Mobility of People

Narrative Report

2024

automotive council UK

ADVANCED PROPULSION CENTRE UK

Produced by the Advanced Propulsion Centre UK on behalf of the Automotive Council UK

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1 | Introduction

1.1 | Foreword to the 2024 roadmaps

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The UK Automotive Council is well known for producing robust and detailed technology roadmaps that define potential routes for Automotive including Commercial Vehicles and Off-Road machinery and related products to achieve our UK environmental and societal goals. Roadmaps are a function of current knowledge and as new ideas and technologies emerge, must be regularly renewed. This exercise, led by the Advanced Propulsion Centre UK, has generated the fourth generation of these roadmaps.

Whilst many organisations develop roadmaps as part of their product planning process, the Automotive Council roadmaps are unique in providing a consented view from the Automotive sector including Commercial Vehicle and Off-Road Machinery, in the UK. This enables us to define common future challenges and where to focus collaborative R&D and capital resources in developing successful, sustainable, net-zero solutions.

These solutions must also meet future consumer needs and not introduce challenges in experience or limitations in operation. Often, more than one technical approach appears viable to meet future needs. It is important that all of these approaches are explored and introduced to market as the carbon reduction goal becomes more urgent. Ultimately, it is possible that one approach may dominate but we cannot afford to wait for this to emerge.

1.2 The purpose of the 2024 roadmaps

The Automotive Council UK roadmaps outline key themes, trends and drivers in the global automotive industry. This narrative report explains and provides insights to support the roadmap's themes. It helps clarify the reasons behind the roadmap's content and how it should be used.

The report aims to guide research and development (R&D), innovation, cross-sector collaboration, and system-level interactions. A list of recommendations for how industry, academia, and government can use this information is shown opposite:

Industry

- Compare in-house R&D priorities with industry trends and drivers in the automotive sector.
- Evaluate supply chain risks and develop strategies for sustainable and circular business models in automotive products.
- Help start-ups by guiding their technology focus, investment choices, and collaboration plans.

Academia

- Address long-term research challenges that need to be solved.
- Align university research, education, and skills development with the automotive industry's needs.
- Strengthen partnerships between academia and industry to apply research to real-world solutions.

Government and policymakers

- Understand key themes and trends in automotive technologies.
- Direct policy and funding to support R&D priorities and innovation for reaching net zero.
- Promote cross-sector collaboration and trade policies that benefit the automotive industry and broader industrial sectors.

1.3 Building a consensus

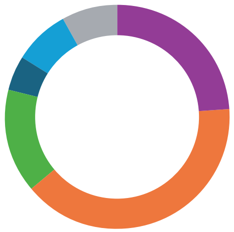
This consensus roadmap has been developed through the facilitation of the Advanced Propulsion Centre UK (APC), with contributions from 436 individuals representing 230 organisations, which include government, industry and academia.

Collating the information required for the 2024 roadmaps has only been possible due to the breadth of contribution and valuable feedback from those who have fed into the process, which began in early 2023. The APC would like to thank everyone who gave their time and input across the various webinars, workshops, and surveys conducted.

As a result of this consultation across industry and academia the 2024 roadmaps build on previous versions and demonstrate the significant change that is happening across the automotive sector and its supporting industries.

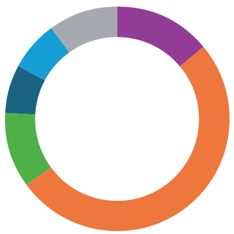
Special thanks go to members of a working group that was formed to support the development of this roadmap. Organisations involved include: Zenzic, Zemo, WMG, SMMT, Connected Places Catapult, CCAV, Innovate UK UKRI, Innovate UK KTN, Mobilize, Nissan Technical, Horiba Mira, University of Leeds, Nissan Technical Centre Europe and Ford.

Figure 1: Representation by individual and organisation



436 Individuals

OEM	24%	(104)
Supply chain / SMEs	40%	(176)
RTO	15%	(67)
Academia	5%	(23)
Government	8%	(33)
Other	8%	(33)



230 Organisations

OEM	14%	(32)
Supply chain / SMEs	51%	(117)
RTO	11%	(25)
Academia	7%	(15)
Government	7%	(17)
Other	10%	(24)

Adrian Hallmark
Chair
Automotive Council UK

Mike Hawes
CEO
SMMT

As we stand on the cusp of a new era in the automotive industry, the importance of strategic foresight has never been greater. The Automotive Council UK Roadmaps 2024 provide a strategic vision that places the automotive sector at the heart of the global transition towards net zero. Evolving the Automotive Council product roadmaps from 2020 into brand new system-level roadmaps 2024 underscores the critical role the automotive sector will play in the broader transport ecosystem.

The roadmaps outlined in this document are the result of extensive collaboration between industry leaders, policymakers, and academic experts. They are designed to navigate the complexities of a rapidly evolving market, where technological advancements, environmental imperatives, and shifting consumer expectations are driving unprecedented change.

Central to our vision is the transition towards a net zero and sustainable transport ecosystem. The roadmaps highlight key areas such as electrification, digitalisation, and advanced manufacturing, which will be crucial in maintaining the UK's leadership in the global automotive industry. They also highlight the critical challenges of supply chain resilience, and regulatory alignment across automotive and the broader transport sector as well as energy sector in an increasingly interconnected world.

All roadmaps are accompanied with a detailed narrative report to offer more details and description of the trends and drivers and support call to action for all stakeholders across the automotive industry. The journey ahead will require agility, collaboration, and a shared commitment to excellence. By embracing the insights and strategies contained within these pages, we can collectively ensure that our automotive sector remains at the forefront of global progress, delivering value not only to the economy but to society at large.

We invite you to explore these roadmaps, to reflect on the opportunities they present, and to join us in shaping a future that is as dynamic as it is sustainable.

Transitions to new technologies are never smooth. Innovation is the starting point, but market shifts depend on many factors: functionality, usability, affordability. Competition can accelerate the pace and stimulate alternative strategies and, indeed, technologies.

The UK's transition to a net zero economy depends on decarbonising road transport. But in doing so we must ensure we maintain mobility for all people and all services. Plotting this transition, therefore, needs roadmaps that anticipate the trends and drivers of change, allowing policymakers, investors, businesses and consumers to make informed decisions.

The Automotive Council last delivered roadmaps in 2020. We were acutely conscious that we were entering a "disruptive decade"; climate change, air quality regulation, societal demand and the expectation of rapid market transformation were compelling heavy investment in electrified powertrains. What was not forecast was the global disruption of covid, constrained supply chains, geopolitical tensions and increasing protectionism, all of which combined with economic conditions, to slow the uptake of new technology vehicles.

Addressing these issues while sustaining societal mobility demands contributions from stakeholders outside the traditional automotive industry. It demands new system-level roadmaps; focussed not just on automotive products and technologies but their role in the broader transport ecosystem – the mobility of both people and goods. Different vehicle applications will require different solutions. There will be a range of complementary private and public transport solutions – some individual, some shared; some requiring high-power solutions, some much less. And this diversity of technologies will apply equally to the mobility of goods.

These two new roadmaps are intended to support the UK in its transition to cleaner, more sustainable and intelligent forms of mobility. At a time of such fierce global competition, the companies and governments that can anticipate the future, plan for it and invest in it, will succeed. We want the UK to succeed, and the benefits shared by all.

Professor Sarah Sharples
Chief Scientific Adviser
Department for Transport

The UK automotive industry is a key driver for growth within the UK economy. Automotive related manufacturing contributes to £22 billion in value to the economy, and invests around £4 billion each year in R&D. It employs in total around 800,000 people in the country.

The system level roadmap responds to a changing automotive environment and provides a resource for automotive industrial strategy community, to build synergies across its system interfaces with the wider transport ecosystem. The roadmap highlights the current and future mobility landscape and shows key mobility trends and regulatory drivers which have potential to shape automotive road transport technologies for the movement of people and goods. The The Automotive Council UK's system level roadmaps highlight the importance of interfaces for automotive industry with adjacent sectors like energy, infrastructure, rail, and mobility services for an accelerated transition to a net-zero future. A true successful zero emission technology transition requires collaboration with key stakeholders across governments, industry, academia, and start-up communities. The roadmaps provide a helpful basis for the holistic system thinking that is needed to pull this complex and transformative path for our future generations and society, by not placing the automotive industry as an isolated innovation island, but as a key actor within the wider transport ecosystem.

Ian Constance
CEO
Advanced Propulsion Centre UK

The automotive industry is uniquely positioned to lead the charge towards a net-zero transport ecosystem. As such we have evolved our 2020 product roadmaps into system-level roadmaps providing a more holistic view of the role of the automotive industry in the transition of the transport sector in the journey towards net zero.

The roadmaps outlined in this document are the result of extensive collaboration across the automotive and the broader transport sector, reflecting the diverse expertise and perspectives necessary to accelerate progress.

The strategic direction and associated partnerships detailed in these roadmaps are key to unlocking the potential of new technologies, from advanced propulsion systems to connected and autonomous vehicles. Equally important is the alignment of policy and funding with these technological advancements, ensuring that the right resources are in place to support innovation and implementation at scale. This coordinated approach will help us overcome the challenges of decarbonisation and make sustainable transport accessible to all.

By setting ambitious targets and fostering innovation, we can drive change not only within our industry but across the broader transport landscape. The Automotive Council roadmaps provide a clear pathway for this journey, highlighting the opportunities and challenges that lie ahead. We invite all stakeholders to explore these roadmaps and join us in driving the next phase of innovation and sustainability in the UK automotive industry.

1.4 | Mobility of People – overview

The Mobility of People Roadmap is an evolution of the 2020 Light Duty Vehicles, Bus and Coach, Private Mobility and Shared Mobility roadmaps.

The roadmap responds to a changing automotive environment and provides a resource for automotive industrial strategy planning, which helps build synergies across its system interfaces with the wider transport ecosystem. The roadmap aims to highlight the current and future mobility landscape, highlighting key trends and drivers which are expected to shape automotive road transport for the movement of people. The roadmap demonstrates the role of the automotive sector in delivering a sustainable net-zero transport system.

The Mobility of People Roadmap focuses on surface-based movement of individuals or groups using personal or shared vehicular modes. A separate Mobility of Goods Roadmap has also been developed.

This roadmap has been produced in place of the 2020 Bus and Coach roadmaps with the aim to bring a more holistic approach encompassing all road transport used to move people. It embraces varying vehicle applications and use-cases requiring a range of powertrain solutions based on their energy and power demands.

The roadmap is split into two sub-roadmaps, covering private mobility and shared mobility:

Private mobility

Vehicles in private use, including passenger cars and small urban vehicles, high-performance and high-power cars, electric micromobility, low-power and high-power motorcycles.

Shared mobility

Vehicles in shared use, including car sharing and car rental, taxis and ride sharing, shared micromobility, shared mopeds, buses, coaches and Digital Demand Responsive Transport (DDRT).

In an update to the 2020 roadmaps, enablers and infrastructure have been included as an additional theme. The roadmap is focused on the UK and EU markets, while this supporting narrative report also includes international references.

Each sub-roadmap contains the following sections:

Energy vectors and propulsion technologies

Internal combustion engine (ICE) fuels, electricity and hydrogen fuel-cell;

Drivers and regulations

Policy, environmental, social and economic drivers that exert influence on vehicle designs and powertrains;

Technology enablers

Engineering and technology enablers that exert influence on vehicle designs and powertrains; and

Infrastructure enablers

Infrastructure enablers that exert influence on vehicle designs and powertrains.

For the ease of narration, the drivers and regulations, technology and infrastructure enablers are combined for private and shared mobility in this report as they share similar product types.

Certainty levels are applied to individual bars within the roadmaps and includes topics at pilot / trial or proof of concept, as well as topics where there is both a reduced or increased level of certainty. The corresponding legend is shown below.

- High level of certainty
- Lower level of certainty
- Pilot / trials / PoCs

1.5 Mobility of People – influencing trends

The transport and automotive sectors have seen significant change and disruption over recent years with more to come in the future. The drivers of these transformations are multi-faceted, encompassing demographic and social, economic, environmental, political and technological factors.

While the adoption of a range of technologies, services and new business models has disrupted transport at a rapid pace, changing the way people and goods move, there has been a significant impact from the COVID-19 pandemic. This posed challenges to the planning and operation of transport systems, the results of which have fundamentally disrupted or accelerated travel trends.

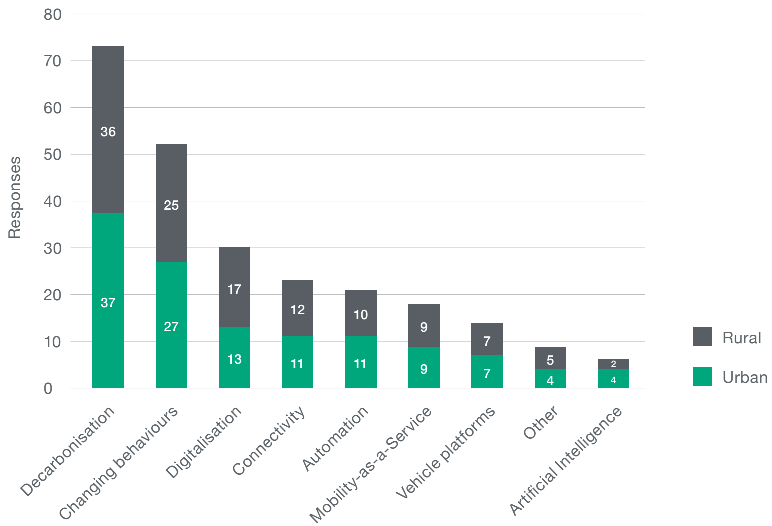
Trends affecting the mobility of people in the UK include the growth of the electric vehicle (EV) market, shared mobility and an uptick in hydrogen trials and pilots.

Battery electric vehicles (BEVs) account for 15.6% of all new car registrations[1] (January – November 2023). EV uptake continues to be driven by the increased availability and range of new models entering the market, tax incentives and the growing awareness of the effects of climate change.

Shared mobility continues to grow across the UK and Europe, with over 30 e-scooter trials (in England) and many bike share schemes. Shared mobility is re-shaping how people travel in urban and rural areas and is an important contributor to transport decarbonisation encouraging mode shift from private cars. There has also been an increase in hydrogen trials and pilots in cities across the world, particularly buses and coaches.

A survey conducted as part of the research for this roadmap asked industry stakeholders to specify the top three trends influencing road transport and the mobility of people by 2030, considering urban mobility and rural mobility separately. Decarbonisation, changing behaviours and digitalisation emerged as the top three trends that were expected to influence both road transport and the mobility of people to 2030 (see Figure 2).

Figure 2: Top three trends influencing road transport and mobility of people by 2030



1 November 2023 New Car Registrations, SMMT

Changing behaviours

There are several expected behavioural changes influencing the mobility of people with the most prominent being:

Focus on sustainability / environmental consciousness

A survey of consumers by McKinsey revealed that 46% of respondents have already switched to more sustainable brands or products, and another 16% plan to make considerable changes to promote sustainability[2]. This will have implications on the travel choices people make. For example, a shift to shared modes and active travel, like walking or cycling; switching to electrified car clubs from petrol and diesel cars.

Flexible working

There has been a slow decline in the number of people commuting over the last 20 years in Europe with potential explanations for this including (aside from working from home) employees working fewer days a week and an increase employment without a usual place of work. Flexible and remote working increased during the COVID-19 pandemic with many employees transitioning to home-working.

Shared economy

The rise of the sharing economy comes as attitudes towards ownership of assets are transitioning. Increasingly people are more open to usership over ownership. Behaviours are changing and the economic value societies traditionally placed on vehicle ownership are shifting. Technology has facilitated the emergence of new ways in which people can access, use and finance their travel, reducing the economic value gained from owning a vehicle for personal use. The transport sector is one that is heavily influenced by this notion of 'sharing', with car-, bike- and lift-sharing gaining traction in recent years.

Key drivers of shared mobility use include:

- rising cost of car ownership and insurance premiums
- increase in road-emission taxes, and in some cases additional congestion charges or ultra-low emission restrictions
- consumer willingness to use more active modes of travel
- convenience of using shared modes (driven by an increase in internet penetration and booking and payment of services using a mobile application); and
- declined need for travel, particularly for commuting purposes, driven by the pandemic

2 Future of public transport (kpmg.com)

2 | Product classification for private and shared mobility

2.1 | Product classification for private mobility

The following page describes the different types of vehicles illustrated in this roadmap.

Passenger cars

Mainstream vehicles that are common globally and include hatchbacks, family cars and sports utility vehicles (SUVs).

High-performance and high-power cars

Specialist vehicles that are sold in smaller quantities compared to passenger cars and include performance and super cars as well as luxury SUVs.

Small urban vehicles

Small urban vehicles include both small passenger cars and emerging dedicated urban BEVs. The Zemo Partnership uses the term powered light vehicles (PLVs) for a range of two, three and four-wheeled vehicles for either passenger or cargo use[3]. PLVs will fall under the EU regulation of L-category vehicles. For the purpose of this roadmap, small urban vehicles include micro-cars (L6e and L7e categories).

This emerging sector of micro-cars includes new models of small low-speed electric vehicles for one or two people with three or four wheels, typically weighing between 100 to 500 kg. These vehicles sit between micromobility and passenger cars.

Electric micromobility

Electric micromobility includes a range of small, light, low-speed electric vehicles such as e-bikes, cargo bikes and e-scooters. They operate at speeds typically below 15.5 mph with a mass typically no more than 250 kg. There are also higher speed vehicles available, e.g. higher speed e-bikes, which can be operated above 25 km/h and below 45 km/h.

3 Powered Light Vehicles | Zemo Partnership

Motorcycles

A powered two-wheeled motor vehicle including everything from high-powered sport motorbikes to low-powered mopeds.

Within the roadmap the motorcycle category is split into two parts:

- High-power motorcycles: engine power of more than 50 kW and engine capacity of at least 595 cc;
- Low-power motorcycles: engine power of below 50 kW and engine capacity lower than 595 cc.

New vehicle types

It should be noted that a range of new types of two- and three-wheelers (L2e – L5e) are being developed by the market.

Figure 3: L-category vehicles

Source: Zemo Partnership

2.2 | Market and product classification for shared mobility

Shared mobility includes shared mobility services like car-sharing, taxis and ride-hailing, shared micromobility, shared moped, bus, DDRT and coach services. The term shared mobility is used to describe both:

- shared trips, e.g. a bus, where individuals travel together in the same vehicle
- shared vehicles, e.g. a bike that is shared by individuals for separate trips.

Cars: car sharing and car rental

Car-sharing, also known as car clubs in the UK, enables individuals or households to enjoy the benefits of access to a car but reduces the need for ownership and, therefore, ongoing vehicle maintenance.

These services provide members with access to vehicles on a pay-as-you-drive basis with cars sited at various locations. Service-users can access the vehicle via their mobile phone.

There are different types of car-sharing models available including peer-to-peer (P2P), where people offer privately-owned vehicles for rent to others via an online platform, and includes insurance.

Car rental differs in that the hirer has access to a vehicle for a longer period of time (days, weeks, months - all apply) and is typically operated via a rental company's local branch. These are often located near airports or in urban areas.

Cars: taxis, ride-hailing

Traditional taxis are hailed on the street, at allocated taxi ranks, or booked by phone or app. Taxi services are governed by an established set of regulations.

Ride-hailing services are provided by drivers who have been booked via an online app / platform which mediates the service between the driver and passenger.

Shared micromobility

Shared micromobility provides short-term access to vehicles including bikes, e-bikes, e-cargo bikes and e-scooters for one-way trips within a defined operating area, typically via an app. Users pay on a trip-by-trip or subscription basis.

Shared mopeds

Shared mopeds schemes provide short-term access to mopeds within a defined operating area, typically via an app. Users pay on a trip-by-trip or subscription basis.

Bus

Product types range from bus-rapid-transit (BRT) vehicles with dedicated lanes and routes, medium-duty community vehicles to single and double-decker buses.

Digital Demand Responsive Transport (DDRT)

DDRT is a flexible service that provides shared transport to users who specify their location and time of pick-up or drop-off. It can complement fixed-route public transport services and improve mobility in low-density areas and off-peak. There are trials and pilots of DDRT around the world assessing the suitability of these services as an alternative to fixed route buses at off-peak hours or for remote neighbourhoods.

Coach

Product types include regional and intercity coaches and buses in semi-urban and rural settings. Typically, coaches are medium-power vehicles as vehicle mass and torque needs are higher. Medium- to high-energy required for long-range travel and national routes is required.

Catenary public transport

Trolleybuses are used around the world, although not currently in the UK. In some Eastern European countries where trolleybuses are in operation, there are existing overhead lines that could be used to electrify a bus line by equipping trolleybuses with small onboard batteries in place of the large, high-capacity batteries used in electric buses[4].

4 Infrastructures | Free Full-Text | Sustainable Use of the Catenary by Trolleybuses with Auxiliary Power Sources on the Example of Gdynia (mdpi.com)

3 | Narrative to roadmap

3.1 | Energy vectors definition for ICE, battery and fuel cell-led technologies

Product classification for private mobility

This roadmap provides a list of relevant energy carriers that support vehicle propulsion technologies. The colour codes are shown against each vehicle application. Within each roadmap, the height of the bar does not necessarily represent the importance of the energy source.

ICE-led

In addition to petrol and diesel, this energy vector covers lower carbon ICE fuels, electricity (in terms of hybrid assistance) and hydrogen ICE. There is expected to be a growing need for very low-carbon liquid and gaseous fuels derived from biomass, waste or renewable electricity sources also known as non-fossil fuels (and combinations of these). Plug-in hybrids, featuring non-fossil fuel ICE and sustainably-sourced electricity, are also possible even beyond 2035.

Battery-led

BEVs: In addition to the electrification of passenger cars, the expanding product range of urban BEVs, including new urban mobility vehicles, require a sustainable electricity source. The demand for clean grid electricity will rise as the electrification of passenger cars is complemented by increasing numbers of low-speed, power-efficient urban solutions appearing in the market.

Fuel cell-led

This includes fuel cell electric vehicles (FCEVs), or where a fuel cell generates electricity to power an onboard electric motor. The most commonly implemented technology is a hydrogen fuel cell (HFC) powered FCEV. The hydrogen is stored at high pressure (700 bar) and then released through a fuel cell to generate electricity to drive one or more electric motors.

3.2 Energy vectors and propulsion type for private mobility

Primary themes

The primary themes offers an overview of the energy vectors section of this roadmap.

Transition from ICE to alternate fuels

Increasing mandates for low-carbon propulsion mean we are seeing greater ICE efficiencies and hybridisation. In the short- to medium-term, this makes way for other zero-emission propulsion technologies, particularly in the UK and Europe.

Globally, the transition point will vary by country as regulation dictates. From 2035, a niche role is expected for ICEs and hybrids using e-fuels.

ICE fuels

Outside of Europe and the UK, stricter emission regulations will move these solutions to dedicated hybrids, in some cases supported by net-zero compliant combustion fuels – e-fuels. Advanced (hybrid) ICEs are expected to endure in the high-power car segment due to their high-power-to-weight capability. The category has a relatively higher cost-tolerance and consumers may continue to demand ICE capabilities where these vehicles are allowed to be sold. As pressures to decarbonise increase, net-zero capability and sustainable fuels will be critical. Together with dedicated hybrids, they can keep this technology relevant, albeit at an expected small scale.

Significant growth of BEV

BEV models are expected to grow in the next 10 to 15 years with UK car stock transitioning to mass-electrification from 2035. According to UK Research and Innovation (UKRI)[5], by 2050, 99% of cars and vans are likely to be battery-powered. Across Europe, the speed of adoption by consumers is expected to depend on the scale of consumer incentives, charging infrastructure provision and a reduction in total cost of ownership (TCO). Increasing battery-energy density and faster charging will support BEV adoption for a wider range of drivers (including those who are not able to recharge at home or work).

BEV prices are likely to continue to fall owing to advances in battery technology and mass-electrification efforts by the industry. Smaller capacity batteries for smaller vehicles may also help reduce purchase costs.

Hydrogen fuel cell

The role of hydrogen fuel cells for private vehicles is uncertain, with early commercialisation possible for passenger cars beyond 2035. There is the potential for cost-competitive FCEVs to serve the longer-range passenger car segment in the future, providing greater flexibility, range parity and faster re-fuelling than equivalent BEVs.

An increase in FCEVs is reliant on the development of a suitable hydrogen infrastructure network, which is currently limited across Europe.

New small vehicle types

Small BEVs (category L6 and L7) and two- and three- wheelers (category L2e-L5e) are being developed. For example, motorised quadricycles have evolved over the last 20 years with new models focused on electric power and designed for personal mobility needs. It is expected that new forms of micromobility vehicles will emerge within the next decade, taking advantage of the possibilities enabled by battery-electric power (following the recent trend with e-scooters). The growth in new vehicle types is likely to depend on suitable regulations with sales demand depending on emerging consumer preferences.

Continued growth of electric micromobility

Electric micromobility, including e-bikes and e-scooters, is anticipated to see continued sale increases supported by an improved cycle network infrastructure and purchase incentives like those seen in France, Italy and the US.

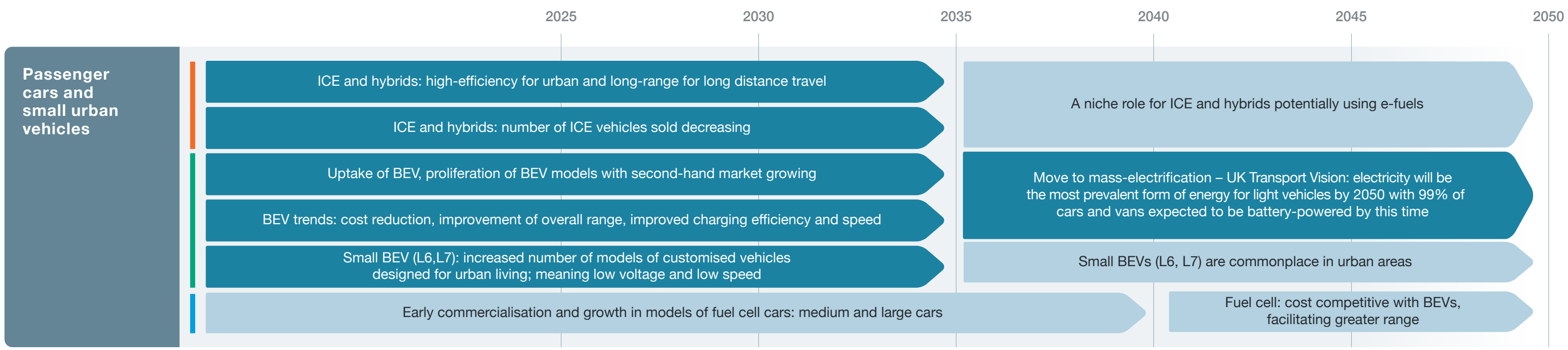
Motorcycles

It is expected low-power motorcycles (in particular mopeds) will continue to transition from ICE to BEV over the next 10 to 15 years.

There is less certainty on the decline in the sale of ICE high-power motorcycles as consumers may continue to demand ICE capabilities. The phase-out is expected to be driven by both regulation and the pace of improvements in battery range for BEVs.

5 https://iuk.ktn-uk.org/wp-content/uploads/2024/02/11312_UK-Transport-Vision-2050-2nd-edition-SP-Final.pdf

This section looks in detail at the line-by-line activity on the Mobility of People Roadmap.



Passenger cars and small urban vehicles

ICE fuels

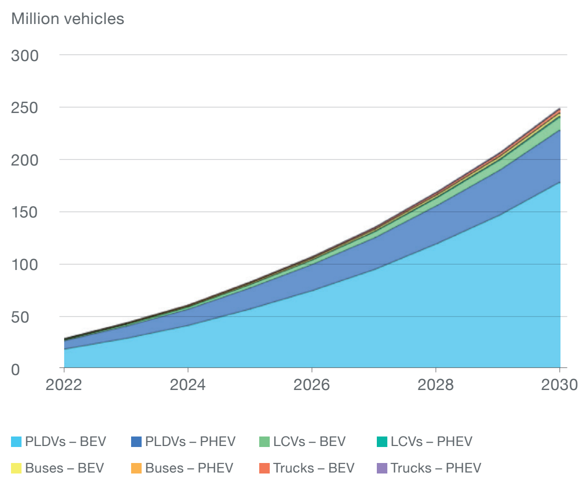
The majority of cars on roads are still expected to have ICE or hybrid engines with the major shift to other energy vectors from 2030 to 2050. The UK Transport Vision 2050 states that in 2030 the dominant energy vector for private vehicles will still be fossil fuels and low-carbon fuels like green hydrogen and biofuels[6].

Passenger car, BEV

The International Energy Agency (IEA) predicts the EV fleet will grow by a factor of 8 by 2030 (see Figure 4). BEV passenger cars are growing in number. According to UKRI, by 2050, electricity will be the most prevalent form of energy for light vehicles with 99% of cars and vans expected to be battery-powered[7]. The availability of a greater variety of EV models with different vehicle range and price points will strengthen consumer confidence in BEVs and drive adoption. The number of electric models available on the global market reached 500 in 2022, more than double of those available in 2018[8]. Lightweight and appropriate-sized batteries will help bring purchase costs down.

The industry believes a move towards mass-electrification can significantly lower lithium-ion (Li-ion) battery cell costs when economies of scale will be reached[9]. The energy density of batteries is expected to continue to improve and the mass of batteries to decrease, allowing for greater range capability[10]. The average battery range of new BEVs has also been steadily increasing. In 2020, the weighted average range for a new BEV was about 350 kilometres (km), up from 200 km in 2015.

Figure 4: Global forecasts for electric vehicle deployment to 2030

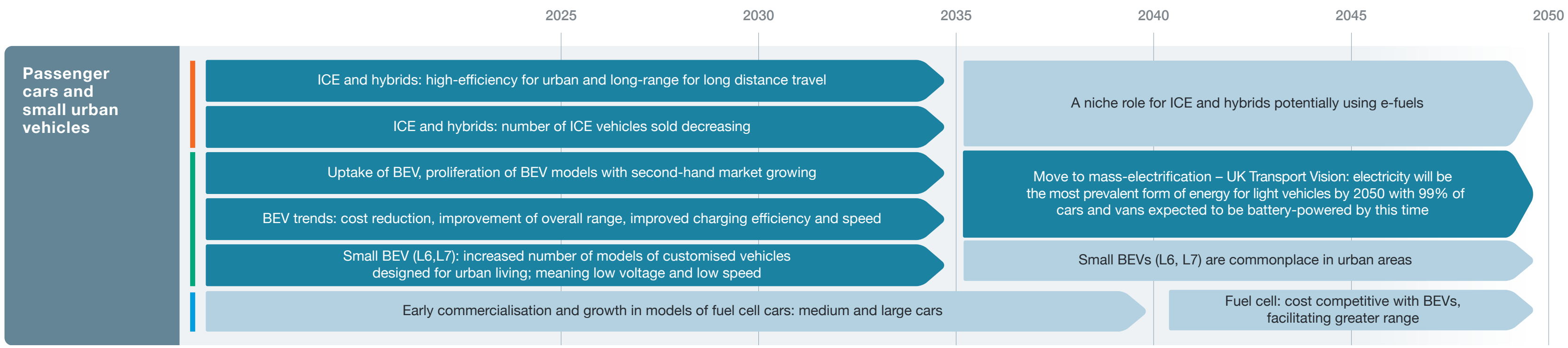


Source: Prospects for electric vehicle deployment – Global EV Outlook 2023 – Analysis – IEA

6 https://www.ukri.org/wp-content/uploads/2022/01/IUK-110122-UK-Transport-Vision-2050.pdf
7 https://www.ukri.org/wp-content/uploads/2022/01/IUK-110122-UK-Transport-Vision-2050.pdf
8 Global EV Outlook 2023: Catching up with climate ambitions (windows.net)
9 According to Wright's Law, also known as the learning curve effect, battery costs fall by 28% for every cumulative doubling of units produced.
10 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/780868/future_of_mobility_final.pdf

High level of certainty
Lower level of certainty
Pilot / trials / PoCs

ICE-led
Battery-led
Fuel cell-led



Passenger cars and small urban vehicles (continued)

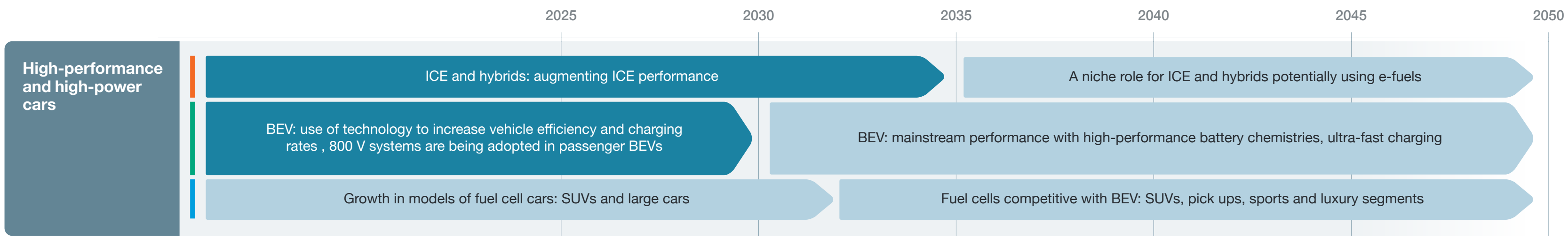
Small urban vehicle, BEV

The major shift to energy vectors other than ICE or hybrid engines is expected to take place between 2030 to 2050. The range of small urban BEVs available in the UK and Europe is expected to increase in the short-term. As these vehicles are designed to operate at low speed in urban environments, they demand the least power and energy of all the light-duty vehicles (LDVs). Batteries are well-suited to these emerging applications and the low voltages and power allow for cost-efficient designs.

Hydrogen fuel cell

FCEVs can potentially support specific vehicle requirements, such as towing. Adoption of this technology will require the development of a suitable urban hydrogen infrastructure network. Competitive and low-cost fuel cells are expected to determine adoption, with technology maturation and benefits likely to be greatest in the heavy goods vehicle (HGV) sector. Early commercialisation has begun in a few markets globally, e.g. Toyota Mirai.

High level of certainty	ICE-led
Lower level of certainty	Battery-led
Pilot / trials / PoCs	Fuel cell-led



High-performance and high-power cars

ICE fuels

Advanced (hybrid) ICEs are expected to endure in this segment. Due to their high-power-to-weight capability, the category has a relatively higher cost-tolerance and consumers may continue to demand ICE capabilities where these vehicles are allowed to be sold. As pressures to decarbonise increase, net-zero capability and sustainable fuel production will be critical.

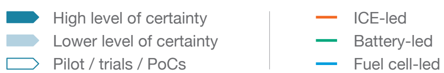
BEV

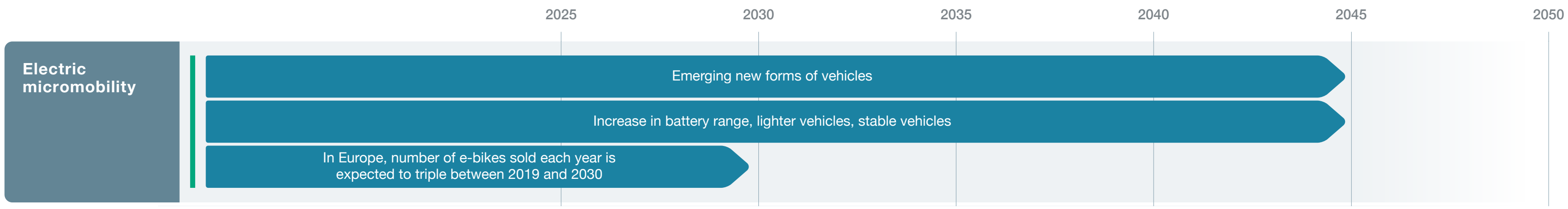
The IEA Global EV Outlook 2023 highlights that SUVs and large cars dominated available electric car models in 2022[11], accounting for 60% of available BEV options in China, Europe and the US. It is expected that high-performance BEVs will focus on technological improvements to increase vehicle efficiency and charging rates, e.g. cell chemistry, 800 voltage and layout, thermal systems and power electronics. There is an increasing number of BEV supercars and hypercars emerging in the market that require specific battery chemistries and designs tailored for their use-case.

Hydrogen fuel cell

FCEVs will be suited to applications where high onboard energy is required, such as heavier SUVs requiring continuous high torque. Current hydrogen cost is high and there are a limited number of hydrogen refuelling stations. These issues need to be resolved for the successful commercialisation of FCEVs.

11 Executive summary – Global EV Outlook 2023 – Analysis – IEA





Electric micromobility

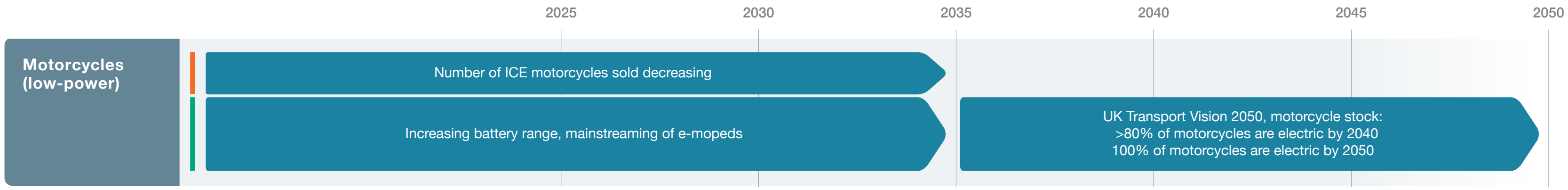
BEV

Construction / delivery of pop-up cycle lanes across cities and e-micromobility purchase incentives, e.g. in countries including Italy, France and the US, have supported the growth of electricmobility vehicles[12]. Electric micromobility vehicles are powered by Li-ion batteries, similar to technologies used in laptops and mobile phones. It is also anticipated for new forms of micromobility vehicles to emerge within the next decade (following the recent trend with e-scooters).

The success of the new vehicle types will depend on the proposed design, use-case, business models and ability to fit within existing regulations. The majority of vehicle design innovation and hardware improvements is focused on vehicle safety and battery range. In Europe, the number of e-bikes sold each year is expected to triple between 2019 and 2030 (from approximately 3.7 million units in 2019 to 17 million units in 2030)[13].

12 https://www.bbc.com/future/bespoke/made-on-earth/the-great-bicycle-boom-of-2020.html
13 Sales of electric bicycles are up all over the world | World Economic Forum (weforum.org)

High level of certainty
Lower level of certainty
Pilot / trials / PoCs
ICE-led
Battery-led
Fuel cell-led



Low-power motorcycles

ICE fuels

As consumers continue to demand ICE capabilities, ICE motorcycles will be seen on the roads in the short- to medium-term.

Predicted regulation, coupled with the pace of range capability in BEVs, will drive the phase-out of ICE with an expectation the lighter power motorcycle segment, particularly mopeds, will transition quicker than high-power.

BEV

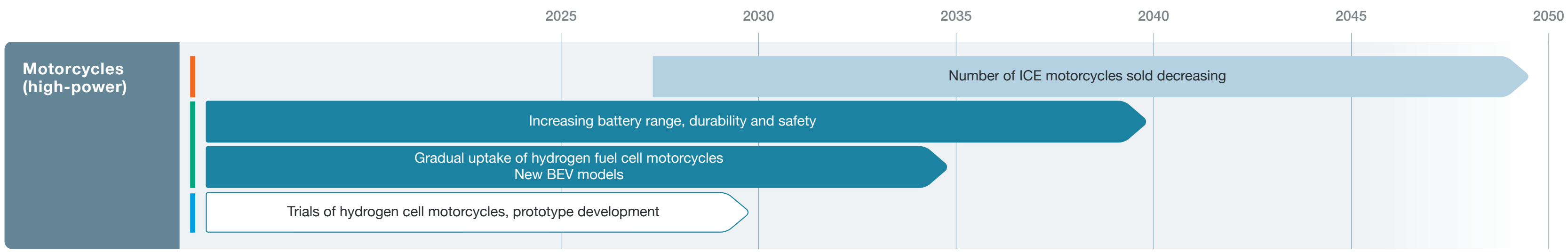
Advances in battery technology have allowed for improved energy density, enabling electric motorcycles to achieve greater range before requiring a recharge.

As the electric motorcycle industry grows, the availability and accessibility of a comprehensive charging network will become increasingly important.

E-mopeds are popular in China and across Asia, while experiencing a more gradual uptake in Europe. The global e-moped / e-motorcycle market is valued at $53 billion in 2021 and is expected to grow modestly at a CAGR of 8-9% until 2029[14].

14 https://www.databridgemarketresearch.com/reports/global-e-scooter-moped-and-e-motorcycle-market

High level of certainty
Lower level of certainty
Pilot / trials / PoCs
ICE-led
Battery-led
Fuel cell-led



High-power motorcycles

ICE fuels

Although uncertain, the sales of high-power motorcycles may decrease from the late 2020s. The European Association of Motorcycle Manufacturers (ACEM) has partnered with the eFuel Alliance to research the topic of conversion of existing ICE motorcycles to run on e-fuels[15].

Battery-led

High-performance electric motorcycles may be designed to take advantage of fast-charging stations or offer compatibility with various charging standards for convenience during long rides[16]. Electric higher power motorcycles (> 595 cc equivalent) will require a step-change in battery technologies for wider adoption. Several manufacturers have introduced prototypes and models of e-motorcycles and e-mopeds, including Kawasaki, Honda and Yamaha[17 18].

Fuel cell-led

Hydrogen fuel cell motorbikes are at the proof-of-concept stage. Investment has been slow, the use-case and business model are not currently clear and the refuelling infrastructure is lacking.

15 https://www.acem.eu
16 (6) Global High-Performance Electric Motorcycle Market Overview with Detailed Analysis, Competitive landscape, Forecast to 2030 | LinkedIn
17 eFuels Might Save ICE Motorcycles – Adventure Rider (advrider.com)
18 Honda will introduce at least 10 fully electric motorcycles by 2025 – The Verge

High level of certainty
Lower level of certainty
Pilot / trials / PoCs
ICE-led
Battery-led
Fuel cell-led

3.3 Energy vectors and propulsion type for shared mobility

Primary themes for the UK and Europe

Transition to BEVs in car-sharing and car-rental fleets

Car-sharing and car-rental fleets are still largely petrol or diesel-fuelled. Several operators are exploring the transition to BEVs (in particular free-floating car-sharing services). In the next 10 to 15 years, as charging infrastructure networks improve and the purchase cost of BEVs decreases, investment in BEVs is expected to grow to form the majority of vehicles in car-sharing and rental fleets.

Taxi and ride-hailing moving towards BEVs, with longer term potential for hydrogen fuel cells

The taxi and ride-hailing fleet generally includes newer and lower emission vehicles than private vehicle fleets due to licensing requirements. The use of PHEVs and BEVs has increased over the last five years. It is predicted this increase will continue worldwide, particularly in Europe, and will be driven by policy initiatives, financial purchase support and an increased number of rapid charging points.

Some ride-hailing operators have pledged 100% zero-emission fleets. Uber in London has promised this by 2025. A fast-charging network is critical to expanding the adoption of BEVs.

The increased use of FCEVs in taxis and ride-hailing fleets will depend on the vehicle cost and the availability of refuelling infrastructure. A key benefit of using FCEVs in taxi and ride-hailing fleets is the potential for a shorter downtime due to fast refuel times.

Growth in shared micromobility

The popularity of shared e-bikes, e-scooters and subscriptions is expected to continue to grow over the next 10 years as the industry matures. Over the next 10 to 15 years, new forms of micromobility vehicles will emerge, following the recent trend with e-scooters. Shared e-mopeds are popular in some European countries, but less so in the UK. Improvements in battery technology will enable greater range and this in turn should improve the operating efficiencies for both shared micromobility and mopeds.

Transition of the bus fleet to BEVs and FCEVs

ICE in buses is expected to decrease over the coming 10 to 15 years playing a supporting role as a range extender for battery hybrid buses. Innovate UK predicts that ICE buses will have largely been phased out by 2040[19] with BEVs accounting for three quarters of a fleet and FCEVs making up around 20%.

The use of FCEVs or BEVs in different geographies is expected to depend on the local context with the two technologies being complimentary and serving various use-cases. Cities that invest in hydrogen refuelling infrastructure are expected to switch to fuel cell buses to ensure high utilisation, which can also reduce the strain on the electricity grid caused by EV fleet recharging.

DDRT

DDRT solutions are being implemented in many locations including in the UK and across Europe, both supporting existing fixed-route bus services and, in some cases, replacing existing services.

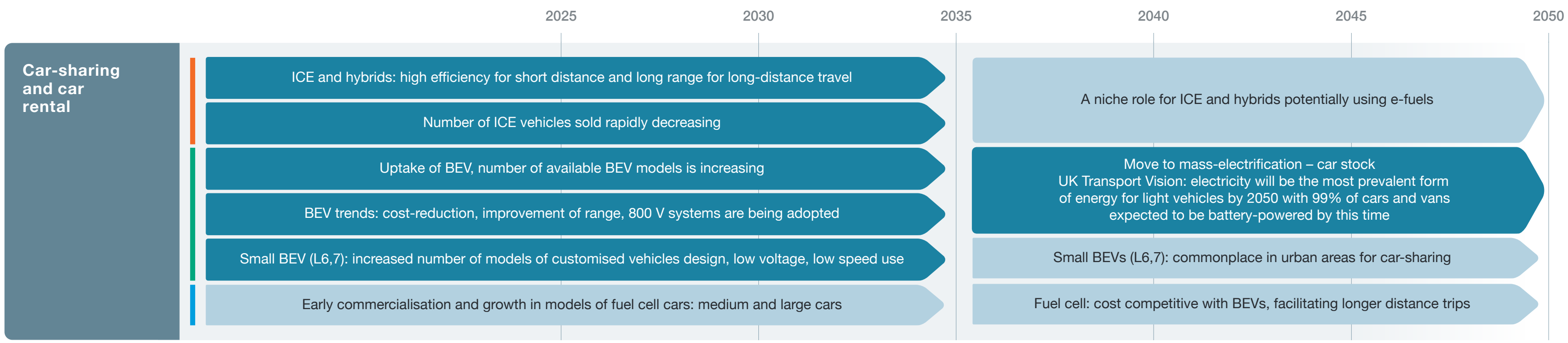
In the next 10 to 15 years, the use of BEVs is expected to grow across DDRT services, although there are limited examples at present beyond some early pilots. FCEVs have not yet been tested in DDRT services (which typically use smaller vehicles than buses) with investment more limited when compared to full-size buses.

Coach

The transition from ICE to battery-electric is less certain for coaches serving long-distance journeys.

Looking forward to 2050, it is possible that coach routes could be served through a combination of BEVs and FCEVs. For some routes, electrification may be utilised for long-distance bus and coach services. FCEVs are well-suited to long-range travel and in settings where refuelling points are far apart, but currently the total cost of operations are not mature.

19 https://iuk.ktn-uk.org/wp-content/uploads/2024/02/11312_UK-Transport-Vision-2050-2nd-edition-SP-Final.pdf



Car-sharing and car rental

ICE fuels

The types of vehicles offered by car-sharing operators and rental companies vary with most operators offering fleets with a range of vehicle sizes. Many fleets worldwide are still largely petrol or diesel-fuelled, but free-floating car sharing services have integrated electric vehicles into their fleets driven by the strategic objectives of the cities.

BEV

There are already a number of electric vehicles available in car-sharing and car-rental fleets and these are expected to grow in prominence in the coming years. Car-sharing operators are being supported by public sector funding and partnering with charge-point operators to enable BEVs to be offered in their fleet. This can allow car-sharing users to charge the vehicles free-of-charge at public charging stations operated by partner organisations[20].

Some fleets already offer a wide range of BEV models of varying size and price point. One example is the Zipacar Flex Fleet in London which boasts 1,000 EVs. It aims to have a fully electric fleet by 2025[21 22].

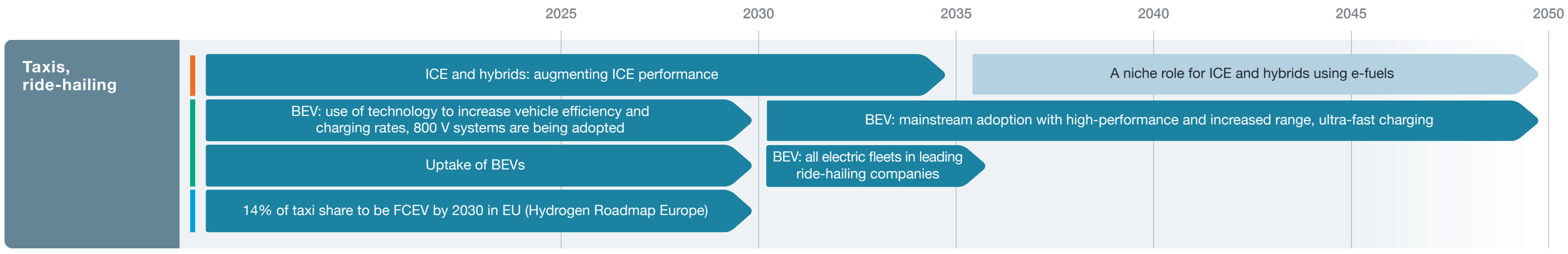
As the charging infrastructure network expands and the purchase price of BEVs decreases, it is expected that the penetration of BEVs in car-sharing fleets will increase, especially in more established markets.

Hydrogen fuel cell

To date, there are limited trials of car-sharing operators using FCEVs, and the use-case will depend on the vehicle cost and availability of refuelling infrastructure.

20 Electric car-sharing from 0,09 €/min.| SHARE NOW (share-now.com)
21 Car clubs: local authority toolkit – GOV.UK (www.gov.uk)
22 Electric Car Sharing | The Alternative to Electric Car Hire | Zipcar

High level of certainty
Lower level of certainty
Pilot / trials / PoCs
ICE-led
Battery-led
Fuel cell-led



Taxis, ride hailing

ICE fuels

In the UK and Europe, due to operating regulations, the taxi and ride-hailing fleet includes a higher number of newer and lower emission vehicles than the private vehicle fleet. Use of PHEVs in the fleet has seen an increase in the last five years, with cities such as San Francisco, Singapore, Montreal, and London leading the transition[23].

BEV

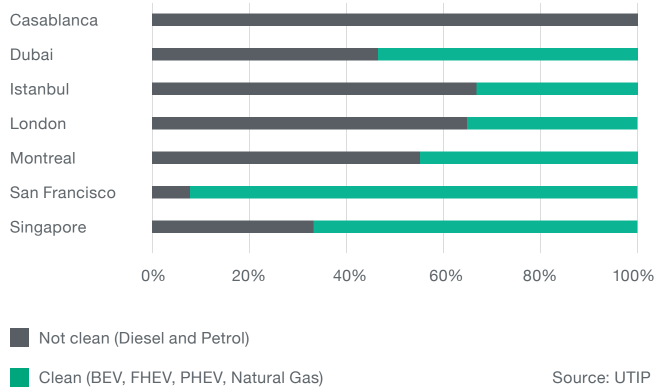
BEVs currently represent only 1% of total ride-hailing and taxi fleet[24]. The adoption of clean fleet vehicles across global cities is not uniform and varies according to local regulatory mandates (see Figure 5). An increased number of EVs for these purposes is anticipated worldwide, particularly in Europe and China. This will be driven by the introduction of policy initiatives, including monetary support for purchases and an improved public rapid-charging network.

Uber has pledged an all-electric fleet in the US, Canada and Europe by 2040 with Lyft pledging the same by 2030[25]. Dedicated taxi and ride-hailing EV charging facilities are also planned in different geographies, for example in 2018 the Mayor of London announced public parking spaces for taxi charging.

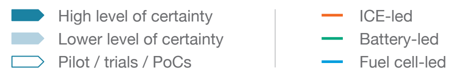
Hydrogen fuel cell

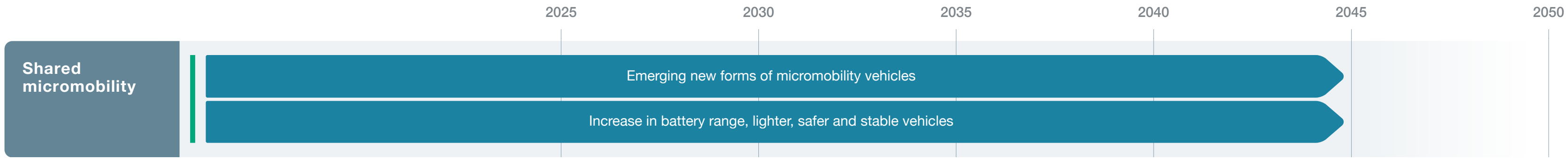
The use-case of FCEVs for taxis and ride-hailing will depend on the availability of a refuelling infrastructure. Hydrogen FCEVs may enable shorter downtime for taxis and ride-hailing, enabling utilisation of the vehicle for a longer period when compared to EVs.

Figure 5: Share of clean taxi vehicles in total fleet in select cities 2021



23 The latest trends in taxi and ride-hailing | UITP
24 The latest trends in taxi and ride-hailing | UITP
25 Uber pledges all-electric fleet by 2040 – BBC News





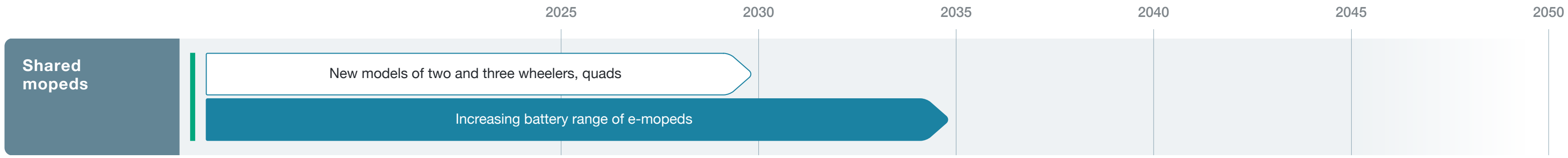
Shared micromobility

BEV

Electric micromobility vehicles run on Li-ion batteries. Within the next decade it is expected that new forms of micromobility vehicles will emerge, similar to what we have seen with e-scooters.

E-scooter bike-share and ride-sharing schemes are playing a key role in the shared mobility space. The integration of e-scooters with ride-hailing app services are currently undertaken to enhance seamless mobility.

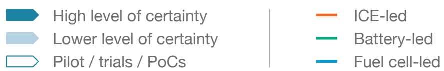
High level of certainty
Lower level of certainty
Pilot / trials / PoCs
ICE-led
Battery-led
Fuel cell-led

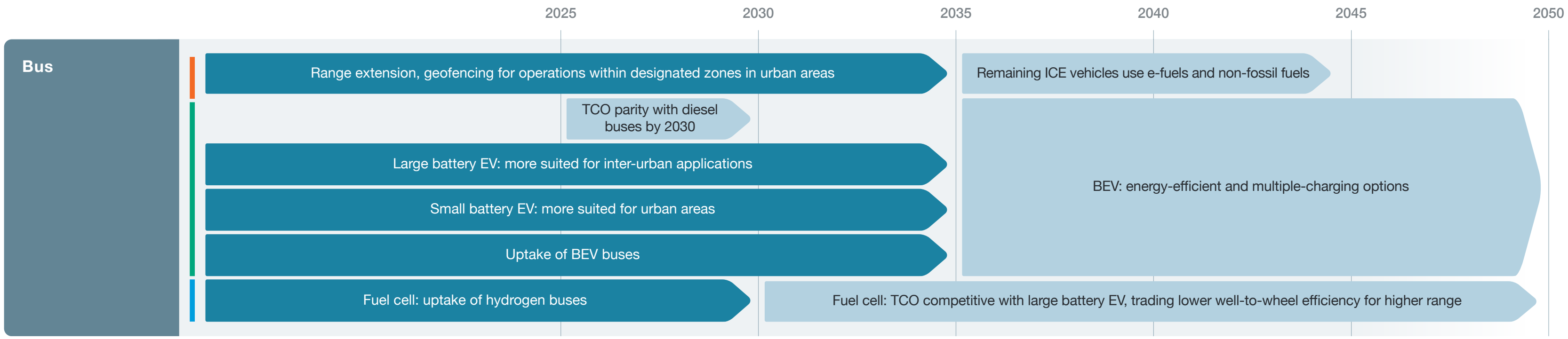


Shared mopeds

BEV

New designs of two-, three- and four-wheel BEV motorcycles are emerging and there is the potential these could be integrated into shared mobility fleets. In terms of geographic distribution, shared e-mopeds are currently most popular in Asia and other areas where the underlying moped culture is stronger.





Bus

ICE fuels

Where routes include zero-emission zones, ICE can act as range extender for battery hybrid buses. Geofencing can prevent ICE operation within designated zones in certain urban settings.

UKRI predicts that 85% of the UK's bus fleet will still be ICE by 2030, with the remaining share split between BEV and hydrogen. By 2040, as ICE buses are phased out, it is anticipated that there will be an equal split between the three technologies. Full- and mild-hybrid technologies are available for buses and offer efficiency improvements over a diesel engine bus.

BEV

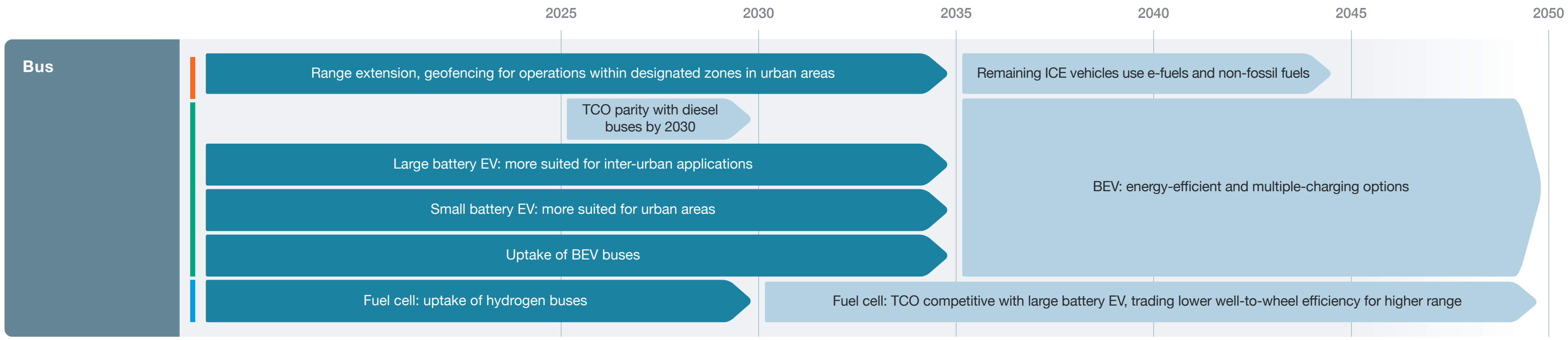
Electrification of public transport modes is expected to rise sharply from 2025 onwards[26]. It is projected that all new vehicles entering the UK fleet will be zero-emission by 2035[27]. Major operators such as First Bus and Go-Ahead have committed to zero-emission fleets by this time[28]. Transport for London (TfL) aims for zero tailpipe-emissions from their buses by 2037. In the UK, it is assumed that by 2050 all buses will be BEV or FCEV.

Currently, there is a trade-off for operators between large and small battery buses. A larger battery may only need charging one or two times per day, but the increased mass means there is less capacity for passengers, and the purchase cost is higher. There are also potential issues around axle weight limits.

Smaller batteries allow for more passengers but need charging more often and require the installation of a rapid-charging infrastructure. For urban applications, where there are shorter defined routes and infrastructure is in place, small batteries may be more appropriate. Large battery vehicles are more suited to longer distance or versatile applications.

26 Future of Mobility the transport system (publishing.service.gov.uk)
27 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1001439/decarbonising-uk-transport-final-report-and-technology-roadmaps.pdf
28 Decarbonising UK Transport (publishing.service.gov.uk)

High level of certainty
Lower level of certainty
Pilot / trials / PoCs
ICE-led
Battery-led
Fuel cell-led



Bus

Hydrogen fuel cell

Offering longer range with less impact on passenger capacity, fuel cells can work well for longer distances. However, fuel cell stack lifetimes and costs need to improve for cost-competitiveness on a TCO basis.

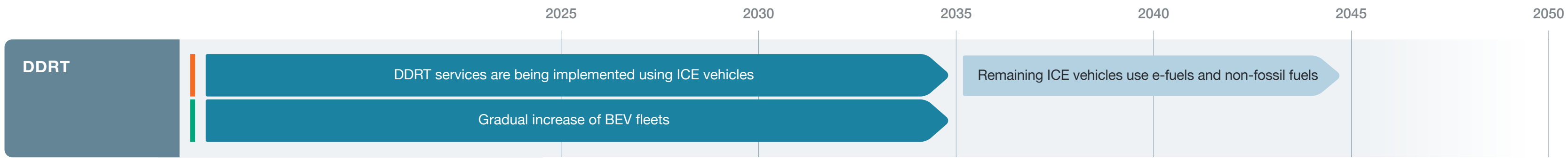
In urban environments, hydrogen technology will be most suited to larger buses, such as articulated or double-decker, and those with high daily mileage. Hydrogen buses are beginning to be trialled in Europe and the UK with bus manufacturer development programmes underway, including Wrightbus and Alexander Dennis[29].

The UK Transport Vision 2050 states that hydrogen will be a major energy vector by 2050 and it will fuel 50% of HGVs, 50% of buses, 25% of air transport and 4% of maritime[30].

First Bus has introduced 25 double-decker hydrogen FCEV buses into service in Aberdeen, Scotland, while Metroline and TfL introduced 20 double-deck hydrogen FCEV buses to London in 2021[31]. In 2023, the Go-Ahead Group introduced a fleet of 54 hydrogen buses and a re-fuelling station in the Gatwick area[32]. Wrightbus has developed a double-decker hydrogen fuel cell bus and now has fleets operating in five cities across the UK and Ireland[33]. In Northern Ireland, Translink has launched fuel cell buses (manufactured by Wrightbus), which are 100% powered by hydrogen from local onshore wind energy (green hydrogen)[34].

Implementing a hydrogen refuelling infrastructure comes with a high price tag. Therefore, cities that invest in the technology will be incentivised to switch to fuel cell buses to ensure high utilisation. This also benefits the city by reducing the strain on the electricity grid caused by EV fleet recharging[35]. The application of fuel cells or BEVs is likely to depend on local context with the two technologies being complimentary and serving various use-cases.

29 Decarbonising UK Transport (publishing.service.gov.uk)
30 https://www.ukri.org/publications/uk-transport-vision-2050/
31 Hydrogen Fuel Cell | Bus Technologies | Zemo Partnership
32 Go-Ahead Group launches UK's largest hydrogen bus fleet (intelligenttransport.com)
33 Case study – Wrightbus: World's first double decker hydrogen fuel cell bus (apcuk.co.uk)
34 Translink launches Northern Ireland's first hydrogen buses – Belfast Live
35 roadmap-report-26-6-18.pdf (apcuk.co.uk)8



DDRT

ICE fuels

New demand responsive urban transport solutions are being tested in many locations, including the UK and Europe. These services provide tailored routes for changing passenger needs with the majority using ICE vehicles.

BEV

There are limited examples of DDRT services using electric vehicles beyond some early pilots[36]. This is expected to change as more suitable vehicles become available from manufacturers, but will also require investment in electric vehicle charging infrastructure. MOIA (ride-sharing service) in Germany is one example that offers a fleet of minibus-sized vehicles that have a range of 300 km and take 30 minutes to recharge to 80%[37].

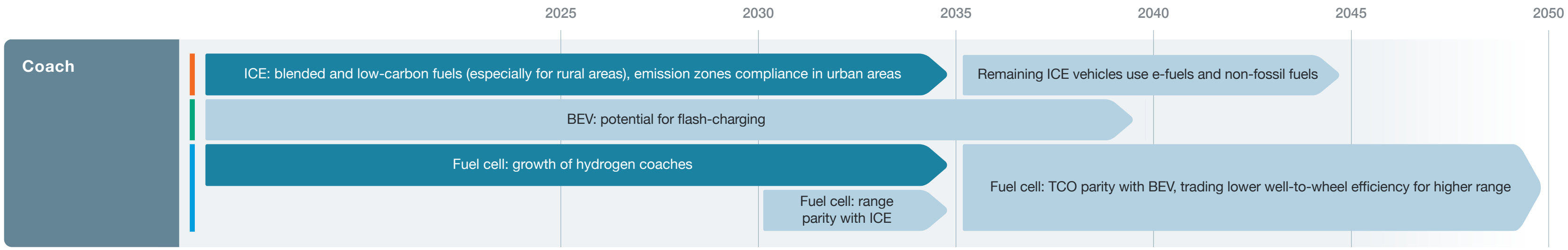
Hydrogen fuel cell

Fuel cells have not yet been tested in DDRT services, which typically use smaller vehicles than buses.

36 https://www.katchalift.com
37 https://www.keybuses.com/article/hamburgs-moia#:~:text=The%20company%20currently%20has%201%2C300,in%20the%20city's%20transit%20network

High level of certainty
Lower level of certainty
Pilot / trials / PoCs

ICE-led
Battery-led
Fuel cell-led



Coach

ICE fuels

Increased use of blended and low-carbon fuels will continue in bus and coach fleets that primarily use diesel to meet their energy needs. Recent innovations in ICE technology improve efficiency for highway and low (but not zero) emission in cities, running on low-carbon fuels.

Advanced hybrid ICEs running on low-carbon fuels provide a combination of long-range travel and short distance zero-emission control. For areas more difficult to decarbonise, such as more rural routes, biofuels are expected to offer a low-carbon solution in the interim. This will aid transition in areas where the charging network is less dense. However, these are also expected to be phased-out in favour of other solutions[38].

BEV

Battery-powered electric engines may suit vehicles where dynamic route charging or depot solutions, such as battery swapping, become available. As battery chemistries evolve to higher energy densities and more efficient charging capability, this will provide opportunities for vehicle-design optimisation and increased use.

Hydrogen fuel cell

Fuel cells are well-suited to long-range travel and in settings where refuelling points are distanced, but longer cell-stack lifetimes and lower costs need to be achieved and demonstrated to compete on a TCO basis.

High level of certainty
Lower level of certainty
Pilot / trials / PoCs

ICE-led
Battery-led
Fuel cell-led

38 Decarbonising UK Transport (publishing.service.gov.uk)

3.4 | Key drivers and regulations in private and shared mobility space

Summary of the key drivers

Emission standards and life cycle impact

Tailpipe pollutants and vehicle end-of-life are governed by regulations in many countries. These are being tightened and will likely feature greater life cycle considerations. A more complete approach to life cycle assessment (LCA) can be expected via the introduction of holistic environmental regulations for vehicles including passenger cars, micromobility vehicles, motorcycles, mopeds and buses.

CO_2 emissions

In 2023, UK Government delayed the ban on the sale of new petrol and diesel cars and vans from 2030 to 2035. However, the Zero Emission Vehicle (ZEV) Mandate will ensure that 80% of new cars sold in the UK are zero emission by 2030 and 100% by 2035. Across Europe a continuation in the reduction in CO_2 emissions for new cars is mandated in stages until 2035. The 'Fit for 55' regulation for new cars requires a 55% CO_2 emission reduction from 2030 to 2034 compared to 2021 levels. From 2035, a 100% CO_2 emission reduction is required.

Across Europe, cities are focusing on improving air quality through a range of clean air initiatives to reduce particulate emissions, e.g. PM10, as well as CO_2. For buses, European CO_2 standards for heavy-duty vehicles (HDVs) apply, which includes 85% of urban buses being zero-emission by 2030 and 100% by 2035.

Light vehicle classification and regulation

A Low-speed Zero Emission Vehicle (LZEV) class, including micromobility, is expected to be introduced in the UK. This new vehicle class will support the increased use of smaller, lighter electric vehicles.

Cities are increasing regulations around shared micromobility, with operators required to bid for tenders and meet stricter vehicle and operational standards. More widely, there is a need to develop regulation to improve the safety of electric batteries to reduce the risk of fire.

Active travel policy

Growth in policies favouring non-car modes in urban centres may evolve into more restrictions on the use of cars in urban areas. Many cities across the UK and Europe are investing in a cycling infrastructure encouraging greater use of active travel. Increased parking restrictions and alternative uses of parking spaces are expected to become more commonplace in urban centres. An increase in car-free city policies is expected to include: removing car parking spaces, increasing road tolls and closing streets to private vehicles or all motor vehicle traffic.

Zone regulation

Many cities are already incentivising the use of cleaner vehicles through diesel bans and differentiated access charges. These are expected to become more widespread over the next 15 to 20 years. Local implementations of road user charging (RUC), congestion charging and low emission zones (LEZ) may be integrated into overarching national RUC systems from 2035 onwards.

Safety regulation

Many governments are mandating stricter advanced driver assistance system (ADAS) and advanced rider assistance systems (ARAS) requirements as part of future regulations. Basic Level 1 (L1) and Level 2 (L2) ADAS features (such as adaptive cruise control) are increasingly being regulated through rules such as Vehicle General Safety Regulation in Europe[39]. It is expected that future approaches to traffic safety will be driven by the Vision Zero approach, which utilises design-led solutions to achieve zero road deaths and serious injuries.

Adoption incentives

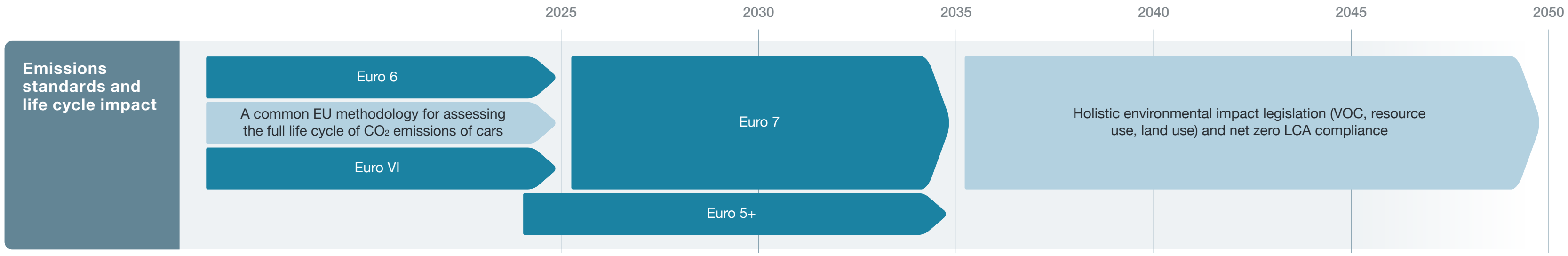
In the next 10 to 15 years, support is expected from UK and European governments to support the transition of buses to ZEVs. Grants and incentives for taxi and ride-hailing drivers, such as the UK's plug-in taxi grant (PiTG) introduced in 2017, are expected to continue to support the uptake of ZEVs.

Total cost of ownership (TCO)

In the short-term, new passenger logistics models and opportunities within Mobility-as-a-Service (MaaS), based on BEV systems, such as car-sharing, need further work to ensure a competitive TCO can be achieved. Improvements in vehicle range and a reduction in purchase price are expected to encourage the transition to BEVs across all use-cases.

From 2030, increased automation of vehicles may reduce operating costs of fleets. LEZs or similar cost-charging schemes for driving in urban areas are expected to increase, which may encourage fewer private vehicle trips leading to an increase in the use of shared mobility.

39 The new Vehicle General Safety Regulation was adopted in 2022: New Vehicle General Safety Regulation (europa.eu)



Emission standards and whole life cycle impact

The European Commission has pledged by 2025 to develop a common methodology for assessing the full life cycle of CO_2 emissions from cars in the market as well as the fuels and energy consumed by these vehicles. The European Commission has adopted new rules for a single type-approval of motor vehicles, engines and components by introducing Euro 7 emission rules replacing current standards for cars and vans (Euro 6) and lorries and buses (Euro 6)[40]. The proposal includes emissions from brakes and microplastic emissions from tyres. It is expected that from July 2025 all new motor vehicles sold in the EU must meet these standards, regardless of their fuel type, with the exception of small manufacturers who will have until 2030 to meet the standard.

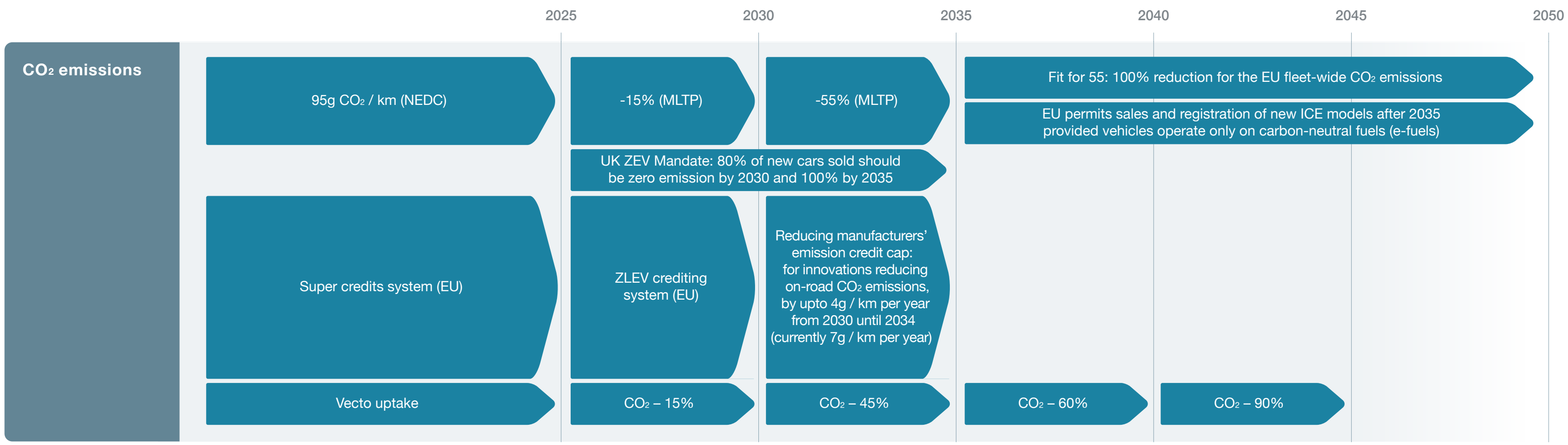
For motorcycles, Euro 5 was introduced on 1 January 2020 for new type-approval with micro-cars (L6e-B), three-wheel mopeds designed for utility purposes (L2e-U), trial (L3e-AxT) and enduro (L3e-AxE) motorcycles having a four-year additional lead-time[41].

There are also plans to introduce another standard Euro 5+ for vehicles sold from 1 January 2025, which is expected to keep the current emission limits. However, the '+' would be used to cover areas such as durability testing and diagnostics[42]. Other markets have adjusted their own national standards to match Euro 5. India, for example, has introduced its Bharat Stage VI (BS VI) standard on 1 April 2020, with emissions limits similar to Euro 5.

Pollutant emissions (NOx, HC, CO) from both buses and coaches are regulated by Euro 6 (and above) and tiered US Environment Protection Agency (EPA) standards. To address public health concerns, urban air-quality standards have been imposed to regulate emissions. As a result, future regulation based on broader environmental impacts can be expected.

40 Commission proposes new Euro 7 standards (europa.eu)
41 Motorcycles and mopeds – AECC – History of motorcycles emissions standards
42 Take A Peek Into The New Euro 5+ Standard (rideapart.com)

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



CO_2 emissions

Over the past decade, OEMs have responded to tailpipe CO_2 regulations with challenging sales-weighted fleet targets. Regulatory emission targets will facilitate the development of zero-emission vehicles, which in turn will drive competition in the market.

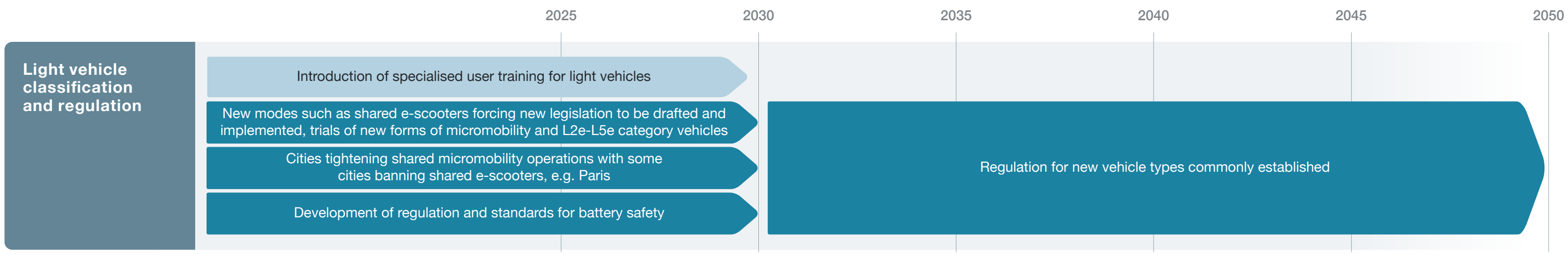
The European Commission's Fit for 55 regulations will impact emissions of new cars, as already noted within this narrative. Additionally, the EU has also agreed to permit the sale and registration of new ICE models post the 2035 deadline if they operate on carbon-neutral fuels (e-fuels)[43]. The e-fuels compromise also agreed to permit the sale and registration of new ICE models after the 2035 deadline, providing those vehicles only operate on carbon-neutral fuels, often generically referred to as 'e-fuels.' The e-fuel compromise also has implications for the pending Euro 7 vehicle-emissions regulations expected to come into effect by 2025, which affect both passenger and commercial vehicles[44].

Heavy-duty vehicles (HDV)

The European Council has agreed on a proposal to strengthen CO_2 standards for HDVs, which 'introduces a 100% zero-emission target for urban buses by 2035, while setting an intermediate target of 85% for this category by 2030'[45]. Inter-urban buses are currently exempt from the target. VECTO is the new simulation tool developed by the European Commission to calculate CO_2 emissions and fuel consumption of HDVs, including buses and coaches.

43 'Fit for 55': Council adopts regulation on CO2 emissions for new cars and vans – Consilium (europa.eu)
44 Europe steps back from 2035 ICE ban (sae.org); In win for Germany, EU agrees to exempt e-fuels from 2035 ban on new sales of combustion-engine cars | Euronews
45 European Council proposes moving the end of diesel/CNG city bus sales in Europe to 2035 (sustainable-bus.com)

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



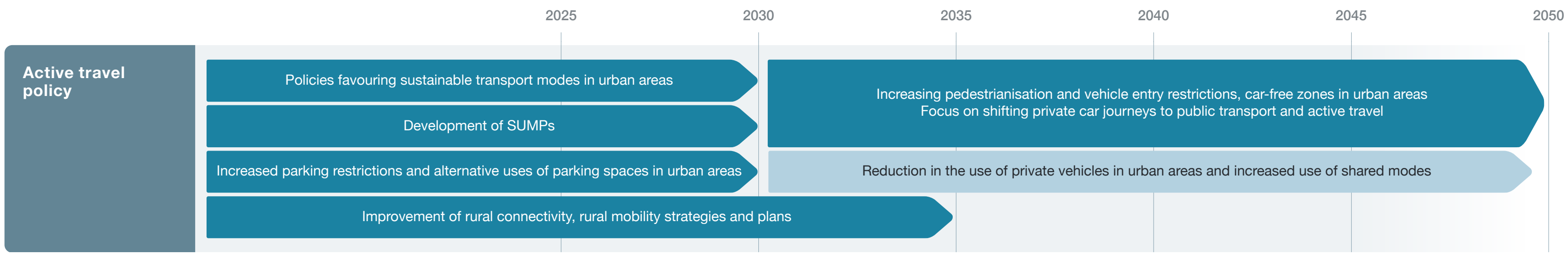
Light vehicle classification and regulation

Proliferation of micromobility vehicles across major cities in the globe requires new regulatory controls. LZEV class of vehicles will benefit from clear classification on vehicle classes and road traffic policies on speed limits. For example, micromobility classification varies across different geographies with new modes, such as e-scooters, forcing new legislation to be drafted and implemented. In the EU regulation (168/2013), L1e-A 'powered cycles' are defined as cycles designed to pedal, equipped with an auxiliary propulsion with the primary aim to aid pedalling.

In the UK, the government plans to introduce a Transport Bill to provide greater regulatory clarity on new forms of micromobility vehicles, including e-scooters and other types of light electric vehicles[46].

46 Shared micromobility within the UK | Local Government Association

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



Active travel policy

The introduction of new policies, such as 15-minute cities and low-traffic neighbourhoods, will increase the uptake of active modes. A move towards cities where services are provided within a walkable / cyclable proximity of residential areas is expected to reduce the number of short car journeys.

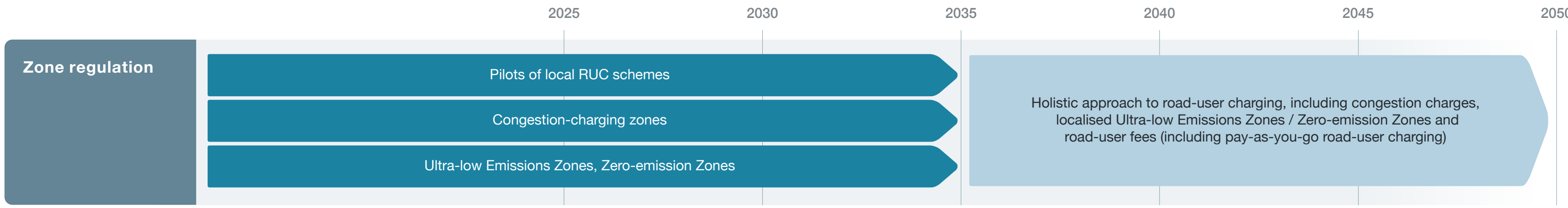
Urban areas across Europe and the UK are investing in the development of better cycling infrastructure and provision of segregated cycle lanes to improve safety. Some cities are also introducing restrictions on SUVs and large vehicles in dense urban environments. Paris, for example, is planning to introduce higher parking fees for residents with larger and heavier vehicles[47].

In Europe, many cites have implemented sustainable urban mobility plans (SUMPs). For example, in Milan the SUMP represents an important change to the city's mobility and transport policy. It is aimed at enhancing public transport, giving value to the urban space and shifting the urban mobility focus from private car ownership to a model based on shared mobility services, such as car- and e-scooter-sharing across the whole metropolitan area[48].

Governments are also assessing ways to improve rural connectivity. In the UK, the Rural Mobility Fund empowers local authorities to test on-demand buses for rural areas[49]. The Future of Transport consultation is also currently underway to determine mobility strategies for more remote locations. In the EU there is the SMARTA Project, a pilot initiative aimed at developing smart transport services for rural areas[50].

47 Paris to charge SUV drivers higher parking fees to tackle 'auto-besity' | Paris | The Guardian
48 https://use.metropolis.org/case-studies/sharing-mobility-strategy-in-milan
49 https://www.gov.uk/government/publications/rural-mobility-fund
50 The SMARTA Project » About (ruralsharedmobility.eu)

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



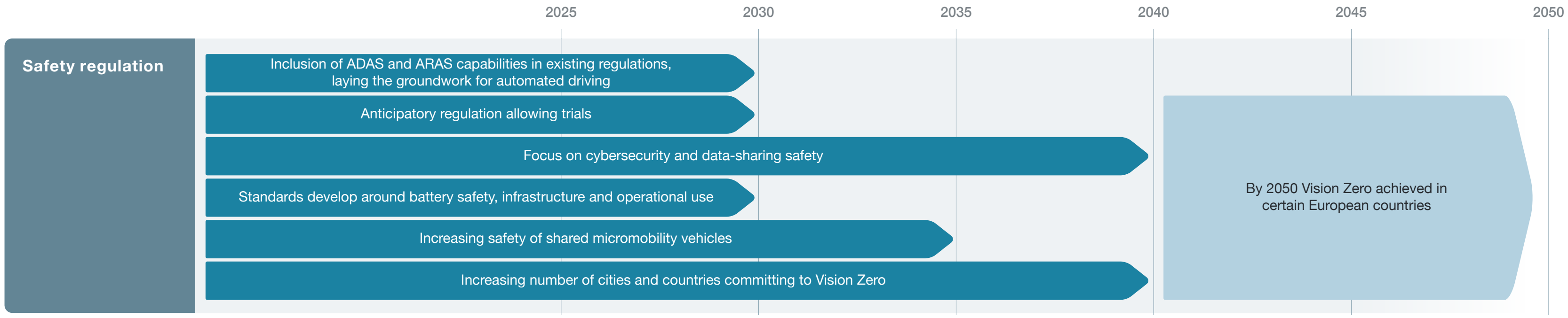
Zone regulation

In the UK, congestion-charging zones, low-emission zones and Low traffic zones (LTZs) have been introduced in several cities including London, Bristol and Leeds. Zero emission zones (ZEZs) are being introduced in urban areas as part of the EU Mission Cities (a target of 100 climate-neutral and smart cities by 2030).

The switch to ZEVs and modal shift away from cars will impact government tax revenues as lower taxes and charges on fuel duty are accrued. It is possible that new taxes or charging methods will be needed to recoup some of these losses[51]. Several states in the US have tested RUC with small-scale pilots operating in Oregon, Utah, and Virginia[52]. Pay-as-you-go RUC will be more feasible in the future with technology developing to harmonise different charges that could be applied, e.g. air quality, congestion or road tolls[53].

51 https://www.ukri.org/wp-content/uploads/2022/01/IUK-110122-UK-Transport-Vision-2050.pdf
52 pr20230213-global-transportation-trends-2022-report-en.pdf (deloitte.com)
53 Pay-as-you-drive Report September 2022 (bettertransport.org.uk)

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



Safety regulation

Many governments are looking into the inclusion of ADAS and ARAS capabilities as part of existing regulations supporting autonomous driving.

Basic SAE L1 and L2 ADAS features (such as adaptive cruise control)[54] are increasingly being regulated through rules, such as Europe's Vehicle General Safety Regulation and The European New Car Assessment Programme (Euro NCAP)[55 56]. NCAP's safety rating led to OEMs developing functions, such as automatic emergency braking (AEB) and automatic emergency steering (AES), which have resulted in more than 90% of all European- and American-made cars offering L1 capabilities as a baseline.

The United Nations Economic Commission for Europe has a rule on automated lane-keeping systems that regulates the introduction of L3 automation for speeds up to 60 km/h and this has been extended to 130 km/h for automated driving systems (ADS) for passenger cars in certain conditions (the amendment No. 157 adopted in 2022 and enforced in 2023). It also allows automated lane changes[57]. Germany has introduced comprehensive legislation on autonomous driving (AD) that has allowed one European OEM to launch the first true L3 feature in a current model. Similar legislation exists in Japan and has recently been authorised in France[58].

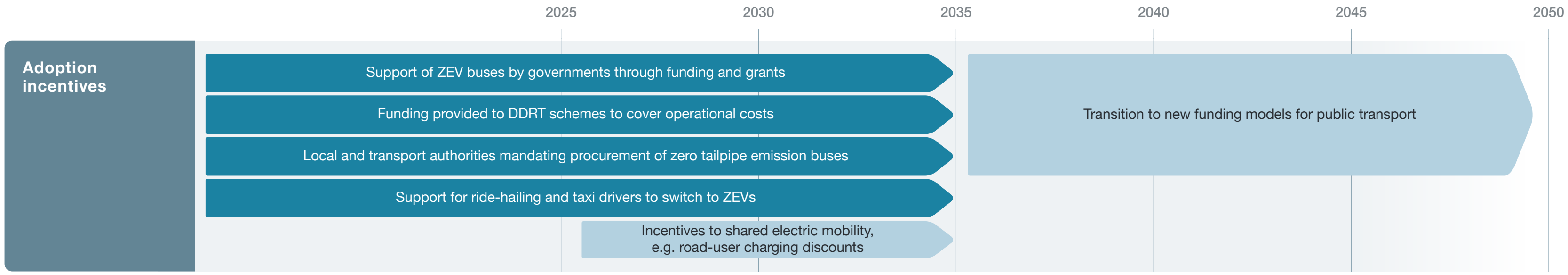
UK Government has introduced the Automated Vehicles Bill 2023[59], which implements the recommendations of a four-year review of regulation for self-driving vehicles carried out jointly by the Law Commission of England and Wales and the Scottish Law Commission (the Law Commissions)[60].

Future approaches to traffic safety will be driven by Vision Zero, or Safe System approach, which utilises design-led solutions to achieve zero road deaths and serious injuries. The Vision Zero approach was first implemented in Sweden as part of its national road policy and has been since adopted by more than 20 cities worldwide[61].

E-scooters are currently excluded from the Machinery Directive's scope and Regulation (EU) No 168/2013 and regulated under the EN17128 standard in Europe. This CEN standard has been in force since April 2021, replacing the previous standard EN14619[62]. EN17128 specifies the safety requirements and identifies the marking and information that personal light electric vehicles (PLEVs) need to carry on reducing the risk of injuries to third parties and the rider.

54 https://www.sae.org/blog/sae-j3016-update
55 https://www.euroncap.com/en
56 The future of autonomous vehicles (AV) | McKinsey
57 UN Regulation extends automated driving up to 130 km/h in certain conditions | UNECE
58 pr20230213-global-transportation-trends-2022-report-en.pdf (deloitte.com)
59 https://bills.parliament.uk/bills/3506
60 Automated Vehicles Bill 2023 – GOV.UK (www.gov.uk)
61 Vision Zero — Vision Zero Challenge
62 EU micromobility regulation

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



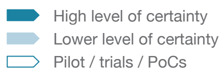
Adoption incentives

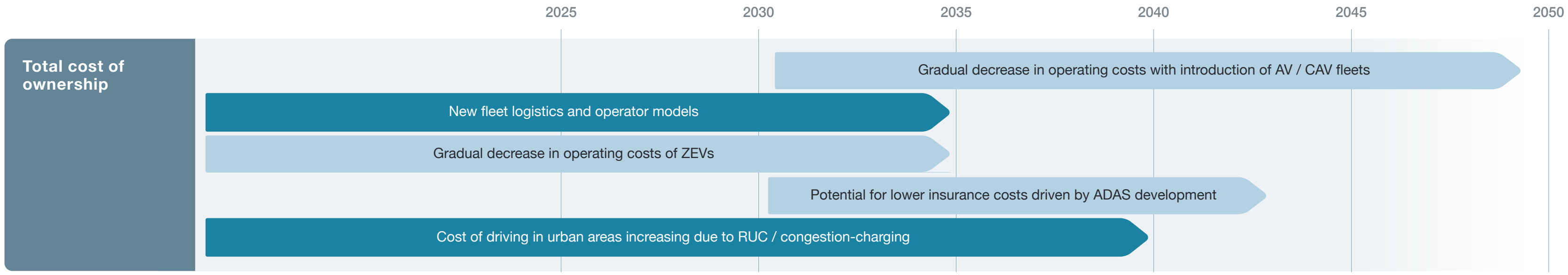
TCO of ZEVs will determine if fiscal measures may still be required for consumer uptake. In countries leading the ZEV uptake in Europe, the number of incentives will decrease over time. For example, Norway re-introduced value-added tax (VAT) on EVs costing more than 500,000 Norwegian kroner (approximately £38,000), while other advantages and incentives have also been gradually reduced[63].

In the UK, subsidies for the purchase of EVs ended in 2022. Outside the major BEV markets (China, US and Europe), countries such as India, Thailand and Indonesia are also supporting the industry. In India, the government has introduced a $3.2billion incentive programme to support EV manufacturing, which attracted $8.3 billion of investment. Thailand and Indonesia are also providing support schemes for industry[64]. However, by late 2023, European countries such as Germany and France stopped incentives to buy plug-in electric vehicles.

Ongoing support from governments will support the transition of buses to zero-emission fleets. For DDRT, services support is expected to be required to assist with operational costs as these services are more widely established.

63 Policy developments – Global EV Outlook 2023 – Analysis – IEA
64 Executive summary – Global EV Outlook 2023 – Analysis – IEA



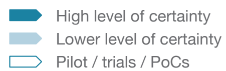


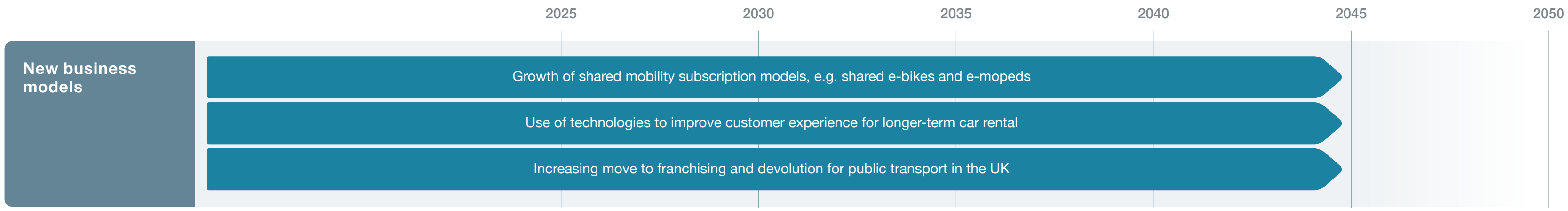
Total cost of ownership (TCO)

The improvement in range and decrease in price will encourage the transition to BEVs when comparing to the overall cost of ICE-vehicle ownership. The electricity cost per mile will become significantly cheaper than the petrol or diesel equivalent (dependent on taxation of electricity). Electric cars also require less servicing, maintenance and repairs as they have fewer moving parts.

The cost of driving private vehicles in cities is likely to increase (higher parking charges, congestion charges, etc.). RUC may also change how driving is paid for (see Zone Regulation section on page 34). This could encourage greater use of shared mobility modes including buses, shared micromobility, taxis and ride-hailing.

New fleet logistics and operator models are expected to reduce costs over the next 10-15 years. The introduction of automated services using CAV fleets has the potential to reduce costs in the longer term, but this is currently uncertain. Public transport must balance customer convenience with affordable fares. High-operating costs from new fleet introductions (for zero-tailpipe emissions), depot upgrades and ridership fluctuations are challenging factors for the sector.





New business models

OEMs and car manufacturers are becoming aware of alternate business models that will allow flexibility for car ownership to private customers. Short-term rental or flexible pay-as-you-go subscription models offer customers alternatives to traditional car ownership. With the adoption of digital technologies and location-based services, there is an opportunity for improved, as well as tailored, customer experiences.

Shared micromobility has become an integral part of mobility solutions in major cities. There are physical docking stations, hub-based stations and geofenced operations that can create virtual geographic boundaries for shared micromobility vehicles. In the UK, there are around 1.8 million members in 39 bike share schemes[65].

High level of certainty
Lower level of certainty
Pilot / trials / PoCs

65 https://www.local.gov.uk/publications/shared-micromobility-within-uk

3.5 Technology enablers for private and shared mobility

Summary of the enablers

Automation

In the UK, automation terminology is moving away from using Society of Automotive Engineers (SAE) Levels 0-5 towards the application of the categories 'user in charge vs. no user in charge' and this is reflected in this roadmap. Connected and Autonomous Vehicles (CAV) are continuing their progression towards high levels of autonomy with cars operating autonomously in certain conditions by 2030. By 2035, it is expected that up to 40% of new vehicles sold will have some self-driving capabilities. By 2050, it is likely that road vehicles will be capable of fully co-operative driving.

The development and deployment of CAVs will be supported by investment in cyber security and digital resilience. Early automated bus and minibus trials are expected to develop more widely. Zenzic predicts[66] that by 2030, automated public transport services will have been deployed within some controlled areas and that vehicles will be manufactured ready to operate with no user-in-charge (NUIC). Beyond 2030, operating areas are expected to expand.

Digitalisation and artificial intelligence

Supply chain interaction on a common digital platform for engineering, manufacturing and procurement allows concurrent vehicle development across multiple companies.

Advanced digital tools, processes and systems for vehicle design and development are growing at pace. Data collected and analysed from a vehicle throughout its life cycle will aid optimisation. Digital twins of vehicles will allow enhanced productivity at the design stage, accelerating development and generating efficiencies in technologies such as batteries and powertrains. The use of artificial intelligence (AI) in transport also has significant scope.

Vehicle platforms

OEMs continue to centralise vehicle designs upon a small number of underpinning platforms, providing a cost-effective production footprint.

The advent of EVs accentuates this. Scalable and modular BEV platforms lend themselves to mass-manufacture, with platforms shared across several OEMs to apply their own body designs and specific powertrain features. These platforms, which are also expected to be adopted by the bus industry, can be tailored through specific body designs and powertrain features.

Fleet management and systems efficiency

Digital solutions are being developed to help improve fleet management. These solutions are likely to include dynamic scheduling to accommodate the charging requirements of EV fleets and more efficient management of shared mobility operations (including car-sharing and shared micromobility).

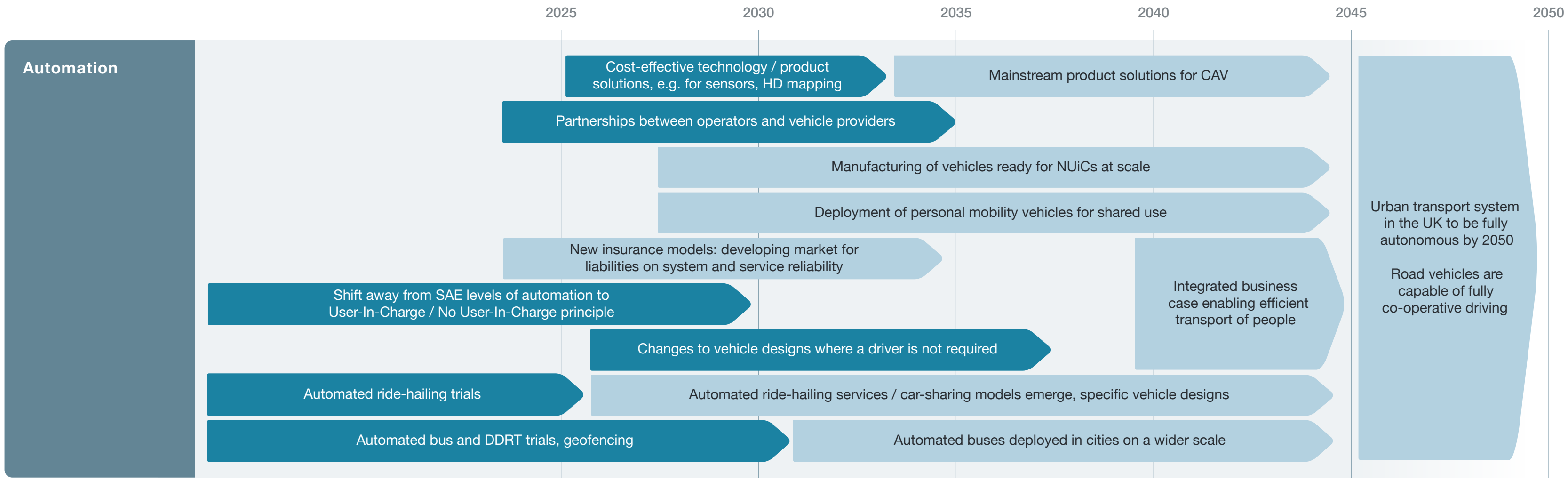
Bus design development is expected to improve vehicle efficiency, in particular relating to the power required for heating and cooling vehicles.

Mobility-as-a-Service

In the short-term, MaaS applications which integrate several modes of transport are expected to continue to emerge. From 2030, it is possible that MaaS will be adopted more widely, combining all public and shared transport options in one place, including subscriptions to simplify travel.

By 2050, it is possible that digital planning, booking and paying for transport will be the norm, potentially in conjunction with CAV technologies.

66 https://zenzic.io/insights/roadmap/



Automation

The UK CAV Roadmap presents key CAM-enablers in the UK for personal mobility vehicles and services presented in the table (see Figure 6, page 43).

The development and deployment of CAVs will be supported by investment in cyber security and digital resilience. For example, UK Government supports operators and the public through advice, guidance and tools provided by the National Cyber Security Centre (NCSC) plus legislation contained in the Network and Information Systems (NIS) regulations[67].

Driverless pods have already been trialled in controlled situations, such as airport shuttles. Automation of services is expected to reduce the costs. Currently, around 40% of bus and taxi service costs are attributed to the driver. Automation would reduce this making these modes more cost-effective for the user[68].

CAVs could also benefit areas where public transport is underserved. However, the move to automation could cause a disruption in the workforce and this will need to be carefully managed. There is also potential to use CAVs as a mass-transit system.

These vehicles could operate on segregated tracks, similar to guided bus systems[69], offering a safe and efficient solution. Zenzic predicts that by 2028, automated public transport services will have been deployed within some controlled areas, and that vehicles will be manufactured ready to operate as NUIC[70].

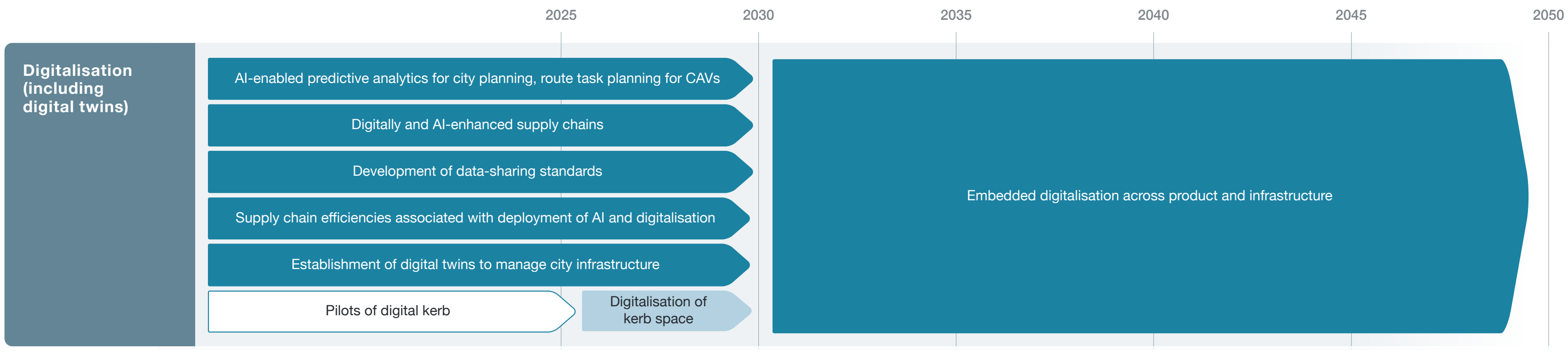
67 Transport Security – An introduction to UK capability (publishing.service.gov.uk)
68 Future of Mobility the transport system (publishing.service.gov.uk)
69 cam-2025-realising-benefits-self-driving-vehicles.pdf (publishing.service.gov.uk)
70 CAM Roadmap – Zenzic

High level of certainty
Lower level of certainty
Pilot / trials / PoCs

Figure 6: CAM roadmap from Zenzic

Short-term (2023–26)	Medium-term (2027–30)	Long-term (2031+)
• Commercial deployment pilots • Introduction of NUICs in specific use-cases such as automated lane-keeping systems (ALKS), valet parking as optional feature in privately-owned vehicles • Deployment trials to support the development of service / business models for personal mobility • Identification of training and skills required for this service • Identification of the CAM supply chain requirements for this service	• Commercial service models ready for investment • Deployment of personal mobility vehicles for personal ownership and services, e.g. sharing and car clubs • Manufacturing of vehicles ready for NUICs at scale • AI-enabled load route / task planning • Partnership between operators and vehicle providers • Cost-effective technology / product solutions, e.g. for sensors, HD mapping, road infrastructure • End-to-end CAM skills pipeline established	• Monitoring and refinement followed by expansion of the operational design domains (ODD). • Integrated business case enabling efficient transport of people

Source: Roadmap-to-2035-–Executive-Summary_v6.pdf (zenzic.io)



Digitalisation

AI has significant scope for transport, playing an important role in the development of autonomous vehicles. Spatial recognition systems understanding a vehicle's movement, the immediate environment and location data, as well as interactions with external objects, all apply AI to function.

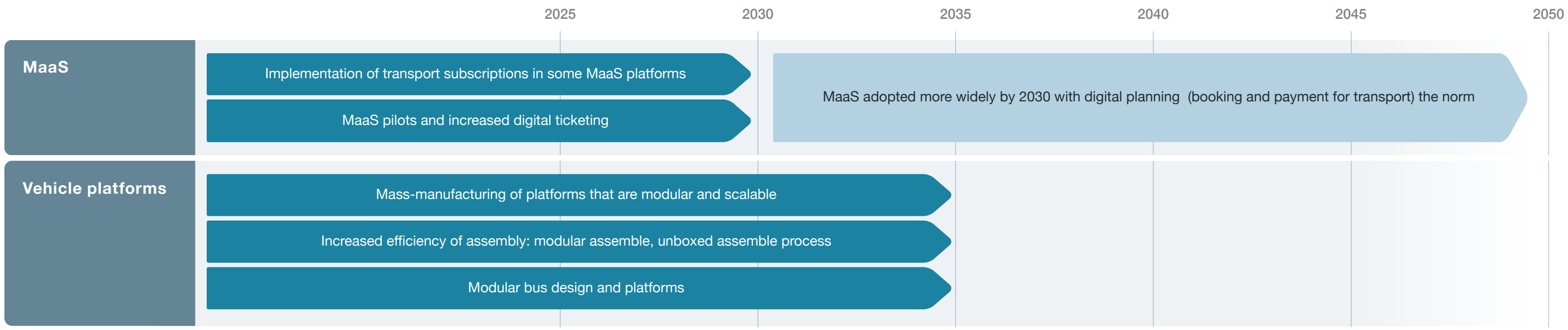
AI-generation of scenarios for virtual CAV testing is already happening. Real-time data management coupled with AI and simulation technologies will improve traffic management systems and enable efficient and well-informed planning and routing. Some ADAS features also use AI, as well as cameras and sensor technology, to assess the environment around the vehicle aimed at improving safety[71].

Digitalisation of the kerb is an area increasingly attracting attention allowing for the kerb space to be used by multiple vehicle types and uses, e.g. taxi pick-up and drop-offs, goods delivery, micromobility parking and private car parking. The UK's Department for Transport (DfT) is undertaking research on the provision of kerbside management[72]. As CAV services become mainstream, it is important they are connected with digital kerb solutions enabling efficient operations.

Connected transport systems can allow for efficiency gains through real-time demand modelling, vehicle diagnostics and the monitoring of users. Passengers are expected to be better informed about the availability of transport for their journey and the best routes for travel. Digital twins can play an important role in optimising public transport and fleet movements.

71 AI-and-Transportation.pdf (enotrans.org)
72 Provision of Kerbside Management Discovery – Digital Marketplace

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



Mobility-as-a-Service

MaaS is expected to evolve beyond MaaS-compatible urban vehicles towards dedicated MaaS vehicles, potentially in conjunction with CAV technologies. Changing future population demands means that vehicle products are expected to evolve, not just for single-person ownership.

MaaS enables alternative commercial and product design solutions for changing mobility needs. MaaS technology users gain instant access to a range of mobility services through an online technology framework known as a 'platform'. Platform economy technologies and mobile services are driving the trend of transport services on demand. Mobility-on-Demand, Mobility Hubs and MaaS are all facilitated by the platform economy, mobile services and the introduction of smart ticketing and electronic payment systems. MaaS provides potential integration for all public and shared transport options in one place, allowing for the easy planning and payment of inter-modal journeys. Transport subscriptions may also be offered, further simplifying access.

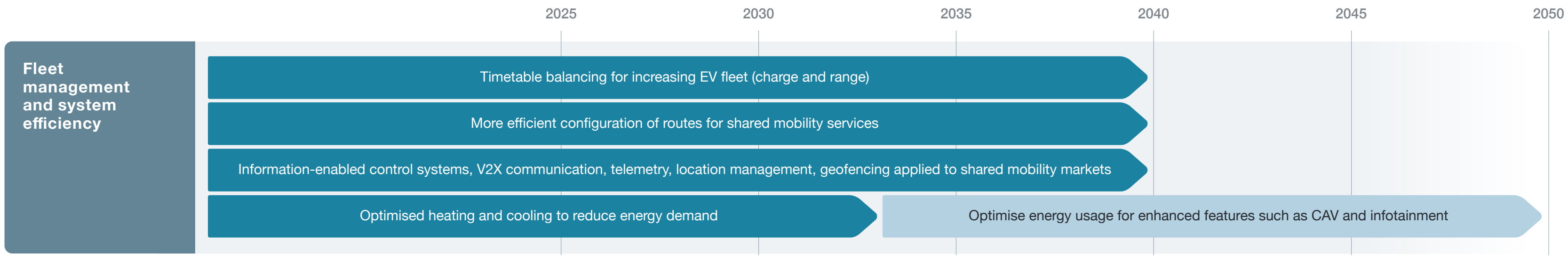
Vehicle platforms

Modular platforms for EVs, known as 'ground up', 'skateboard' and 'bespoke' EV architectures, are widely used. EVs contain far fewer moving parts, so the layout can be optimised for this new technology. The advantages are a more spacious interior, room for more batteries and a reduction in weight resulting in improved space availability and range efficiency.

The development of EV platforms may extend to buses. Modular bus designs can help achieve local zero-emission requirements. Interchangeability of parts enable vehicle optimisation by providing components that best suit the needs of a given application or route.

These platforms enable emerging manufacturers to develop vehicles without the costs of producing their own hardware. They can purchase a platform and assemble pre-made components from individual suppliers. Due to the shared hardware, manufacturers will likely differentiate or sell their vehicles based on their software. It will also allow vehicles to be customised to the owner's needs.

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



Fleet management and systems efficiency

Digital solutions for more effective fleet management are being developed, combining both data and insights.

New mobility fleets are expected to continue to grow with improved efficiencies in logistics and operations. Digitalisation can support the recharging schedule and redistribution of vehicles.

The geographic areas in which these fleets operate are expected to continue to expand, dependent on user demand and the profitability achieved by operators / financial support from the public sector.

There are several other developments in bus design which are anticipated to improve their efficiency. The mass of buses is being reduced through design optimisation and the use of lighter materials. Systems on buses, such as heating, ventilation and air conditioning (HVAC), onboard entertainment and lighting are also a considerable drain on the battery and shorten range. The use of technology and smart automation through onboard monitoring and intervention can optimise the energy usage of large vehicles like buses and coaches.

High level of certainty
Lower level of certainty
Pilot / trials / PoCs

3.6 | Infrastructure enablers for private and shared mobility

Summary of infrastructure enablers

Charging infrastructure

The transition to ZEVs will need to be supported by an extensive charging network offering various types of charging for different needs. Government investment into the charging infrastructure will serve to increase public confidence in electric vehicles.

Public charging, such as rapid-charging hubs and on-street parking, will provide charging opportunities for those without access to private parking (around 25% of people in the UK). Scaling-up opportunities for non-rapid charging will be particularly important in urban areas.

ZEV adoption will be further aided by technologies such as bi-directional charging which includes vehicle-to-grid (V2G), vehicle-to-home (V2H) and vehicle-to-load (V2L). Other methods to manage electricity demand will also be deployed. Depot-charging is likely to be the primary method for buses and coaches imposing a potential infrastructure challenge for large power needs at sites, e.g. London bus depots.

Hydrogen refuelling

Currently, hydrogen is expensive to produce, transport and store. Regulatory frameworks will be introduced to guide and support the technology development. The costs of hydrogen distribution are expected to be reduced by economies of scale.

The hydrogen refuelling network in the EU is in the early stages of development with central Europe leading the way, while north-eastern Europe is lagging with very limited infrastructure development. Hydrogen refuelling stations are due to be introduced in Europe in the coming years, initially for HGVs.

Cooperative Intelligent Transport Systems (C-ITS)

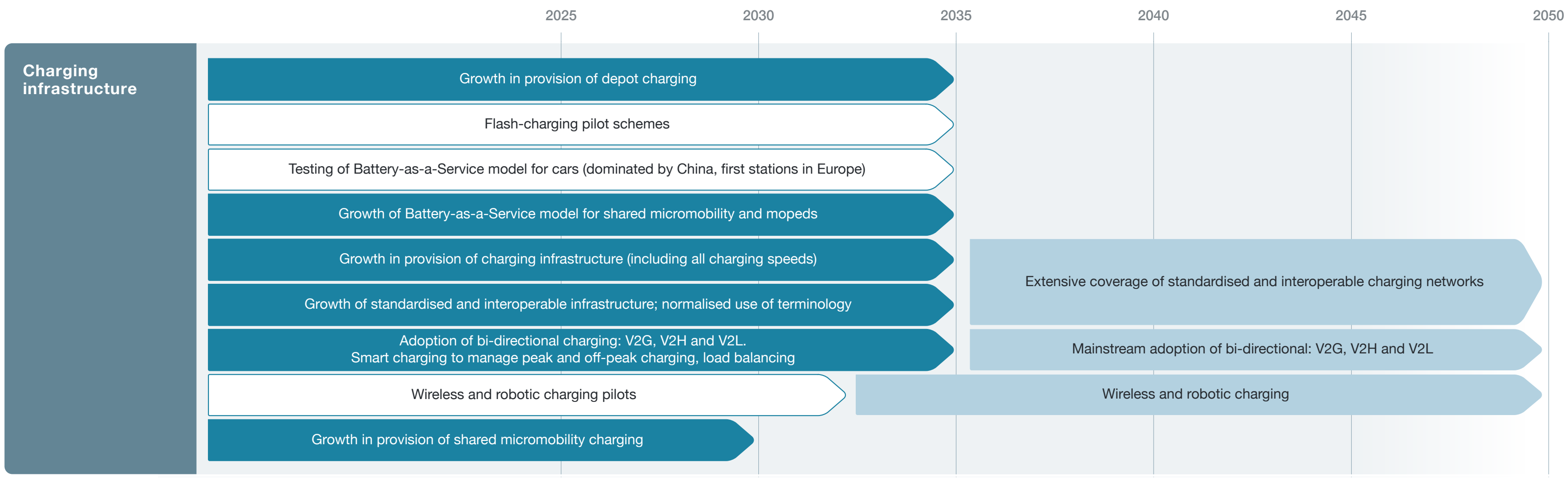
It is expected for connectivity and innovation in C-ITS to facilitate efficiency in existing services and to support the introduction of new services and products.

C-ITS technological development will see road vehicles connected with each other, facilitating a centralised traffic management system. UK Transport Vision 2050 states that by 2050 road vehicles will be capable of fully cooperative driving, improving traffic flow. In Europe, countries have committed to developing large-scale testing sites of connected and automated driving on European motorways as cross-border corridors. These corridors help Europe reach its ambition of being a leader in the large-scale testing and deployment of 5G infrastructure, which would enable connected and automated mobility.

Active travel infrastructure

The uptake of micromobility transport modes (bikes, e-bikes and e-scooters) will be encouraged and supported by an increase in a cycling infrastructure. Separation from other road-users means safer journeys and facilitates uptake. The pandemic triggered investment into the active travel infrastructure and this is expected to continue. These factors will aid mode shift to active travel with more people willing to reduce private car use and, in some cases, car ownership, particularly in dense urban areas.

Mobility Hubs networks have been developed in Belgium, Austria, Norway and Germany, e.g. in Bremen and Berlin, with plans developing for networks across the UK.



Charging infrastructure

UK Government has committed £90 million to fund the rollout of a local EV charging infrastructure which will support the implementation of larger, on-street schemes and rapid hubs across England. It has also allocated £1.6 billion to expand the UK charging network with an additional 300,000 public chargers by 2030[73].

The European Commission has also agreed on mandatory national targets for the deployment of an infrastructure to support the uptake of alternative fuels. A "charging infrastructure for cars with at least a 400 kW output will have to be deployed at least every 60 km along core TEN-T network by 2026, with the network's power output increasing to 600 kW by 2028"[74].

ZEV adoption will be further aided by technologies such as bi-directional charging, which includes V2G, V2H and V2L[75]. There will be a large increase in energy demand for the charging of ZEVs, which will need to be managed. Bi-directional charging will manage peaks in the demand for home-charging on local grids. It is expected that selling energy back to the grid will become widespread for EV owners with energy stored in their plugged-in car.

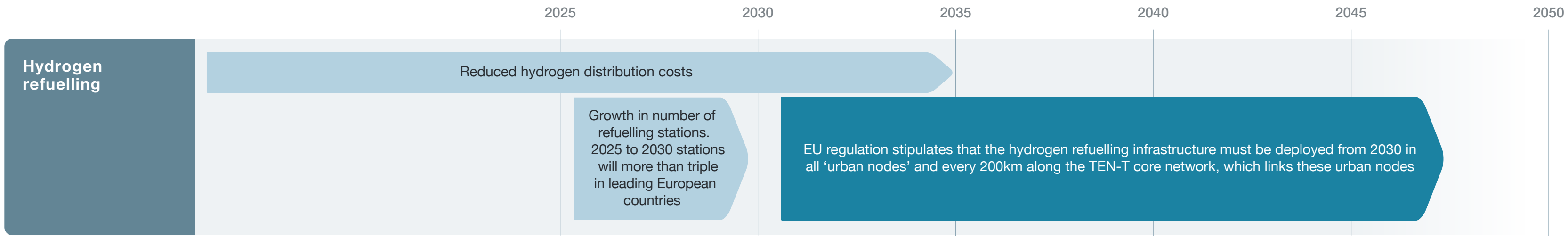
Some manufacturers are starting to advertise their electric trucks with bi-directional charging as the source of power generation for the home. For example, an ability to power the home from a truck is one of the key selling points for the Ford F150 Lightning pick-up truck[76].

Battery-leasing and battery-swapping models are currently being explored, e.g. in China. However, there are challenges around standardisation and dedicated business models for commercial scaling globally.

Depot-charging is likely to be the primary method for buses and coaches imposing a potential infrastructure challenge for large power needs at sites, e.g. London bus depots. Flash-charging for electric buses has started to be introduced in some cities. In Italy, Genoa will be the first city to develop a bus line with a flash-charging system by the end of 2025[77].

73 Tenfold expansion in chargepoints by 2030 as government drives EV revolution – GOV.UK (www.gov.uk)
74 Fit for 55: deal on charging and fuelling stations for alternative fuels | News | European Parliament (europa.eu)
75 https://esc-production-2021.s3.eu-west-2.amazonaws.com/2021/08/Cenex-WP-2-True-Value-of-V2G-Report.pdf
76 2023 Ford F-150 Lightning® | Onboard Generator with Intelligent Backup Power
77 Hitachi Energy to provide flash-charging technology in Genoa for new BRT line (sustainable-bus.com)

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



Hydrogen refuelling

Stakeholders indicated that much of the hydrogen refuelling infrastructure growth will be led by HGVs with some provision for cars. Vehicles using stations will be both hydrogen ICE vehicles and FCEVs.

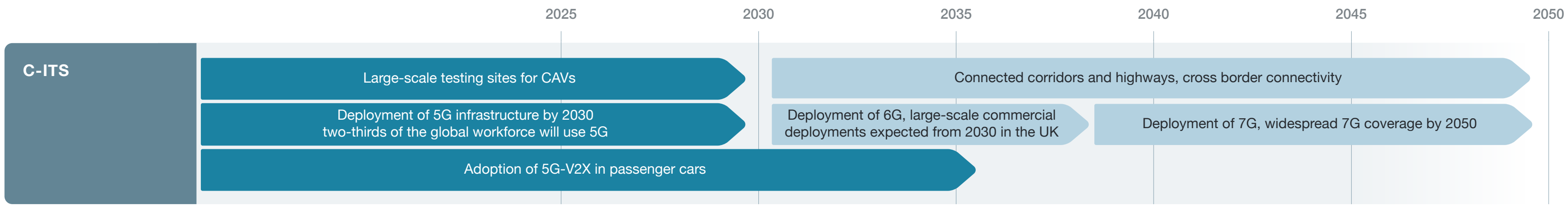
The hydrogen refuelling network in the EU is at early stages of development with central Europe leading the way. Northeastern Europe is lagging with very limited infrastructure development. Hydrogen refuelling stations are due to be implemented in Europe in coming years initially for HGVs. They will see increased use as more hydrogen-powered vehicles are made available. It is anticipated from 2025 to 2030, the number of these stations will more than triple in the leading European countries. Germany is projected to have 300 stations by this time, and the UK 150[78].

In a recent update to the UK Hydrogen Strategy, it was stated that "the role of government support for hydrogen in transport would change towards 2030 and beyond, with continued R&I investment necessary alongside policy to support the technologies' rollout"[79].

In the EU, the Alternative Fuels Infrastructure Regulation (AFIR) 2023/1804 (which came into force on 12 October 2023), article 6 mandates the construction of one gaseous hydrogen refuelling station (HRS) every 200 km on the TEN-T core network by the end of 2030, as well as one HRS in every urban node[80].

78 Europe: hydrogen refueling stations forecast by country 2030 | Statista
79 Hydrogen strategy: update to the market, July 2022 (publishing.service.gov.uk)
80 How a UK hydrogen car industry could cut fuel costs and carbon emissions (theconversation.com)

High level of certainty
Lower level of certainty
Pilot / trials / PoCs



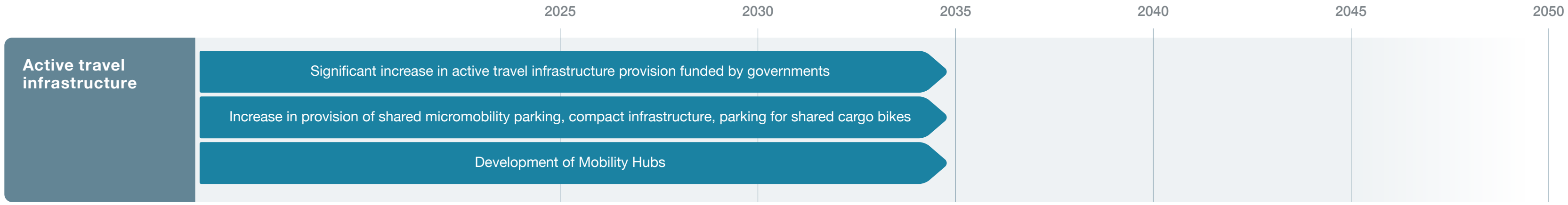
Cooperative Intelligent Transport Systems (C-ITS)

C-ITS technological development will allow for road vehicles to be connected with each other, facilitating a centralised traffic-management system.

UK Transport Vision 2050[81] states that by 2050 road vehicles will be capable of fully cooperative driving improving traffic flow. R&D projects in the UK are focusing on the development of 6G and the roadmap forecasts commercial deployments from 2028. Larger-scale commercial deployments will be seen from 2030 onwards.

High level of certainty
Lower level of certainty
Pilot / trials / PoCs

81 IUK-110122-UK-Transport-Vision-2050.pdf (ukri.org)



Active travel infrastructure

Mobility-hub strategies have been developed by a number of EU countries and local authorities in the UK. There are also successful Mobility-Hub networks developed in Belgium, Austria, Norway and Germany, e.g. in Bremen and Berlin.

High level of certainty
Lower level of certainty
Pilot / trials / PoCs

Glossary

ACEM	The European Association of Motorcycle Manufacturers
AD	Automated driving
ADAS	Advanced driver assistance system
ADS	Automated driving system
AEB	Automatic emergency braking
AES	Automatic emergency steering
AFIR	Alternative Fuels Infrastructure Regulation
AI	Artificial intelligence
ALKS	Automated lane keeping system
ARAS	Advanced rider assistance systems
AVP	Automated valet parking
BAAS	Battery as a service
BEV	Battery electric vehicle
BRT	Bus rapid transit
C-ITS	Co-operative intelligent transport systems
CAGR	Compound annual growth rate
CAM	Connected and automated mobility
CARB	California Air Resources Boad
CAV	Connected and autonomous vehicle
CNG	Compressed natural gas
CO	Carbon monoxide
DDRT	Digital demand responsive transport
DfT	Department for Transport
EES	Electrical energy storage
EPA	Environmental Protection Agency
EU	European Union
EV	Electric vehicle
FCEV	Fuel Cell Electric Vehicle
HC	Hydrocarbons
HD	High definition
HDV	Heavy-duty vehicles
HGV	Heavy goods vehicle
HRS	Hydrogen refuelling station
HVAC	Heating, ventilating and air-conditioning
ICE	Internal combustion engine
IEA	International Energy Agency
LCA	Life cycle assessment
LEZ	Low emission zones
Li-ion	Lithium ion
LNG	Liquefied natural gas
LTZ	Low traffic zone
LZEV	Low-speed zero emission vehicle
MaaS	Mobility-as-a-service
MIT	Ministry of Infrastructures and Transport
NCAP	North America's Car Assessment Program
NCSC	National Cyber Security Centre
NEDC	New european driving cycle
NIS	Network and information systems regulations
NMHC	Non-methane hydrocarbons
Nox	Nitrogen oxides emission
NPF	National policy framework
NUIC	No user in charge
ODD	Operational design domains
OEM	Original equipment manufacturer
ONMC	On-road motorcycles
P2P	Peer-to-peer
PHEV	Plug-in electric vehicles
piTG	Plug-in taxi grant
PLEV	Powered light electric vehicle
PLV	Powered light vehicle
PM10	Particulate matter
R&D	Research and Development
RUC	Road user charging
SAE	Society of Automotive Engineers
SUMP	Sustainable urban mobility plan
SUV	Sports utility vehicle
TCO	Total cost of ownership
TENT-T	Trans-European Transport Network
TfL	Transport for London
UK	United Kingdom
UKRI UK	Research and Innovation
ULEV	Ultra low emission zZone
US	United States
V2G	Vehicle-to-grid
V2H	Vehicle-to-home
V2L	Vehicle-to-load
V2X	Vehicle-to-everything
VAT	Value added tax
VECTO	Vehicle energy consumption calculation tool
VOC	Volatile organic compounds
WiCET	Wireless charging of electric taxis
WLTP	Worldwide harmonised light vehicle test procedure
ZEFER	Zero emission fleet vehicles for european rollout
ZEV	Zero emission vehicle
ZEZ	Zero emission zone
ZLEV	Zero and low emission vehicle

System-Level Roadmaps

- Mobility of People
- Mobility of Goods

Technology Roadmaps

- Electric Machines
- Power Electronics
- Electrical Energy Storage
- Lightweight Vehicle and Powertrain Structures
- Internal Combustion Engines
- Hydrogen Fuel Cell System and Storage

Find all the roadmaps at

www.apcuk.co.uk/technology-roadmaps

automotive council UK

ADVANCED PROPULSION CENTRE UK

Established in 2013, the Advanced Propulsion Centre UK (APC), with the backing of the UK Government's Department for Business and Trade (DBT), has facilitated funding for 304 low-carbon and zero-emission projects involving 538 partners. Working with companies of all sizes, this funding is estimated to have helped to create or safeguard over 59,000 jobs in the UK. The technologies and products that result from these projects are projected to save over 425 million tonnes of CO_2.

The APC would like to acknowledge the extensive support provided by industry and academia in developing and publishing the roadmaps.

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