



A Fuel Roadmap for the UK

Commissioned by the LowCVP

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LowCVP
Low Carbon Vehicle Partnership

A fuel roadmap for the UK – objectives and approach

- The LowCVP commissioned Element Energy to do an analysis of the UK options to meet the Renewable Energy Directive (RED) transport target (10% renewable energy in transport by 2020)¹ as well as extend the analysis by developing a **fuel roadmap to 2030**
- Both analyses benefitted from wider industry input through a consultation exercise
- The objective of the fuel roadmap is to align the existing powertrain roadmaps, while being consistent with both supply constraints and policy targets such as the RED and the UK emission reduction targets
- Structure of the report

 - A. Fuel roadmap 2015-2030: summary of criteria
 - B. Fuel roadmap 2015-2030
 - Fuel types and blends
 - Potential energy split delivered by powertrain and fuel roadmaps
 - Enabling milestones

The fuel roadmap must be consistent with the recommended strategy in meeting the 2020 RED targets and published powertrain roadmaps

The fuel roadmap takes the following criteria into account, developed in more details next:

1 Consistency with the 2020 RED scenario analysis, that found:

- The recommended strategy is to roll out E10, blend up to B7 and maximise the use of double counting feedstock such as waste oils (mainly Used Cooking Oil)
- Some potential for E2G¹ & drop-in fuels by 2020, if policy certainty is in place

2 Consistency with the Auto Council and LowCVP powertrain roadmaps, that are informed by:

- UK emission targets and the resulting Carbon Plan
- European Commission (EC) targets for emissions regulation

3 Consistency with supply constraints for renewable fuels

- Liquid biofuels – sustainable volumes for 1st generation fuels and possible volumes under policy support for fuels not yet produced at scale but with high emission savings potential
- Gas and biogas/bio-methane – supply and WTW emission saving potential
- Competition for use, e.g. from aviation for diesel type fuels and other energy sectors

4 The roadmap also takes into consideration other published energy system analysis/ fuel roadmaps:

- ETI analysis of UK light vehicles
- Industry consortium proposed Auto-fuel biofuel roadmap – EU level

1 – Ethanol made from waste or lignocellulosic material that deliver high WTW emission savings

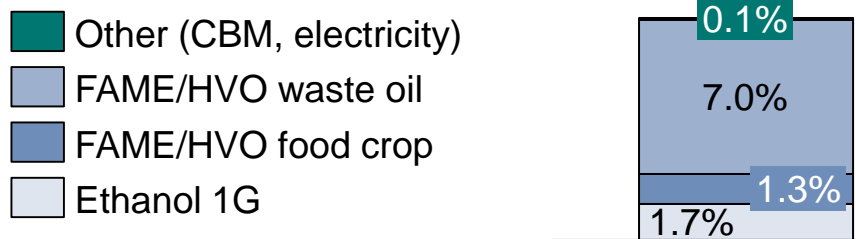
Analysis of the UK options to meet the RED transport target of 10% renewable energy in 2020 recommends E10 and B7 blends

- Four scenarios under which the RED target is met were derived:

E10 & B7: no blends higher than E10 and B7, rely on double counting fuels	E85case: E10, B7 as well as E85 at forecourts, with 6% of cars being E85 compatible by 2020
DepotB30: E10, B7 and B30 for c. 35% of trucks & buses refuelling at depots	Depot&E85: E10, B7 as well as E85 at forecourts and B30 in depots

- The emerging recommendation for the UK to reach the RED target, based on considerations such as cost effectiveness, sensitivity to double counting rules, reliance on commercialisation of new fuels, reliance on FAME made from food crop, and implementation challenges, is to pursue the **E10&B7 approach**, namely:
 - Roll out E10 and increase the biodiesel blending up to the existing B7 specification
 - Maximise the use of double counting fuels that do not use food crop feedstock; this implies a high reliance on Used Cooking Oil and other waste oils, as fuels based on other feedstock will still be in limited supply by 2020
 - Despite the limited role of drop-in fuels for the 2020 target, a supporting framework should be put in place, as they offer a better prospect to decrease emissions, and could displace / make up for supply shortfall of UCO feedstock and FAME based on food crop over time

Contribution to RED target in 2020 – E10&B7 case



Up to 20% of the FAME/HVO share could be HVO, based on the projection of 15 PJ (~450 MI) of HVO available for the UK road transport sector¹

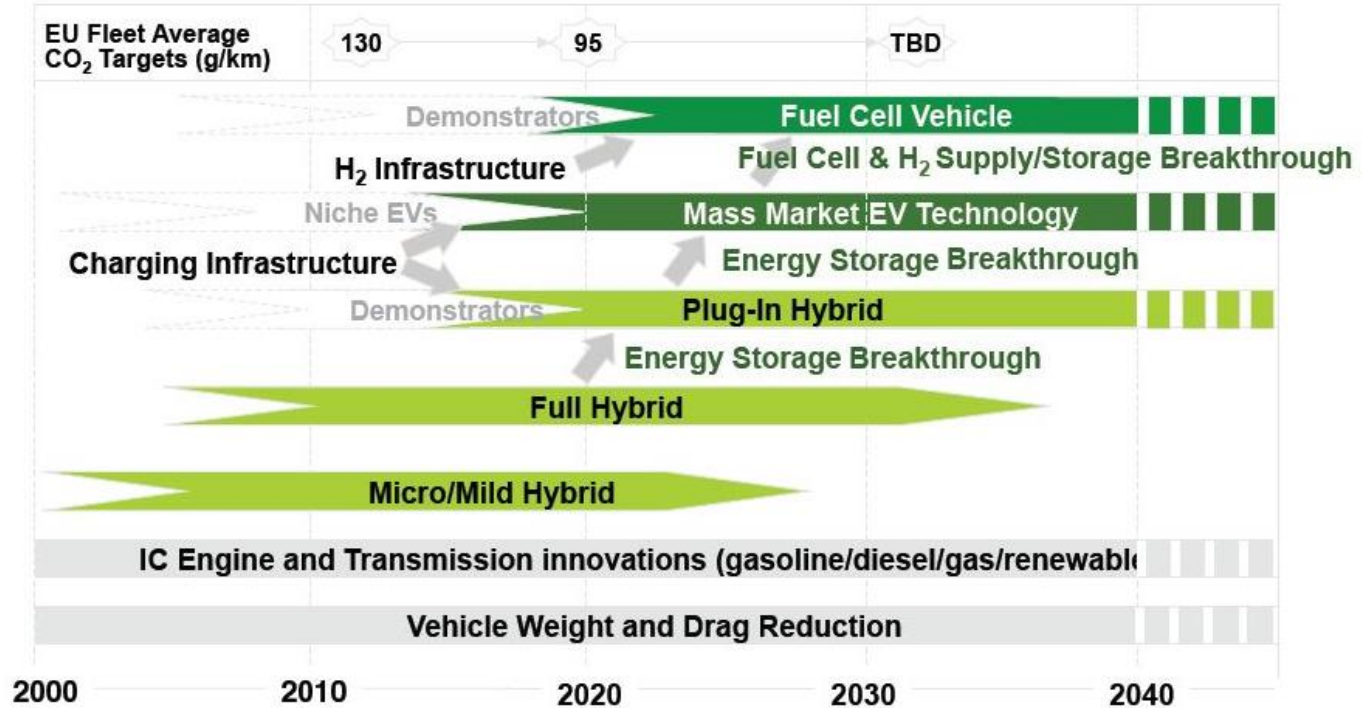
Source: Element Energy, Options and recommendations to meet the RED transport target, a report for the LowCVP, 2014

1 – Assuming UK fair share (13%) of the EU potential identified in E4tech, *A harmonised Auto-Fuel biofuel roadmap for the EU to 2030*, Nov 2013

2 Existing roadmaps: focus on powertrain and efficiency technologies but no cross cutting view on fuels (1/2)

Passenger cars roadmap

Source: Auto Council



- Efficiency improvements, driven by EU level tailpipe emissions targets and air quality regulations, underpin the roadmap
- The 2020-2030 period is the decade when **EVs** (PHEVs, BEVs and/or FCEVs) become a mainstream offer – under energy storage breakthrough condition, assuming adequate grid capacity. Development of these technologies driven by the need to meet the long term UK CO₂ targets¹.
- The EC transport goals are also expected to become a driver for Zero Emission Vehicles, e.g. CO₂-free city logistics in major urban centres by 2030 and phasing out conventionally fuelled cars in cities by 2050²

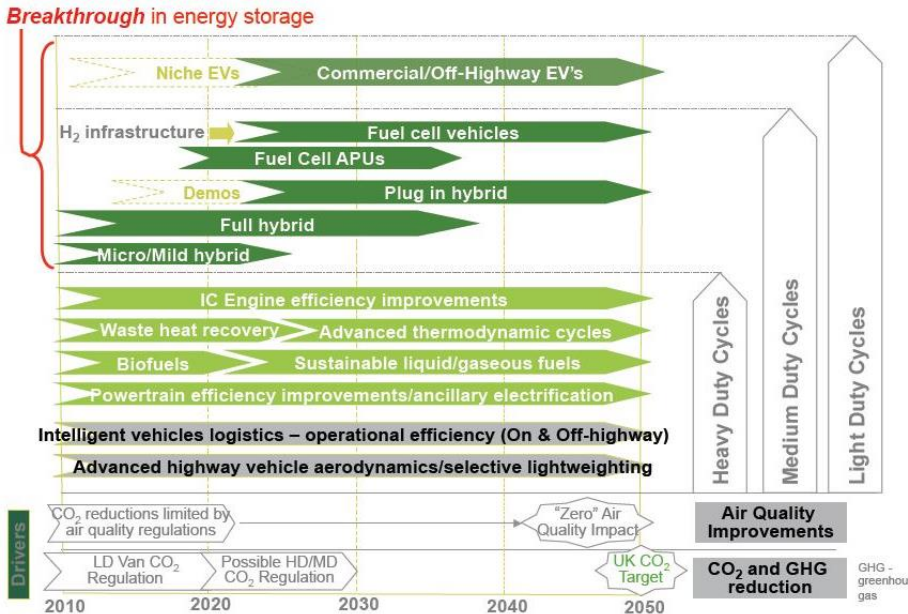
1 – Climate Change Act, 80% GHG emission reduction by 2050 compared to 1990

2 – EC Transport 2050 Strategy, Transport White Paper 2011

2 Existing roadmaps: focus on powertrain and efficiency technologies (2/2)

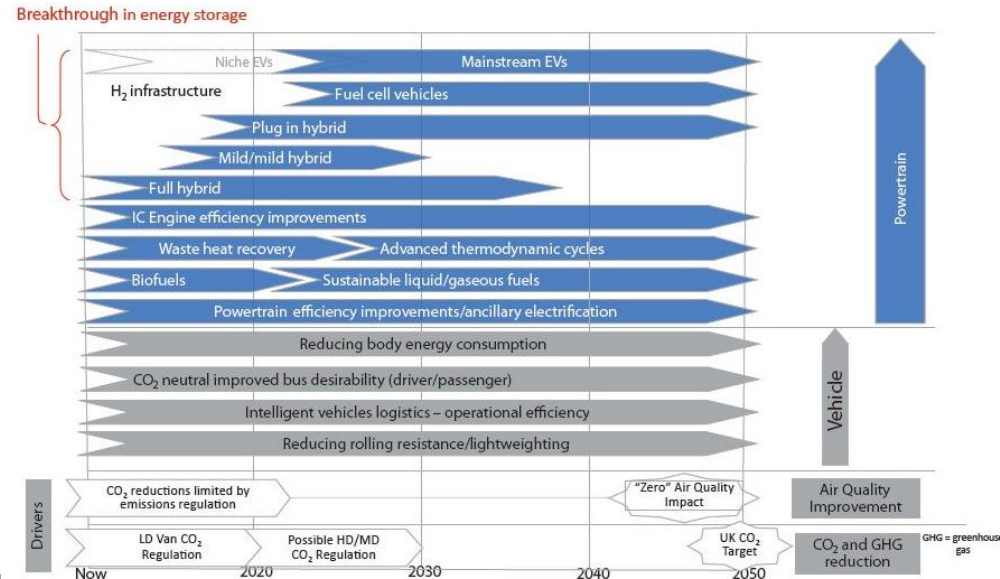
Commercial & Off Road Vehicles

Source: Auto Council



Buses

Source: LowCVP and Ricardo



- As for cars, efficiency gains are an essential part of the commercial vehicle roadmaps and the 2020-2030 decade when powertrains are increasingly hybridised, with full electric (BEV and FCEVs) expected to be adequate for some duty cycles
- The roadmap does not include a cross cutting liquid fuel strategy (e.g. type and blends of biofuels, diesel/gasoline balance), and there is no explicit roadmap for gas vehicles

Role of the fuel roadmap to be developed

- The fuel roadmap must align these 3 vehicle roadmaps and be consistent with the underlying drivers, namely the EU and UK level emission targets

3 Supply of liquid biofuels in 2020-2030: potential to increase ethanol blend up to E20 identified at EU level (1/2)

- Conclusions from E4tech study of biofuels supply potential at EU level and cost considerations:
 - **Enough sustainable ethanol supply for a move to E35** (but E20 recommended when considering the needed vehicle and infrastructure modifications)
 - The supply of sustainable biodiesel and economics of vehicle/infrastructure modifications **do not justify going beyond B7**
 - Up to 10 Mtoe¹ (420PJ) of biofuels not based on food crops available to the EU by 2030, with supporting policy framework in place. Note the limitation comes from the production capacity (high investment) as opposed to availability of waste feedstock

For gasoline blends

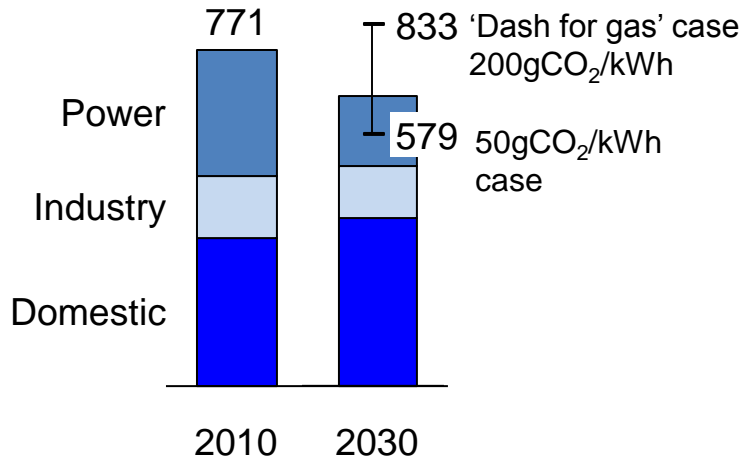
Fuel	EU supply + import (Mtoe)		Comments
	2020	2030	
Ethanol 1G	5 to 7.5	7.5 to 15	Food crop based
Substitutes 2G	1 to 1.5	2 to 3.5	Covering Ethanol 2G, butanol 2G and drop-in gasoline

For diesel blends

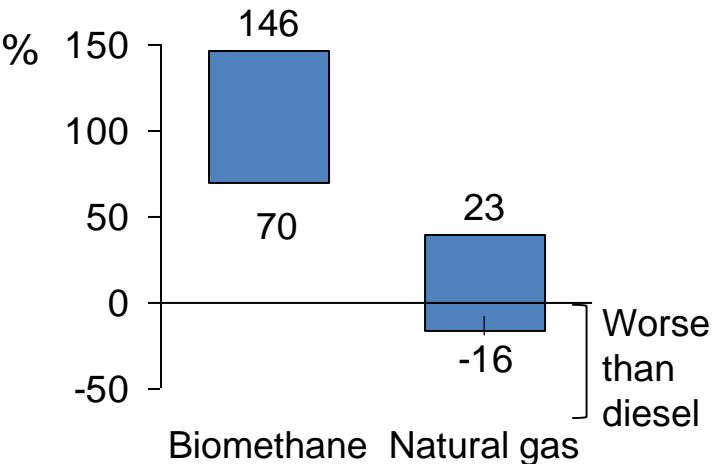
Fuel	EU supply + import (Mtoe)		Comments
	2020	2030	
HVO/FAME/ renewable jet fuel	3.5/8.5 to 5.2/6.8	4.7/10.3 to 11.7/4.3	The ranges correspond to min-max scenarios Study assumes at least 20% would be used by aviation sector. Undefined share of non-food crop feedstock
FT and PO	~ 0.5	1.5 to 3.5	Mainly Fischer Tropsch

3 Natural gas: decarbonisation potential through biogas blend limited by supply potential, production pathways not all saving emissions (2/2)

UK gas demand¹, TWh



WTW benefits over diesel (based on buses)³



Bio-methane

- It can bring **substantial WTW emission savings but limited supply potential**: 32TWh in 2030¹, including crop based bio-methane. This would translate into:
 - c. 5% of the total 2030 UK gas demand
 - c. 5% of 2020 energy use from vans, HGVs, buses

Natural gas

- No supply constraints but WTW savings variable**:
 - Over 50 years of global natural gas *proven reserves*², with reserves likely to continue to increase, e.g. through the authorisation of shale gas extraction
 - WTW CO₂ benefits of NG vary from an increase compared to diesel to a significant benefit depending on engine technology and gas pathway³
- Opportunities to reduce NG WTW emissions:
 - Reduction of transport distance, e.g. if increase of domestic production
 - Use of 6,000 km Local Transmission System (LTS), instead of low pressure distribution system, reducing compression needs (and thus electricity needs, up to -80%); this might require investment to increase capacity

¹ – EU funded Green Gas Grid project, 2013 and DECC analysis (2012) for power demand range proven reserves 2012 > 2,000,000 TWh. Source: US Energy Information Administration ² – World use 2011: <40,000 TWh, world ³ – Ricardo, *Preparing a low CO2 technology roadmap for buses*, 2013

Relevant recommendations from existing analysis: maintain/increase petrol demand, move to E20 and support ‘advanced’ biofuels

Energy Technology Institute - light vehicles

- Scope: UK, to 2050
- Analysis of “affordable transition to sustainable and secure energy for light vehicles in the UK”
- Found that the least cost, lowest risk path is a liquid (with biofuels) and electricity (mainly through PHEVs) fuel mix
- Recommends a move back towards gasoline:
 - to decrease the gasoline/diesel imbalance
 - to avoid exporting petrol to nations with less ambitious emissions mitigation plans (would negate UK efforts)
 - as there are more sustainable routes to producing gasoline type biofuels than diesel-type biofuels

E4Tech/ industry consortium - all vehicles

- Scope: EU, to 2030, focus on liquid fuel
- Consortium: Daimler, Honda, Neste Oil, OMV, Shell and Volkswagen
- Studied the supply of biofuels from bottom- up approach (land area, yield, plant capacity) – *numbers shown previously*
- Finds E20 meets deployment criteria: sustainable supply of ethanol and reasonable cost of vehicle & infrastructure modification
- Supports the development of ‘advanced biofuels’ (not based on food crops and achieving >60% WTW savings)

From 2025 in 3-grade systems (late 2020s in 2-grade systems such as in the UK)



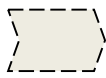
2025: c. 60% fleet E20 compatible, with E20 tolerant vehicles introduced from 2013 and all vehicles E20 homologated from 2018

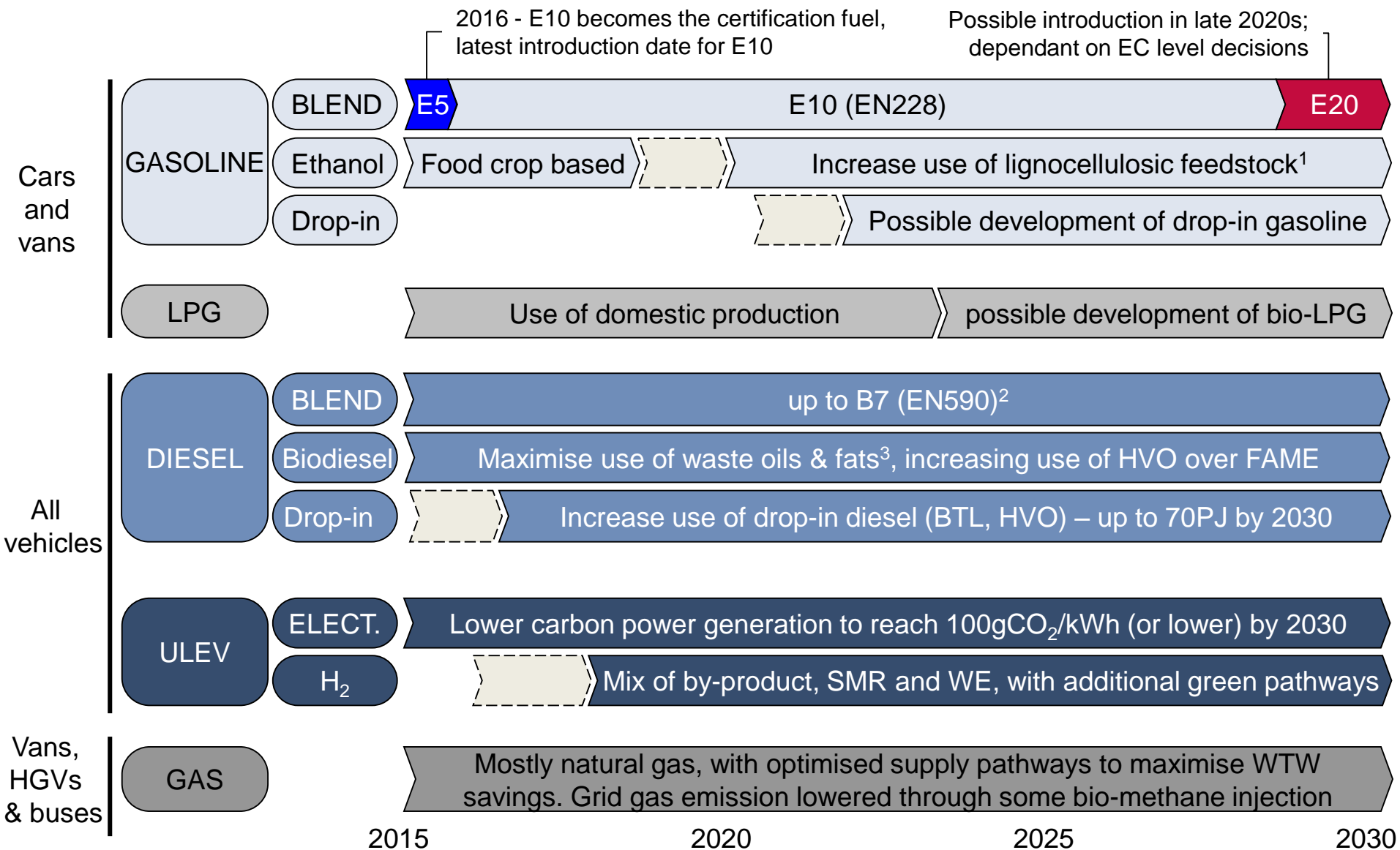
A. Fuel roadmap 2015-2030: summary of criteria

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2015-2030 fuel roadmap: fuel types and blends

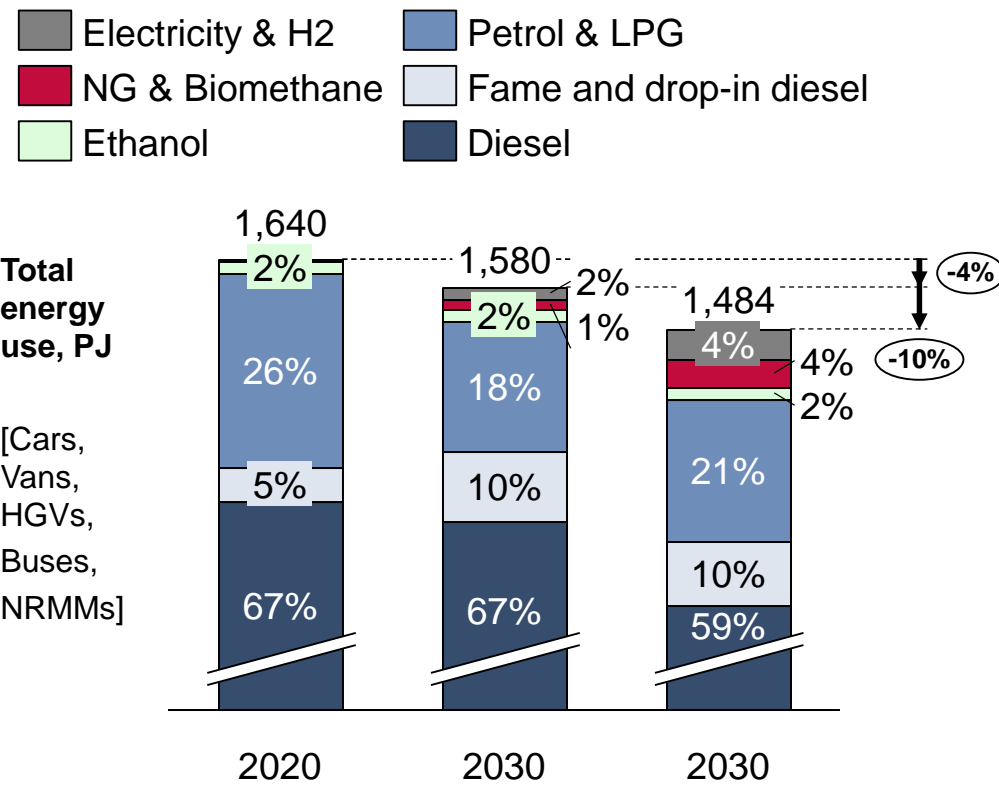
 Uncertain ramp up start or rate, dependent on policy support or framework



SMR: Steam Methane Reforming; ULEV: Ultra Low Emission Vehicles; WE: Water Electrolysis; 1 – Possible development of butanol
 2 – Effective blend likely to stay at B2 for Non Road Mobile Machinery 3 – With measures in place to ensure fuel quality

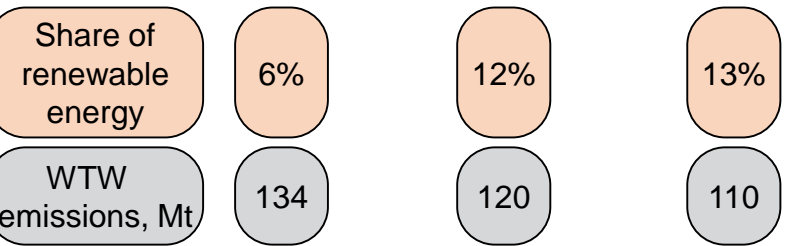
Powertrain & fuel roadmaps have the potential to deliver c. 20% WTW emission reductions between 2020 and 2030, and a doubling of renewable energy share

Illustrative impact of the fuel roadmap¹



[Cars, Vans, HGVs, Buses, NRMMS]

- The combination of powertrain roadmaps and fuel roadmap will deliver a reduction of emissions through:
 - An improvement in the fleet energy efficiency to the extent that total energy use decrease, by 4 to 10% between 2020 and 2030 (depending on powertrain technology uptake)
 - An increasing use of biofuels, gas and grid decarbonisation
- By 2030, FAME, drop-in diesel and ethanol are still providing the most of the renewable energy due to dominance of petrol and diesel vehicles
- The rise of diesel ICE among cars is assumed to stop as emission requirements are becoming more difficult to meet by diesel ICE



2030 sales share assumptions

Powertrain scenario	Base	High AFV
ULEV [cars]	30%	60%
ULEV + gas [vans]	10%	20%
Gas [HGVs]	7%	26%
ULEV + gas [buses]	7%	15%


1 – Based on emissions, vehicle efficiency, fleet and travel assumptions in consistency with approach developed in *Options and recommendations to meet the RED transport target*, Element Energy for the LowCVP, 2014

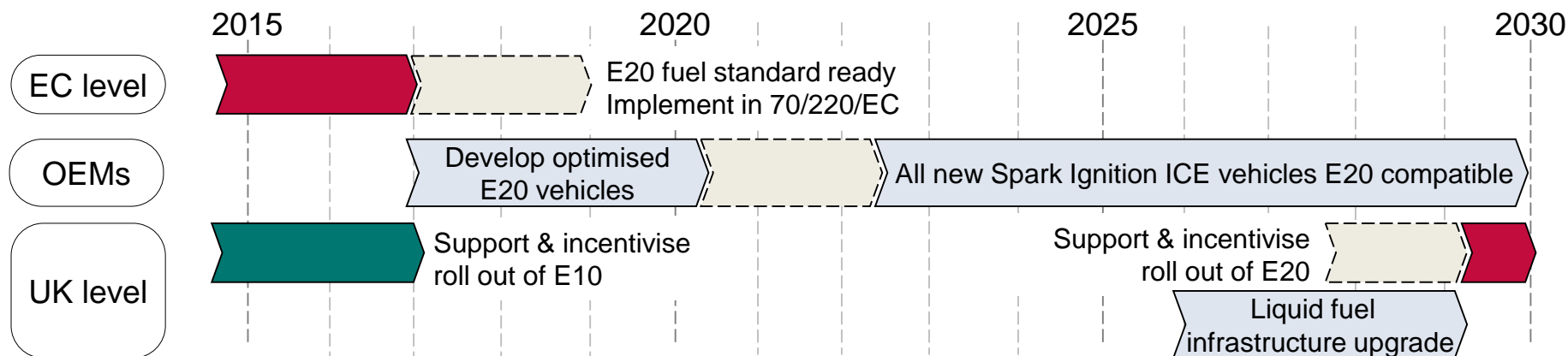
A new gasoline blend beyond E10 will require EC level decision and would be implemented in the UK in late 2020s at best (1/4)

- **The introduction of E20** would bring further carbon savings from ICE fleet but first requires action at EC level, with the definition of a E20 fuel standard (for which work has started). This needs OEMs and fuel producers to agree on the E20 fuel octane number, a decision that balances higher WTW emission savings (through better fuel efficiency, high octane) and refinery costs (cheaper with lower octane)
- A fleet of E20 compatible ICE must be built ahead of the introduction of E20 optimised vehicles and the E20 fuel rollout must be timed to minimise the use of E20 optimised vehicles with lower blends¹. Several main OEMs already sell E20 compatible ICE (e.g. VW engines have been E20 compatible since 2010, BMW sell E20 vehicles in Thailand)
- The time needed for new fuel standard definition and build up of compatible fleet for a 2-grade system means E20 adoption in UK is estimated to start in late 2020s at best (see timeline below)
- For **E2G¹ to ramp up** from early commercial, policy clarity (accounting, waste categorisation, post-2020 vision) and certainty is required at EC level, and support mechanisms set up at UK level

Roadmap for introduction of new gasoline blends

if E20 decision is taken at EC level

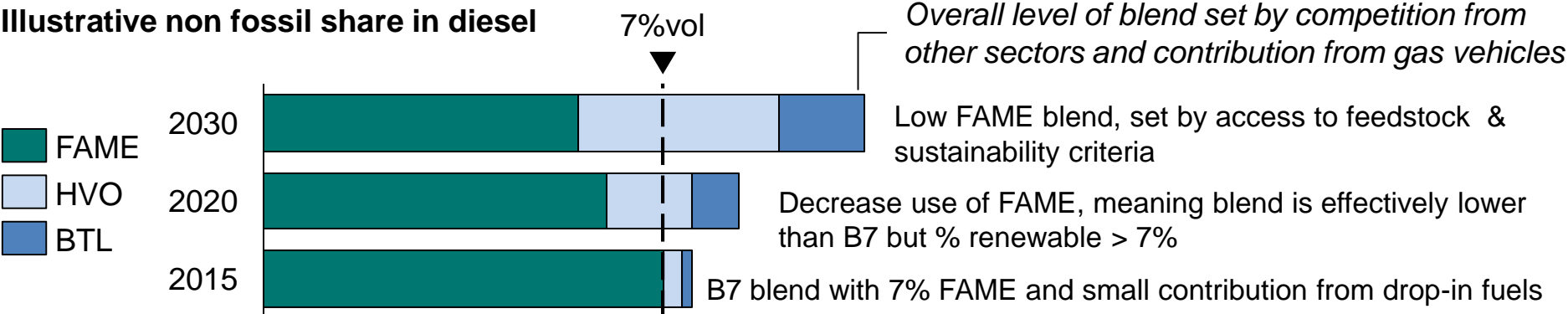
 Uncertainty in timeline, mainly dependant on time needed to define fuel standard at EC level



¹ – E20 optimised ICE do not achieve good performance when run on lower blends (higher fuel consumption and hence higher emissions) ² – Ethanol (or butanol) made from waste or lignocellulosic material that deliver high WTW emission savings

The limitation in sustainable FAME means the rollout of renewable diesel based on non-food crop, low ILUC feedstock must be supported (2/4)

- The current blend limit (B7) does not need to be increased as the access to sustainable FAME from food crop will be constrained (although a move from crop feedstock to waste oils can mitigate this) and because of the economics of a higher blend (vehicle and infrastructure modifications). Emission reductions will instead come from an increase in the share of drop-in fuel (which does not require a change in fuel standard). The use of biodiesel might however require refined fuel standards to ensure fuel quality.¹
- For **drop-in fuels to ramp up** from early commercial, policy clarity (accounting, waste categorisation, post-2020 vision) and certainty is required at EC level, and support mechanisms set up at UK level.
- The overall use of biomass feedstock and biofuels dedicated to diesel vehicles must take into account:
 - The need from the aviation sector
 - The other energy sectors, e.g. the 2012 Bioenergy Strategy² identifies a cost effective use of bio-energy in 2030 split between c.60% transport and 40% other (heat, power, other uses)
- The use of bioenergy is currently incentivised more in the heat sector (through Renewable Heat Incentive) than in the transport sector. Future incentives will need to account for the desired best use of biomass.



1 – The *Options and recommendations to meet the RED transport target* report (EE, 2014) recommends refined biodiesel standards to ensure FAME quality level that does not compromise engine behaviour under winter conditions and a possible revision of the diesel standard e.g. for cold flow properties.
 2 – DECC/DfT/Defra 2012 UK Bioenergy Strategy

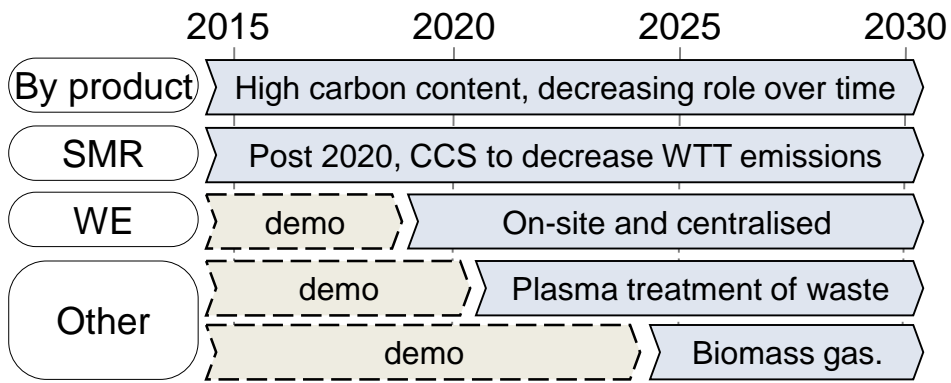
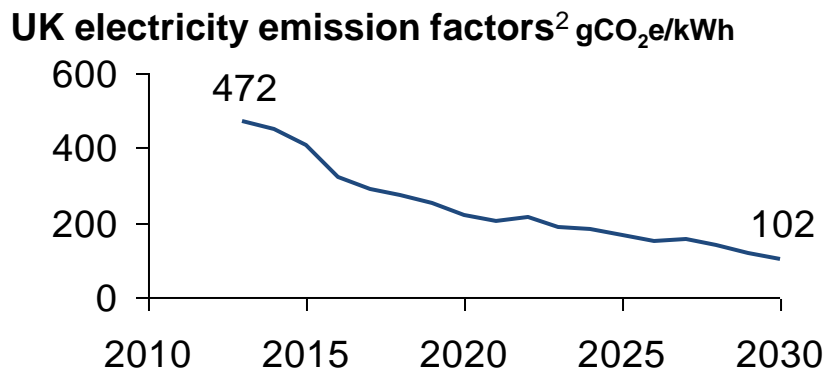
Ultra Low Emission Vehicles: decarbonisation pathways for electricity & hydrogen will require investment in upgrade or new technologies (3/4)

Electricity

- DECC projects a baseline reduction of grid carbon intensity from c. 500gCO₂/kWh today to 100gCO₂/kWh in 2030; the CCC recommends a target of 50gCO₂/kWh by 2030
- Both cases imply the integration of more renewable generation. This, along with the integration of new loads (heat pumps, EVs) will require investments in networks and 'smart' systems
- Investment need in power transmission and distribution are estimated at £42-49 billion¹
- New commercial arrangements e.g. to allow Demand Side Response are currently being investigated and trialled under the Ofgem Low Carbon Network Fund

Hydrogen

- Hydrogen currently mostly an industrial by-product or made from Steam Methane Reforming, i.e. through a high carbon pathway
- Water Electrolysis, thanks to the decarbonisation of the grid, is the most promising option for the early 2020s. Electrolysers present the advantage of helping integrate renewable generation by acting like storage and providing services to the grid
- In the longer term, additional green pathways include waste gasification, Carbon Capture and Storage (with SMR) and biomass gasification
- WTW emissions to be 35g CO₂/km for mid-size Fuel Cell Electric car by 2030 based on projected UK hydrogen mix³



1 – Versus £26bn in a 'No climate action' scenario. Element Energy analysis for the CCC, 2013

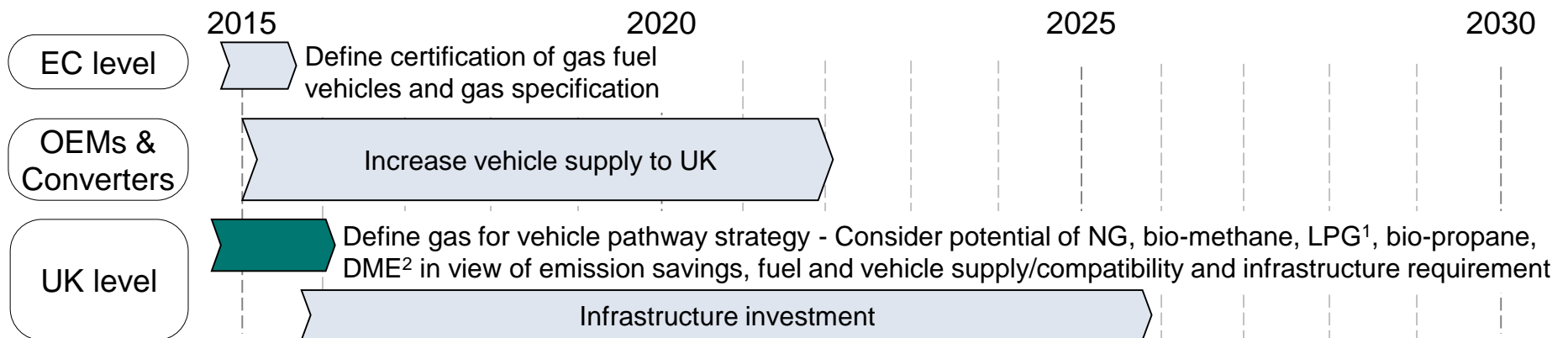
2 – DECC appraisal guidance September 2013

3 – UK H₂Mobility Phase 1 report, 2013

The deployment of gas vehicles requires a dedicated gas pathway strategy to ensure WTW emission benefits (4/4)

- Recent encouraging developments for gas vehicles include tax regime (differential between the main rate of fuel duty and the rate for road fuel gases [NG, bio-methane] is maintained until 2023, announced 2013Q4) and National Grid introducing a new process to reduce the capital costs and time associated with connection to the LTS, in recognition of CNG potential for the transport sector.
- Bio-methane supply is limited and is not 'earmarked' for transport, instead gas vehicles must be fuelled by **gas produced and delivered through a pathway consistent with UK emission reduction targets**
- The fuel roadmap implies:
 - A certification procedure for gas fuel vehicles and a gas specification (e.g. energy content and sulphur content) is agreed at EC level
 - The UK defines a strategy to incentive the uptake of gas vehicles (commercial vehicles and buses) as well as incentivise the best gas pathway in terms of WTW emission reductions, consistency with Carbon budgets and feedstock/gas supply potential
 - Supply of gas vehicles to the UK market is improved as OEMs develop Euro 6 gas vans, trucks, buses

Roadmap for the deployment of gas vehicles in the UK



1 – The UK produces c. 3,900 kt of LPG p.a. and is a net exporter (over 1,100 kt p.a.). Greater LPG uptake could save 0.1Mt CO₂ emissions p.a. by 2030 in car sector alone (Element Energy analysis for UKLPG, 2013) 2 – While there are no Dimethyl ester production plants nor initiatives in the UK, other countries are considering its use in transport, e.g. the US and Sweden, where the first bioDME pilot plant was opened in 2010

Acronyms

AFV	Alternative Fuel Vehicle	NG	Natural Gas
BEV	Battery Electric Vehicle	NRMM	Non Road Mobile Machinery
BTL	Biomass to Liquid	OEM	Original Equipment Manufacturer
CBM	Compressed Biomethane	PHEV	Plug-in Hybrid Electric Vehicle
CNG	Compressed Natural Gas	PO	Pyrolysis Oil
DECC	Department of Energy and Climate Change	RED	Renewable Energy Directive
DEFRA	Department for Environment, Food and Rural Affairs	RTFC	Renewable Transport Fuel Certificate
DfT	Department for Transport	RTFO	Renewable Transport Fuel Obligation
DME	Dimethyl ester	SG	Steering Group
E2G	Ethanol made from waste or lignocellulosic material	SI	Spark Ignition
EC	European Commission	SMR	Steam Methane Reforming
FAME	Fatty Acid Methyl Ester	UCO	Used Cooking Oil
FCEV	Fuel Cell Electric Vehicle	UK	United Kingdom
FT	Fischer Tropsch	ULEV	Ultra Low Emission Vehicle (Fuel Cell Electric Vehicles and plug-in vehicles)
HDV	Heavy Duty Vehicle	WE	Water Electrolysis
HGV	Heavy Goods Vehicles	WTW	Well To Wheel
HVO	Hydro treated Vegetable Oil		
ICE	Internal Combustion Engine		
LBM	Liquid Biomethane		
LNG	Liquefied Natural Gas		
LPG	Liquefied Petroleum Gas		
LTS	Local transmission System		