

# Transport Energy Infrastructure Roadmap to 2050

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## MAIN REPORT

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Prepared for the LowCVP by Element Energy Ltd  
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**elementenergy**

JUNE 2015



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Renewable Energy Association  
Transport for London  
Transport Scotland  
UK Petroleum Association

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## **Background and objectives**

Approach

Transport Infrastructure Roadmaps

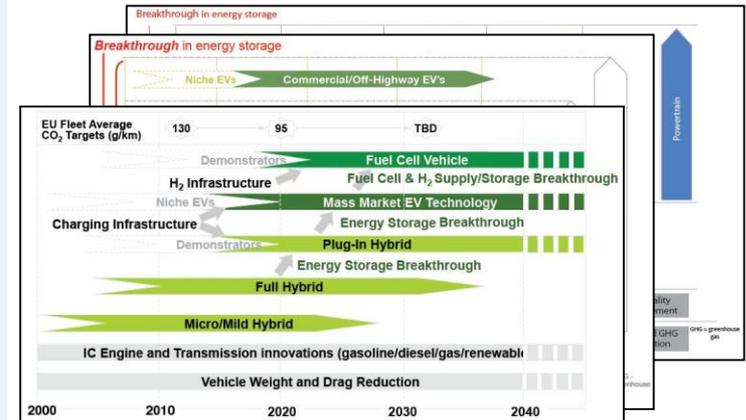
Conclusions

# Background - a 'Transport Infrastructure roadmap' is needed to complement existing vehicle and fuel roadmaps

- In the context of the expected transition to lower carbon powertrains and fuels, the **Auto Council vehicle roadmaps** have proven to be a useful tool **to focus research, funding and policy**, bringing into one place the industry's views on future technology options, deployment steps and corresponding policy drivers.
- To complement these powertrain technologies roadmaps, the **LowCVP commissioned a Road Transport Fuels Roadmap in 2013-14**, which also proved successful in bringing clarity to the fuel options available and mapping the enabling milestones.
- This Infrastructure roadmap is the 'missing piece' that will support new powertrains and new fuels. This roadmap is all the more necessary as the **needs and barriers for deployment of electric, hydrogen and gas refuelling stations differ significantly** and refuelling/recharging infrastructure is a key enabler for low emission vehicles.
- The objectives of the Infrastructure Roadmap are to:

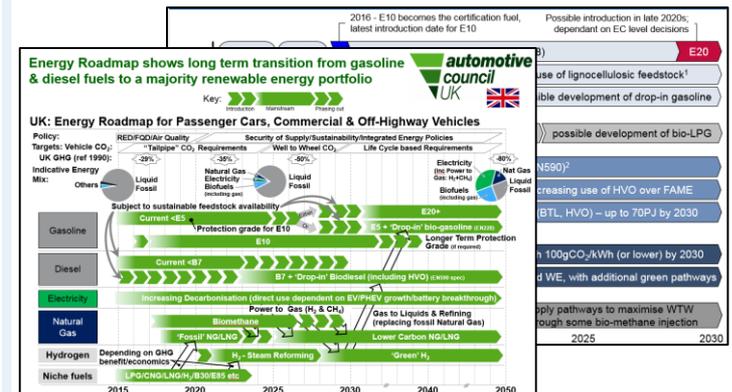
  - Assess the infrastructure needs** and barriers for deployment of electric, hydrogen and gas refuelling stations to 2050, including impact on upstream distribution, as well as to consider 'conventional' liquid fuels
  - Make **recommendations for delivery** of infrastructure deployment, both at national and local government level.

## Vehicle roadmaps



Source: Auto Council and LowCVP

## Transport fuel roadmaps



Source: Auto Council and Element Energy for the LowCVP

# The Infrastructure Roadmap covers private and public infrastructure, for all main road vehicles and both current and future fuels

## Fuels / energy vectors considered

- Zero tailpipe emission fuels: **electricity and hydrogen**
- 'Conventional' **liquid fuels**: gasoline (E5 to E20, in line with the Transport Fuels Roadmap), diesel, LPG/bio-propane
- **Methane**: Compressed Natural Gas (CNG), Liquefied NG (LNG) and biomethane
- Niche/future fuels: methanol, liquid air and a high bioethanol blend (E85)

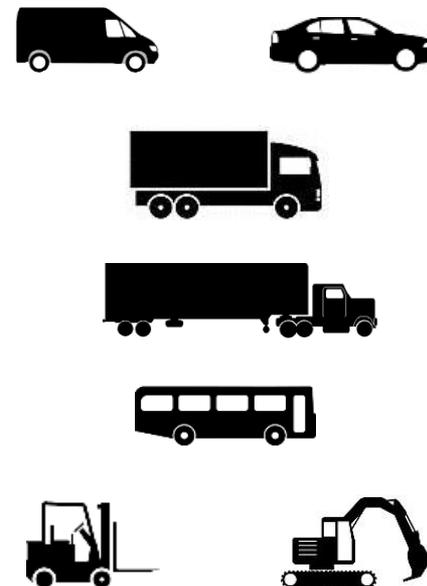
## Refuelling infrastructure types

- Depot based refuelling for fleet operators and return to base operators
- Home recharging for private and (some) commercial vehicles
- Public forecourt refuelling/recharging

## Drivers for change in the transport energy system

- The UK's legally binding target to **reduce total GHG emissions by at least 80% (relative to 1990 levels) by 2050**, and transport contributes to c. 25% of UK total GHG emissions;
- EU level regulations (gCO<sub>2</sub>/km, **Air Quality targets** and EURO spec), Directives (Renewable Energy, Fuel Quality, Clean Power for Transport) and Transport White Paper

## Vehicle types



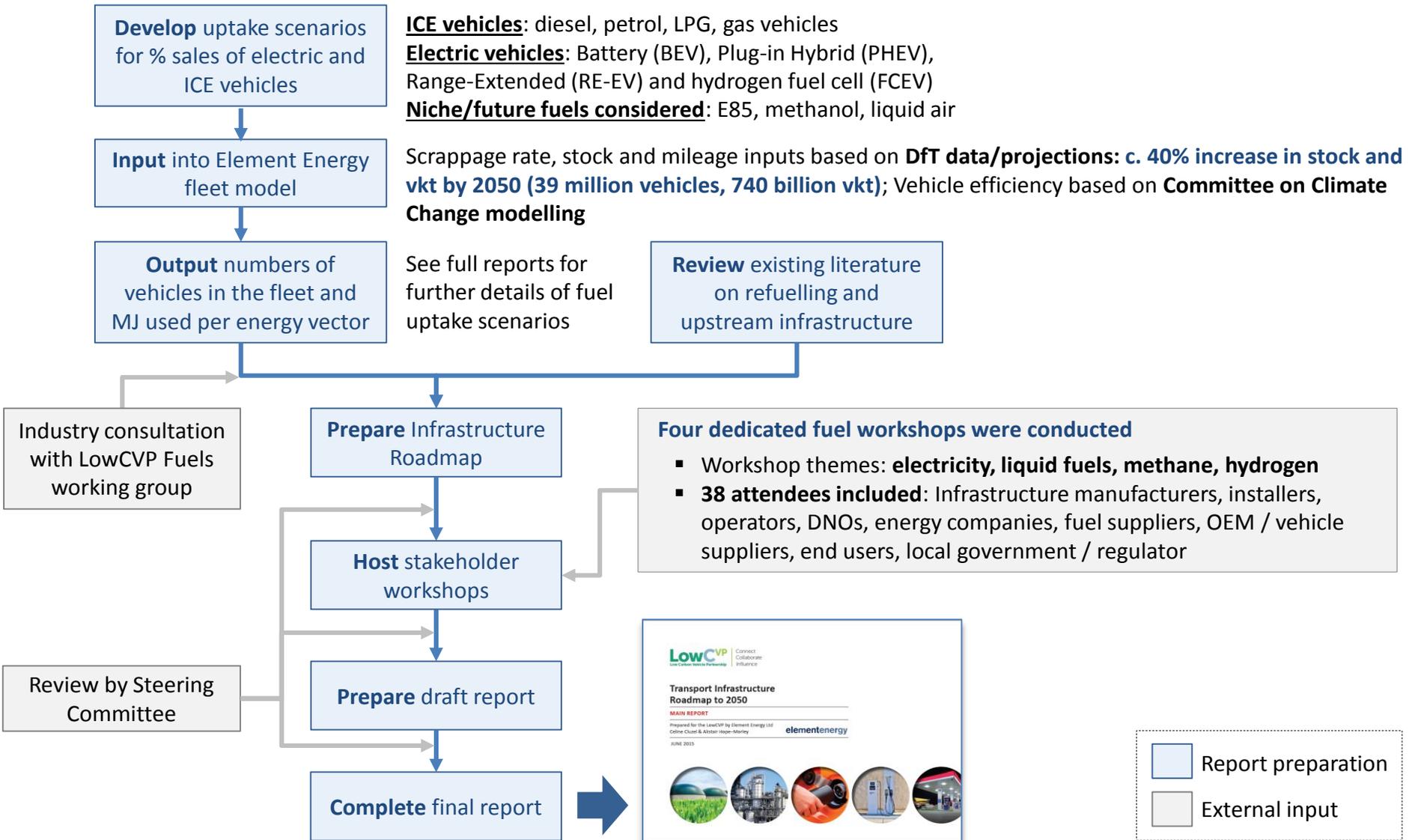
Background and objectives

**Approach**

Transport Infrastructure Roadmaps

Conclusions

# The development of the Infrastructure Roadmap benefitted from input from a wide range of stakeholders, many consulted through workshops

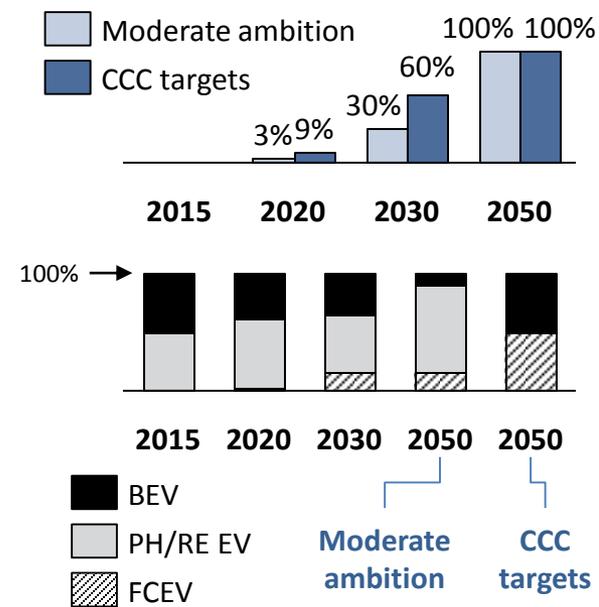


# The future fuel demand and associated infrastructure needs are based on ambitious vehicle uptake scenarios in line with the UK GHG reduction targets

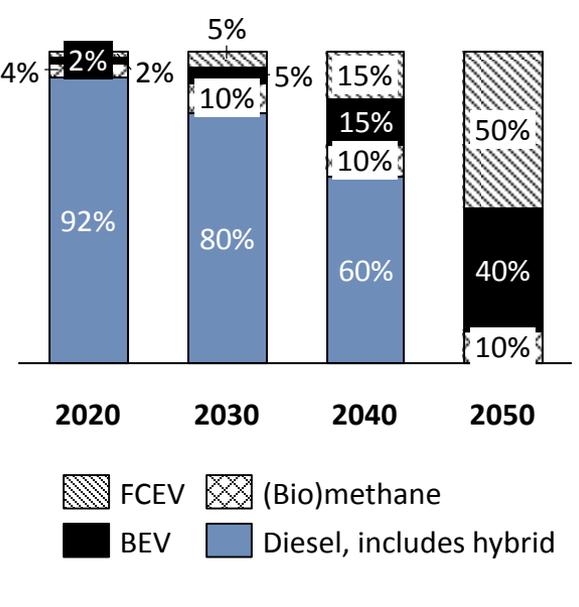
## Proposed policy-led uptake scenarios – focus on alternative fuels

- The scenarios are not intended to cover all possible outcomes but instead focus on cases with **ambitious uptake of alternative fuels** in line with targets set by the Carbon Plan
- They represent possible futures where **low and ultra low emission powertrains are successfully deployed**, and are illustrative rather than based on detailed modelling of technology costs and customer decision making behaviour
- In accordance with the LowCVP Fuels Roadmap, blends higher than B7 are not considered for the mainstream fuels and E20 is considered only from the 2030s

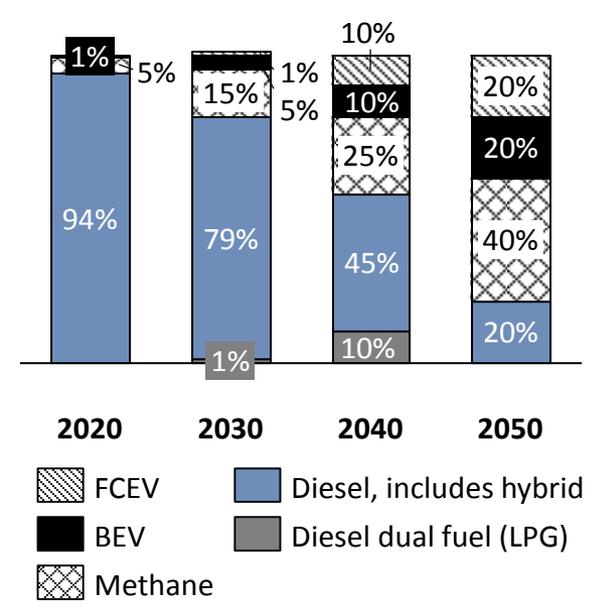
### New car/van EV sale scenarios:



### New bus sales scenario:



### New truck sales scenario:



Source: Element Energy in consultation with LowCVP Fuels Working Group. Refer to the full reports (issued separately) for more detail. 'Diesel' refers to a blend of B7 and drop-in renewable diesel, as per the Fuel Roadmap

# Four different roadmaps have been developed to best capture the diverse challenges of each type of energy vector

- The roadmaps and associated recommendations are presented next for each energy vector:

Sections for each fuel are indicated by a specific tag:



- A structured approach was adopted to assess the **background and status quo for each fuel** identifying current supply pathways and trends, geographic distribution and key stakeholders
- This enabled **identification of future infrastructure requirements and barriers to deployment** supported by quantification of projected fuel demand and stations numbers
- The focus of the roadmap is on the barriers to infrastructure rollout, the wider barriers to adoption of alternative fuelled vehicles (such as cost premium, supply etc.) are not investigated here
- The **cost estimates also focus on the refuelling/recharging infrastructure** (capital costs) and exclude costs such as new fuel production units, potential vehicle subsidies and costs to set up new distribution systems
- This report contains only the key findings, the extensive analysis supporting them is issued separately, in four distinct reports (electricity, methane, liquid fuels, hydrogen)

Background and objectives

Approach

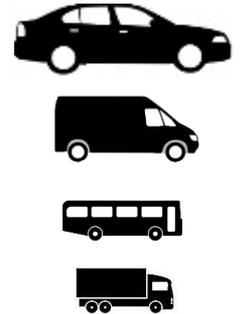
**Transport Infrastructure Roadmaps**

Conclusions

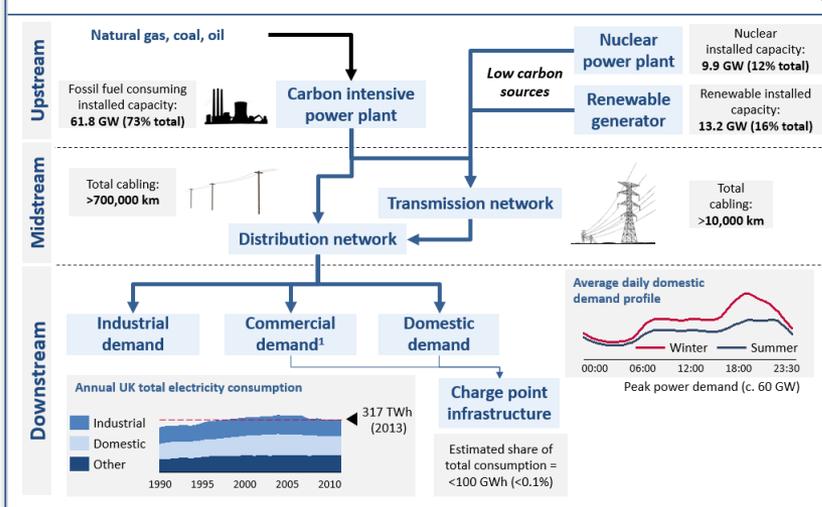
# The existing electricity network, exploited with smart technologies, is well suited to support the electrification of transport

electricity

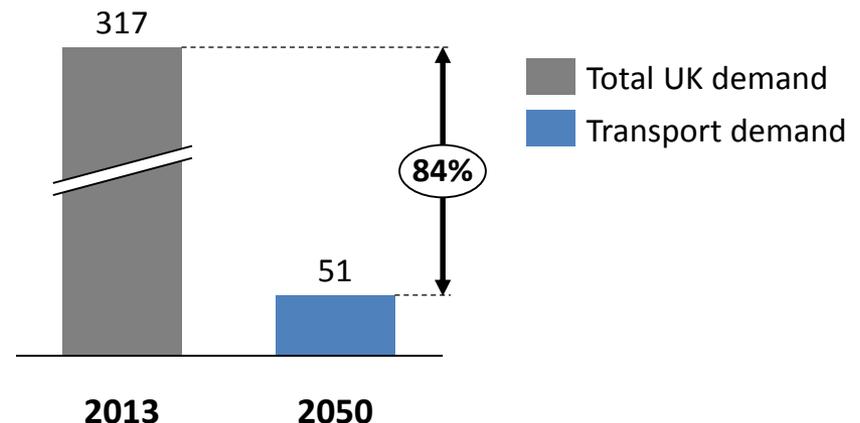
- Electricity transmission and distribution systems already in place, for other purposes than transport, and electricity is in process of being decarbonised (-80% and -50% gCO<sub>2</sub>/kWh by 2035 compared to 2013 in 'No progression' and 'Slow progression' projections from National Grid)
- Additional transport demand will present a **peak demand (GW)** challenge rather than a production (TWh) challenge: without charging management, EVs could add 28 GW of demand (c.+50% of current peak demand). However, EVs are only one contributor to the future peak demand, among other technologies earmarked as part of the UK decarbonisation plan (notably heat pumps)
- The main demand for electricity will be from **cars**, which require both residential charge points and a national public network



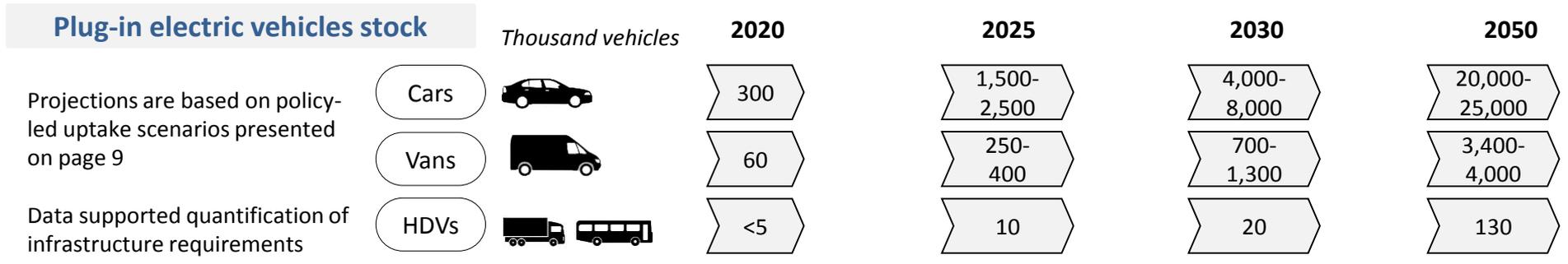
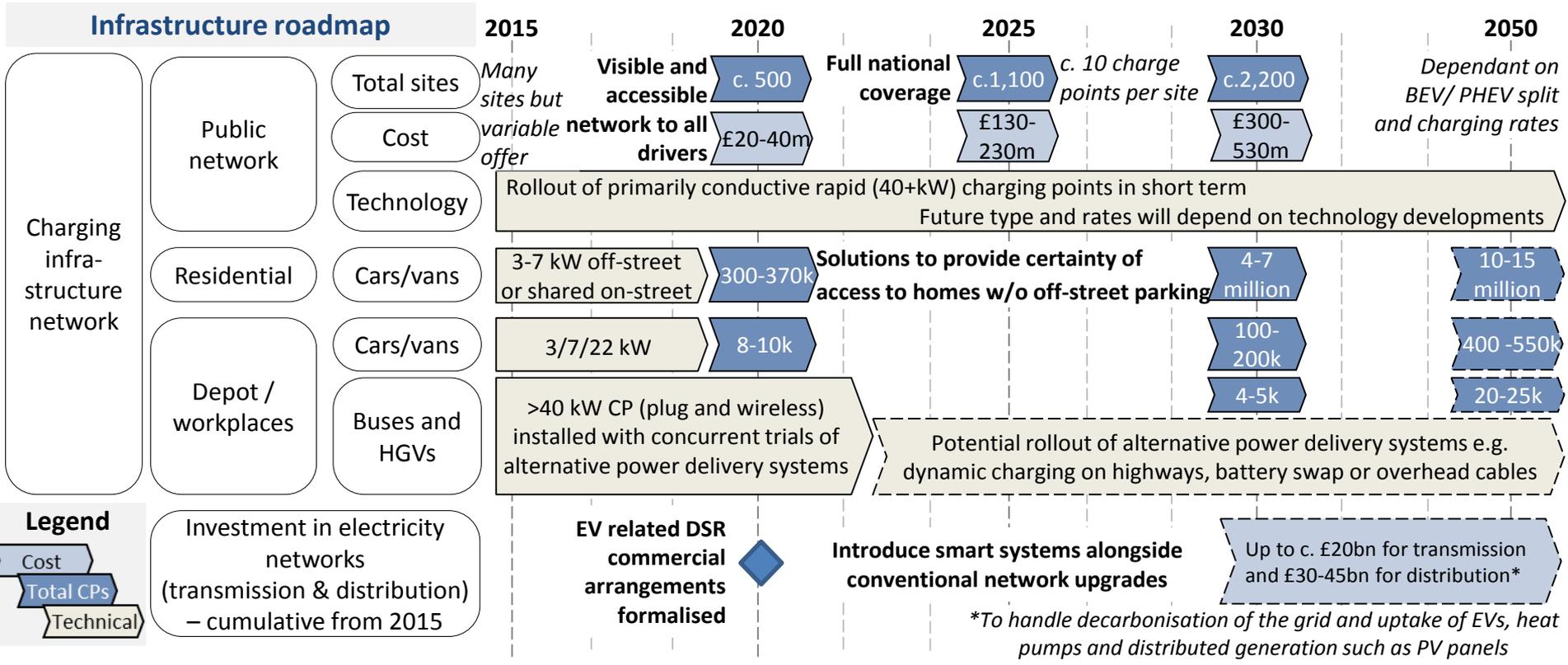
## The national electricity grid provides an existing distribution pathway for supplying power to electric vehicles across the UK



## Electricity demand TWh/year



# Millions of charge points (mostly residential) will be needed to support widespread EV deployment, with uncertainty over charging technologies



# A visible, accessible and reliable public charging network should be rolled out for light vehicles

## 1 End user experience of public charge points

- Current public infrastructure is fragmented with several operators offering various access conditions and variable reported reliability
- Beyond the number of charge points, a network should meet some criteria to be useful to EV drivers:
  - Well marketed to drivers (e.g. clear signs, uniform signage across the country)
  - Easy to operate (e.g. multi socket connections, simple payment system, etc.)
  - Immediately accessible (e.g. PAYG, dynamic booking systems, live status information)

### Recommendations

**R&D / industry / LAs:** Improve and build on existing network and develop a national platform compatible with multiple vehicle types to remotely communicate with public infrastructure (e.g. dynamic booking, simple payment systems, availability notification) and consider joining cross platform projects (e.g. EMI<sup>3</sup>); embed criteria in relevant funding programs

## 2 Economics of public charge points

- The business case for public charge points remains challenging

### Recommendations

**Central gov.:** Continue funding program and monitor progress, embed end user experience criteria in support programs

**Local Authorities:** support programs where local fleets can provide a base load to charge points that can also be accessible to the general public; facilitate exchange between relevant stakeholders (DNOs, end user, charge point operators) to help optimum siting; share best practise findings with other LAs

**On-going trial programs:** Share key learnings relevant to business case and end user experience (e.g. current Rapid Charging Network project)

**Industry:** DNOs could communicate areas of adequate network capacity to infrastructure developers to avoid high connection costs

# Solutions to facilitate overnight charging will be required across residential areas and depots

## 3 Residential areas

- Purchasing an EV requires certainty of access to charging, which is best provided by access to overnight home charging
- Ambitious uptake scenarios and unbalanced access to off street parking in urban/rural areas mean many households will need new solution for access to 'home charging'

### Recommendations

**Local Authorities:** Continue (or begin) to investigate solutions to infrastructure for home owners without off-street parking and share findings; implement a tenants' right to install infrastructure for rented properties; support car club installation of charge points in dedicated bays; implement rules for new builds and retrofit to be 'socket ready' (successfully done in Westminster City Council)

**R&D bodies & industry:** develop identification systems for residential infrastructure shared between multiple users

**Central Government:** Continue to monitor private sector investment trends for residential and depot based infrastructure and adjust support as needed

## 4 Depots / workplaces and fleets

- Fleet operators of HDVs are likely to be faced with high local network reinforcement costs (already observed) – an investment in assets not own by the fleet operator: an unfamiliar risk and procedure

### Recommendations

**Local gov. :** facilitate the interface between DNOs and fleet operators and prediction of 'demand cluster' for optimised investment; socialise early adopter case studies to share lessons learnt

**Central gov. and regulator:** align EV uptake ambition with network reinforcement needs to allow/encourage 'top-down' strategy (upfront investment in advance of need)

**R&D bodies:** support trial of new technologies (e.g. inductive, ultra fast conductive, 'automatic plug-in' etc.) that would be more practical for fleets than current technologies

# Mitigating the impact of electric vehicles on the network will require new technologies and new commercial arrangements

## 5 Impact on electricity network

- Without management of the charging time, EVs could (when added to other technologies such as heat pumps) require large investment in new distribution infrastructure (substations, cables) and possibly new generation / interconnection capacity. The Smart Grid Forum identified that 'smart' technical and commercial solutions could save in the order of £15bn on distribution network reinforcement costs by 2050
- DNOs will need information on EV location and uptake to plan investment and smart solutions rollout accurately
- Research is needed to understand relative impact of 3kW vs 7kW charge point deployments
- Although less studied benefits to the grid could also be available: as flexible loads, recharging EVs could provide important grid balancing services to maintain grid frequency, to manage supply and reduce renewable curtailment

### Recommendations

**Central Gov. & regulators:** support DNOs to access geographically disaggregated EV uptake data;

**Installers and DNOs:** improve platform for compiling charge point installation notifications (as stipulated by IEC)

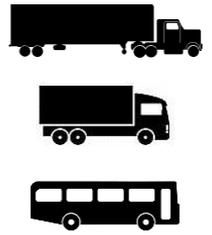
**Regulators, electricity suppliers and DNOs:** develop new commercial arrangements and tariffs required for the uptake of smart charging solutions and for customer engagement [Ofgem's Low Carbon Fund already supports these activities]

**On-going trial programs:** disseminate findings on local network management solutions to DNOs and related stakeholders

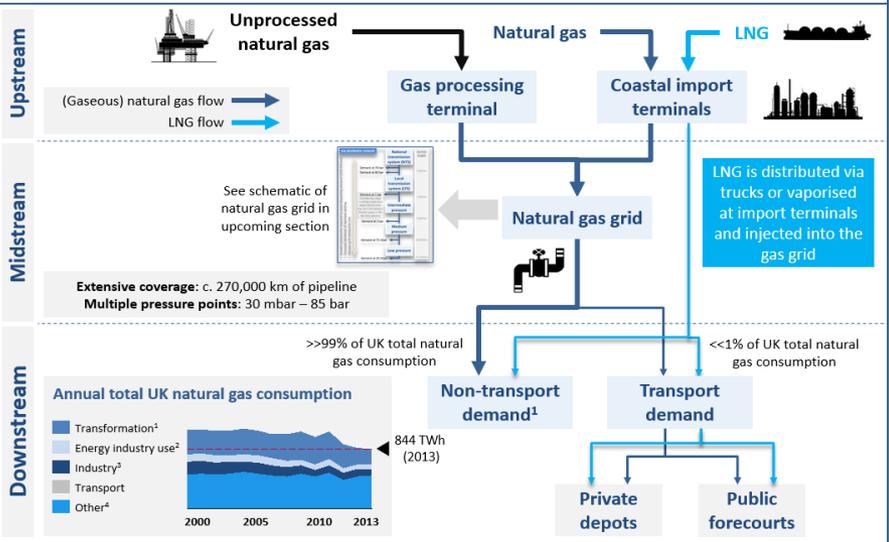
**R&D bodies & DNOs:** Investigate network related topics: charging/demand management technologies, Vehicle-2-Grid, impact on battery life, co-locating energy storage devices with rapid charge points to alleviate strain on weak grid

# Many opportunities exist for Heavy Duty Vehicles to use natural gas supported by mature refuelling technologies

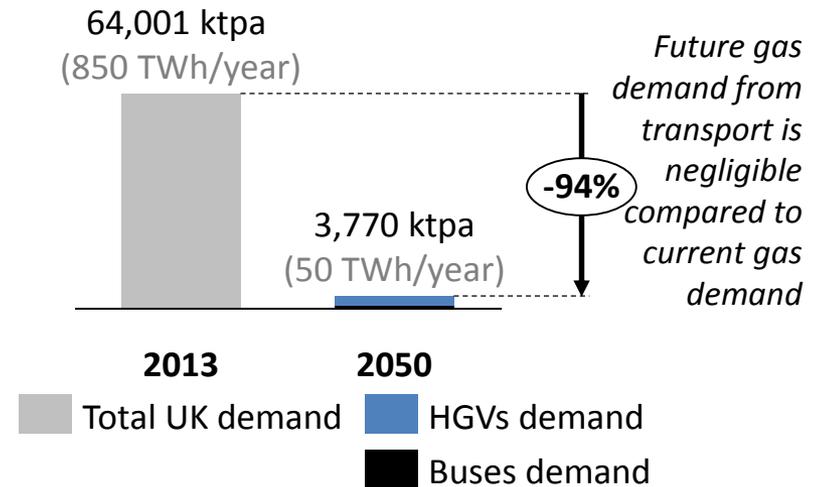
- The UK benefits from an extensive and advanced (unique high pressure network ) gas grid, although not fully exploited for transport applications yet.
- Even if the current network in the UK is limited (<50 stations), internationally 1000s of gas stations are active indicating technology maturity
- The projected added demand from transport is negligible compared with the current gas demand. However, further distribution infrastructure might be required for Liquefied Natural Gas (terminals)
- The main demand for gas will be from **heavy duty vehicles**, which require both bunkered refuelling (at depots) and public refuelling for the case of long haul applications



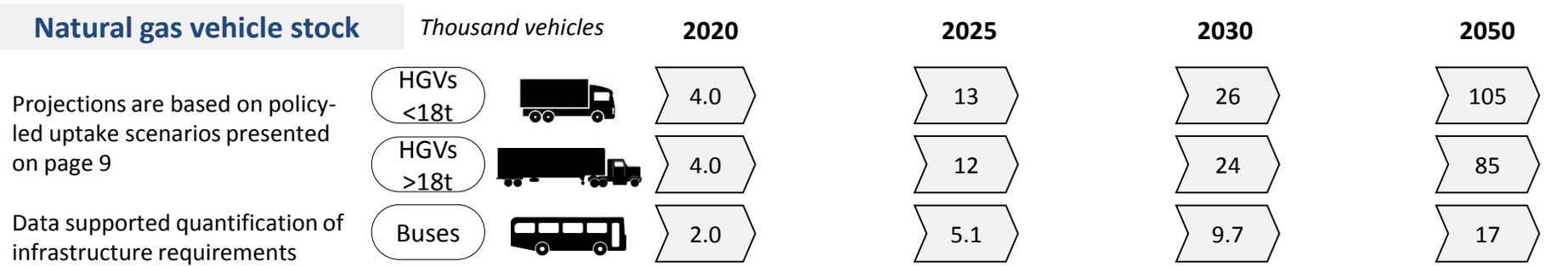
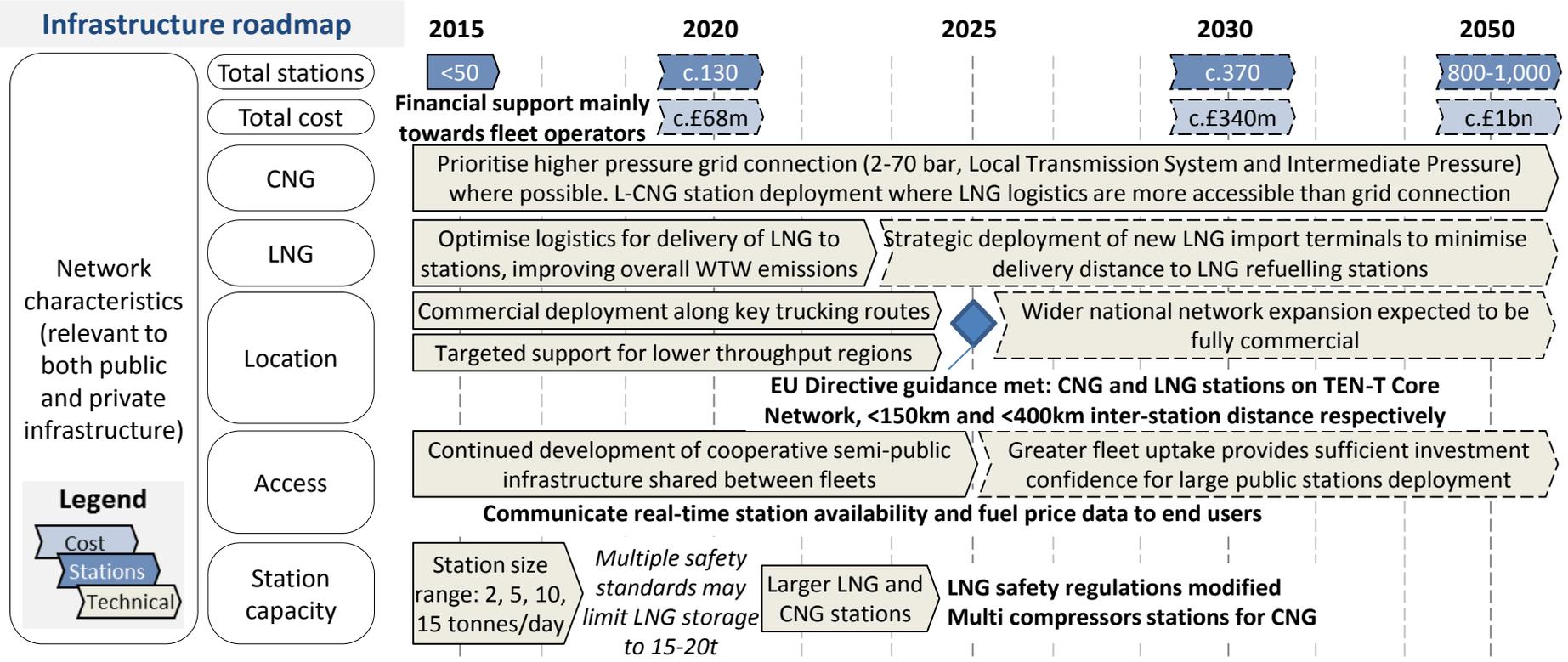
## The extensive natural gas supply chain in the UK can support the development of natural gas refuelling infrastructure



## UK natural gas demand



# Regulatory barriers will be the primary focus for enabling natural gas infrastructure, whilst a number of technical issues must also be resolved



Dashed lines represent high uncertainty

Major milestone/enabler

Indicative fuel economy: dual fuel HGV = 60 kg/day, dedicated HGV = 75 kg/day  
Costs based industry input, future cost reductions not included

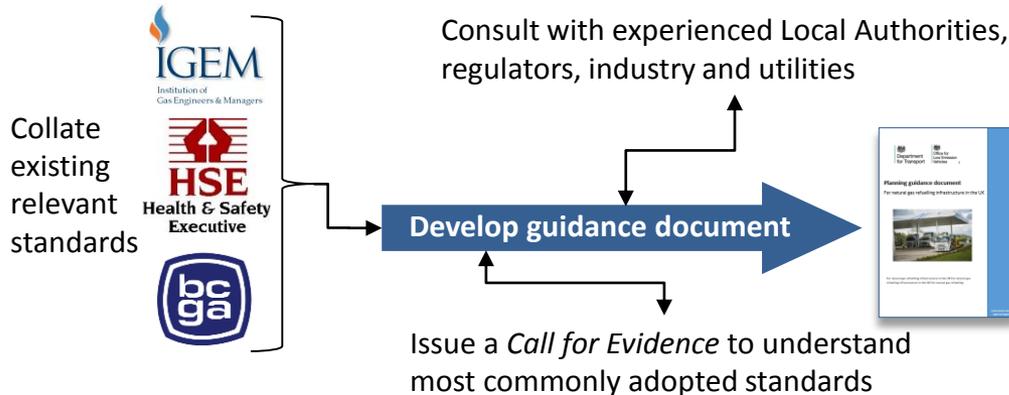
# Planning guidance for Local Authorities will help speed up station deployments with key outstanding safety issues addressed

## 1 Planning guidance

- A number of well informed, robust standards have been developed to address technical issues associated the installation of natural gas refuelling stations
- Infrastructure operators have identified inconsistent interpretation of these standards by Local Authorities to significantly delay station installation

### Recommendations

**Central Government:** develop planning guidance document to facilitate the uniform implementation of infrastructure equipment standards



## 2 Safety issues

- Health and safety regulations and codes of practice only partially address infrastructure requirements
- For example, natural gas infrastructure operators have identified on-site storage allowances and safety distances to be incompatible with refuelling station deployment due to regulator unfamiliarity with the use of natural gas as a road fuel



### Recommendations

**Regulators:** Re-evaluate and consider amendment of existing standards for on-site natural gas storage allowances and safety distances

**Cross cutting recommendation: Central Gov., LAs and regulators:** Establish regular dialogue with the NGV Network, to address planning, safety and other technical issues as well as get industry input on funding/infrastructure strategies

# End user experience should be harmonised across UK network through standardisation of equipment and improved communication systems

## 3 Station economics and support

- Industry asserted that economics for operating infrastructure in high throughput areas does not need support, as evidenced by commercial organisations offering turn-key solutions
- A minority of UK infrastructure projects have received grant funding<sup>1</sup>; further support should target areas of lower vehicle throughput/lower base demand
- Areas for optimisation include costs for high pressure grid connection and venting prevention technologies

### Recommendations

**Central Government:** Focus on long term support for natural gas vehicle deployment and the associated infrastructure will follow growing demand if the correct regulatory and legislative arrangements are in place

**Gas network operators:** allow competition in LTS connection to reduce connection costs

**R&D bodies:** Reduce costs for venting prevention / methane capture technologies

## 4 End user experience

- Inconsistent infrastructure implementation has led to a fragmented driver experience at stations
- Vehicle tank receptacles are compatible with different nozzle types and dispensing pressures but no standard stipulates a specific requirement
- Station downtime (e.g. for maintenance) is often not communicated to drivers and fuel price variations can significantly impact fleet operations

### Recommendations

**Central Gov. & regulators:** Work with industry to develop the most appropriate nozzle/pressure standard to meet UK fleet operator needs for CNG, LNG and L-CNG stations

**Industry:** Develop communication system to notify drivers of technical/economic factors for infrastructure (e.g. station type, fuel price and maintenance schedules)



1 - e.g. TEN-T funded projects and OLEV £4m fund for future station deployments  
LTS: Local Transmission System (high pressure gas grid)

# Innovative approaches such as semi-private stations provide a transition strategy before wider vehicle and station deployment in the 2020s-2030s

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## Depot infrastructure sharing

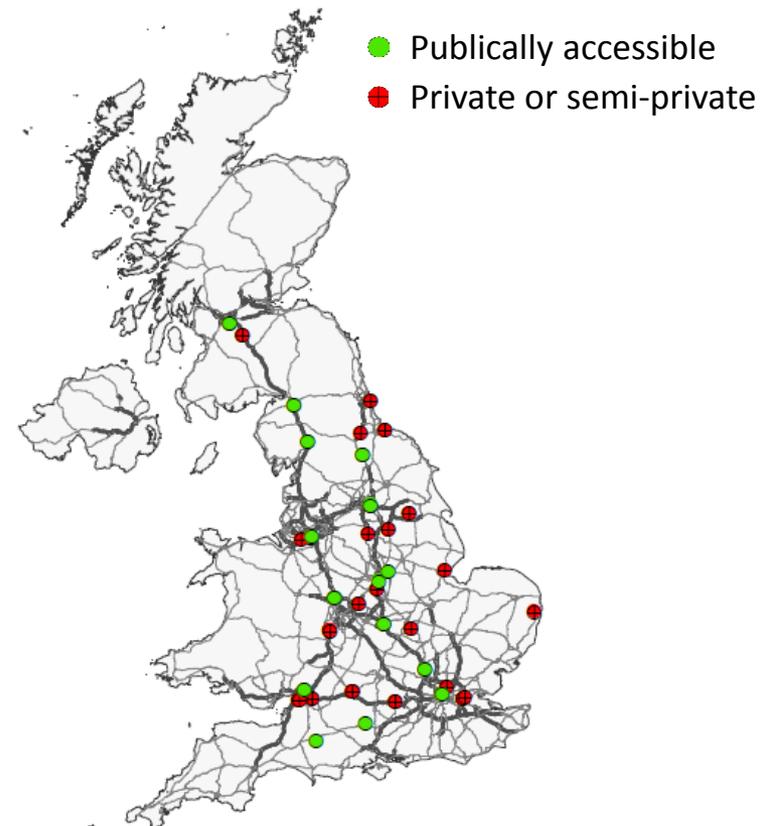
- A number of fleet operators have deployed semi-private refuelling facilities under cooperative contractual arrangements allowing pre-agreed operators to share each others facilities
- Advantages of this approach include maximising station throughput and reducing dependency on public infrastructure rollout
- Opportunities for further adoption of cooperative station ownership models will enable a transition to significant vehicle uptake when sufficient investor confidence exists for larger public infrastructure deployment

### Recommendations

**Central Government:** consider counting semi-private stations (where facility is shared between multiple, pre-agreed users) as 'public' in the Implementation plan to be submitted to the EC as part of Directive 2014/94/EU<sup>1</sup>

**Industry:** develop commercial arrangements that facilitate further adoption of the cooperative model

## Natural gas refuelling station network



### Key infrastructure operators:



<sup>1</sup> Clean Power for Transport program – Directive on 'the deployment of alternative fuels infrastructure' (October 2014)

# While further research is needed, measures that minimise the GHG emissions related to distribution and dispensing of gas should be adopted

6

## Well-to-Tank (WTT) emissions

- In keeping with national targets for reducing transport GHG emissions, emissions relating to logistics and dispensing of gas should be minimised
- Current analysis is incomplete and UK non-specific, however some emission factors are well understood:
  - CNG station siting activities should aim to access **high pressure grid** connection points
  - LNG / L-CNG station siting activities should aim to **optimise delivery logistics** and adopt state-of-the-art **venting prevention** and capture systems
- Biomethane achieves greater WTT emission savings than natural gas but UK production is limited and incentives in place divert it to applications other than transport

### Recommendations

**Local Authorities:** Consider WTT emission factors in conjunction with planning guidance when approving natural gas station installations

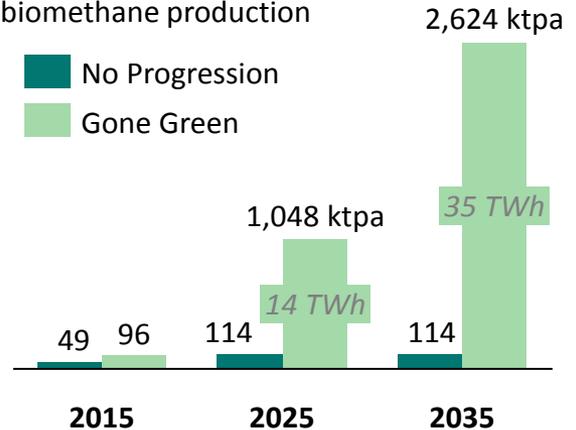
**Central Government:** Future infrastructure strategy should consider UK specific findings (on-going ETI led analysis)

**R&D bodies:** Reduce costs for venting prevention / methane capture technologies

## UK biomethane production potential

Graph units: ktpa (TWh shown as reference)

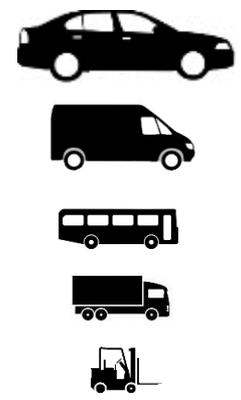
National Grid upper and lower bound scenarios for biomethane production



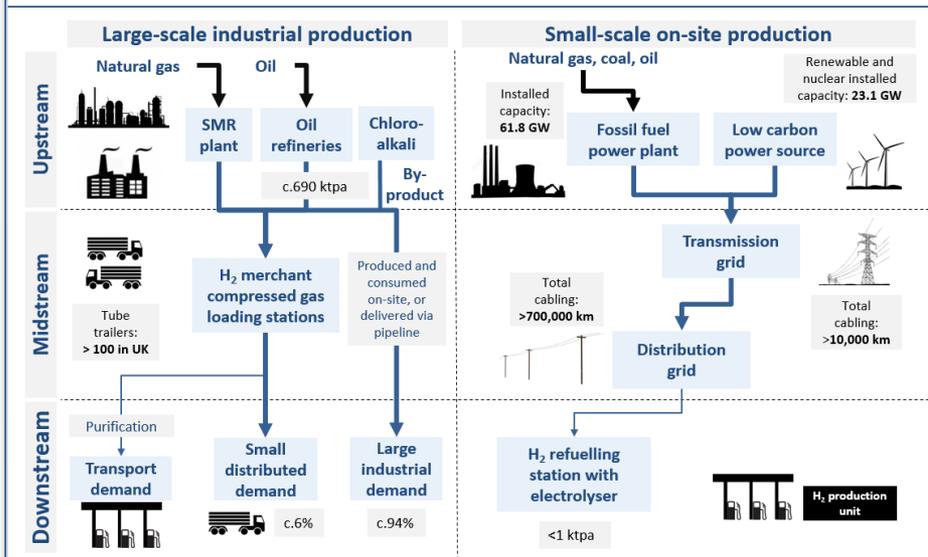
- National Grid has developed several scenarios of biomethane production, in the highest case it's 35TWh/year i.e. <5% of total gas demand
- Under present incentives, the 'No progression scenario' is the most likely case

# The widespread use of hydrogen for mobility will require substantial growth in existing production and distribution infrastructure

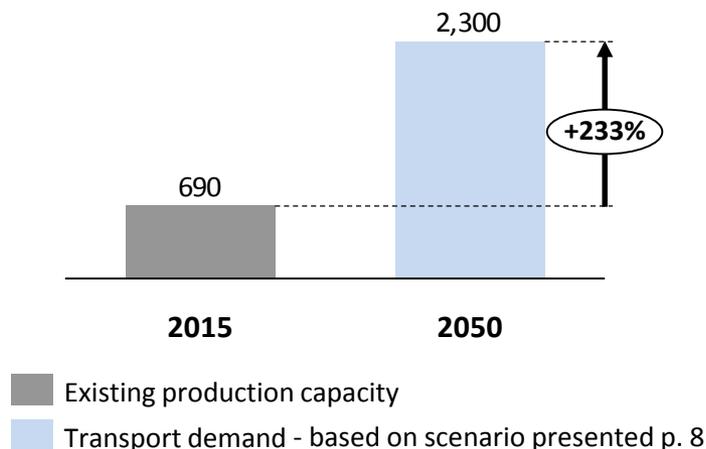
- Production of hydrogen is currently limited to meet mostly an industrial demand and often used on-site, with limited distribution by road in gaseous and liquid forms
- Strong growth in demand for mobility, driven by uptake of hydrogen vehicles such as **passenger cars, commercial vehicles, buses and fork lift trucks**, will need to be met by new production
- A successful rollout in all vehicle types (i.e. reaching millions of vehicles after 2030) will require a **quadrupling of existing production capacity**, met by conventional and green sources
- While the relative growth of hydrogen in each vehicle type remains uncertain, it is clear that a **national refuelling network** will be required to support passenger cars and private customers



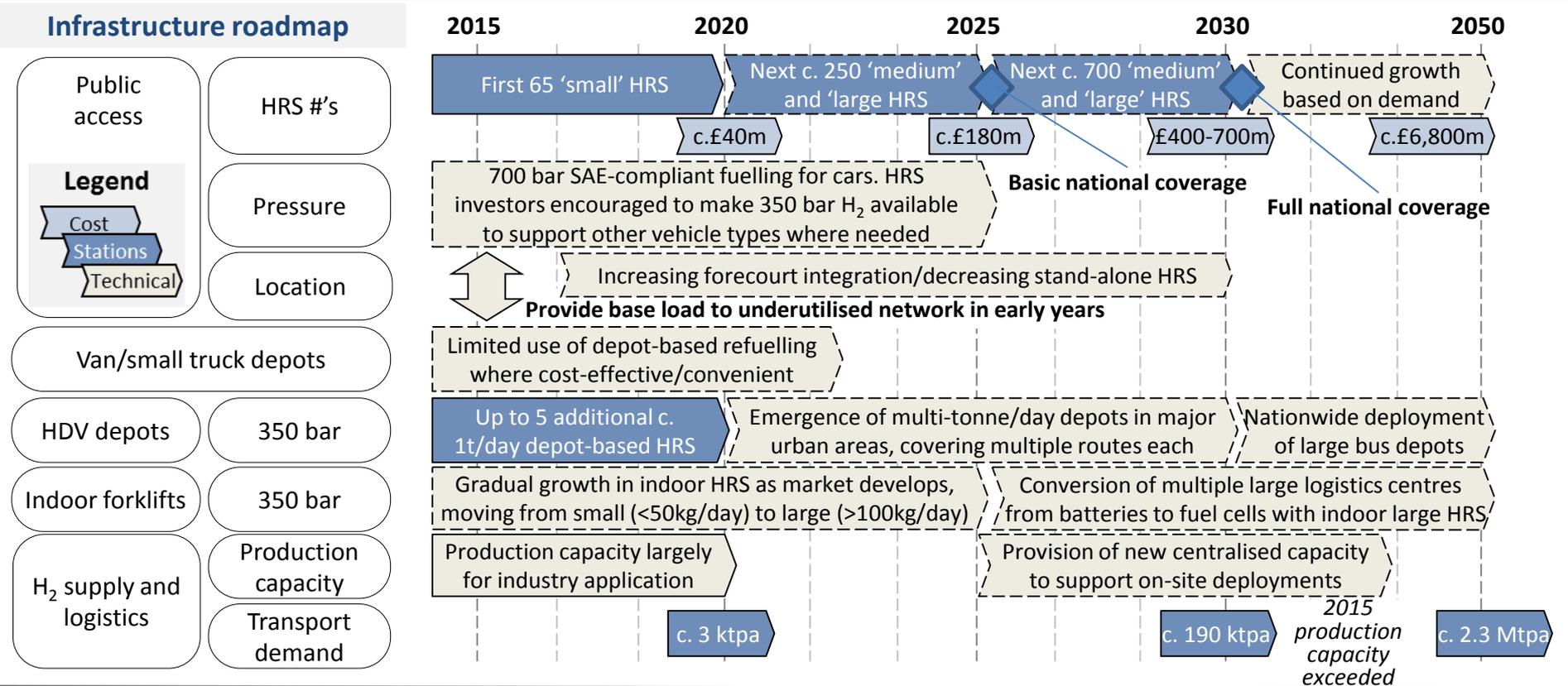
Until now, the UK hydrogen industry has been overwhelmingly geared towards meeting demand in refinery and industrial processes



## Current total UK hydrogen production capacity and future transport demand



# The H<sub>2</sub> infrastructure roadmap reflects the diverse refuelling needs of different vehicle types and the uncertainty about the speed of the rollout



<b>Hydrogen vehicle stock</b>		Thousand vehicles	2020	2025	2030	2050
Projections are based on policy-led uptake scenarios presented on page 9	Cars		2	180-350	680-1,400	4,200-16,800
	Vans		<1	30-60	100-200	750-3,000
Data supported quantification of infrastructure requirements	HDVs		<1	3	8	130

Dashed lines represent high uncertainty

**Major milestone/enabler**

HRS: hydrogen refuelling station

# Industry and government will need to work closely to secure the deployment of the early public HRS network and hydrogen vehicles

## 1 Securing deployment of the early public HRS network

- A certain number of HRS (e.g. 65 set out by the H<sub>2</sub>Mobility strategy) is likely to be needed to meet the needs of the earliest customers and to continue to attract OEMs to the UK
- Low utilisation means that these early HRS will need public funding to attract private investment
- HRS investors will also require confidence from vehicle suppliers on the timing and ambition of vehicle deployments
- Customer incentives are likely to be needed to encourage early vehicle sales as OEMs transition to lower cost second generation vehicles
- The network will also need to offer a consistent and high quality customer experience, in terms of the station 'look and feel', ease of use, payment methods etc.

### Recommendations

**Central Government:** Provide financial support to early HRS, using funding conditions to ensure high quality user experience and coherent geographic strategy. Provide support to vehicles through existing ULEV incentives

**Local Government:** Help provide 'base load' demand to public HRS (e.g. FCEV procurement for public fleets) and make sites available for refuelling stations where possible

**OEMs:** Provide transparency on numbers and locations of vehicle deployments (as far as possible) to maximise confidence of HRS investors

**HRS operators/suppliers:** Work closely with vehicle suppliers and their customers to ensure that HRS siting and specifications meet their needs

# Ensuring infrastructure is compatible with all vehicle types and publicly accessible will maximise station utilisation

## 2 Maximising utilisation of early stations

- Early network is likely to use 700 bar refuelling, based on requirements of OEM passenger cars
- Other vehicle types (e.g. vans, small trucks) currently use 350 bar tanks which are not compatible with higher pressure dispensers
- The use of dual-pressure stations (700/350bar) allows public HRS to meet refuelling demands of these vehicles, increasing early usage where demand exists
- Fleet vehicle users should also be encouraged to use public HRS rather than depot solutions where feasible to further increase utilisation

### Recommendations

**HRS investors:** Work with vehicle suppliers to identify needs for dual-pressure HRS sites

**Local government:** Encourage fleet stations to be publicly accessible for private customers where feasible (e.g. through planning system)

## 3 Coordination

- As the network grows, coordination of HRS siting is likely to be needed to optimise coverage and customer convenience
- Coordination is also likely to be needed on cross-cutting topics e.g. securing deployments of 'green hydrogen' production capacity, metering and billing, progress towards fully forecourt-integrated stations
- If use of standalone HRS continues, HRS operators should work closely to define a consistent approach to siting and 'look and feel' to allow drivers to find and use the infrastructure

### Recommendations

**All H<sub>2</sub> stakeholders:** Identify an appropriate forum to allow discussion of these coordination activities, and to present an aligned UK strategy in outreach to international OEMs to maximise appetite to bring vehicles to the UK

# Existing regulations should be amended to harmonise the planning approval process, thereby streamlining infrastructure installation

## 4 Siting and planning process

- Lack of guidance on HRS safety requirements can lead to planning delays and inconsistent user experience
- Transition from standalone to forecourt-integrated sites likely towards 2020
- Work to include hydrogen in the Blue Book<sup>1</sup> is underway to represent hydrogen, in particular addressing electrical hazardous zones and safety distances, giving clear guidance for use by developers and petroleum officers in designing and approving HRS on forecourts

### Recommendations

**Local Authority planning teams and regulatory authorities:** Support the approval of integrating hydrogen infrastructure into existing forecourts; produce guidance documents for standalone HRS

## 5 Innovation opportunities

- Reducing the cost of HRS, H<sub>2</sub> production and distribution and vehicles will be required to allow mass-market deployments
- Quality assurance of H<sub>2</sub> (lower cost analysis, continuous monitoring etc.) needs to be further developed and standardised
- Engineering solutions are required for large scale depot refuelling beyond current fleet sizes (e.g. c.100 bus depot requiring c.2 tonnes/day)
- Full integration of water electrolyzers into the grid will require further trials of technical and commercial arrangements

### Recommendations

**Innovation funding bodies:** Work with industry to define clear innovation needs that can be delivered through R&D funding and trials

<sup>1</sup>National Guidance document jointly published by the Energy Institute and Association for Petroleum and Explosives (APEA) used to assess and sign off the safety of new forecourt installations and upgrades

# New policy may be required in the medium term to ensure that the future hydrogen production mix delivers CO<sub>2</sub> emissions savings

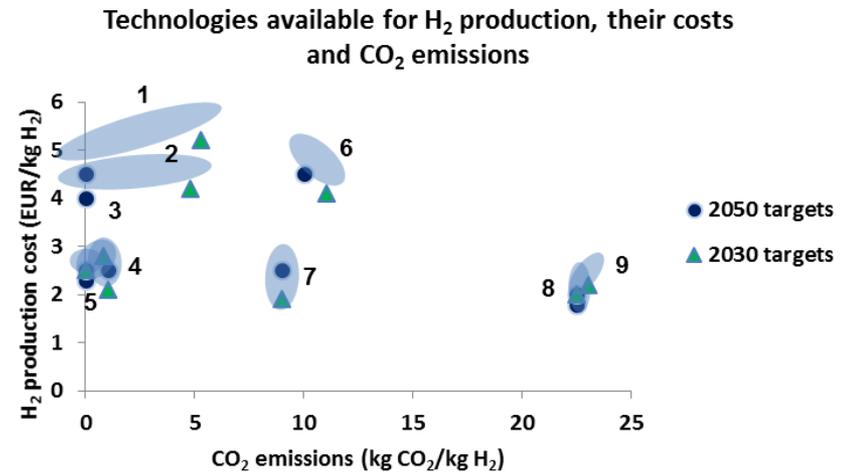
## 6 Hydrogen production pathways

- Current UK hydrogen production capacity is insufficient to meet transport demand from the mid 2030s
- Therefore new production capacity will need to be introduced concurrently with vehicle demand growth, taking into account GHG emission reduction targets
- A strategy will be needed on how this capacity will be delivered (based on the expected volumes of hydrogen vehicles) while ensuring that the overall production mix delivers very low well-to-wheel emissions

### Recommendations

**Central Government:** Consider policy mechanisms to ensure sufficient volumes of low carbon hydrogen sources

**R&D bodies:** Investigate low cost green hydrogen production technologies

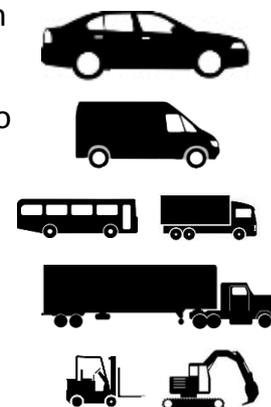


### Technology type

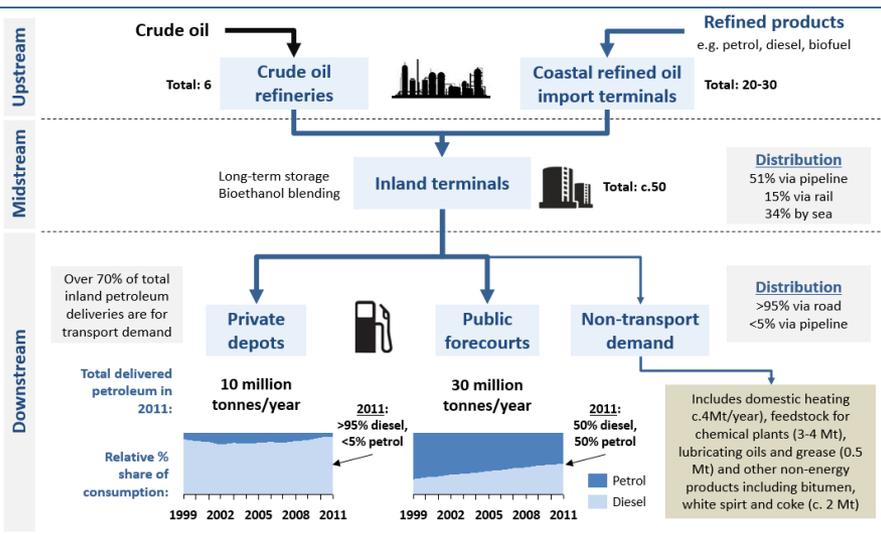
- Distributed water electrolysis
- Conventional water electrolysis
- Coal gasification + carbon capture and storage
- Centralised SMR + carbon capture and storage
- IGCC + carbon capture and storage
- Distributed steam methane reforming
- Conventional steam methane reforming
- Internal gasification combined cycle
- Coal gasification

# A fully functioning infrastructure for dominant liquid fuels exists to supply the UK vehicle parc

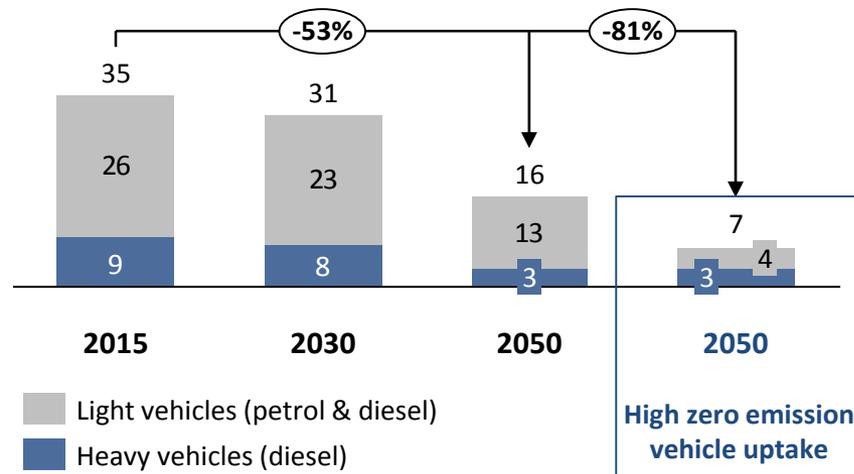
- Liquid fuels (petrol and diesel) are the current dominant fuels for **all road transport vehicles** and as such have an extensive distribution and refuelling systems, for both public forecourts and private bunkering
- Demand for liquid fuels in transport will **significantly decrease post-2030**, with a total decrease of 50% to 80% by 2050 compared to today (depending on the uptake of Plug-in hybrid EV vs. battery or fuel cell EVs)
- The case of **LPG** is different, with a possible increase in demand (mostly based on Air Quality policy drivers) from c. 100 kt today to around 300-400 kt by 2030, well within UK production capacity
- Among niche/future fuels investigated, **liquid air** is the most promising one, especially for transport refrigeration units



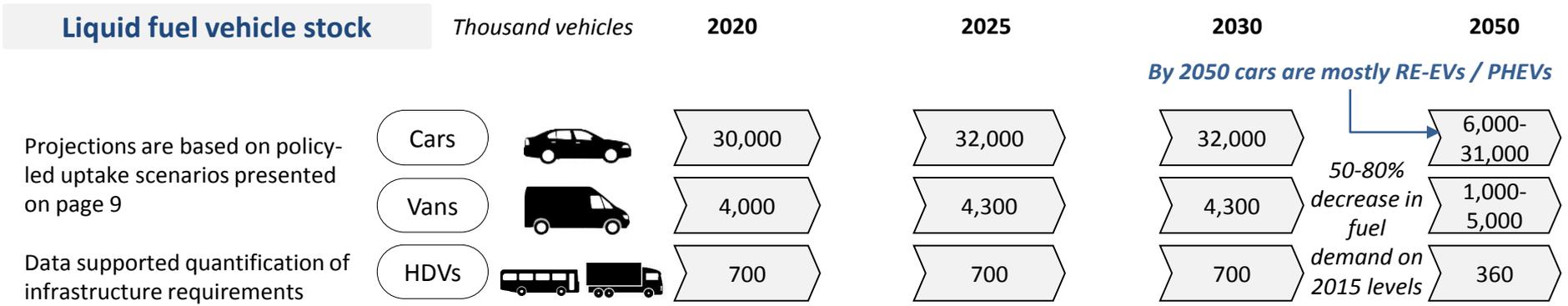
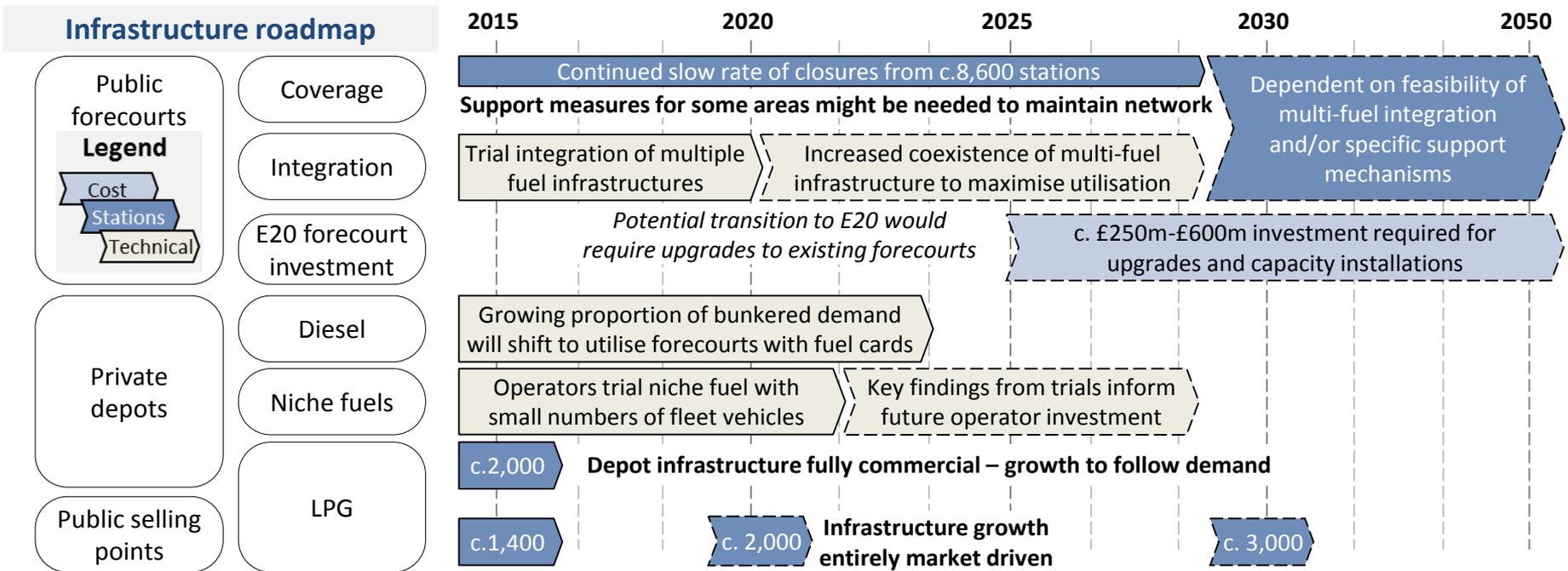
## The extensive national infrastructure supporting the UK's liquid transport fuel demand can be divided into three streams



## Liquid fuel transport demand Million tonnes/year



# With a predicted demand decrease for liquid fuels, forecourts may have to integrate new fuels and/or receive support in certain locations



Dashed lines represent high uncertainty / Major milestone / enabler

# Delays to planning to modify forecourts should be minimised to avoid investor uncertainty and financial support may be needed in certain areas

## 1 Station economics and support

- Steep decline in demand beyond 2030 is likely to significantly impact commercial viability of fuel retailing, (particularly for small public forecourts located in rural areas of the UK to start with, but more widespread issue in long term)
- A transition to a higher biofuel blend will require large investments for tank replacements and/or upgrades

### Recommendations

**Central Government:** Consider mechanisms to ensure minimum filling station coverage, particularly in rural areas

**Local Authorities:** Identify any local supply shortages and forecourts most affected by declining fuel demand

## 2 Planning permission guidance

- Acquiring planning permission to upgrade existing forecourt facilities can often be delayed or rejected
- Delays for upgrade approval can cause partial unavailability and negatively impact commercial operation, thereby directly accelerating forecourt closure, particularly for underutilised areas

### Recommendations

**Central Gov. and LAs:** Work with regulators to identify common causes of delays and improve planning permission guidelines as appropriate

## 3 Innovation opportunities

- Biodiesel and bioethanol require additional handling considerations
- Higher bioethanol blends can damage regular refuelling facilities by causing stress corrosion cracking of steel and degradation of elastomers, therefore significant investment will be required to upgrade existing infrastructure

### Recommendations

**R&D bodies:** Investigate cost reduction opportunities for station upgrades to handle higher biofuel blends

# As declining liquid fuel demand causes station closures, facilitating optimal use of remaining forecourts is likely to be required

## 4 Multi-fuel infrastructure integration

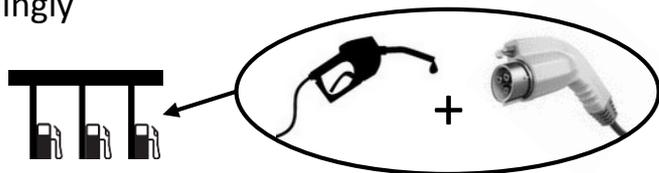
- The transport system is expected to be decarbonised through multiple alternative fuels / energy vectors
- Existing forecourts are strategically sited to optimally service driver needs by major roads and junctions
- Co-locating infrastructure for multiple fuels at forecourts could ensure utilisation is maintained

### Recommendations

**Regulators:** Develop standards for co-locating multiple infrastructures and work with central government to develop planning guidance for Local Authorities

**R&D bodies:** Identify technical barriers to co-locating multiple infrastructures (e.g. high power rapid charge points adjacent to liquid fuels)

**Industry and gov.:** Liaise with APEA to update Blue Book<sup>1</sup> accordingly



## 5 Communication of forecourt availability

- As forecourt closures continue (and new blends are introduced), there will be an increasing need to ensure drivers can easily access information detailing station & blend availability and location
- Communication systems to inform drivers of real-time fuel availability at nearby public forecourts supported by a national database could be developed
- Central coordination of software development will ensure a consistent interface between drivers and public infrastructure e.g. allowing use with existing navigation system providers

### Recommendations

**Industry:** Develop communication system



<sup>1</sup>National Guidance document jointly published by the Energy Institute and Association for Petroleum and Explosives (APEA) used to assess and sign off the safety of new forecourt installations and upgrades

# Liquid air has the highest potential and developing a distribution infrastructure for transport might require investment in UK skills

## Methanol

- Consulted industry stakeholders are doubtful of the potential of methanol in the UK, on the basis of **safety concerns** and need for **new HGVs engine development** (HGVs are target vehicles for methanol in the UK)
- Furthermore, **the air quality benefits and CO<sub>2</sub> benefits are not unclear**
- If used for UK transport, high blend **methanol will likely be bunkered** (not at forecourts)
- UK would need to **develop codes of practise for storage and handling** of methanol as well as planning guidance; input from industry players and countries familiar with methanol will be valuable

## Liquid Air (LAIR)

- Existing liquid nitrogen (LIN) production will be used first, before dedicated liquid air production is started
- LIN/LAIR will be used mostly for cooling and/or for hybrid applications, as opposed to becoming a prime mover
- It is expected LAIR will be used **exclusively by fleets with depot refuelling**
- Specialist **skilled workers will be needed** for liquid air distribution (e.g. cryogenic engineers and technicians )
- Skill-set overlap with other sectors must be investigated and consistent training programmes developed as required
- Production of LIN / LAIR require electricity but the energy vector can also be used as a form of energy storage

## E85

- Consulted industry stakeholders are doubtful of the potential of E85, on the basis of the **lack of vehicle supply, barriers to adoption of new grade at inland terminals and forecourts** and **low energy content** (adding issue to consumer acceptance and fuel duty issue if price parity with E5/E10 (per km) must be supported)
- **Adoption of E85 could not be possible if E20 is adopted** (limit to number of grades)
- Distribution would be as for E10: blended at inland terminals and transported by trucks to forecourts

# Local Authorities will have a significant role in the delivery of the Infrastructure Roadmap

- In practice, the Infrastructure Roadmap must be translated into infrastructure strategies **developed and led at local level** as demand for fuels and opportunities are specific to a region/city. Cities also have varying focus on CO<sub>2</sub> emissions or Air Quality issues
- Local refuelling strategies must account for:
  - the local demand from fleet and public transport, and the current infrastructure in place
  - the local opportunities for production of low carbon fuel or distribution (e.g. access to high pressure gas grid, to high voltage network)

## Specific actions LAs can take to support the rollout of refuelling infrastructure

- **Encourage and contribute to the uptake of low carbon vehicles** – e.g. adoption in Council fleet, setting local incentives
- **Use planning guidance to deliver strategy recommendations for infrastructure** – e.g. regarding siting and technical specifications
- **Assist infrastructure providers in finding/assessing land for installation** – e.g. identify owner, provide road access and traffic data
- **Streamline planning processes for renewable fuel production and infrastructure**
- **Include low carbon fuels for transport into the development of energy system strategies** – e.g. transport considerations can be integrated to review of waste strategy (biomethane can produce heat, electricity or used as fuel)
- **Work closely with private fleets on demonstration and deployment activities for low carbon vehicles** – e.g. encourage formation of stakeholder group for experience sharing, joint procurement and consortia formation for funding

## Birmingham City strategy



Background and objectives

Approach

Transport Infrastructure Roadmaps

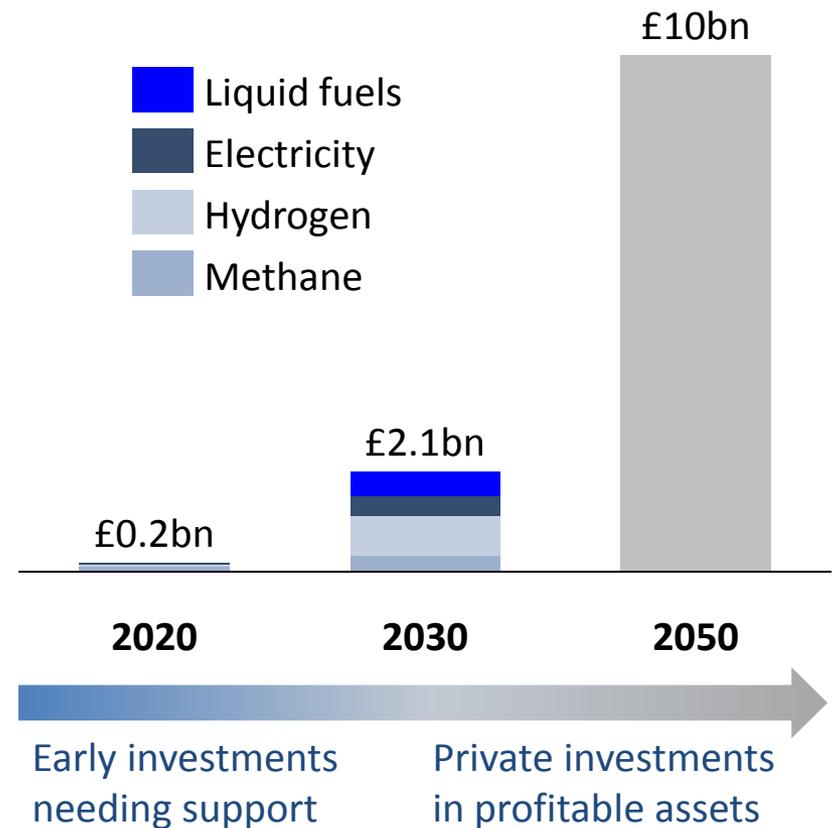
**Conclusions**

# The deployment of public refuelling infrastructure for transport will require significant new investment and long term policy clarity

Investment to deliver the future refuelling/recharging infrastructure will require:

- **Strong confidence for private investors**, i.e. clear and long term government position for different fuels and policy drivers, confidence in long term revenues to justify upfront investment
- **Funding support in some cases** in early years (when asset utilisation levels are low)
- **Coordination across government, regulators and industry** to remove certain barriers to installation of new infrastructure e.g. lack of/unclear planning guidance, harmonisation of safety procedures, integration of new fuels in existing forecourts

Cumulative public infrastructure investment<sup>1</sup>



<sup>1</sup>Includes stations capital costs only, opportunities for cost reduction to 2050 are not included. Investment related to grid reinforcement not included

# Both central and local Governments and industry have roles to play in this deployment – coordination of efforts will be needed

## Role of Central Government

- The Roadmap could be used for **future policy design**, for example supporting early infrastructure investments, mechanisms to encourage continued/increased production of low carbon fuels, targeted R&D activities, identifying strategic needs in specific UK locations
- **Coordinating LAs** and communicating consistent infrastructure planning guidelines will avoid delays and ensure consistent infrastructure rollout

## Role of Local Authorities

- The Roadmap could be translated into **local strategies** developed and led at local level as demand for fuels and opportunities are specific to a region/city with varying focus on CO<sub>2</sub> emissions or AQ issues
- Local strategies should consider **local demand** from fleet and public transport, **existing infrastructure**, and **local opportunities for production and/or distribution** of low carbon fuel

## Role of industry

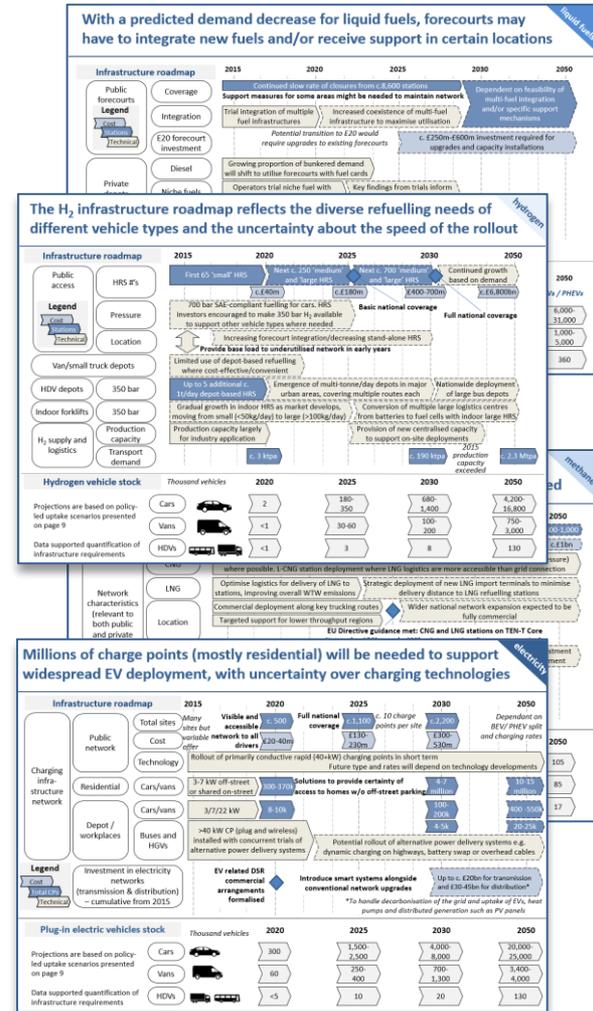
- The Roadmap highlights the importance of deploying a nationally harmonised infrastructure for each fuel type requiring an industry led, **coordinated approach**
- **This role extends to ensuring a consistent and high quality customer offer for new fuels**
- Industry are also well positioned to pursue **infrastructure cost reduction opportunities** provided a business case can be established

# End user experience key to acceptance and uptake of new fuels; further innovation is required to fully meet the needs of mass-market customers

- Ensuring sufficient access to public refuelling/recharging infrastructure as well as **harmonising the end user experience of infrastructure** is key to supporting low emission vehicle uptake
- **Innovation** will be needed:
  - Communication/IT solutions: for sharing charge points or refuelling stations across private users, for new services such as dynamic booking, forecourt choice and availability
  - Technologies: e.g. to identify most appropriate recharging technology for depots; hydrogen metering and quality assurance; optimising equipment for handling higher biofuel blends
  - Commercial arrangements: e.g. to minimise network impact of EVs with ‘smart’ solutions (e.g. Demand Side Management) allow water electrolyzers to secure revenues from providing grid services
- **Minimising WTT emissions** associated with production and logistics of fuels (in particular methane and hydrogen as decarbonisation targets are already in place for electricity) should be considered for future infrastructure siting and technology selection decisions

# The Infrastructure Roadmap will have to be updated to evolve with the expected innovations in both refuelling and vehicle technologies

- The roadmap captures the future infrastructure development needs based on today's **knowledge of refuelling/recharging technologies** and based on ambitious uptake scenarios for alternative fuels
- The Roadmap will have to be updated on a regular basis for its outputs to remain relevant as technologies evolve:
  - **Innovations on infrastructure technologies** are expected, especially around charging technologies, where deployment of new solutions could significantly change the strategy (e.g. dynamic wireless vs. ultra fast charging)
  - Vehicles are expected to change too, notably with the introduction of **autonomous vehicles**. Opportunities and development enablers for autonomous vehicles to refuel/recharge during non-operational windows, thus removing the need for driver-infrastructure interaction need to be better understood and included in future roadmaps



# Acronyms and references

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# Acronyms

BEV	Battery Electric Vehicle	LCNG	Liquefied and Compressed Natural Gas
CCC	Committee on Climate Change	LIN	Liquid Nitrogen
CNG	Compressed Natural Gas	LNG	Liquefied Natural Gas
COMAH	Control of Major Accident Hazard	LPG	Liquefied Petroleum Gas
CP	Charge Point	LTS	Local Transmission System
DECC	Department of Energy & Climate Change	Mt	Million tonnes
DfT	Department for Transport	NGVA	Natural Gas Vehicle Association
DNO	Distribution Network Operators	OEM	Original Equipment Manufacturer
DSR	Demand Side Response	OLEV	Office for Low Emission Vehicles
EC	European Commission	PAYG	Pay AS You Go
ETI	Energy Technologies Institute	PHEV	Plug-in Hybrid Electric Vehicle
EU	European Union	R&D	Research and Development
EV	Electric Vehicle	REEV	Ranger Extender Electric Vehicle
FCEV	Fuel Cell Electric Vehicle	SGF	Smart Grid Forum
FCH JU	Fuel Cell Hydrogen Joint Undertaking	SME	Small and medium enterprises
H <sub>2</sub>	Hydrogen	SMR	Steam Methane Reforming
HGV	Heavy Goods Vehicle	STOR	Short Term Operating Response
HRS	Hydrogen Refuelling Station	TEN-T	Trans-European Transport Networks
HSE	Health and Safety Executive	ToU	Time of Use
ICE	Internal Combustion Engine	TSO	Transmission system operator
IEC	International Electro-technical Commission	TTW	Tank-to-Wheel
IGEM	Institute for Gas Engineers and Managers	ULEV	Ultra-Low Emissions Vehicle
ktpa	thousands tonnes per annum	WE	Water Electrolysis
LA	Local Authority	WTT	Well-to-Tank
LBM	Liquid Biomethane	WTW	Well-to-Wheel

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