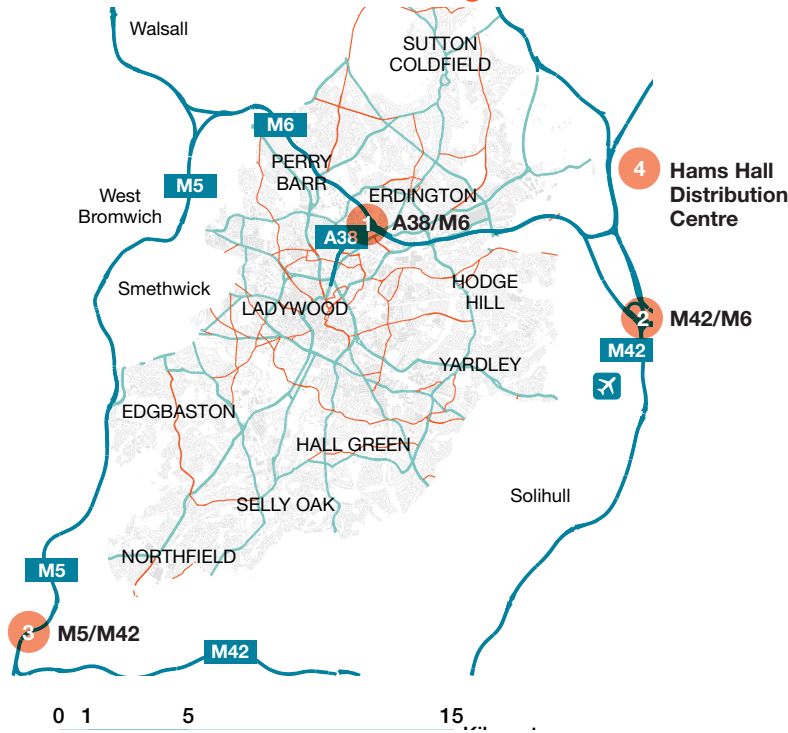


Although LNG is currently preferred for long-haul operations, some operators may use CNG due to the greater emissions benefits and therefore there may be a demand for motorway CNG sites. There are several opportunities for such sites; **Figure 27** shows potential gas grid connections near the M6/A38, M6/M42 and M5/M42 junctions. As discussed in Section 4.2.2, these junctions were identified in consultation with fleet operators as locations for public stations to support uptake of gas vehicles on freight routes into and via Birmingham. As indicated in **Figure 27**, three of these junctions lie outside the Birmingham region. However, for installation of gas stations near key junctions, interest from outside Birmingham is likely, with potential opportunities to work with Local Enterprise Partnerships to address pollution from HGVs in a wider area.

Figure 26. Opportunity for a CNG station in the city

The LTS pipeline runs close to all 3 junctions (within 500m for M6/A38 and M6/M42, and within 1km for M5/M42) and it is likely that the business case for a CNG station would be strong if a sufficiently large site and baseline demand can be identified. Connection to the LTS would be likely to be in the region of £500,000.

Opportunities for public gas stations on trunk routes near Birmingham



Hams Hall distribution centre (based in North Warwickshire) lies very close to the M42/M6 junction and offers a good opportunity to connect to the Intermediate Pressure network. Given the existing function of the site, it could be an ideal opportunity for refuelling for long-haul gas trucks, whether CNG or LNG.

Figure 27. Opportunities for CNG stations near motorway junctions

LNG SITING

Siting of LNG stations is flexible, provided that a sufficiently large area (100-300m²) is available, as gas grid connection is not required. However, some city-based fleets may choose to use LNG, particularly if siting a CNG station proves to be too expensive or impractical.

To maximise the CO₂ savings, LNG stations should be as close possible to liquid biomethane production sites; this will reduce the CO₂ footprint from transport and may improve the business case for direct use as a transport fuel.

4.2.4 FUEL SOURCE AND EMISSIONS ACCOUNTING

There are several possible pathways for CNG and LNG. Both compressed and liquefied forms are available in fossil fuel form, or as biomethane, which includes production routes such as anaerobic digestion, landfill gas and gasification of biomass. Biomethane offers much greater CO₂ savings than fossil gas on a WTW basis⁷⁹. However, competition with biomethane demand for other applications means that there are some constraints on its use for transport.

WELL TO WHEEL EMISSIONS OF BIOMETHANE

WTW emissions account for energy efficiency and emissions throughout the supply chain. For gas, this includes methane slip as well as energy consumption of compression and liquefaction. Liquefied biomethane (LBM) typically has about 30% higher emissions from liquefaction and trucking, compared to compression of grid gas for compressed biomethane (CBM), as well as higher risk of methane slip.

Methane slip is when methane is released to the atmosphere at some point in the supply chain (or from the exhaust pipe) rather than being combusted in the engine. This significantly decreases WTW emissions savings, due to the high global warming potential of methane⁸⁰.

There is considerable uncertainty over the quantity of methane released in exhaust emissions under normal operation, as well as along the distribution pathway and, for LNG, during boil-off. Field trials to measure these emissions will enable more accurate quantification of tailpipe emissions for LNG and CNG vehicles.

BIOMETHANE SUPPLY

Biomethane can be used directly for transport, but the current policy landscape favours use for heating, under the Renewable Heat Incentive (RHI) or for power with the Feed-in Tariffs. Revenues for Renewable Transport Fuel Certificates are currently much lower than those gained via the RHI or FIT, and there is currently no floor price (and no guaranteed revenues). RTFCs for biomethane are currently under consultation to address this, but feedback from gas station providers and gas fleet operators indicates that any increase in value is unlikely to enable the RTFC to compete with the RHI. The various incentives and end uses are summarised in **Figure 28** (next page).

GASEOUS BIOMETHANE

Compressed biomethane is injected into the gas grid, whereby it can be indirectly purchased for transport via the Green Gas Certificate Scheme, as indicated in **Figure 28**. While the RHI incentivises grid gas injection (biomethane is more expensive to produce than fossil gas), the Green Gas Certificate scheme tracks sales of compressed biomethane through the gas grid from production to end use, and enables users (including

⁷⁹ Ricardo-AEA for the DfT, Waste and Gaseous Fuels in Transport – Final Report, 2014

⁸⁰ The Global Warming Potential of methane is 34 times the GWP of carbon on a 100 year time horizon (Intergovernmental Panel on Climate Change, 2013)

gas fleet operators) to account for their purchase of biomethane. Some operators already use this mechanism to indirectly reduce the WTW emissions of their gas vehicles, but others are reluctant to use the scheme because it is not acknowledged by DECC or Defra in the reporting of their company GHG emissions.

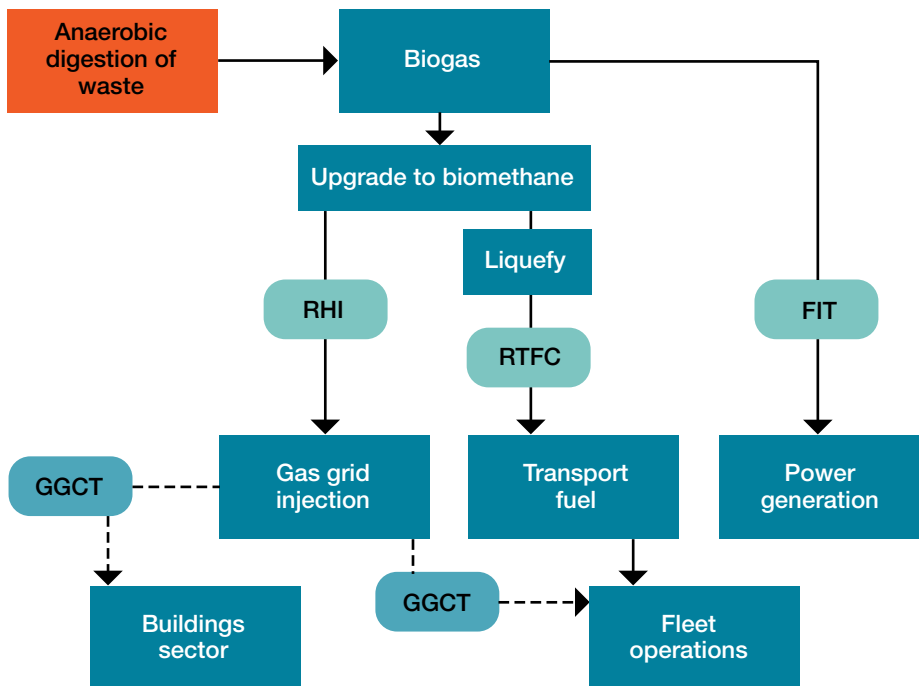
The main source for grid-injected biomethane in Birmingham is the Severn Trent sewage treatment facility in Minworth (shown in **Figure 29**), which is due to increase its grid injection volume to 63 GWh/year (approx. 5,000 t) by 2015. Vale Green Energy, near Eversham, also injects biomethane, and is planning to increase injection volumes, and there are several other potential sources of biomethane from waste in the area. However, access to this biomethane for transport applications will depend on changes to the policy landscape.

On a national level, production is increasing quickly, with 130,000 tonnes worth of Green Gas Certificates to be available in 2015.

Incentives for different end uses for biogas in the UK

Feed-in Tarrif (FIT)	Renewable Heat Incentive (RHI)	Renewable Transport Fuel Certificates (RTFC)	Green Gas Certificate Trading (GGCT)
Power generated using biogas receives: 9-12p/kWh	Grid injected biomethane receives: c. 7.5p/kWh	Biomethane used directly in transport receives: c. 3p/kWh*	Trading system for tracking sales and use of biomethane (for emissions accounting)

Figure 28. Incentives for different end uses for biogas in the UK



*Value of Renewable Transport Fuel Certificates is set by the market and is not guaranteed

LIQUID BIOMETHANE

There is currently no nearby production of LBM. Its production is limited nationwide, with only one site (in Surrey, owned and operated by Gasrec). Opportunities for liquid biomethane are waste sites that are not close enough to the gas grid to make injection viable. When the Council considers options for the use of its waste (for which the contract with Veolia ends in 2019), the conversion of waste to LBM could prove an interesting option; depending on demand from local fleets and general site economics.

Figure 29 maps the existing and planned waste to energy sites in and around the Birmingham area. This indicates that there is a well-developed and growing network of sites and thus skills: around 900,000 tonnes of Municipal Solid Waste are processed each year for power and/or heat. Within Birmingham City, the main resource for biomethane for transport is treatment of sewage by Severn Trent, at Minworth, producing 3,400 Nm³/h of biomethane (c. 22,000 tonnes annually). Approximately 40 km south of Birmingham, the Vale Green Project also injects biomethane, producing 600m³/h.

Existing waste to energy sites in the Birmingham area

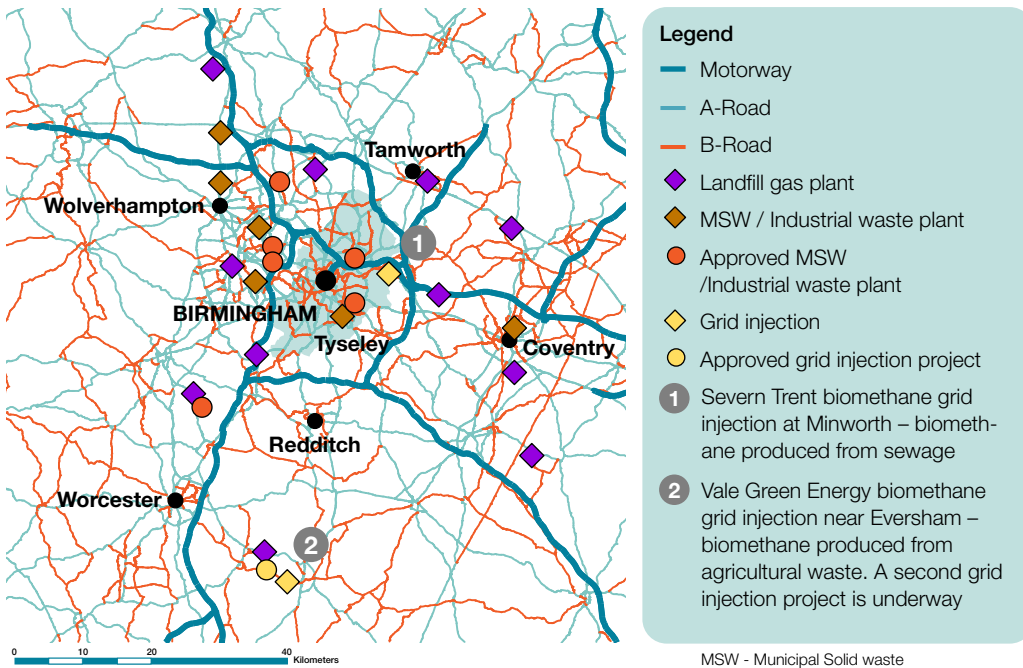


Figure 29. Existing waste to energy sites in the Birmingham area

This network of waste to energy sites presents the opportunity for existing and future gas infrastructure to develop closer links to potential biomethane suppliers; in particular, infrastructure providers could develop a closer relationship with the grid injection sites to support the increased provision of biomethane for transport in the area. Potential grid injection and biomethane production opportunities at other sites could also be explored; for example, one infrastructure provider is engaging with the Packington waste-to-energy facility to investigate options for renewable gas production.

4.2.5 UPTAKE SCENARIO AND IMPACTS

UPTAKE SCENARIO

Figure 30 presents a roadmap for deployment of gas fleet vehicles up to 2035, and provides indicative numbers for the corresponding infrastructure demand. There could be c. 500 gas (methane / biomethane) vehicles on the roads in Birmingham by the 2030s, consisting mainly of buses and heavy good vehicles above 8t GVW. The level of uptake would be mainly supported by in-depot stations but 2 to 4 public stations would also be required. Uptake will be strongly dependent on the realisation of numerous enabling factors and trigger points, as summarised here, determined on the basis feedback from fleet operators and station providers.

Figure 30. Illustrative uptake of gas vehicles and gas refuelling infrastructure

Illustrative uptake of gas vehicles and gas refuelling infrastructure

		Short term	2020	Medium term	2025	Long term	2030/35
Vehicles	HGVs <8t GVW	Number of vehicles on the road [% of all vehicles registered in Birmingham]					
		trials (mainly dedicated)		10s [<1%]		50-100 [5%]	
	>8t	10s	<100 [3%]	100-200 [5%]	300-350 [10%]		
		(dual fuel) (increase dedicated)					
	RCVs	trial	<5 [<3%]	5-10 [5%]	15-20 [10%]		
	Buses	<10 (dedicated)	10-50 [1%]	100-150 [3%]	200-250 [5%]		
Infrastructure needs	Gas refuelling	1 public station (800 kg/day) <5 in-depot stations		2 public stations (800 kg/day) <10 in-depot stations		2-4 public stations (800 kg/day) <20 in-depot stations	
Triggers / enablers	<ul style="list-style-type: none"> Release of dual fuel EURO 6 trucks and further dedicated gas trucks and buses Evidence and publication of TTW and WTT performance of gas vehicles, e.g. TSB trial results Policy support for use of biomethane in transport Improvement of national gas refuelling infrastructure 		<ul style="list-style-type: none"> Increased range and engine power of dedicated gas trucks Improved efficiency of gas engines (compared to diesel) Continued policy support for biomethane in transport 		<ul style="list-style-type: none"> Continued increase in model availability and efficiency Continued policy support for biomethane in transport 		

IMPACTS

Table 19 presents the CO₂ reductions that could be achieved under the uptake scenario in Figure 30. The adoption of gas vehicles in Birmingham could save around 2,000 tonnes of tailpipe CO₂/year by the 2030s. On a WTW basis, CO₂ savings could amount to around 26,000 tonnes/year⁸¹. These figures represent the best case scenario for fuel supply pathways, with maximum use of biomethane. Low-end emissions savings are provided in **Table 19**, calculated on the basis of current emissions data for fossil-fuel pathways.

Table 19.
Illustrative uptake, impacts and fuel demand of gas vehicles

Illustrative uptake, impacts and fuel demand of gas vehicles

	2020	2025	2030/35	Comments
Vehicles on road [% HGV, RCV and bus fleets]	135 [2%]	300 [4%]	550 [7%]	See Appendix for detailed assumptions
km travelled (millions)	7	15	28	Based on annual mileage as per workshop data
Gas needed t/year [GWh]	1,900 [24]	3,600 [46]	6,000 [76]	c.5,000 t biomethane will be injected in Birmingham in 2015
CO ₂ TTW emissions saved compared to diesel (tonnes)	460	1,000	2,000	Assumes 71.4gCO₂/MJ for diesel, 56.6gCO₂/MJ for gas
CO ₂ WTW emissions saved compared to diesel (tonnes)	900-8,000	1,900-15,600	3,500-26,300	Upper range: based on -19.5g/MJ (injected biomethane) Lower range: based on 65.1g/MJ natural gas (20% WTW savings compared to diesel)

The estimated maximum demand for gas in Birmingham, for an average fleet uptake of 7%, is 6,000 tonnes. It is likely that the majority of this demand could be met by compressed biomethane, depending on the policy landscape, the relative cost of biomethane compared to natural gas, and the proportion of LNG and CNG vehicles. In 2015, at least 5,000 tonnes of biomethane will be grid-injected in Birmingham and it is likely that a number of potential waste-to-gas projects will be realised by 2030. As such, access to gas biomethane is unlikely to be restricted by local production capacity, whereas LBM supply is severely limited nationwide.

⁸¹ For detailed assumptions, please refer to the appendix.

4.3 RECOMMENDATIONS FOR DELIVERY

Unlike plug-in and hydrogen vehicles, **natural gas** vehicles are solely fleet vehicles. There is therefore no consideration of private drivers when siting gas stations. Instead, the siting must closely follow the fleet operators' needs. The Council can support a deployment of new gas stations that meets user needs and maximise consistency with Carbon and AQ plans through the following actions:

<p>Support the development and installation of a gas refuelling infrastructure</p>	<ul style="list-style-type: none"> • Engage with Government to develop a streamlined planning permission process, for both public and depot-based gas stations, including clear referral to existing safety guidelines • Assess available public land for compatibility with gas stations (in terms of recommended corridors, cost of connection to gas grid if relevant and proximity to heavy duty vehicle fleets). Suitable sites could be earmarked to facilitate siting and planning processes
<p>Ensure that gas infrastructure meets customer needs</p>	<ul style="list-style-type: none"> • The Council, e.g. through planning policy or guidance, should encourage gas stations to: <ul style="list-style-type: none"> o To be semi or fully publically accessible to encourage sharing across several fleets, where siting justifies it (e.g. where there are existing clusters of fleet bases) o To prioritise 'missing corridors' when siting public stations, as identified in section 4.2.3 o To meet customers' expectations, i.e. follow standards and best practices regarding station reliability, provision of back up storage, service level, and station design
<p>Encourage and contribute to the uptake of gas vehicles</p>	<ul style="list-style-type: none"> • Assess BCC Refuse Collection Vehicles depots for gas station installation, and consider trialling/ deploying gas RCVs • The Council could also consider the opportunity to share or host a station based at RCV depot with its sub-contractors, or with neighbouring depots (see section 4.2.3)
<p>Ensure the benefits of gas vehicle uptake and consistency with the Birmingham Carbon Roadmap</p>	<ul style="list-style-type: none"> • At planning stage, require evidence of a supply strategy pathway (for both biomethane and fossil fuel methane) and station design that maximises GHG emission savings. These requirements will have to be developed/tailored according to research findings regarding the tailpipe / WTW benefits of gas vehicles (e.g. TSB trials, the ETI 'well to motion' study⁸³). Initially they could focus on the sourcing of biomethane, targeted level of blending and methane slip mitigation strategy • Support production of biomethane through a streamlined planning process for new production sites • Assess the potential and feasibility of using the Council waste for biomethane production

⁸³ <http://www.eti.co.uk/wp-content/uploads/2014/04/RfP-Gas-Well-to-Motion-Modelling-for-HDV-r1.pdf>

The Council has identified the air quality benefits of converting older Hackney Carriages to LPG. For these benefits to be harnessed beyond the DfT funded conversions of winter 2014-15, the Council can:

- Advertise, among the taxi community and local garages, the funded conversion program and its results;
- Support the installation of new LPG station(s) close to taxi operations in the City Centre, e.g. by leasing Council-owned land.

LIQUID AIR VEHICLES

According to the Birmingham Connected White Paper, Heavy Good Vehicles currently contribute to a number of problems in the city centre



5

LIQUID AIR VEHICLES

5 LIQUID AIR VEHICLES

According to the Birmingham Connected White Paper⁸⁴, Heavy Goods Vehicles currently contribute to a number of problems in the city centre. As well as contributing to poor air quality, HGVs can exacerbate traffic problems and are over-represented in terms of traffic collisions. One measure proposed by Birmingham Connected to address these issues (and advocated by the West Midlands Freight Strategy) is the use of consolidation centres, whereby delivery vehicles use a shared site outside the city as a base to optimise operations and reduce the number of trips into the city. This approach could be effective in reducing the overall impacts of HGVs within the city. In terms of air quality and greenhouse gas emissions, technology choices such as adoption of gas or plug-in delivery vehicles will bring further improvements.

However, in the specific case of refrigerated vehicles (e.g. for food deliveries), measures to improve air quality should also include consideration of the technology for refrigeration units (TRUs). TRUs are classified as non-road mobile machinery, and their emissions are currently unregulated and untreated, with the majority of refrigerated trucks and trailers currently using red diesel auxiliary engines to power refrigeration. As a consequence, TRUs can account for over 80% of NO_x and PM emissions for refrigerated HGVs, despite only constituting 20% of overall fuel consumption. Regulations for TRUs are currently being developed, and may encourage treatment of auxiliary engine emissions, but for air quality hotspots such as Birmingham, alternatives to red diesel TRUs are likely to be required in order to achieve recommended European NO_x levels. One such alternative is the liquid air engine. The following section discusses the potential applications of this technology and considers how the associated refuelling infrastructure could be combined with a consolidation centre approach.

5.1 TECHNOLOGY ROADMAP

TECHNOLOGY OVERVIEW

The liquid air engine is an emerging technology with the potential to achieve significant reductions in emissions for HGVs. The technology is based on the rapid expansion of liquefied air to simultaneously drive a piston engine and provide cooling, and as such it has particularly strong compatibility for 'power and cooling' applications in refrigerated trucks. The current options for refrigeration in vehicles are summarised in **Figure 31**; the majority of refrigerated trucks and trailers currently use red diesel auxiliary engines. Liquid nitrogen (N₂) evaporation technology (distinct from the liquid air engine) has been trialled as a zero-emission alternative. While this provides net fuel savings, evaporation alone cannot meet ancillary cooling demands such as air circulation in the refrigeration unit; these demands are therefore met by the main engine, and the diesel consumption of the main

⁸⁴ Birmingham Connected – Birmingham Mobility Action Plan White Paper, November 2014

engine is increased. Liquid air technology could offer improved efficiencies and emissions reductions compared to N₂ evaporation technology, via conversion of waste heat to additional shaft power.

Two liquid air engine concepts currently in development, summarised in **Figure 32**, are likely to be viable for trial/ small deployment in the near term. Both concepts are based on the Dearman engine, a piston engine powered by phase-change expansion of liquid air. Liquid air is not the primary fuel (the main engine uses diesel), but it provides cooling and improves the overall vehicle efficiency.

Figure 31.
Current fuel options for trailer refrigeration units

Refrigeration modes

Refrigeration mode	Main ICE	Auxiliary ICE	Dominant Refrigeration modes	N ₂ evaporation	
Typical use	Most vans and small trucks	Most trucks and trailers			Trucks – UK trials with 6 vehicles (1,000 vehicles worldwide)
Refrigeration fuel and running costs	White diesel - relatively expensive but small refrigeration demand	Red diesel - cheap to run			Liquid N ₂ – more expensive than red diesel due to use of main engine for ancillary cooling power
Emissions from refrigeration	Low levels due to regulation of vehicle engines	High levels of PM and NO _x due to lack of regulation		No direct emissions but higher emissions from main engine	

A heat exchange fluid enables rapid heat transfers and high thermal efficiencies, leading to fuel savings of up to 20% for the power and cooling engine, which would apply to refrigerated trucks and trailers. The heat hybrid concept, described in **Figure 32**, would apply to non-refrigerated HGVs, buses and coaches, and could reduce diesel consumption and associated emissions by up to 25%, depending on the cooling (i.e. air conditioning) demand for these vehicles and on the efficiency performance of the incumbent vehicles.

The Liquid Air Energy Network recently published a report presenting a summary of the business case and market projections for liquid air vehicles in the UK⁸⁵. According to this report, once large scale production has been achieved, payback periods for power and cooling vehicles are estimated at 1-3 years, with slightly longer times for heat hybrid vehicles (about 4 years). However, these applications are currently at a pre-demonstration stage and the real-world costs and benefits will only become clear once the technology has been tested in on-the-road trials.

⁸⁵ Liquid Air Energy Network, Liquid Air on the Highway, 2014

Two applications for Dearman Engine liquid air technology

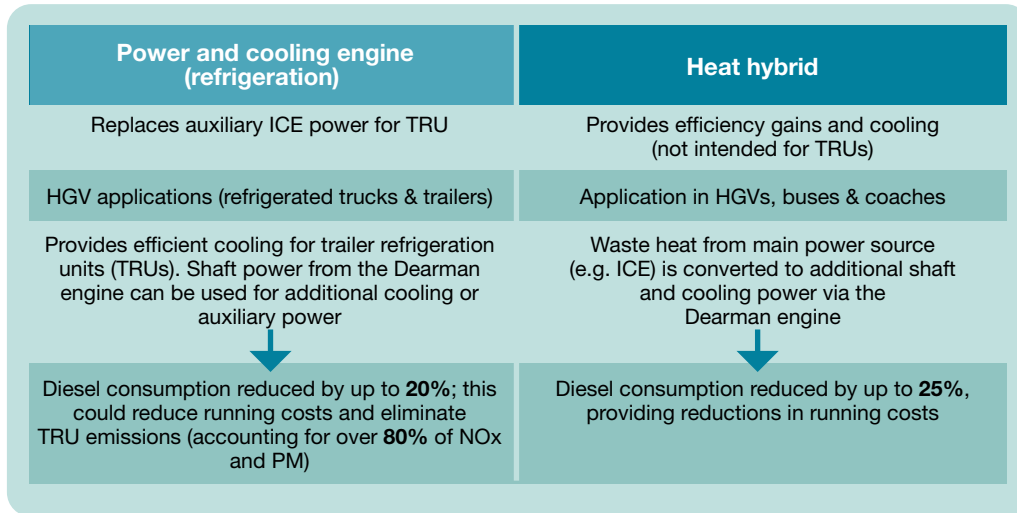


Figure 32. Two applications for Dearman Engine liquid air technology

COMMERCIALISATION TIMESCALE

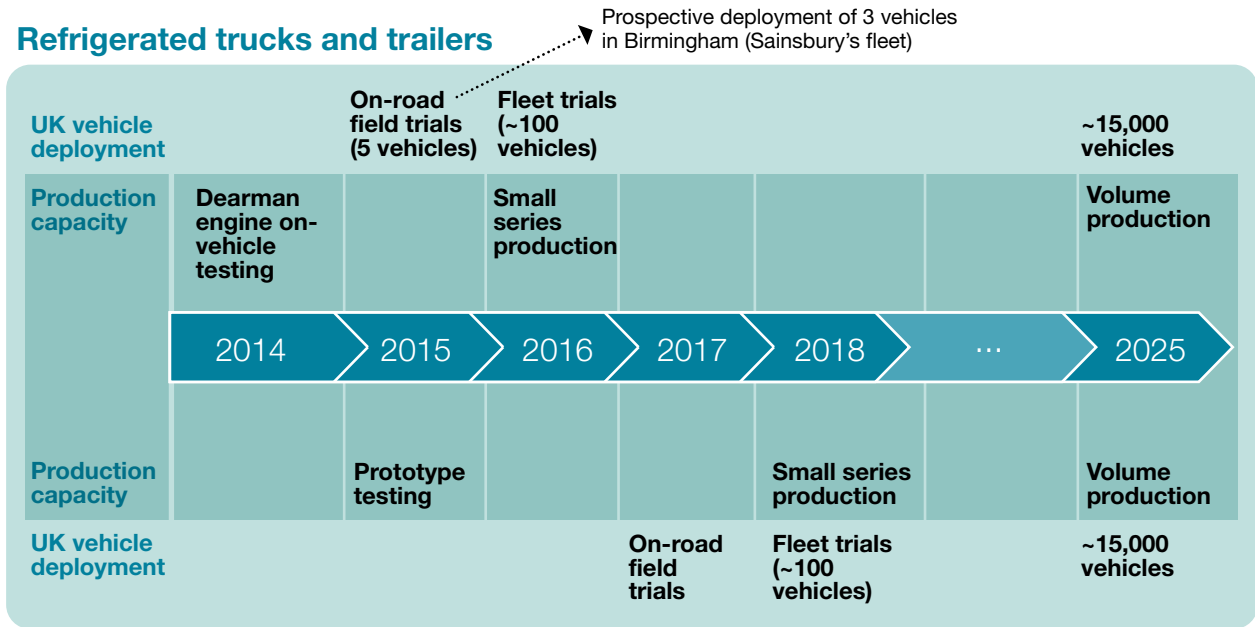
Figure 33 provides an estimated timeline for commercialisation of Dearman engine vehicles, with distinct timescales for power and cooling and heat hybrid applications.

On-vehicle testing of power and cooling technology is currently underway, and the Dearman Engine Company is likely to deploy trial vehicles within the next two years (potentially in Birmingham, depending on demand from fleets). Commercial release of TRU engines for refrigerated trucks and trailers is currently set for around 2025.

Heat hybrid technology is set to be tested on buses and HGVs next year, with commercial deployment to follow a similar timeline to power and cooling, depending on the success of early trials.

Timeline for commercialisation of liquid air vehicles

Refrigerated trucks and trailers



Heat hybrid applications (buses and HGVs)

FLEET COMPATIBILITY

Power and cooling applications for liquid air in refrigerated trucks and trailers are likely to see higher uptake than heat hybrid buses and HGVs. The benefits of the latter technology apply mainly to vehicles with some demand for cooling, e.g. air conditioning, and this excludes many UK fleets. For example, the largest bus operators in Birmingham (National Express and Arriva) indicated that they no longer fit cooling units to their buses. In terms of efficiency gains and emissions reductions, there are several alternatives to liquid air technology, including hybrid vehicles and improved diesel engines; in the timescale of this project, these are likely to be more cost effective than heat hybrid vehicles.

However, some supermarket fleets indicated an interest in liquid air technology for their refrigerated vehicles; Sainsbury's, for example, is considering Dearman Engine technology as a possible alternative to red diesel for some of their refrigerated vehicles and are currently entering a trial as part of a consortium with Birmingham City Council and the University of Birmingham.

Marks and Spencer is also considering Dearman engine technology. The retailer has been using liquid nitrogen evaporation technology (i.e. the precursor to liquid air) since 2010, and now has 20 vehicles in operation. Experiences to date have been positive, but the technology has only been used for chilled vehicles rather than frozen goods; frozen goods

Figure 33. Timeline for commercialisation of liquid air vehicles⁸⁶

⁸⁶ Source: Dearman engine company

vehicles have a greater cooling demand which cannot be met using one tank of nitrogen. It is likely that liquid air vehicles will face similar constraints on routes and applications, as greater volumes of liquid air are required for cooling, compared to diesel.

Increased tank sizes can address this to some extent; liquid air tanks will be 200-300 litres, compared to 30 litres for an auxiliary diesel tank. This has minimal impact on volume payload as tanks are cylindrical and hang under the chassis of the truck or trailer. In terms of weight, the tank results in a payload reduction of ~300kg, but this is unlikely to affect uptake; volume is usually the limiting factor for payload in food transport.

Supermarket fleets (and other refrigerated vehicles) usually refuel in depots or at distribution / consolidation centres; this would be appropriate for liquid air infrastructure.

5.2 INFRASTRUCTURE PLAN

REFUELLING FREQUENCY AND PROCESS

Refuelling will largely resemble conventional refuelling; liquid air will be dispensed by the driver, from a tank into the vehicle, with the process taking a few minutes. Liquid air is unlikely to be produced locally or onsite (see below, Liquid air supply) and therefore the footprint required will be low; refuelling will take place in operator depots on an individual fleet basis.

For refrigerated vehicles, liquid air will be consumed at a much greater rate than diesel on a volume basis and refuelling will be required every day. For this reason, liquid air refrigeration may not be appropriate for duty cycles exceeding ~8 hours, depending on the details of typical operations.

The Birmingham Connected transport strategy advocates the implementation of an Urban Freight Consolidation Centre focused on consolidating deliveries to supermarkets and retail, and optimising delivery routes into the city centre⁸⁷. Liquid air engines for refrigerated vehicles would be a potential solution to reduce the air quality impacts of 'last-mile' deliveries to supermarkets in the city, and installation of liquid air refuelling infrastructure within a future consolidation centre would be an ideal opportunity to support uptake of the technology in a number of supermarket fleets.

UPTAKE SCENARIO AND LIQUID AIR SUPPLY

In accordance with estimated UK uptake figures in the Liquid Air Energy Network report, the daily liquid air demand for refrigerated vehicles in Birmingham is unlikely to exceed 42 tonnes/day by 2025-2035. As indicated in **Figure 34**, this equates to approximately 190 refrigerated vehicles (approximately 5% of all HGVs registered in Birmingham, and an estimated 45% of the equivalent number of refrigerated vehicles⁸⁸). Use of heat hybrid

⁸⁷ Birmingham Connected – Birmingham Mobility Action Plan White Paper, November 2014

⁸⁸ According to Non-Road Mobile Machinery Usage, Life and Correction Factors (Netcen, 2004) and DfT data, refrigerated vehicles account for approximately 10% of HGVs in the UK

technology in non-refrigerated freight vehicles could increase the demand in Birmingham to 110 tonnes/day. This does not include buses, as they are unlikely to have cooling demand (consulted local bus operators indicated they do not fit cooling units in their buses) and therefore the uptake potential is limited.

Estimated Liquid Nitrogen demand in Birmingham

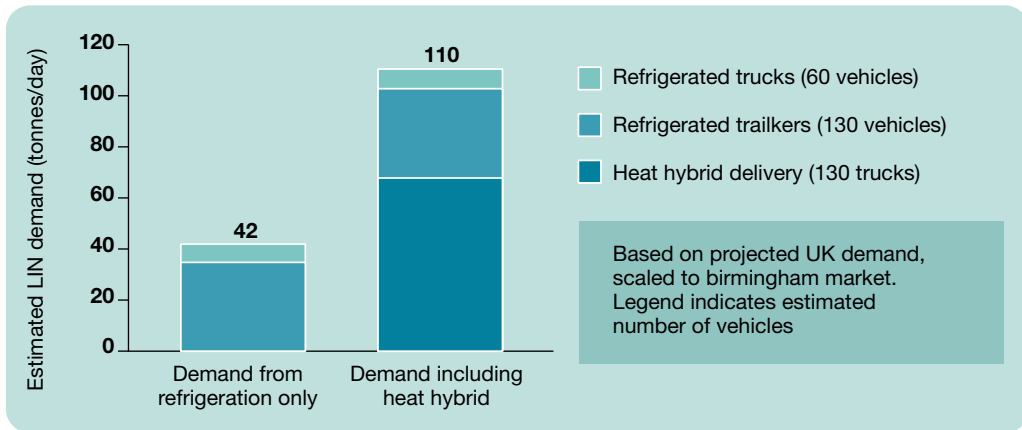


Figure 34. Long term daily demand for liquid nitrogen (LIN) in Birmingham

Liquid air is not currently produced commercially, but liquid nitrogen (LIN), which can be used in the same way, is produced on a large scale and has an established UK supply network. Liquefaction is energy intensive, and existing production plants operate mainly at night, using off-peak electricity. In the early stages of liquid air vehicle deployment, these plants could produce LIN to meet transport demand during the day.

The estimated supply to Birmingham, based on existing plants is 140-725 tonnes per day. This would be more than enough to meet the projected demand.

In the long term, local production of liquid air could be economically viable. An expansion of the liquid air market could bring specialised technology for local production, which could work well in combination with a source of very cheap electricity. The required plant capacity for local production (based on the demand estimates above) would be between 0.7 - 2 MW (assuming operation at 100% capacity). In terms of economics, viability would be dependent on availability of very low electricity tariffs, e.g. from excess renewable generation, and also on the opportunities for grid connection.

5.3 RECOMMENDATIONS FOR DELIVERY

Liquid air engines will be a strong contender as a zero-emission alternative to red diesel in TRUs, and uptake for refrigerated vehicles in Birmingham would bring air quality and CO₂ improvements within HGV fleets.

To support the uptake of this technology, Birmingham City Council should engage with and initiate projects that provide opportunities for trials of vehicles in Birmingham. Through maintaining involvement in such projects, the Council can contribute to commercial development and maintain close links with the manufacturers, as well as helping fleets to gain real experience of the technology. This could be combined with engagement with supermarket fleets for the development of an Urban Freight Consolidation Centre as part of the Birmingham Connected transport strategy, as liquid air engines for city-centre delivery vehicles would be well-aligned with Birmingham Connected objectives for air quality improvement. Shared refuelling facilities within such a facility could facilitate adoption of the technology in a number of refrigerated vehicle fleets.

CONCLUSIONS

The study has shown a high potential for GHG emissions savings through low carbon fuels, and in particular through electric powertrains (plug-in and hydrogen vehicles)



6

CONCLUSIONS

The study has shown a high potential for GHG emissions savings through low carbon fuels, and in particular through electric powertrains (plug-in and hydrogen vehicles). The key infrastructure plan characteristics to support vehicle uptake among fleets in Birmingham have been identified, and barriers or uncertainties and recommendations for delivery have been developed. These findings and recommendations are briefly summarised here, before the suggested next steps for the Council to deliver the Blueprint vision.

6.1 Impacts of low carbon vehicle uptake in Birmingham

This report has studied the refuelling needs of local fleets and their interest in low carbon vehicles, as well as opportunities and constraints for the supply of low carbon fuels (both in terms of fuel production and siting of infrastructure).

Based on feedback from operators of compatible fleets, as well as published projections, vehicle uptake has been estimated for the next 20 years. It assumes that availability of low carbon vehicles will continue to increase, and that technology performances will continue to improve, along with various other market enablers.

Table 20 summarises this uptake scenario within different fleet segments by 2030-2035 and shows the corresponding fuel demand, alongside estimates of the maximum GHG savings possible as a consequence of vehicle uptake. These estimates are based on best-case scenarios in terms of renewable, low carbon production of each fuel, the feasibility of which will be strongly dependent on policy and industry support for these routes.

Table 20. Potential uptake and impacts of low carbon vehicles in 2030-2035

Potential uptake and impacts of low carbon vehicles in 2030-2035

	Potential fleet uptake (average across fleets)	Annual fuel demand	WTW GHG savings (tonnes CO _{2e} /year)	Percentage WTW savings for road transport emissions (2005 baseline)
Plug-in vehicles	20% (taxis, LCV fleets, private cars, buses and small trucks)	138 GWh	190,000 tonnes (based on 100% renewable electricity)	12%
Hydrogen vehicles	3% (taxis, LCV fleets, private LCVs and buses)	1,600 tonnes of hydrogen (66 GWh electricity demand if all produced through electrolysis)	48,000 (based on carbon neutral electrolysis)	3%
Gas vehicles	7% (buses, HGVs, RCVs)	6,000 tonnes of gas	26,000 tonnes (based on injected biomethane)	2%

The relatively high uptake figures for plug-in vehicles reflect the maturity of the vehicle market by the 2020s, and strong policy support for electric vehicles. Uptake of hydrogen and gas vehicles is lower; in the case of hydrogen, this reflects low vehicle availability, high vehicle costs and current lack of infrastructure. The low uptake projections for gas vehicles are due to the slower rate of stock turnover among heavy duty vehicles, lower policy support, and some concerns from fleet operators over the emissions savings of natural gas.

The potential for liquid air adoption in HGV fleets was also estimated. Based on estimates published by the Liquid Air Energy Network⁸⁹, maximum uptake of liquid air vehicles in the timescale of this project is likely to consist of 300 HGVs, mostly refrigerated vehicles (representing an estimated 45% of the refrigerated vehicles registered in Birmingham). These vehicles would represent a demand of approximately 40,000 tonnes of liquid nitrogen per year (20 GWh)⁹⁰.

6.2 FUEL DEMAND AND SUPPLY

Realisation of the vehicle uptake and CO₂ savings summarised in **Table 20** will be dependent on the availability of renewable, low carbon fuel for these vehicles. The scope for provision of such fuels has been determined through estimations of resources in Birmingham and the surrounding area.

ELECTRICITY FOR PLUG-IN VEHICLES

Renewable electricity production in the West Midlands is currently around 1,000 GWh/year, which is more than enough to meet the demand from plug-in vehicles even in 20 years. Infrastructure providers can ensure that vehicles are charged from renewable sources by entering Power Purchase Agreements, while owners of domestic charging points and other small users have the option to access green tariffs. However, proportions of renewable electricity feeding the grid are likely to increase significantly over the next 20 years, in line with targets for decarbonisation of electricity, and such agreements might become unnecessary as the grid average CO₂ footprint falls.

HYDROGEN SUPPLY

If fulfilled, the potential renewable electricity capacity could also be used to meet the demand for green hydrogen production, through similar Power Purchase Agreements for onsite electrolysis. In the long term, this will be dependent on the development of a secure business case for electrolysis; onsite electrolysis may not be economically viable for all hydrogen infrastructure providers.

Alternative routes of low carbon hydrogen production (e.g. Steam Methane Reforming coupled with Carbon Capture and Storage) have not been evaluated as they would not be locally based solutions, and are currently very immature.

⁸⁹ Liquid Air Energy Network, *Liquid Air on the Highway*, 2014

⁹⁰ Liquid nitrogen can be used as a substitute for liquid air. Energy production is c. 0.5kWh/kg liquid nitrogen <http://large.stanford.edu/publications/coal/references/docs/sae98.pdf>

BIOMETHANE SUPPLY

Biomethane, as opposed to natural gas, is needed to achieve the emissions savings in **Table 20**. Compressed biomethane is currently injected into the gas grid, and can be purchased via trade of Green Gas Certificates; on a local level, Severn Trent is expected to inject 5,000 tonnes/year of biomethane by 2015 and supply by 2030 is likely to have increased. As such, supply constraints for compressed biomethane are unlikely. However, the demand for gas is likely to include a certain proportion of liquefied gas, and access to liquid biomethane is currently limited, due to economics and incentives being more favourable to biomethane injection into the gas grid. As such, the realisation of optimal emissions savings from gas vehicle uptake is uncertain.

LIQUID AIR

As discussed in Section 5.2, the liquid air demand in 2030-2035 is likely to be too small to justify local production, and instead it is likely that existing liquid nitrogen production facilities would be able to meet demand from transport.

WASTE FOR RENEWABLE TRANSPORT

The Council will have the opportunity, from 2019 (when the current contract in place for waste ends), to make use of the waste collected in Birmingham. A potential use is energy production; waste can provide fuel for heat and power, or alternatively can be used in anaerobic digestion or gasification to produce biomethane. Waste from the Council and various other sources within the city have not been included in estimates of potential electricity and biomethane capacity, and could be used to increase the renewable fuel supply for low carbon vehicles.

6.3 INFRASTRUCTURE PLAN FOR BIRMINGHAM

The demand for refuelling infrastructure for low carbon vehicles will be strongly linked to the numbers of vehicles deployed over the next two decades. **Table 21** and **Table 22** provide an indication of the scale and format of infrastructure requirements, corresponding to the uptake scenario presented in the previous section.

As shown in the tables, only a proportion of the required infrastructure will be public; many fleet vehicles refuel within depots and will consider their specific refuelling needs in parallel to adoption of low carbon vehicles. The scale of public and shared access infrastructure will depend on actual deployment within fleets using these modes of refuelling, as identified below. In early stages of gas and hydrogen vehicle deployment, it is likely that fleets with low numbers of these vehicles, that would usually refuel in-depot, will use shared-access stations with other compatible fleets as this will improve station economics. Public infrastructure for plug-in and hydrogen vehicles has the potential to support both the fleet and private low carbon vehicle market and this synergy should be exploited, to maximise the usage level of the chargers/HRS.

Indicative infrastructure demand for low carbon vehicles in 2015-2025

Infrastructure demand	In-depot	Shared access	Public
Charge points (light vehicles will use mainly overnight residential charging)	3-5 depots Buses, HGVs, some LCVs (up to 30 per depot)	10-20 CPs Dedicated to taxis & LCVs	100-150 CPs Taxis, LCVs
Hydrogen stations	5-10 depots Buses, LCVs		3-5 stations Taxis, LCVs
Gas stations	5-10 depots Buses, HGVs, RCVs		2 stations Long-haul HGVs
Liquid air stations	1-5 depots Refrigerated HGVs Heat hybrid HGVs		

Table 21. Indicative infrastructure demand for low carbon vehicles in 2015-2025

Longer term infrastructure requirements may reflect changes in technology, such as the increased charging rates and adoption of wireless charging. Depending on the available rates, some taxis and buses may use wireless charging as an alternative to depot charging during the day, and CPs may be on roads and within taxi ranks, rather than at off-street parking sites. It is also likely that the numbers of in-depot gas and hydrogen facilities will increase relative to shared access stations, as demand from individual fleets increases, improving the business case for private refuelling.

Indicative long term infrastructure demand for low carbon vehicles, 2030-2035

Infrastructure demand	In-depot	Shared access	Public
Charge points (light vehicles will use mainly overnight residential charging)	5-10 depots Buses, HGVs, some LCVs (up to 50 per depot)	20-30 CPs Taxis (move to wireless charging)	150-200 CPs Taxis, LCVs
Hydrogen stations	10-15 depots Buses	>5 Stations LCVs	3-5 stations Taxis, LCVs
Gas stations	15-20 depots (maybe a few shared access) Buses, HGVs, RCVs		2-4 stations Long-haul HGVs
Liquid air stations	5-10 depots / 1-2 consolidation centres Refrigerated HGVs Heat hybrid HGVs		

Table 22. Indicative long term infrastructure demand for low carbon vehicles, 2030-2035

6.3.1 BARRIERS TO REFUELLING INFRASTRUCTURE DEVELOPMENT

The delivery of infrastructure that maximises the CO₂ savings of low carbon fleets will depend on a number of factors that could facilitate or present obstacles to renewable fuel supply and infrastructure development.

CHARGING POINTS

For plug-in vehicles, deployment of infrastructure to support uptake may be constrained by the costs of upgrades to the distribution grid. This applies in particular to fleets of heavy duty vehicles with high power rate charging needs, for which network upgrades may be a necessity and costs could be prohibitively high. Increased transparency and understanding between the DNO and operators of plug-in fleets could ease this constraint by helping to ensure negotiations start with a clear picture of the available options.

HYDROGEN STATIONS

Beyond the station cost, identifying suitable sites can be a key obstacle for installation of hydrogen stations, due in part to the cost and scarcity of land. In addition, due to the lack of certainty around safety distances, planning bodies tend to be very cautious and therefore finding appropriate sites within urban areas can be difficult. The development of an industry standard for safety distances is currently underway and is likely to ease these constraints. However, use of onsite electrolysis for hydrogen production (a key requirement in terms of reducing WTW emissions) might require connection to the High Voltage network. This will increase station costs and is likely to lengthen the planning process for station development. Sharing of best practices for electrolyser installation, and cooperation between fleet operators and technology providers will be essential to support the development of low carbon hydrogen infrastructure.

GAS STATIONS

Siting for CNG stations is constrained by the need to connect to the gas network; costs vary according to location and proximity to existing pipelines and connection may not be economically viable for all depots. Use of shared access stations will be a potential solution to this, for some fleets.

For CNG, the availability of locally produced biomethane (at Minworth) provides a good opportunity to link production and use in transport (although the gas would be used indirectly, through green gas certificate trading). However, there is a need to clarify policy support for biomethane in transport on two levels:

- i. The combination of the Renewable Heat Incentive and the Green Gas Certificate scheme means that biomethane production supported through the RHI (and therefore intended for use in heat) can currently be used for transport. However, some fleet operators choose to use LBM, rather than using the Green Gas Certification scheme to purchase biomethane, as the latter route will not be acknowledged by DECC/Defra in WTW emission accounting. Clearer policy support for CBM for transport will be required if the potential WTW CO₂ savings of gas vehicles are to be realised.

- ii. While WTW accounting for LBM is straightforward, the business case for LBM use (particularly in dedicated gas vehicles) is not strong due to its higher cost than CBM. Specific policy support might be required to bring optimal CO₂ benefits for vehicles that store liquid gas.

6.3.2 PRIORITY ZONES FOR PUBLIC INFRASTRUCTURE

Figure 35 shows several zones that have been identified for potential siting of public infrastructure. The zones for plug-in and hydrogen vehicles account for feedback from fleet operators, as well as likely locations for early adopters of private vehicles. Gas station zones have been identified by fleet operators and account for accessibility to high pressure gas grid.

Illustrative zones for deployment of public stations

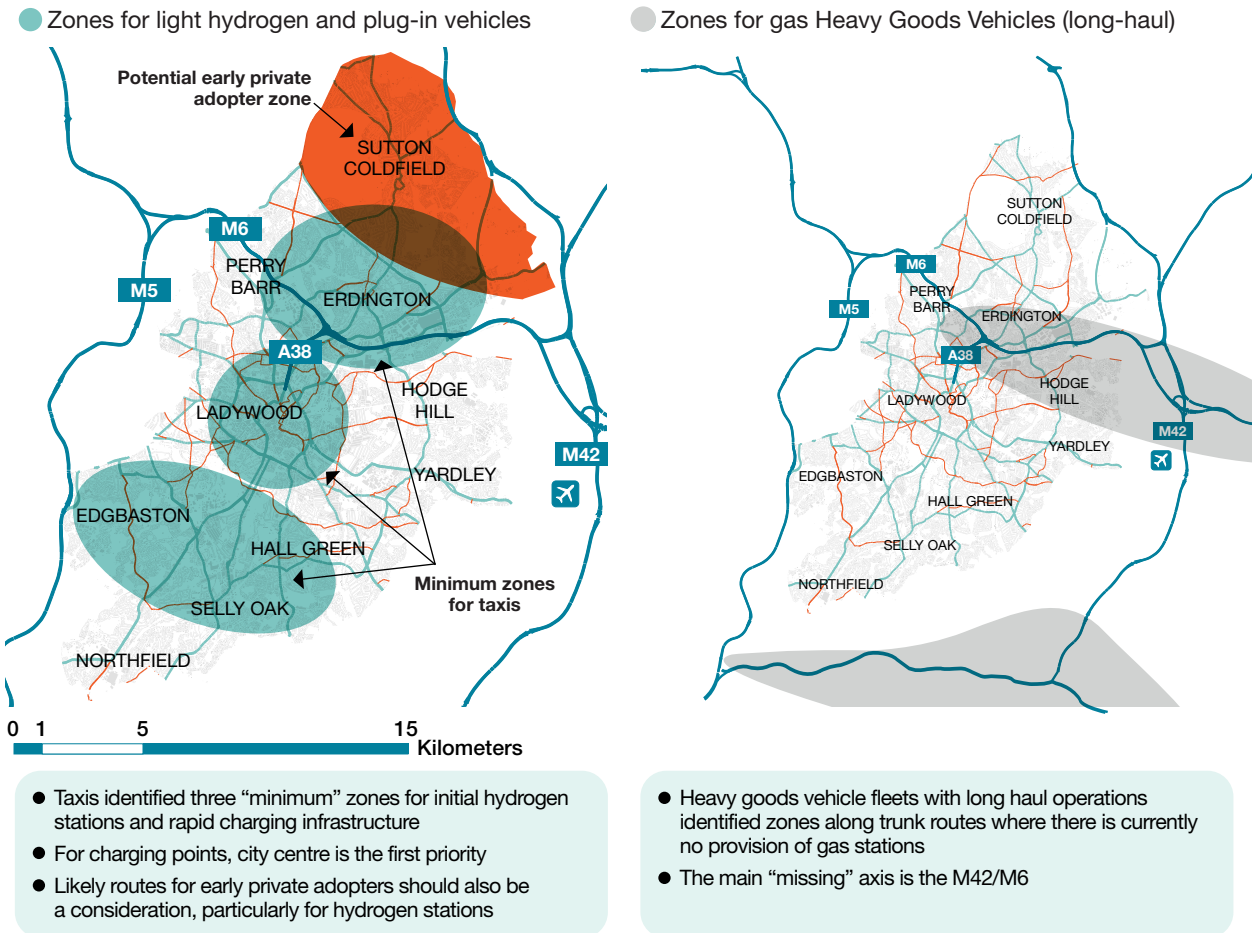


Figure 35. Illustrative zones for deployment of public stations

6.4 RECOMMENDATIONS FOR DELIVERY OF THE INFRASTRUCTURES PLANS

This report presents an upper bound scenario for uptake of low carbon fleet vehicles in Birmingham, and provides estimates of the potential benefits of this uptake. To achieve the identified significant potential reductions in CO₂ from road transport (260,000 tonnes or 17% compared to a baseline scenario), Birmingham City Council can take a number of direct actions in relation to the development of refuelling infrastructure, summarised in the following recommendations:

ADOPT LOW CARBON VEHICLES FOR COUNCIL FLEETS WHERE SUITABLE AND CONSIDER ADDITIONAL LOCAL INCENTIVES FOR LOW CARBON VEHICLES

Procurement of low carbon vehicles within Council owned fleets will contribute to market expansion and infrastructure utility, as well as provide a useful case study (for the process and cost of a local network upgrade for the case of plug-in vehicles and/or of a gas station installation).

Additional local incentives, e.g. parking/permit charges, taxi licence costs, could be used to improve the total cost of ownership of low carbon vehicles, complementing national incentives provided by OLEV.

WORK CLOSELY WITH PRIVATE FLEETS ON DEMONSTRATION AND DEPLOYMENT ACTIVITIES FOR LOW CARBON VEHICLES

The Council should encourage formation of stakeholder forums to enable sharing of experiences, and formation of partnerships to deploy vehicles and infrastructure. These groups should consider working with other UK and European cities on joint procurement of low carbon vehicles (e.g. hydrogen or electric buses) to secure economies of scale; participation in demonstration projects and trials, via such groups, would provide support for the less mature technologies and contribute to commercialisation. In addition, such groups should foster links between infrastructure providers and renewable fuel suppliers; for example, Severn Trent's biomethane injection at Minworth could be linked to the deployment of a new gas station.

Stakeholder forums will also provide opportunities to share experiences regarding logistics and costs of infrastructure installation.

USE PLANNING GUIDANCE TO DELIVER THE INFRASTRUCTURE PLAN FINDINGS

Encourage infrastructure providers to meet various customer needs by producing planning policy and/or guidance in relation to siting requirements, accessibility, availability, fuel Well To Tank emissions etc., based on the developed infrastructure plans. In the case of charging infrastructure, for which no planning permission is required, only guidance can be provided to installers.

STREAMLINE PLANNING PROCESSES FOR RENEWABLE FUEL PRODUCTION AND INFRASTRUCTURE

Streamlining of planning processes for infrastructure could open more opportunities for potential sites and increase the renewable fuel available for transport, along with associated CO₂ reductions.

ASSIST INFRASTRUCTURE PROVIDERS IN FINDING/ASSESSING LAND FOR INSTALLATION

The Council can identify areas of Council-owned land that are compatible with the footprint and siting needs of public infrastructure: this land could be used for infrastructure in demonstration projects, or leased to providers of public infrastructure.

In practise, the land of interest for infrastructure is likely to be privately owned – or owned by other bodies such as the Highways Agency. The Council can help identify owners and help developers to liaise with them. The Council can also assist in providing data, such as data related to road access and traffic, that help assess the commercial case and/or that are part of planning considerations e.g. the assessment of impact on local traffic must be provided in the planning application.

INCLUDE LOW CARBON FUELS FOR TRANSPORT INTO THE DEVELOPMENT OF THE ENERGY SYSTEM STRATEGIES

The energy system, from heat and electricity networks to energy storage and production, is set to change under the City's ambitious CO₂ reduction targets. When developing strategies around these themes, the benefits and integration with the transport system must be considered. For example, biomethane and/or electricity could be produced from Council waste. The economic viability of such a scheme and its role in meeting the local transport demand should be considered when the waste strategy is reviewed, ahead of the end of the current waste contract (2019).

6.5 NEXT STEPS FOR INFRASTRUCTURE IMPLEMENTATION

The recommendations made above are intended to be implemented over the next two decades, and should take account of changes in national policy and changes in vehicle technology. The immediate actions the Council can take are:

RAISE AWARENESS WITHIN THE COUNCIL AND INTEGRATE RECOMMENDATIONS INTO COUNCIL POLICY

Set up workshops within the Council to raise awareness of refuelling technologies and of the emission saving potential brought by the adoption of low carbon vehicles. Engage with Council teams to ensure that recommendations are aligned and integrated with policy frameworks such as the Birmingham Connected transport strategy, the Carbon Roadmap and the Future Waste Strategy. Engage with planners and work with planning requirements that assist infrastructure developments that enable the 60% carbon reduction by 2027.

BEGIN THE NEAR TERM DEPLOYMENTS

Deployments where the Council has a leading role should be started. The cases of rapid chargers to support the adoption of electric taxis and conversion of existing older taxis to LPG were identified as an early opportunity to impact on the area with the most severe air quality issues. The Council can start engaging with taxi OEMs and drivers as well as identifying several land options for the charging points, to then select the most appropriate sites, in collaboration with both WPD (given the strong variation in connection costs between sites) and taxi drivers.

BUILD LOCAL SUPPLY CHAINS FOR VEHICLES, INFRASTRUCTURE AND RELATED SERVICES

To support/encourage the establishment of the supply chains needed to support the implementation of low carbon fleets (from conversions or manufacturing of vehicles and infrastructure to maintenance and installation) the Council should study the supply chain for the technologies of interest and determine the opportunities for the development of local businesses. The analysis might identify gaps in the supply chain that could be filled by local businesses – this identification will require an analysis of the required skill sets and related value chain.

Once key stakeholders have been identified, the Council will be able to build relationships with OEMs and specialist maintenance providers as well as with industry/SME partners along the value chain as detailed below.

INITIATE STRATEGIC PARTNERSHIPS AND SOURCE FUNDING

To support the identification and near term deployment of trial fleets, the Council must identify sources of funding (national or European). Funding could also help to address high installation costs which often present a barrier to infrastructure deployment.

Access to economies of scale could be gained through joint vehicle procurement as part of national or European consortia. Strategic partnerships/consortia for interested parties for low carbon infrastructure with specific groups for each fuel can be set up to that effect. These groups would facilitate ongoing discussions with suppliers around the conclusions of this report. Stakeholders could include:

- Utilities (i.e. Western Power Distribution, National Grid, Severn Trent)
- Fuel supply chain (e.g. biomethane producers, electrolyser providers)
- Infrastructure providers
- Local vehicle manufacturers (e.g. engineering firms that could be capable and interested in developing niche hydrogen, electric or gas vehicles)
- Fleet operators in the public and private sector
- The Highways Agency
- Local universities with specialisms in low carbon transport (e.g. University of Birmingham, Aston University, Birmingham City University, Coventry University)
- Other cities or close Local Enterprise Partnerships

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APPENDIX

7.1 TECHNOLOGY STANDARDS

The table below summarises the refuelling infrastructure standards recommended or required by Directive 2014/94/EU. The Directive is due to be updated at regular intervals to reflect the advances in recharging/refuelling technologies, hence the lack of specifications for e.g. wireless charging, LNG and CNG stations and electric bus recharging.

Technical specifications from Directive 2014/94/EU

Energy vector	Standard or technology type	Comments
Electricity	<p>AC charging points to have at least Type 2 socket outlets (as described in standard EN 62196-2)</p> <p>DC charging points to be equipped at least with connectors of the combined charging system 'Combo 2' (as described in standard EN 62196-3)</p>	Compatibility with the existing electric vehicles is encouraged, e.g. charging points can be fitted with several sockets / connectors.
Hydrogen	<p>Outdoor hydrogen refuelling points shall comply with the technical specifications of the ISO/TS 20100 Gaseous Hydrogen Fuelling specification</p> <p>The hydrogen purity shall comply with the technical specifications included in the ISO 14687-2 standard</p> <p>Connectors for motor vehicles for the refuelling of gaseous hydrogen shall comply with the ISO 17268 gaseous hydrogen motor vehicle refuelling connection devices standard</p>	ISO/TS 20100 refers to other standards, such as ISO 17268 for the high-pressure fuelling connector and ISO 22734-1 for hydrogen production from water electrolysis
Natural Gas	CNG connectors/receptacles shall comply with UNECE Regulation No 110 (referring to ISO 14469, parts I and II)	The Directive recommends a focus on the TEN-T core network for gas stations.

Table 23. Technical specifications from Directive 2014/94/EU

UNECE: United Nations Economic Commission for Europe

The map of the Trans-European Transport Network (TEN-T) core network corridors in the UK (**Figure 36**) shows Birmingham is a key location on the network, being the midpoint between London and Manchester and the connecting point for the Felixstowe branch.

TEN-T Corridors

Trans-European transport network



Figure 36. TEN-T core network corridors in the UK. Source: European Commission⁹¹

7.2 MODELLING ASSUMPTIONS

The Birmingham vehicle fleet emission was modelled using the following data sources and assumptions.

The **number of vehicles** registered in Birmingham in 2013 is based on DfT and Birmingham City Council data (see table below). This stock size is increased over time in line with DfT national traffic projections (DfT statistic table TRA0101). The future car fleet size is adjusted down to be in line with DECC allocation of national emissions to Birmingham and the taxi fleet is assumed to stay of constant size.

Numbers of vehicles registered in Birmingham in 2013 and 2035 projections

	2013	2035	Source for 2013 value
Cars	548,967	549,825	DfT statistics, table VEH0105
Taxis	6,110	6,110	Birmingham City Council licence data
LCVs	82,335	121,343	DfT statistics, table VEH0105
HGVs	4,193	4,954	DfT statistics, table VEH0105
GVW ≤ 8t		39%	As per HGV split reported in DfT statistics, table VEH0606
8t < GVW ≤ 31t		32%	
31t < GVW		29%	
Buses	4,491	4,619	DfT statistics, table VEH0105
RCVs	150	177	Birmingham City Council data

Table 24. Numbers of vehicles registered in Birmingham in 2013 and 2035 projections

⁹¹ <http://ec.europa.eu/transport/themes/infrastructure/doc/ten-t-country-fiches/ten-t-corridor-map-2013.pdf>

The annual mileage of vehicles used in the model is reported in **Table 25**.

Annual mileage assumptions for road vehicles

	km	Source
Cars	7,960	National average adjusted down to in line with DECC allocation of national emissions to Birmingham ⁹²
Taxis	71,630	Based on workshop input
LCVs	20,580	National average, in line with workshop input
HGVs	53,770	As per Element Energy for the LowCVP, 2014 and in line with average workshop input
Buses	28,400	National average (DfT table VEHO105)
RCVs	15,000	Birmingham City Council data

Table 25. Annual mileage assumptions for road vehicles registered in Birmingham in 2013 and 2035 projections

The vehicle stock turnover is based on the observed turnover rate and corresponds to an average lifetime of 9 years for HGVs, 11.5 for LCVs, 12.5 for cars and 13.5 for buses. The model assumes new vehicles have an energy assumption as per the Committee on Climate Change modelling⁹³ and adjusted to reproduce DECC fuel consumption⁹⁴.

For fossil fuels, the emission factors are based on data published by Defra, reported in **Table 26**. For electricity, two cases are modelled:

- A 'grid average' case where the DECC target of 50gCO_{2eq}/kWh is reached in 2030 (giving 66 gCO_{2eq}/MJ by 2020, 13.9 gCO_{2eq}/MJ by 2030 and 8.3 gCO_{2eq}/MJ by 2035)
 - A 100% renewable electricity case where no emissions are associated with electricity production (0 gCO_{2eq}/MJ)
- For hydrogen, two electrolysis production cases are modelled:
- Based on UK average grid (as above) and electrolyser efficiency improving from 60% today to 70% by 2035, giving an emission factor of 101 gCO_{2eq}/MJ by 2020, 18.5 gCO_{2eq}/MJ by 2030 and 11.9 gCO_{2eq}/MJ by 2035
 - Based on 100% renewable electricity (0 gCO_{2eq}/MJ)

For gas, two cases are considered:

- Natural gas, based on Defra factor (65.09 gCO_{2eq}/MJ Well to Wheel emissions)
- Biomethane at -19.5 gCO_{2eq}/MJ Well to Wheel emissions, based Well To Tank emissions that assume anaerobic digestion plants consuming a range of agricultural waste to make biomethane that is injected into the gas grid – as per Ricardo, Preparing a low CO₂ technology roadmap for buses, for the LowCVP, 2013

⁹² Local and Regional CO₂ Emissions Estimates are published by DECC at <https://www.gov.uk/government/statistics/local-authority-emissions-estimates>

⁹³ Based on Ricardo-AEA, A review of the efficiency and cost assumptions for road transport vehicles to 2050, f or the Committee on Climate Change, 2012

⁹⁴ As per Element Energy, Options and recommendations to meet the RED transport target, for the LowCVP, 2014

Emission factors and energy content

	Well to Wheel emissions in gCO _{2eq} /MJ	Tank to Wheel emissions in gCO _{2eq} /MJ	Energy content
Diesel	86.86	71.39	36 MJ/l
Petrol	82.03	68.75	32 MJ/l
CNG	65.09	56.61	45.86 MJ/kg

Table 26. Emission factors and energy content. Source: Defra/DECC GHG Conversion Factors

7.3 CHARGING POINT LOCATIONS

Charging points

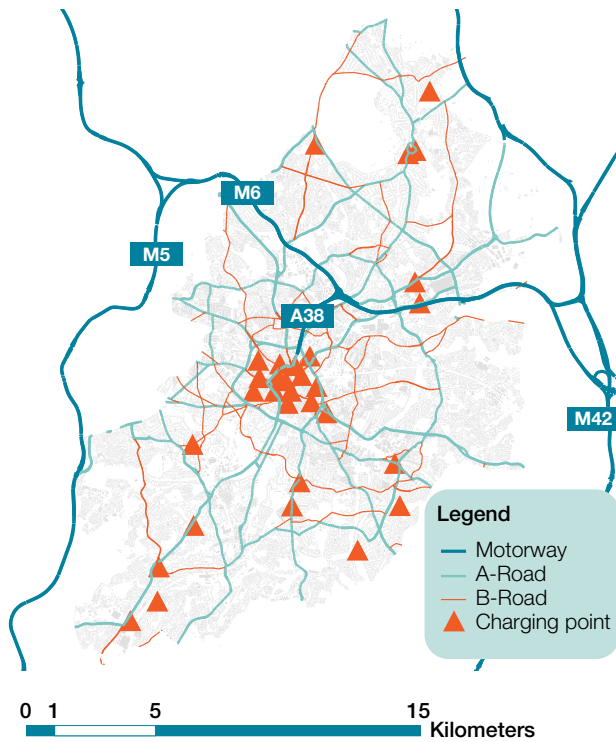


Figure 37. Charging points in the Birmingham region. Source: Element Energy using data provided by Zap-Map.com in June 2014

7.4 LOCAL ENTERPRISE PARTNERSHIP AREA



Figure 38.
Wider Birmingham
and Solihull LEP
area

ABOUT THE AUTHORS

Element Energy Limited is a low carbon consultancy providing a full suite of services from strategic advice to engineering consultancy in the low carbon energy sector. Element Energy's strengths include techno-economic forecasting and delivering strategic advice to clients on all opportunities connected to the low carbon economy. Element Energy has experience in the design of strategies for the coordinated deployment of low carbon infrastructure.

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NOTE ON MAPS

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