# PATHWAYS TO DEEP DECARBONIZATION

## of the passenger transport sector

## IN THE UK

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*UCL Energy Institute*

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## THE TRANSPORT DEEP DECARBONIZATION PATHWAYS PROJECT (DDPP-T)

The Transport Deep Decarbonization Pathways Project (DDPP-T), an initiative of the Institute for Sustainable Development and International Relations (IDDRI), aims to demonstrate how countries can transform their transport system by 2050 in order to implement a deep reduction in their greenhouse gas emissions, consistent with ambitious climate goals.The DDPP-T builds on the Deep Decarbonization Pathways Project (DDPP), which analyzed the deep decarbonization of energy systems in 16 countries in the lead-up to COP21. The two projects share key principles. The analysis is conducted at a country scale, by in-country research teams, working independently of their governments. It adopts a 2050 time horizon to reveal the short-term requirements of long-term climate and development objectives. Finally, country research teams openly share methods, modelling tools, data and results in order to enable knowledge sharing among project partners in a highly collaborative way and to facilitate engagement with sectoral experts and decision makers.

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# Foreword

This analysis considers passenger transport, encompassing the mobility of resident citizens including domestic and international air flights and non-motorized travel. Freight transport will be considered in future work.

The analysis starts from an acknowledgment that profound transformations of the passenger transport sector, that could deliver deep greenhouse gas emission reductions consistent with an ambitious climate goal, go beyond technological change. They require considering a more systemic approach to build decarbonization storylines, including key drivers like the evolution of demographic and economic situation, individual behaviours, lifestyles, infrastructures and spatial organization. The approach also recognizes the need to provide quantification of these storylines for key indicators characterizing mobility patterns such as distances travelled by trip purposes, by location of people, by modes or budget and time dedicated to transport activities. The methodology of the DDPP-T, adopted by all country research teams in the project, connects these two complementary approaches to long-term deep decarbonization analysis of the transport sector consistent with emission reductions computed in previous DDPP national scenarios..

The structure of the report reflects this approach. The key determinants of mobility are described by the storylines in the second section. These storylines are then translated into a quantitative sector-wide representation of the transport sector, which form the core of the third section. Finally, a sub-set of these indicators have been chosen as key quantitative metrics to engage stakeholders and decision makers, and are presented in the Annex.

# Executive Summary

Travel by private passenger car is the dominant travel mode of choice for UK residents. Cars currently provide more than 80% of all travel needs, with approximately one car for every two people living in the country. While the growth of cars on the road and social trends linked to car ownership has been very rapid since the 1950s, there are some indicators that suggest demand for travel by car might have recently decoupled from population and economic growth. Whether or not history will reveal the current plateau in demand growth as a temporary interlude or a turning point in mobility trends remains to be seen. It is an open question for policymakers and one that has critical implications in terms of investment, regulation, and the future strategic planning of national infrastructure.

A key challenge for transport policy in the UK is the Government's own domestic climate legislation, which mandates "at least" an 80% reduction in greenhouse gas (GHG) emissions relative to 1990 levels by 2050. Accounting for various demographic, economic, and technological trends as well as the pattern of demand across different sectors, past analysis reveals that achieving this target translates into a requirement for the carbon intensity of transport to decline by around 70% on average by 2050. This implies a need for radical solutions over the next 20-30 years in order to achieve the kind of structural changes in the energy system that can meet the goal of deep decarbonisation.

The analysis presented in this report is intended to support engagement with transport experts and decision makers regarding actionable policies towards transport emissions reductions in the UK context. Rather than pursuing a narrow focus on technological solutions alone, the analysis explicitly seeks to uncover and explore other important determinants of transport demand and emissions such as changes to demographic and economic structure, urban planning, culture, lifestyles and values. This is because past research and engagement with energy system stakeholders in the UK shows clearly that experts view the social dimension of energy use to be at least as important as technological change.

We describe two new scenarios that provide distinctive visions of how passenger transport could evolve in the future, driven by rapid technological progress, changes to societal mobility trends, and the requirement to transition towards low or net-zero energy systems. Both of the scenarios presented achieve similar levels of decarbonisation by 2050, but take very different pathways towards that destination. The two scenario narratives, which focus on passenger transport, are:

- Freedom to Roam (F2R): a future where new communication and transport technologies reinforce existing societal tendencies towards maximizing individual comfort, convenience and autonomy, and economic activity remains concentrated in existing centres of power.
- No Place Like Home (NPLH): a future characterized by a focus on localism, where new technologies are harnessed for the purposes of strengthening communities, facilitating the sharing of pooled resources and assets, and for diversifying regional economic activities so that multi-polar centres of education, leisure and commerce emerge across the country.

These two scenarios embody quite different visions of the passenger transport future. F2R is very much supply side focused with patterns of mobility demand remaining similar to those seen today, rooted in the development of new technologies, notably autonomous vehicles, that strengthen the motivation for car use, due to convenience and meeting the demands of mobile lifestyles. NPLH, on the other hand, sees technology development shift mobility trends in another direction, towards a sharing services model that is also built around greater use of other modes of transport, particularly in metropolitan areas.

For both scenarios, a shift to electro-mobility is key to keeping emissions reductions in line with climate policy targets. This underscores the importance of UK action to ensure that a zero-carbon electricity supply is achieved in the 2030s. For mobility transitions to develop in the direction of the future imagined in the F2R scenario, an essential precondition would be the successful early development of highly autonomous vehicles (i.e. SAE J3016 Levels 4 and 5). Mobility transitions in the direction of the NPLH scenario may require government to take a more active role in regional spatial planning. Finally, both scenarios arrive in 2050 with the transport sector emissions being dominated almost entirely by international aviation emissions. Achieving currently legislated national targets for 2050 requires that further options in both energy supply and demand will need to be explored if the UK is to move towards a net-zero emissions position in line with the Paris Agreement in the second half of the century.

# Description of the passenger transport sector

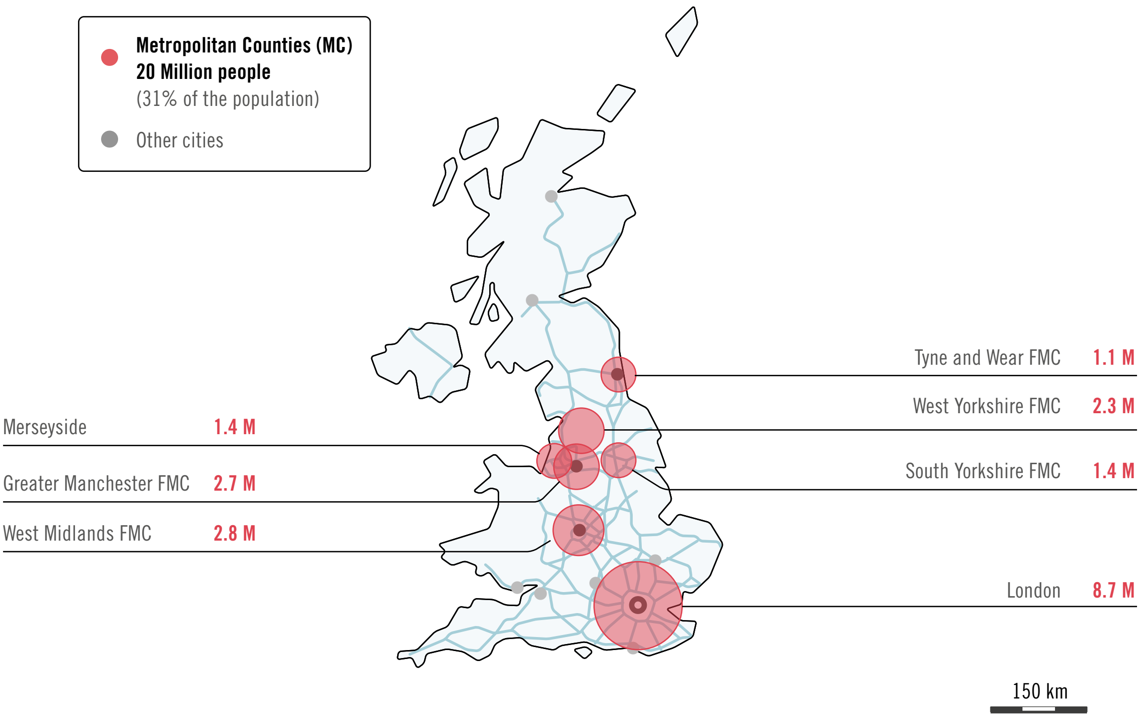
## *Historical and current situation of passenger mobility*

### *Mobility trends*

The historical passenger mobility trend from 1955 is captured in **Figure 2**, showing the strong growth in passenger car mobility, and its current dominance as the main mode of choice. In 2015, cars met 83% of mobility demand, compared to 35% in 1955 (black dotted trend line in **Figure 2**). There are now around 30 million registered cars on the road in the UK to provide this share of mobility services, meaning approximately one car for every two residents.

Growth in overall mobility demand increased rapidly between 1955 to 1990, at a rate of just over 3%/yr, driven by the increasing affordability of car ownership and an expanding road infrastructure. Growth then slowed to just under 1%/yr during the 1990s, and since 2000,

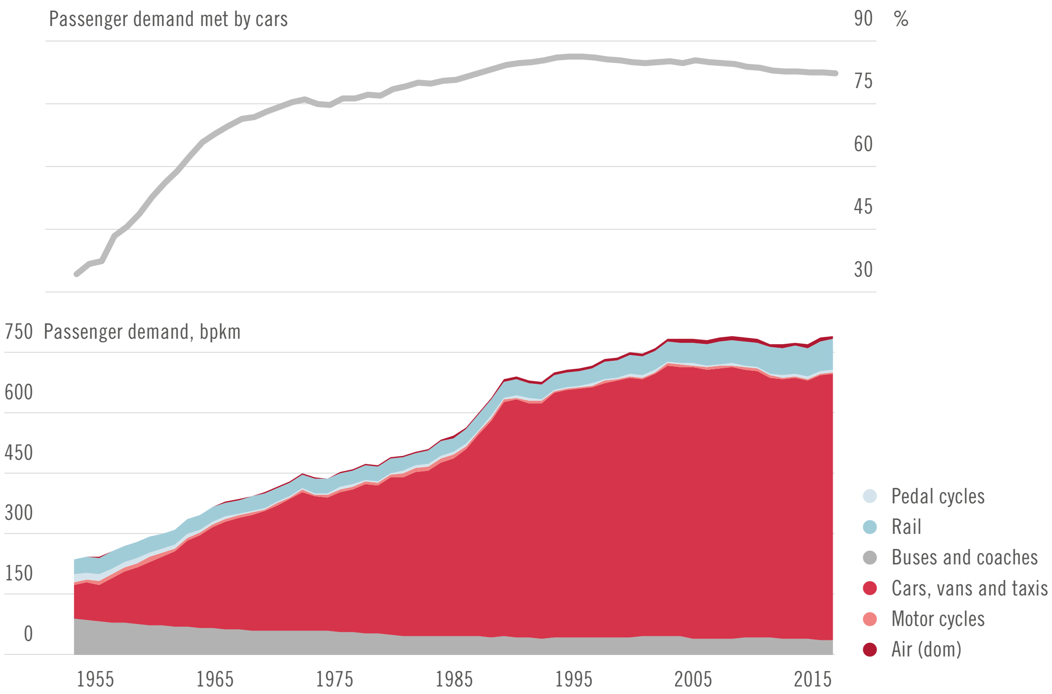
**Figure 1.** Schematic view of UK, metropolitan areas, largest cities and main road network in 2015



has been much lower, at around 0.4%/yr. In fact, recent trends in population growth have not led to higher demand for car mobility, with per capita demands actually falling (**Figure 3**).

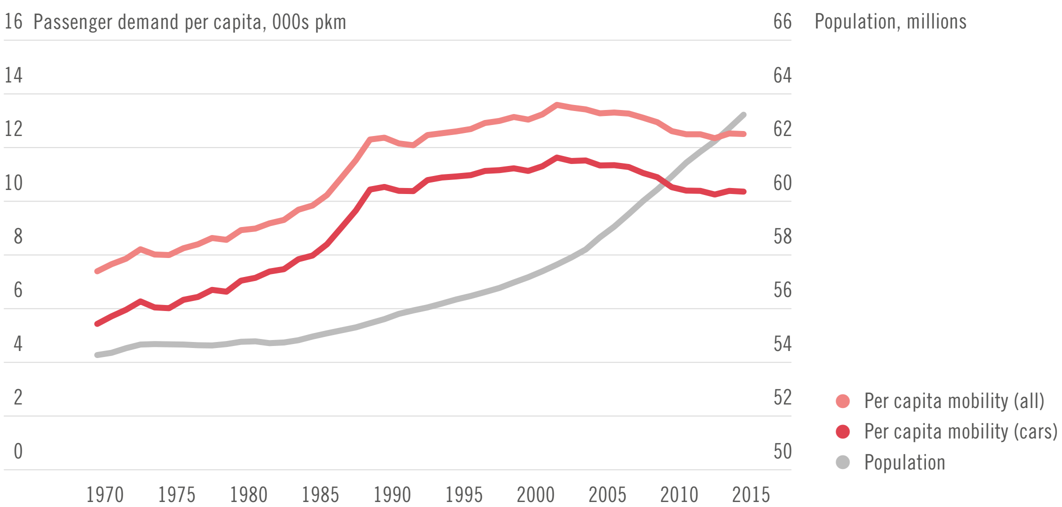
There is a live debate about whether this recent plateauing in per capita demand (see **Figure 3**), which is also observed in a number of other OECD countries, reflects an important decoupling between income and mobility

**Figure 2.** Domestic passenger transport demand in Great Britain, 1955-2015




Source: UK DfT, 2016

**Figure 3.** Per capita domestic passenger transport demand in Great Britain, 1970-2015




Source: DfT, 2017; ONS, 2017

demand, resulting from greater access and choice of services, changing daily mobility patterns due to population aging and lifestyle change, and the constraints on increasing vehicle travel speeds [2],[3]. So called demand saturation or 'peak car' [4] concepts have important implications for the future demand of car-based mobility, and its likely drivers.

At this stage, it remains an open question for policymakers how future mobility demands may evolve. Will historical trends towards greater personal mobility and travel by car re-emerge, or does the status quo represent a pivot point in the direction of a radically different transport future, characterised by falling demand and a shift to different modes? The landscape of future mobility demands will have critical policy implications, in respect of investment, regulation and the future strategic planning of national infrastructure.1

### *Car mobility*

Average per capita demand for car mobility is currently at 10,700 pkm/yr, with 70% of this road-based demand driven by the following purposes – leisure (39%),2 commuting (19%), and shopping (13%), as reported in the National Travel Survey (NTS)[5]. There are some important regional variations between metropolitan and non-metropolitan areas, with average per capita demand much lower in urban areas, primarily due to lower car use and ownership, ease of access to services and the higher availability of public transport. For example, in urban conurbations in England, average per capita mobility is 21% lower than the average, and 47% lower than in the most rural areas[5].

The car stock on the road is predominantly fossil-based, and this fact is one of the main reasons why the transport sector remains the largest single contributor to UK greenhouse gas (GHG) emissions. Of the 30 million vehicles registered in 2016, ultra-low emission vehicles (ULEVs) accounted for 1.5% of new sales (at 40,000). While this does constitute rapid growth (x10) from an observed level of less than 4000 car sales in 2013, the ULEV market segment remains small in absolute terms. At the same time, infrastructure is being developed to support the electrification of mobility; for example, the total number of publically available charging connectors of all types has increased from 10,000 in June 2016 to 12,800 in June 2017[6]. The average $CO_2$ emissions for newly registered cars was just over 120 grams per km, below the European Union (EU) 2015 target of 130 $gCO_2$/km.3 However, there has been a recent slowing of progress in this area, especially when viewed in the context of the 2020/21 target of 95 $gCO_2$/km[6].

### *Other modes*

Of the other domestic travel modes, rail accounts for 10% of total passenger demand, while non-motorised transport (i.e. cycling) accounts for 0.7% and domestic aviation 1.1%. Rail demand has grown substantially since 2005, by around 50%. Major new infrastructure projects continue to be implemented (CrossRail in London) and pursued (HS2, the planned high speed rail link between London and Birmingham), with a view to increasing capacity. Cycling rates in the UK are low compared to other EU countries[7]; at 66 km/capita, this compares to the EU cycling mobility lead of the Netherlands, at 850km/capita[8]. However, as discussed later, ambitious plans are being proposed to increase cycling rates.

Since domestic aviation hit a peak of 9.88 billion pkm in 2006, it has seen an overall decline of 12% (to 2015) [1]. However, international aviation continues to grow; since 2006, international passenger movements have increased by 13%, to 210 million.4 The Government's position on new airport capacity remain uncertain, despite a high profile review highlighting the need to accommodate demand growth[9].

## *Emissions related to the passenger sector*

The UK transport sector accounted for 29% of total $CO_2$ emissions in 2015, while the share of passenger transport alone was 19% (with freight transport accounting for the other 10%). The above figures exclude the international

1 For example, see Phil Goodwin's 2012 article *Due diligence, traffic forecasts and pensions*, published by the Campaign for Better Transport - *http://www.bettertransport.org.uk/campaigns/roads-to-nowhere/ltt-130412*

2 Leisure travel defined as *Visit friends at home and elsewhere, entertainment, sport, holiday and day trip*

3 New car registrations from DfT's Vehicle Licensing statistics:2016, Table VEH0150 *https://www.gov.uk/government/statistics/vehicle-licensing-statistics-2016*

4 From DfT's aviation statistics, Table AVI0105 (2016). *https://www.gov.uk/government/collections/aviation-statistics*.

aviation sector, which of course represents another important source of GHG emissions, particularly as the UK government climate advisors, the Committee on Climate Change (CCC), have recommended its inclusion in UK climate policy targets.[5] **Figure 4** below shows the dominance of passenger cars in the overall emissions picture. Emissions from cars remain significant and even though there has been a minor decline since 2005, the most recent data show that this trend may have plateaued out in recent years. Emissions associated with the international aviation bunker category increased by 43% in the period 1990 to 2015, from 15 to 33 $MtCO_2$. This sector's relative contribution to the national total has become increasingly important, almost doubling since 1990, from 16% to 30% of total passenger transport emissions.

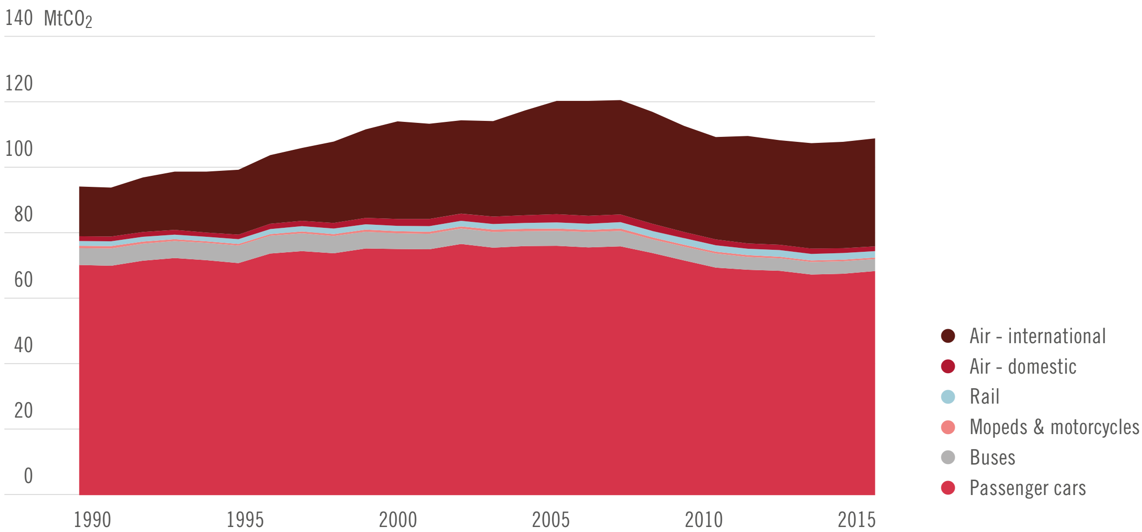
The overall carbon intensity of domestic passenger demand has fallen from 115 $gCO_2$/pkm in 1990 to 96 $gCO_2$/pkm in 2015, a decline of 16%. This is in the context of similar per capita domestic mobility demands in 2015 as compared to 1990, at around 12,500 pkm/person, and therefore sector shows some gains in terms of the energy efficiency of travel, especially from passenger cars. While this is encouraging from a climate perspective, analysis shows that even greater reductions are likely to be required. The challenge of the UK's own domestic climate legislation is for the carbon intensity of mobility demand to decline by around 70% by 2050[10], and extend towards zero emissions soon after 2050 in view of the Paris Agreement goals[11]. This will mean a requirement for radical solutions over the next 20-30 years in order to realise the structural changes in the energy system that can meet the goal of deep decarbonisation.

5 The international aviation sector is not part of the UK Carbon Budgets (interim climate targets to 2032) but is part of the long term 2050 target.

## *National policy framework on mobility and climate*

The UK's national framework for action on climate change is provided by the Climate Change Act 2008[12]. This sets out the long term goal of "at least" an 80% reduction in GHG emissions by 2050, relative to 1990, and establishes the requirement for periodic mid-term carbon budgets in 5-year intervals that put the UK on this emission reduction trajectory. Carbon Budget 5 was agreed last year (2016), and sets the necessary reductions (in the form of a 5-year budget) for the period 2028-2032, which are around 57% relative to 1990.

**Figure 4.** Transport sector emissions from the UK, 1990-2015




*Note that the rail and international aviation sectors will include a small proportion of freight transport emissions*

Source: BEIS, 2017

The Committee on Climate Change (CCC), the Government's independent advisors on climate change, provide an important function of monitoring progress each year towards the UK Carbon Budget goals. Their latest report in 2017 shows a developing gap in the reductions under current policies versus what is needed to meet the 5th Carbon Budget[6]. They estimate that the most cost-effective means (accounting for mitigation across all GHG emitting sectors) of meeting this objective in 2030 would be for the transport sector to reduce emissions to under 70 $MtCO_2$ (from 120 $MtCO_2$ currently). However, current and planned policies are forecast to only reduce emissions to around 110 $MtCO_2$ in 2030, and with all associated policies deemed to have 'delivery risks'.[6] In addition, at the time of writing, the future of UK transport policies that are derived from a requirement to align UK policies with those of the European Union (EU) are also potentially at risk due to ongoing uncertainty associated with Brexit and the UK's planned departure from the EU.

On 12th October 2017 the Government launched its Clean Growth Strategy[13], which set out the necessary policies (some established, others yet to be formulated) to deliver the necessary mitigation across different sectors, and crucially exploit the growth opportunities growing industries bring, notably electric vehicle manufacture and offshore wind. This supersedes the previous strategy document, The Carbon Plan, from 2011[14]. For domestic passenger transport sector, the main policies currently in place and underpinning action in the sector are as follows -

- *Passenger vehicle standards*. EU regulations are in place that put targets on the average $CO_2$ intensity of a manufacturer's fleet of new cars. These regulations have a target of 95 $gCO_2$/km for new cars sold in 2020/21, and in recent years have been slowing, in part due to a shift to larger vehicles. While these standards relate to the test cycle, there is an increasing gap between test results and real world emission intensities. The International Council on Clean Transportation (ICCCT) have shown that the gap between official vehicle $CO_2$ emissions and the real-world $CO_2$ emissions has grown significantly, from 8% in 2001 to 38% in 2014[15].
- *Promotion of low emission vehicles.* The UK have identified electric vehicles as a critical part of the national low carbon economic strategy, as a means of developing domestic industries around battery technology and electric vehicle manufacture. In June 2017, BEIS[7] announced the £246 million Faraday Challenge, to boost domestic development of battery technology.[8] Grants are also available for consumers wishing to purchase low emissions vehicles, with grants (capped) of up to 35% of the purchase price available depending on the zero emission range.[9] Funding announcements for new infrastructure are also being put forward, with £80 million for charging infrastructure (administrated by the Office for Low Emission Vehicles (OLEV) currently proposed to fund vehicle chargers at homes and in workplaces[6]. Additionally, the UK Government has recently followed France in announcing that it intends to ban all sales of new petrol and diesel engine cars and vans from 2040. In the UK case, this regulated move away from internal combustion engine technology from the private vehicle fleet is explicitly intended to address air quality problems but also to accelerate the transition towards electro-mobility[16].
- *Biofuels obligation*. The UK's existing Renewable Transport Fuels Obligation (RTFO) sets a target of 4.75% biofuels by volume, for transport fuel suppliers. This has been capped at this level in recent years due to sustainability concerns about imported bioenergy, but this cap has been subject to review recently under a government consultation and could be amended in future. This legislation does not cover biofuels in aviation.
- *Non-motorised transport*. The UK's Cycling and Walking Investment strategy includes £1.2 billion to improve walking and cycling rates.[10] This includes a target of doubling the rate of cycle trips taken by 2025.
- *Aviation*. International aviation sector emissions are set to be covered by the new ICAO agreed scheme, CORSIA (Carbon Offset and Reduction Scheme for International Aviation). This will require offsets across

6 One or more of three assessment criteria around delivery risk are not met; i) design and implementation can tackle barriers, ii) incentives are sufficient, and iii) adequate current and future funding is in place.

7 BEIS is the UK Government Department for *Business, Energy and Industrial Strategy*.

8 Announcement of Faraday Challenge, *https://www.gov.uk/government/news/business-secretary-to-establish-uk-as-world-leader-in-battery-technology-as-part-of-modern-industrial-strategy*

9 Grant eligibility in the UK, *https://www.gov.uk/plug-in-car-van-grants*

10 Government announcement of £1.2 billion plan to increase cycling and walking *https://www.gov.uk/government/news/government-publishes-12-billion-plan-to-increase-cycling-and-walking*

other sectors for any aviation emissions growth above 2020 levels. For the UK, the CCC have proposed that emissions from both domestic and international aviation should not be higher than the 2005 levels of 37 $MtCO_2$ in 2050. At this level, they would account for 25% of the permitted emissions in 2050[17].

Arguably, given the level of ambition to decarbonize, the current UK policy framework is relatively weak, although there is a clear strengthening of purpose in relation to electric vehicles, a major component of any transport decarbonisation strategy, as reflected in the recently published Clean Growth Strategy[13].

# Storylines for the mobility determinants of two contrasting deep decarbonization pathways: Freedom to roam (F2R) and No place like home (NPLH)

In this section of the report, we describe two new scenarios that provide distinctive visions of how passenger transport could evolve, driven by rapid technological progress, changes to societal mobility trends, and the need to transition towards low or net-zero energy systems.

These scenarios have been constructed in such a way as to provide a more explicit representation of the different demand drivers for future mobility. They attempt to provide a counterpoint to the more typical approach of characterizing transport sector futures through technological change alone. Instead of focusing only on the technological composition of the vehicle fleet, they seek to describe a broader range of factors. The many different determinants considered include - demographic and economic structure, human settlement and urban planning, culture, lifestyles and values, infrastructures and mobility service deployment, vehicle technologies and energy generation and distribution technologies.

While many of these elements could be investigated further and in greater detail, it is hoped that their inclusion here both provides a more informative description of how the transport sector could evolve and provides a starting point for discussing the socio-technical aspects of transition, in a world where technology may rapidly change the interaction of society with transport systems.

While our scenario narratives deal principally with the passenger transport sector, our analysis is carried out in the context of the broader energy system and in the context of a multi-sectoral approach to decarbonisation as required by UK climate legislation. For consistency, we have chosen to describe narrative elements outside of the transport sector (such as the evolution of the power system) in terms of their relationship to a core scenario (R-DEM) from the UK Deep Decarbonisation Pathways Project (DDPP) report[10].

## *Storyline descriptions*

The UK analysis explores two distinctive narratives for the future of the transport system in the UK, differentiated largely by how societal and cultural preferences around the adoption of innovative new technologies plays out over a multi-decadal time horizon. The two narratives, focusing on passenger transport are:

- Freedom to Roam (F2R): a future where new communication and transport technologies reinforce existing societal tendencies towards maximizing individual comfort, convenience and autonomy, and economic activity remains concentrated in existing centres of power.
- No Place Like Home (NPLH): a future characterized by a focus on localism, where new technologies are

harnessed for the purposes of strengthening communities, facilitating the sharing of pooled resources and assets, and for diversifying regional economic activities so that multi-polar centres of education, leisure and commerce flourish across the country.

## Common Elements

As noted above, our scenario narratives are distinguished from one another largely by having distinctive future societal trends and priorities. The evolution of social preferences for mobility in response to the availability of new technologies is therefore different in each case, leading to divergent transport futures. However, a number of narrative elements are common to both of our scenarios.

*Demography*. The UK population grows by 23%, to a size of 77.5bn in the period to 2050, following central projections from the UK Office of National Statistics[18]. Existing demographic trends towards an aging population and an increase in single-person households continue. Over-65s comprised 17.8% of the population in 2015, and are expected to form 24.6% by 2045.

*Car technologies*. The UK's existing sustained political pressure towards cleaner mobility options in the transport sector continues: Pollution charges and incentives in favour of low emission vehicles result in the national vehicle stock moving towards zero emissions technologies (see Results in Section 3). After an initial shift towards much more efficient fossil fuelled vehicle designs, much of the private car fleet eventually becomes electrified through electro-mobility solutions such as battery electric vehicles or plug-in hybrids. Accordingly, a massive expansion in the provision of electric vehicle charge points occurs across the country. By 2040, electricity, from both PHEV and BEV type vehicles comes to dominate private road transport demand (cars and 2-wheeled vehicles). Fossil fuelled vehicles have only a negligible share of the passenger vehicle market, primarily as a niche occupied by collectors and car enthusiasts.

*Fuel transformations.* Energy system wide decarbonisation initiatives lead to a progressive reduction of the carbon content in major energy carriers. The carbon intensity of electricity production is rapidly reduced during the 2020s and reaches zero by 2035. This is based on a mix of nuclear power, fossil fuel generation with carbon capture and storage (CCS) and renewables, although the recent lack of progress on UK CCS development, the increasing costs of the UK's proposed new nuclear plants, and the falling costs of offshore wind power suggest that the highest share of power generation will come from renewables. Decarbonisation is however, not only limited to electricity, but also occurs in other vectors such as liquid fuels and gas. Bus and bus rapid transit (BRT) systems operate on a mixture of electric and gas/electric hybrid engines. A limited amount of biokerosene is available for air transport; it does not reach its full technical potential as the majority of the bioenergy resource is used elsewhere in the energy system (especially in power generation). A much higher share of the passenger rail system is electrified when compared to the present day, with all high speed rail being supplied from electricity.

## Freedom to Roam (F2R): Comfort, Convenience, and Autonomy

In the *Freedom to Roam* narrative, the pattern of future settlement in 2050 is comparable to that of today, with 33% of the population living in metropolitan areas. Although there is a measure of success in moving public institutions outside of the capital and creating a number of new creative hubs, London and the South East of the country continue to dominate the broader economy, attracting a large share of inward migration from other regions. Current trends towards more urban living stabilise, with new technologies enabling more people to live further away from their places of work and travel longer distances with much greater ease. The "housing crisis" experienced by the UK at the turn of the century is eventually resolved through a relaxation of planning controls across much of the country, which enabled developers to create more affordable housing for sale on low cost land. Large suburban developments house much of the growth in population outside of the major cities (an additional 10 million as compared to 2010 levels), and satellite leisure, dining and retail parks connected to major roads become increasingly common. Urban planning focuses on maximizing traffic flow and vehicle accessibility. Road speed limits remain comparable to the present day, with maximum highway speeds at 70 mph (~113 km/h) and urban speeds in most residential areas being 30 mph (~48 km/h).

The 2020s and the 2030s witness significant technological trends towards improved communication and transport technologies, particularly in the area of autonomous vehicles. Automotive manufacturers are able to rapidly progress the development of autonomous vehicles through successful field trials and the public at large comes to accept their presence on the roads. Autonomous vehicles with SAE J3016 Level 4 standards of autonomy are in widespread use by the 2030s and in the 2040s SAE J3016 Level 5 vehicles are available for purchase.[11] These are fully autonomous cars that allow the driver to concentrate elsewhere, partaking in leisure or business activities while travelling. As a result of shrewd marketing and numerous high profile success stories, there is widespread public acceptance and trust in the technology. National legislation is passed to legalise the use of fully autonomous vehicles on public highways in nearly all conditions. Privately owned autonomous cars are viewed as highly desirable, representing the ultimate expression of individual comfort, convenience, freedom and autonomy. They are also prized for their ability to enhance the lifestyles of older persons and individuals with disabilities that would otherwise preclude them from self-driving.

Autonomous vehicles with high speed network connections are used increasingly as a means of enabling lifestyle flexibility and freeing individuals from many of the time constraints imposed by self-driving. The ability to travel long distances between home and work is enthusiastically adopted by millions of "super-commuters", who make the private ownership of autonomous cars a mass market phenomenon. Many businesses adopt more flexible working hours and many employees spend some of their time working at home, or even in their cars. There is moderate growth in the adoption of e-commerce platforms, resulting in a small reduction in individual travel for routine purchases such as groceries and household products. However, as a result of the ease and convenience of travel, physical retailing of goods at dedicated locations remains a popular leisure activity. Environmental concerns remain an important factor in the public and political sphere, although they continue to rank behind economic, healthcare and education priorities. The majority of the public is in favour of reducing net societal impact on the environment, although only a niche minority are tempted to significantly change their lifestyles for purely environmental reasons.

The increased ease of point-to-point travel by car leads to a revitalization of the domestic tourist industry, with national parks, camping grounds, weekend festivals and heritage sites all popular destinations for short trips. The convenience of leisure travel by car leads to a relative increase in the number of people choosing to take a "stay-cation" in the UK rather than to fly overseas. Road trips with friends and family are very popular, not only with younger people and families, but also a large and growing population of retirees, many of whom live semi-nomadic lifestyles, shifting their location seasonally to optimise for the best weather. International aviation demand follows existing trends out to the 2020s before stabilizing at 17% above 2015 per capita levels.[12] Limited new airport expansion occurs, although domestic flights for business travel remain common, particularly over longer distances, such that demand for domestic aviation continues, albeit at a low rate as per existing trends.

Policymakers recognize that public transport in urban areas must continue to be maintained and improved over time to cope with a growing population. Public transport investment remains stable in metropolitan areas and autonomous vehicles are viewed as a complimentary mode of transport, with a number of cities having Mobility as a Service (MaaS) systems in operation. However, the popularity and ubiquity of autonomous vehicles leads to a fall in overall ridership numbers and a decline in public transport provision outside of major cities, particularly for commuting and leisure travel. Large investments in road traffic infrastructure and congestion management systems continue to be a political priority. New highways as well as bridges, flyovers and tunnels (particularly to bypass historic city centres) are delivered through major civil engineering projects. Urban congestion remains a challenge, although many commuters have come to accept long traffic delays as a fact of life, passing the time by working, socialising virtually with friends and family, or entertaining themselves while in transit.

A national telecommunications infrastructure supports traffic information provision, route finding, time-of-use pricing and congestion pricing. In many cities, urban driv-

11 SAE description of driving autonomy levels, *https://www.sae.org/misc/pdfs/automated_driving.pdf*

12 This leads to a 40% increase over the same period (+51% from a 2010 baseline) in total international passenger activity.

ing is subject to daily charges linked to pollution monitoring as a means of improving air quality in cities. Time-of-use road pricing is used by city authorities as a means of controlling both demand and air pollution. Rail capacity increases on commuter lines into major cities, but high speed rail development is limited to the London to Birmingham high speed rail link (HS2), which is successfully completed in the 2030s as planned but is viewed by the British public as largely obsolete by the time it is completed. Consequently, there is little political will or societal demand to expand the high speed network further.

## *No Place Like Home (NPLH): Urbanism, Localism, and Community*

In *No Place Like Home*, existing trends towards more urban living accelerate rapidly. Urban lifestyles and living as part of a community come to be perceived as increasingly aspirational, authentic, fashionable and desirable. 45% of the population is found to be living in metropolitan areas in 2050, up from 31% in 2010. In comparison to the early 2000s, where London and the South East dominated the economic narrative, the geographical pattern of settlement in the 2050s is for a larger number of high density regional metropolitan hubs. Technological advances in communications coincide with changing trends in lifestyles and societal preferences towards regional decentralization, community living, and localism.

The UK's "housing crisis" phenomenon of the 2010's is partially resolved, although housing remains a significant household expenditure and an area of significant concern for families and individuals. Average dwelling sizes become smaller and in cities there is an increase in co-housing accommodation and shared living arrangements to make better use of local community facilities. Successive governments attempted to mitigate pressure on household finances through stronger controls on real estate speculation and property purchasing by investors, reinvestment in social housing provision, and much stricter enforcement of regulations to force land developers to offer "affordable" housing as a condition of planning permissions being granted. These trends lead to large-scale redevelopment of many existing brownfield sites into dense housing developments. This density of development in turn, makes abundant local service provision economically viable.

In *No Place Like Home*, the challenges associated with developing fully autonomous private vehicles are not achieved until much later than originally anticipated. Vehicles that can operate at autonomy levels associated with SAE J3016 Level 4 and 5 are slow to come to market, and find difficulties operating in older British cities with complex road layouts. Early-stage difficulties with navigation and collision detection in many of the UK's densely populated cities negatively skews public opinion. Accidents in the 2020s involving autonomous vehicles, although statistically much lower than accidents involving human drivers, result in negative media coverage and a degree of public backlash against automated driving. This in turn results in strict legal controls being placed on where and when full automation can be used. The hopes of global automotive manufacturers for autonomous vehicles to completely revolutionize personal travel are therefore not realized in the UK market. Level 4 and 5 vehicles enjoy some success in capturing market share for suburban residents, but they are largely banned from urban town centres, which are increasingly pedestrianised and have the roads converted into routes for public transport.

Autonomous vehicles are less trusted and socially accepted in the *No Place Like Home* scenario as compared to the *Freedom to Roam* scenario. As they do not become a mass market phenomenon, costs for autonomous vehicles remain relatively high, and they are viewed as a largely niche option for high income individuals living and working outside of major cities, as well as in Mobility as a Service (MaaS) applications in lower density areas with modern road infrastructure. Additionally, UK consumers, many of whom are enamoured with the cultural ideal of urban community living, increasingly shy away from car ownership, and many younger people prefer to rent vehicles on demand for short trips or use ride hailing services. Autonomous vehicles are seen as an expensive, depreciating asset, with the technology being perceived as being best reserved for specialist applications, such as mobile hospitals, ambulances, traffic enforcement, rubbish collection, and road maintenance.

Sustainable living, intertwined with the cultural narrative of the urban community, becomes a mainstream trend, with wasteful consumption discouraged and conscious purchasing of environmentally low impact products becoming heavily promoted by celebrity social media influencers (e.g. bloggers, streaming videographers). Many people now organize their daily activities so that they can work, study, and play close to home. There is a stronger propensity for home working or short trips to local co-working hubs, enabled by advances in communications technology and shifting workplace cultures, which reduce commuting. Widespread adoption of e-commerce platforms leads to a sharp reduction in routine individual travel specifically for the purpose of shopping for goods. Many people simply choose to have their purchases delivered, to their homes, workplaces, or purpose-built delivery hubs. High speed internet provision, even in rural areas, allows for a range of in-community economic activities to occur without frequent long distance commutes.

Non-motorized transport grows rapidly, with a vibrant national cycling culture emerging. Locally grown food is

**Table 1.** Characteristics of F2R and NPLH scenarios

| | | Freedom to Roam (F2R) | No Place Like Home (NPLH) |
|---|---|---|---|
| Demographic and economic changes | | | |
| Population | | Population growth as per central ONS forecasts[1], from 62.7 to 77.4 million, an increase of 23%. Over 60 population increases from 23 to 31% | |
| Economic | | GDP growth rate continues to grow at similar rates to those observed in recent years (1.5-2%) | |
| Human settlements and spatial organizations of activities | | | |
| Human settlement and population distribution | Metropolitan areas[2] | The metropolitan area population is 31% in 2010, increasing to 33% by 2050 under ONS central population forecasts[3] | The metropolitan area population is 31% in 2010, but increases to 45% by 2050, driven by both a societal preference for increased localism and additionally by investments in more "liveable" urban environments |
| Mixed land use | | No strong change in the use of land, and impacts on transport system | Enhanced planning to allow for increased levels of non-motorised transport (NMT). Increasing road space taken up by other modes, disincentivising cars.<br>Reduction in the difference between car mobility level between metropolitan and non-metropolitan areas (which are 42% higher), by 25% in 2050, due to enhanced infrastructure planning |
| Sociocultural practices and lifestyle changes | | | |
| Travel purpose | | Purpose for mobility is split into constrained and non-constrained, where non-constrained is leisure mobility.[4]<br>The 2010 split is 62% and 38% for constrained and non-constrained (with limited differences between metropolitan and non- metropolitan areas. | |
| Virtual activity development | Working from home | No significant change | Average person spends 1.5 days working at home a week by 2050 due to improved home working technology, leading to reduction in mobility demand (30% of car commuting) |
| | e-Commerce | 15% reduction in mobility by car to meet shopping demand | 50% reduction in demand for mobility for shopping by 2050, driven by both lower consumer purchasing and increased e-commerce (with some shift to freight mobility not captured in this analysis) |
| Shift to sustainable modes | Cars to NMT | 10% reduction in non-motorised transport (NMT) by 2050 due to strong car mobility | Per capita NMT in metropolitan areas rises from 290 to 700 pkm, and to 450 in non-met, based on analysis in Pye and Daly, 2015. Analysis based on trip analysis and international experience /potential. |
| | Cars to bus | 10% reduction in bus travel in metropolitan areas, 15% in non-metropolitan areas by 2050, relative to today, with a shift to cars | Bus travel in metropolitan areas doubles on a per capita basis by 2050, and by 50% in non-metropolitan areas (based on potential in Pye and Daly, 2015) |
| | Cars to rail | 5% reduction in rail travel in metropolitan areas, and a 10% reduction in non-metropolitan areas by 2050, relative to today with a shift to cars | Rail travel in metropolitan areas increases on a per capita basis by 75% by 2050, and by 35% in non-metropolitan areas (based on potential in Pye and Daly, 2015) |
| | Domestic aviation to rail | 2.5% shift by 2050 from domestic air travel to rail travel | 15% shift by 2050 from domestic air travel to rail travel |
| | International aviation | Slowing of growth in demand for international aviation, with per capita demand in 2050 only 17% above 2015 levels (compared to 75% under the central forecast) | Limited slow down on current growth trends, with per capita demand in 2050 at 37% above 2015 levels (compared to 75% under the central forecast) |

1 2014-based National Population Projections, ONS. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/2014basednationalpopulationprojectionstableofcontents

2 These include Greater London and the metropolitan county areas of Tyne and Wear, Greater Manchester, Merseyside, South Yorkshire, West Yorkshire and West Midlands. Population density ranges from 900 (S. Yorkshire) to 5500 (London) inhabitants per sq. km.

3 Subnational population projections for England: 2014-based projections, ONS. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/subnationalpopulationprojectionsforengland/2014basedprojections

4 'Non-constrained' mobility is travel defined as visiting friends at home and elsewhere, entertainment, sport, holiday and day trip, as per National Travel Survey mobility by purpose (Table NTS0410, Average distance travelled by purpose and main mode: Great Britain, 2010), https://www.gov.uk/government/statistics/national-travel-survey-2016. Constrained mobility relates to all other purposes for which mobility is required.

big business, and community and regional sports events are popular leisure activities. Urban planning focuses on creating "liveable" cities, with an emphasis on "revitalizing the high street" through the creation of mixed use urban spaces and diversification away from retail in favour of leisure sites. Pedestrianisation, cycling, abundant public space, convenient public transport, community facilities, and clean air are all urban design priorities. Despite growing concerns about global climate impacts associated with air travel, the allure of international travel remains strong, spurred on by a public obsession with travel programmes and social media channels which glamourize overseas trips. International aviation demand on a per capita basis grows by 37% in 2050, and new runways and terminals are needed across the country to meet rising demand.[13] Domestic air travel on the other hand, is 13% lower in 2050 than observed in F2R, due to some shifting of domestic passenger journeys from air to rail. However, overall demand has doubled relative to 2010 levels.

Strong demand for urban living creates political pressure to create high quality public transport infrastructure, for both inter-urban and intra-urban travel, even in cities with no recent history of developing public transport. The increasingly dense pattern of urban living means that investment in local transport systems is a political priority. Local authorities engage in major efforts to create separated cycleways for bicycle traffic in line with the Dutch model, and successfully re-engineer existing highways to allow for light rail, trams, and bus rapid transit systems. Short-term car rental, car sharing, and ride hailing services remain popular, with some cities successfully integrating public and private transport modes into seamless single-payment Maas schemes enabled by mobile internet technologies.

Most rail capacity expansion, local bus rapid transit or MaaS schemes are delivered through a mixture of public and private financing and operated privately with oversight by regional transport regulators. In many metropolitan areas, private vehicles are banned from "clean air zones" (around public spaces, schools, hospitals, and parks) at certain times of day as a means of managing air pollution concerns, with strict controls on vehicles with tailpipe emissions at all other times. Traffic congestion remains an issue for drivers as many urban centres have had the road space that was previously dedicated to private vehicles converted into use by public transport and cyclists, and urban speed limits in most areas have been reduced to 20 mph (32 km/h).

The UK's high speed rail link between London and Birmingham (HS2) is successfully completed on time in the 2030s, and the success of the scheme has led the government to adding Manchester, Leeds, York, Sheffield to the network by 2050. Expansion of the high speed rail network enjoys strong political and societal support, and the government has green-lit plans to expand the network to Glasgow and Edinburgh in the coming decades.

13 This leads to an 63% increase over the same period in total international passenger activity.

# Results – evolution of emission drivers and related transformations for F2R and NPLH scenarios

In this section of the report, we compare and contrast outcomes for the passenger transport sector under the two narratives described in Section 2, *Freedom to Roam* (**F2R**), and *No Place Like Home* (**NPLH**). In particular, we explore the implications for demand, technologies, and emissions.

## *Passenger mobility demand*

**Figure 5** shows divergent pathways for total passenger mobility demands under the F2R and NPLH scenarios. In F2R, overall domestic demand grows by 32% between 2010 and 2050, with the majority of this increase driven by car use (which is up 34%), reflecting the trends towards an increasingly mobile and car-enabled lifestyle. In NPLH, on the other hand, overall domestic mobility demand reaches a peak in 2030 before plateauing, leading to an overall 8% increase in 2050 relative to 2010 levels. The limited growth reflects a falling per capita demand, as discussed later, driven by technological domestic changes, societal preferences and urban planning.

The other major trend observed in NPLH is a reduction in the share of car mobility, dropping by 15% in 2050 relative to 2010, as other modes start to play stronger roles, particularly in the metropolitan areas.

The car demands can be compared to the forecasts produced by the UK Department for Transport[19] (**Figure 6**). While F2R sits in the centre of the range, and is relatively similar to that used in the UK DDPP report[10], it can be observed how different the NPLH trajectory is, reflecting the quite radical nature of the demand-side shift envisaged under this scenario.

In the NPLH case (**Figure 5b**), one of the main drivers of reducing mobility demand is the larger share of the population living in metropolitan areas. The lower per capita demand for travel in urban areas results in lower overall demand, with over 9 million extra persons found living in urban areas in NPLH compared to F2R. In **Figure 7**, the breakdown of mobility demand per capita by mode is compared for metropolitan and non-metropolitan areas.

**Figure 5.** Total UK domestic passenger transport demand projections, 2010-2050

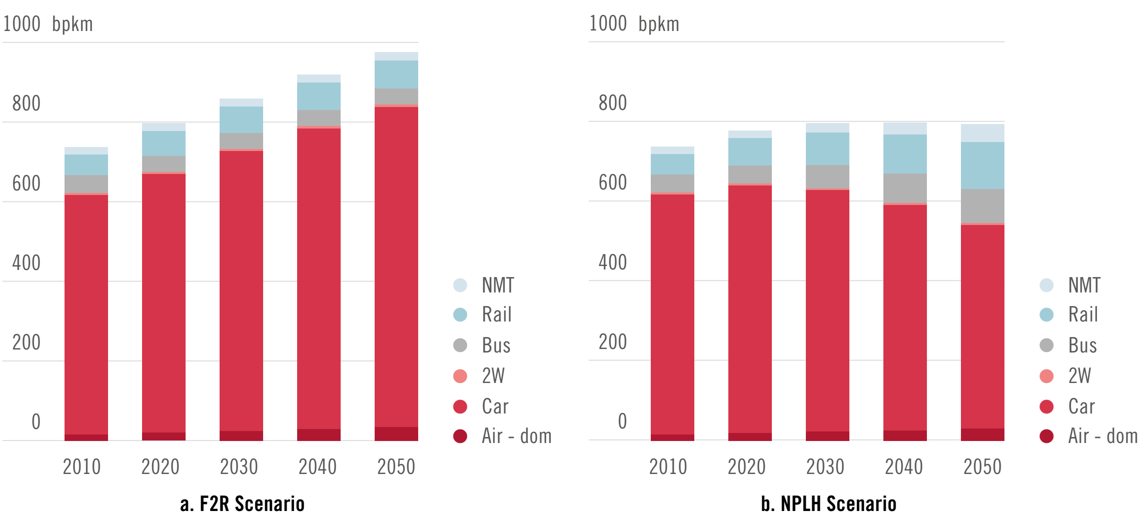
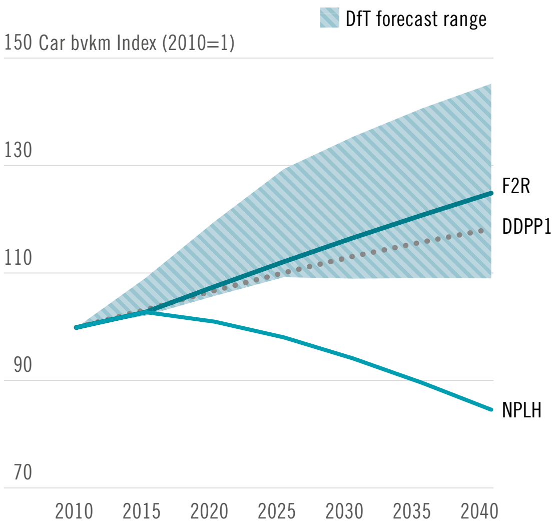


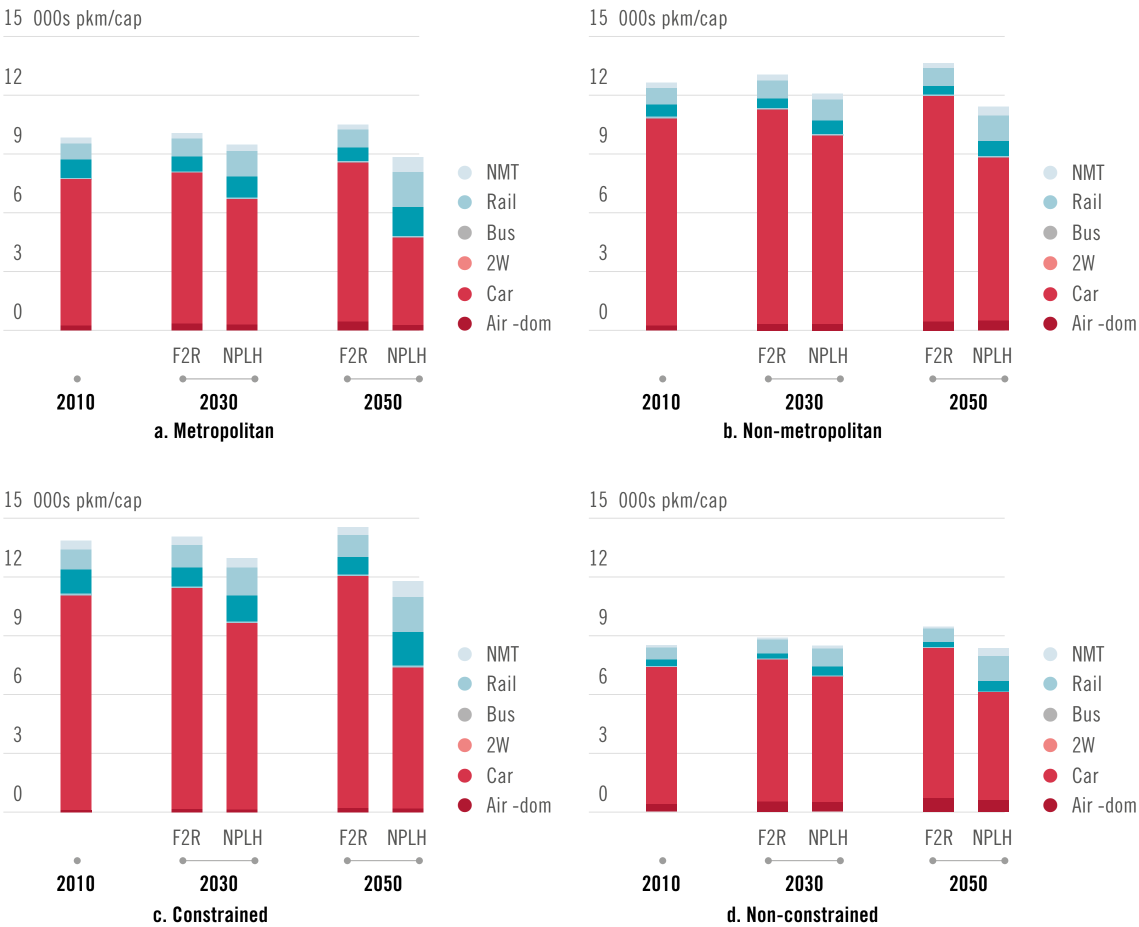
**Figure 6.** Comparison of car demand projections with $DfT_{19}$ and $DDPP_{10}$, 2010-2050




Travel demands in metropolitan areas are 23% lower than in non-metropolitan areas, reflecting the increased density of habitation and accordingly, shorter average trip distances. Hence, a higher population living in urban areas reduces overall transport demand significantly, contributing to the trends observed in **Figure 5b**.

A strong modal shift in the metropolitan areas of the UK (**Figure 7a**) also drives the mobility trend away from car use. Cars meet around 50% of mobility demand in 2050, compared to 76% in 2010. A degree of modal shift is also seen in the non-metropolitan areas (**Figure 7b**), with per capita car demand reducing from 84% to 73% over the same period. The overall per capita mobility reduction in non-metropolitan areas is primarily driven by enhanced planning of new non-metropolitan communities that allows for lower trip distances and demand for car, and some increased movement to other modes.

**Figure 7.** Per capita passenger transport demands by (a) metropolitan & (b) non-metropolitan areas, and for (c) constrained & (d) non-constrained purposes, 2010-2050

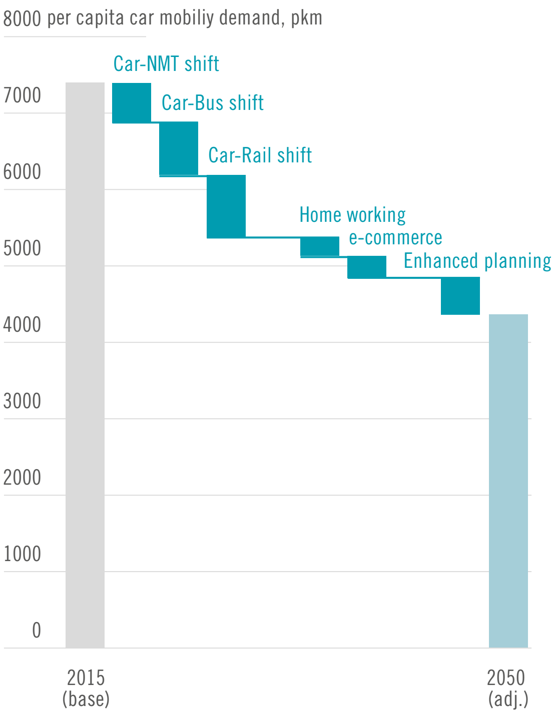


In contrast, under F2R, average mobility demand per capita increases for all modes, with modal shares remaining broadly constant, albeit non-car modes increasing slightly in metropolitan areas. By 2050, per capita mobility is 8% higher than in 2010, compared to NPLH, which sees a reduction in per capita mobility of 10%. As described in section 2, this narrative sees a particular growth in per capita demand for car travel driven by increasing vehicle autonomy.

Demands are also disaggregated according to how mobility per capita across different purposes changes. **Figure 7c** and **Figure 7d** show that most of the change in demand under NPLH is across the constrained demand category i.e. mobility purposes that meet essential requirements (commuting, shopping, education), as these are the demands most impacted by changes to mobility patterns e.g. home working, e-commerce.

To illustrate what is driving reductions in per capita car demand in metropolitan areas, **Figure 8** provides an overview of the different factors at play in NPLH. A large proportion of the car demand reduction (over half) relates to a shift away from cars to other modes, including walking and cycling. Further shifts away from car use relate to technological and societal changes facilitating lower demand for travel. These include allowances for increased home working and stronger e-commerce (although some of the shift due to e-commerce will fall on the freight sector, which we do not address directly in this analysis). Finally, some additional reductions also come from improved urban planning, reducing the need for travel by car.

**Figure 8.** Contribution of different drivers to per capita car demand reduction in metropolitan areas from 2010 to 2050




There are of course important infrastructure implications arising from the modal shift illustrated in **Figure 8**. For example, rail demand increases by over 120% relative to 2010, requiring large investment in new capacity, compared to F2R, which only sees growth of around 40% due to a 3% drop in per capita demand, with the popularity of autonomous vehicles dampening demand for rail. Similarly, the shift to NMT found in the NPLH scenario means a large investment in cycling infrastructure, and enhanced urban design to accommodate this.

## *Shift to low carbon technologies*

As detailed earlier, both scenarios see a similar shift to low carbon technologies for the provision of mobility services, driven by Government policy to prevent the sale of oil-using vehicles, and the fall in the cost of ultra-low emission vehicles. For cars, there is a strong push towards electrification, enabled by the decarbonisation of the power generation sector. By 2030, the carbon intensity of electricity is less than 50 $gCO_2$/kWh, falling to zero by the 2040s. The magnitude of the necessary changes in the power sector, including detail on individual generation technologies, is further described in the R-DEM scenario of the UK DDPP pathway report[10].

The shift away from conventional liquid fossil fuel vehicles to electric vehicles (EV) is shown in **Figure 9**. By 2050, there are very few fossil fuel vehicles (including hybrids) left in the passenger car stock, with the majority of the fleet either being full electric (BEVs) or hydrogen-based (accounting for a more niche market). Overall, oil use in cars falls from over 960 PJ in 2010 to around 70 PJ / 130 PJ in 2050 in NPLH / F2R respectively. Plug-in hybrid electric vehicles (PHEVs), which are principally electric vehicles but with the ability to use fossil fuels as a secondary energy source, play an important bridging role in the 2030s, accounting for the fact that more affordable BEVs with a lower maximum range may not meet the travel distance requirements of a significant share of the mobility demand during this period.

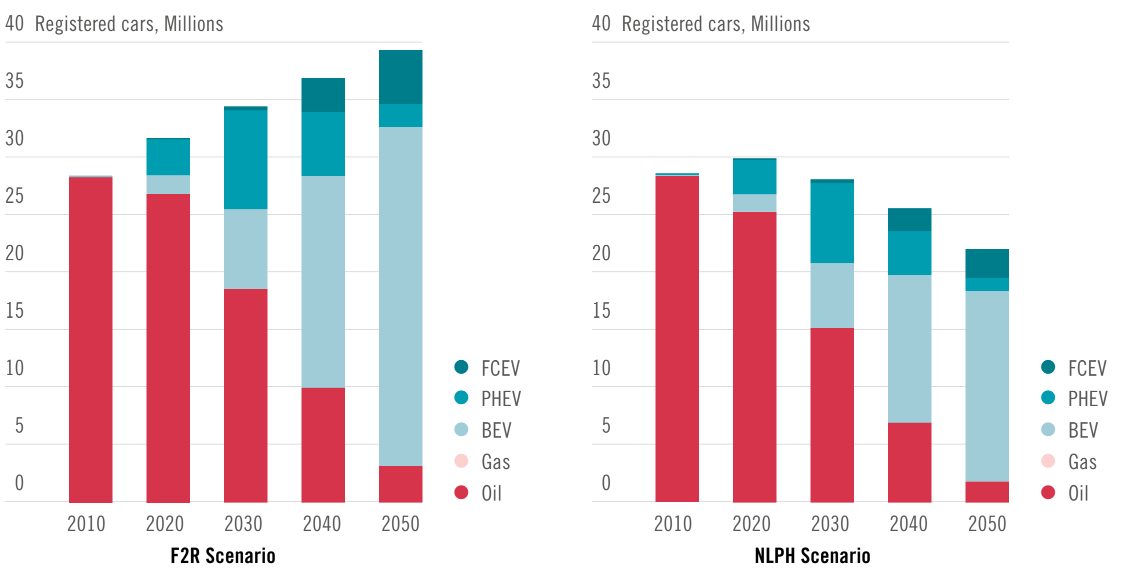
The large difference in the numbers of cars between scenarios reflects firstly the difference in overall mobility demand (**Figure 9**). However, a second driver is the increase in average occupancy per vehicle under the NPLH scenario, which is assumed to rise from 1.6 to around 1.9 persons in metropolitan areas, and 1.8 persons in non-metropolitan area. This results in a huge difference in registered cars; 22 million cars in 2050 compared to just under 40 million under F2R. This means that on average a car in NPLH is delivering 13% more passenger-km per year in 2050 than in F2R. This trend towards fewer cars per capita is based on the assumption of a progressive move away from an asset ownership model for private vehicles to one where cars are increasingly viewed as a cost-effective means of delivering on-demand mobility services. This also has important implications for congestion, parking, and the embodied emissions in the vehicle, which would be evident in consumption-based emissions accounting.

All other modes see a strong shift towards electrification. Electricity consumption in the passenger transport sector increases from around 3.7 to over 65 TWh in the F2R case between 2010 and 2050, and to almost 40 TWh under NPLH. In the DDPP R-DEM scenario, this would be equivalent to having the transport sector account for around 14% (F2R) and 9% (NPLH) of total electricity consumed in 2050. This technology shift also results in car mobility energy use savings of 70% in 2050, relative to 2010, dropping from around 2.5 MJ/km to below 0.8 MJ/km.[14]

For international aviation, the per capita growth is strong across both scenarios, rising by 17% in F2R and by 37% in NPLH between 2015 and 2050 (reflecting the narratives around consumer preferences). However, sector emissions in 2050 are assumed to remain at the same level (NPLH) or just below (F2R) in 2050 as observed in 2010 (as per the CCC's advice[17]). This is due to a 40% improvement in average fuel efficiency for passenger aircraft and a shift in aviation jet fuel to a 20% biofuel share by 2050.

14 This does not take into account the conversion efficiency in the power sector, where fossil fuels may still be being used, with CCS, to generate electricity.

**Figure 9.** Car stock by type under F2R and NPLH scenarios, 2010-2050




*"Oil" means thermal motorization fueled by liquids (gasoline, diesel, liquid biofuels);"Gas" means thermal motorization fueled by gas (natural gas, biogas)*

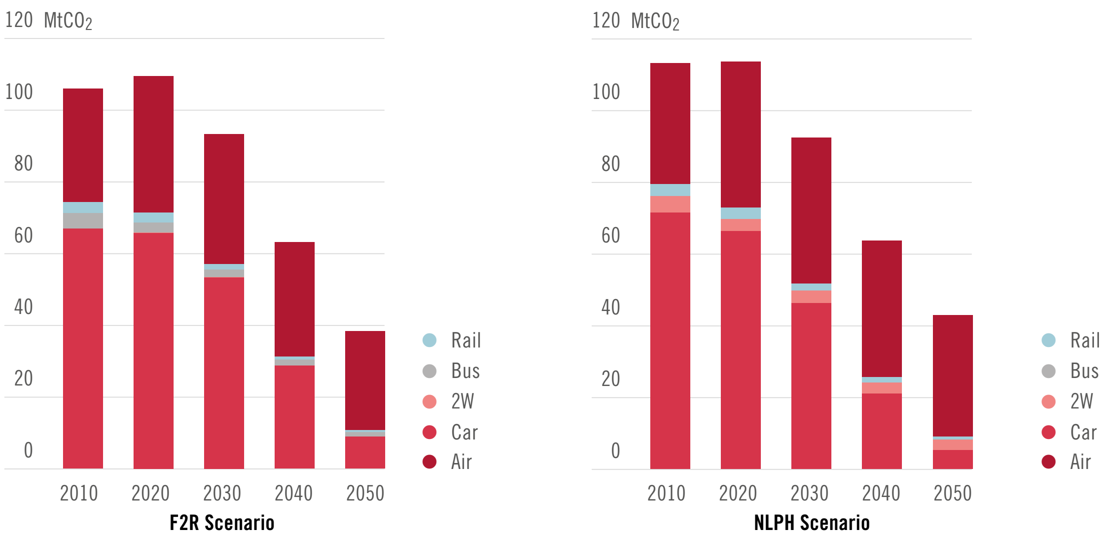
## $CO_2$ emissions from passenger transport

The net result of the changes to demand levels and the technology mix on $CO_2$ emissions from the passenger mobility sector can be seen in **Figure 10**. In 2010, total domestic passenger transport emissions (i.e. excluding international aviation) were 74 $MtCO_2$. Over the period 2010 to 2050, they fall by 86% under the F2R scenario (to 11 $MtCO_2$) and by 90% under the NPLH scenario (to 8 $MtCO_2$). In both scenarios, road vehicle transport is almost completely decarbonised, and to the levels required under the UK's domestic climate change legislation (discussed in the introduction). It is also important to highlight that the demand reductions achieved in the NPLH scenario allows for a much lower level of emissions in the 2030s and the 2040s as compared to the F2R scenario. From a cumulative emissions budget perspective this is important, and has the potential to ease the level and timing of mitigation in other sectors, including road freight. It also mitigates against the risk of vehicle technology solutions not deploying as rapidly as envisaged, and points to the advantage of a focus on more demand side measures.

International aviation, however, remains a major source of emissions in 2050 under both scenarios, accounting for 28 $MtCO_2$ in F2R and 34 $MtCO_2$ in NPLH. The projections of international aviation emissions are based on estimates of departing passengers on international flights, as proposed by the CCC[20]. [15] The levels observed in the NPLH scenario for 2050 (34 $MtCO_2$) reflect the level in the R-DEM scenario (in the UK's DDPP report), accounting for over 30% of total remaining $CO_2$ emissions in the UK, as compared to a 6% share in 2010. While demand for international aviation grows by 55% (F2R) and 81% (NPLH) between 2010 and 2050, emissions are kept in check by efficiency gains and the aforementioned shift to 20% biofuels. However, much stronger consideration must be given to action in this sector if indeed total UK emissions are to move towards a net-zero emissions goal, as required to meet Paris Agreement obligations[21].

15 Current accounting shows this departing flight approach is closely aligned with emissions associated with UK bunker fuels.

**Figure 10.** Total UK passenger transport emissions, 2010-2050



# Policy and measures implications

The two scenarios presented embody quite different visions of the passenger transport future. F2R is very much supply side focused with patterns of mobility demand remaining similar to those seen today, rooted in the development of new technologies, notably autonomous vehicles, that strengthen the motivation for car use, due to convenience and meeting the demands of mobile lifestyles. NPLH, on the other hand, sees technology development shift mobility trends in another direction, towards a sharing services model that is also built around greater use of other modes of transport, particularly in metropolitan areas.

The challenge from a policy perspective is that these two distinctive shifts are driven both by technological change, the evolution of societal aspirations, and also policy direction from government. For the Government to actually help realise either vision, a set of key policies is required that can both set the direction of travel but also be responsive to rapid change in technology and societal preferences.

*For both scenarios, a shift to electro-mobility is key to keeping emissions reductions in line with climate policy targets.* This means pushing forward on existing plans to develop the UK's capacity in battery technology and vehicle manufacturing, and enhance the nation's vehicle charging infrastructure. The UK Government's 2017 Clean Growth Strategy certainly signals a commitment to developing battery technology innovation, promoting significant uptake of low emission vehicles, and investing in the necessary infrastructure. However, this technology pathway also means pushing towards a zero-carbon electricity supply in the 2030s, through the continued promotion of offshore wind, the phase out of coal power (as committed to, by 2025), and the development of flexible grids (including interconnection, storage, and demand response). All three aspects are being actively taken forward but could be reinforced in policy terms by the UK Government passing legislation to ensure an explicit carbon intensity target for the electrical power grid (as called for by the CCC[22]).

*Mobility transitions in the direction of the NPLH scenario may require government to take a more active role in regional spatial planning.*
Such a move may well be catalysed in large part by the need to improve urban air quality, a highly political topic at present that could drive radical change. For example, a key driver of the Government's move to ban sales of conventional petrol and diesel vehicles by 2040 has been the serious air pollution problems in the UK's major metropolitan areas. This comes in response to serious pressure from NGOs and civil society to address air quality problems. However, the currently proposed sales ban is decades away, and other policies are required in the meantime, including finding new ways to meet mobility needs in urban areas.

Part of the solution may lie in the development of urban centres based on concepts of liveability, including mixed land-use planning for co-location of leisure, business, retail and residential activities, walkable neighbourhoods, ease of accessibility to public transport and other services (such as healthcare), and provision of outdoor recreational space and parks. In addition, strong investments in non-motorised transport (NMT) are crucial to mode shift short trips, in particular cycling infrastructure, but also more car free areas and enhanced pedestrianisation. Explicit support and funding for the development of public transport systems across a variety of modes is also crucial, and in areas that have little or no provision at present.

Critically, issues of decarbonisation, improved air quality and other indicators of improved liveability (noise, congestion, urban design, local services, reduced commuting through local workspace provision) need to be considered together in an integrated manner to identify the strong synergies. Mobility solutions also need to be provided in a more integrated way e.g. through promotion of Mobility as a Service (MaaS) and through disincentives on private car transport e.g. through fiscal measures.

*For mobility transitions to develop in the direction of the future imagined in the F2R scenario, an essential precondition would be the successful early development of highly autonomous vehicles (i.e. SAE J3016 Levels 4 and 5).* Policy action in this area could include:

- A continued policy emphasis on developing the UK as a leading centre of innovation in autonomous vehicle R&D
- Explicit support and funding for the expansion and upgrading of road and highway infrastructure to handle increased levels of traffic
- Explicit support and funding to develop the UK's digital communications infrastructure to support increased data traffic associated with autonomous vehicle service provision as well as traffic system monitoring
- Development of time-of-use and pollution-indexed road travel charging systems to manage congestion and air pollution levels

In conclusion, this report provides two very different visions of passenger transport in the UK, both of which deliver deep decarbonisation. An important distinction is that F2R relies almost wholly on technological solutions to ensure that societal aspirations for individual mobility can be met while also achieving climate targets, while NPLH also provides a preliminary assessment of demand side levers. While part of the story in NPLH relies on technology facilitating demand side changes, it is ultimately demographic and societal changes that make this possible e.g. the push towards stronger urbanisation. While there is no doubt that policies could be enacted to affect such trends, this would represent a break with the established pattern of government policy making in recent years, which has de-emphasised central government's role in regional spatial planning. However, the NPLH scenario highlights that much could be done to explore demand side levers to achieving transport decarbonisation, which could reduce the reliance entirely on supply side solutions, and also potentially meet the needs of other policy priorities (air quality, improved urban environments). However, much more research is needed to understand what drives consumer preferences for mobility and how future changes in technology and society might cause these to change over time.

Furthermore, to develop this transport analysis further we would need to consider the different approaches to integrating solutions to tackle freight emissions, and those arising from international aviation. Technical options for improving aircraft efficiency and an increased use of biofuels do appear to be able to stabilise aviation emissions at or close to 2010 levels, but they do not appear to be able to take emissions anywhere close to zero. Both of our scenarios arrive in 2050 with passenger transport emissions being dominated almost entirely by international aviation. In the context of achieving the UK's currently legislated national targets for 2050, further options will need to be explored if the UK is to move towards a net-zero emissions position in line with the Paris Agreement in the second half of the century.

The latest Government climate change strategy published in the 2017 Clean Growth Plan, actually shows emissions from aircraft increasing substantially over the 37.5 $MtCO_2$ ceiling recommended by the CCC for 2050, and does not propose a concrete strategy for reducing aviation emissions. To take action in this sector, it may be necessary to not only look at new aircraft designs and technologies, but also re-planning airport layouts and locations and exploring options for mode shifting or reducing actual air travel demand. Such ideas could include exploring concepts such as high carbon taxes on airfares, personal flying allowances, or the effects of enhanced virtual business communication or virtual leisure travel experiences (which may reduce the need to fly). While these ideas may seem to lie at the margins of policy discussions today, the striking requirement to decarbonise aviation if the world is to move towards a climate stabilised future means that research in these areas will be needed in order to keep these options on the table for future generations to use if necessary.

# Standardised DDPP graphics for UK scenarios

***Freedom to Roam (F2R)***

***No Place Like Home (NPLH)***

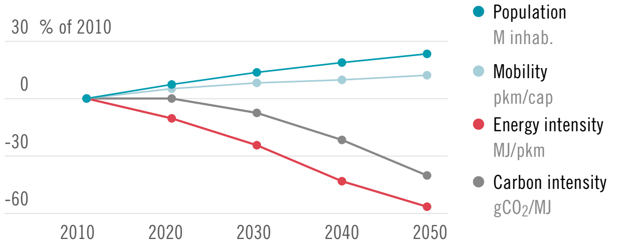
# UK - Freedom to Roam (F2R) Scenario



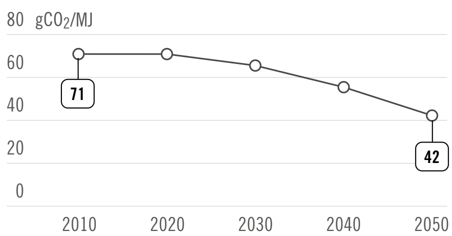
The projections of international aviation demand are based on estimates of the distance travelled by passengers on departing flights from the UK. In 2010, the UK estimate of total international passenger demand was 565 bpkm, of which approximately half were from departing flights. The UK projections are therefore based from an activity number of 283 bpkm in 2010. It is important that the analysis uses this accounting basis, as it is the one recommended by the CCC in view of the UK's LT legislated targets. However, it must be stressed that these activity estimates obviously include mobility demand of non-UK residents. For all other modes in this analysis, only the passenger demand for UK residents are reflected.

## A1. National energy consumption and related emissions

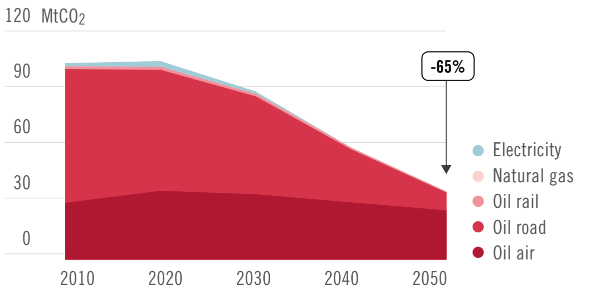
**1.a** Emission drivers



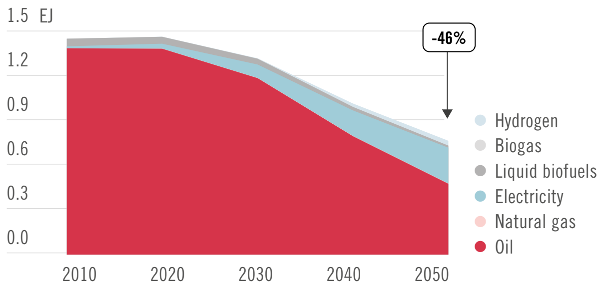

**1.c** Carbon content of energy




**1.b** $CO_2$ emissions




**1.d** Final energy consumption

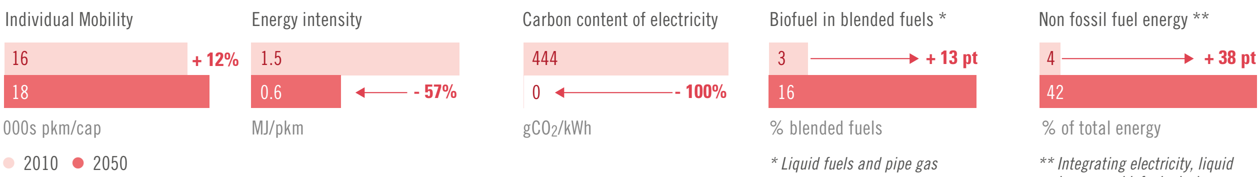



## A2. The pillars of decarbonization

**Pillar 1**
Energy efficiency

**Pillar 2**
Decarbonization of electricity and fuels

**Pillar 3**
Shifting to low carbon fuels

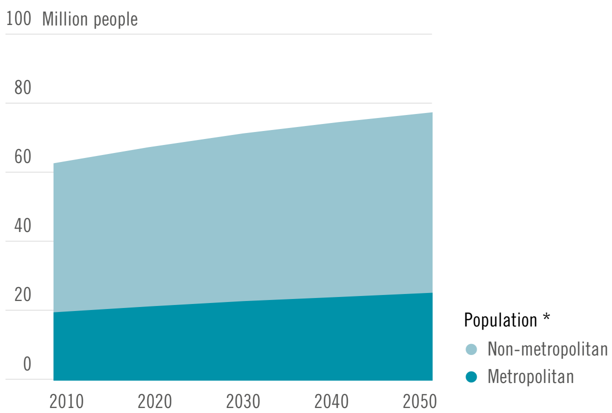



** Liquid fuels and pipe gas*

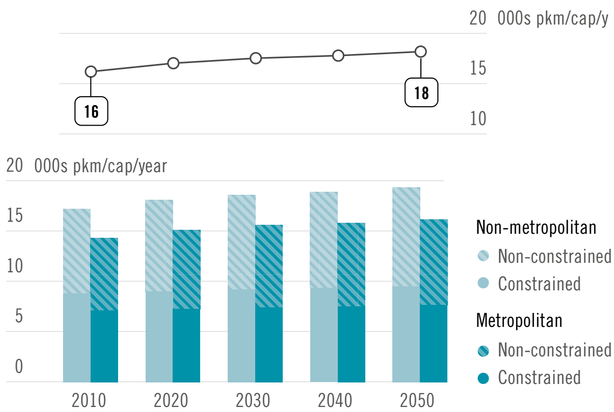
*** Integrating electricity, liquid and gaseous biofuels, hydrogen*

## A3. Population and mobility

**3.a** Metropolitan and non-metropolitan population



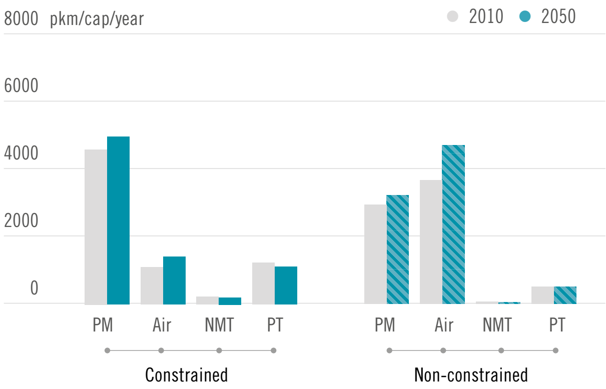

**3.b** Constrained and non-constrained mobility



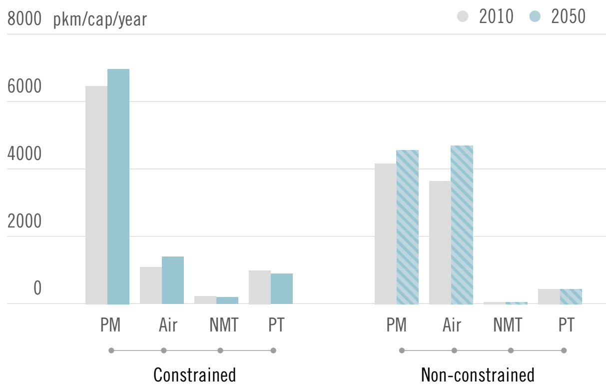

** The "metropolitan areas" category integrates data for the Greater London area with the Former Metropolitan County (FMC) regions of Greater Manchester (City of Manchester, City of Salford, Bolton, Bury, Oldham, Rochdale, Stockport, Tameside, Trafford, Wigan), Merseyside (City of Liverpool, Knowsley, St Helens, Sefton, Wirral), South Yorkshire (City of Sheffield, Barnsley, Doncaster, Rotherham), Tyne and Wear (City of Newcastle upon Tyne, City of Sunderland, Gateshead, South Tyneside, North Tyneside), West Midlands (City of Birmingham, City of Coventry, City of Wolverhampton, Dudley, Sandwell, Solihull, Walsall), and West Yorkshire (City of Leeds, City of Bradford, City of Wakefield, Calderdale, Kirklees).*

## A4. Modal structure

**4.a** Metropolitan



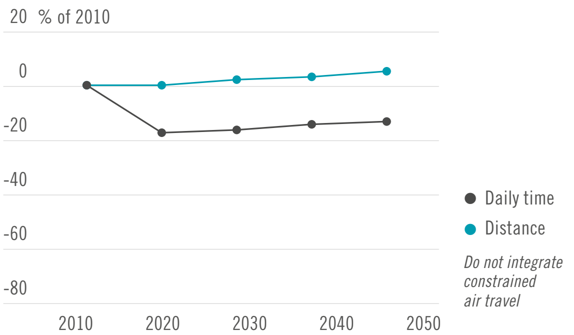

**4.b** Non-metropolitan



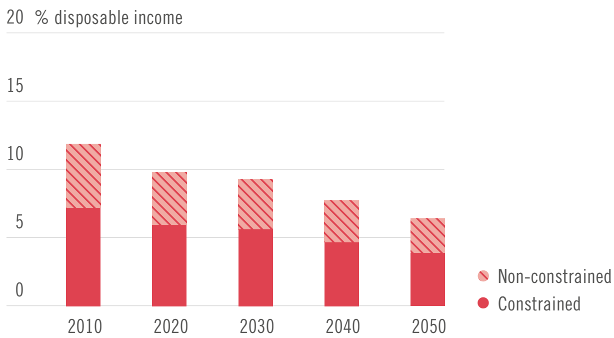

*PM = Private Mobility (car and 2W), NMT = Non-motorized transport (walking, biking…), PT = Public transport (bus and rail)*

## A5. Mobility indicators

**5.a** Indicators for constrained mobility



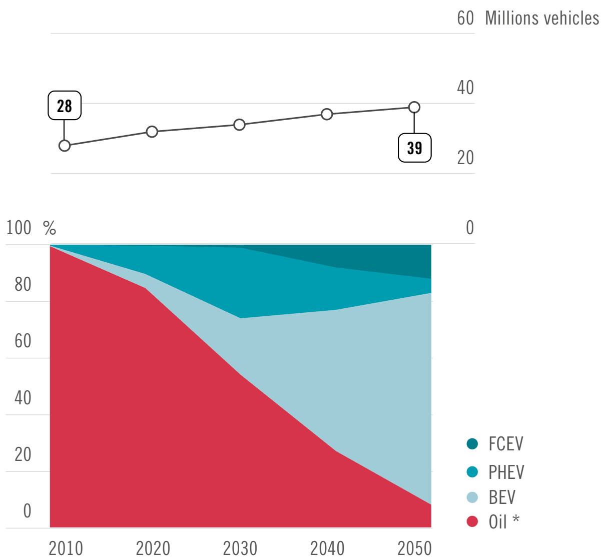

**5.b** Transport budget, car only



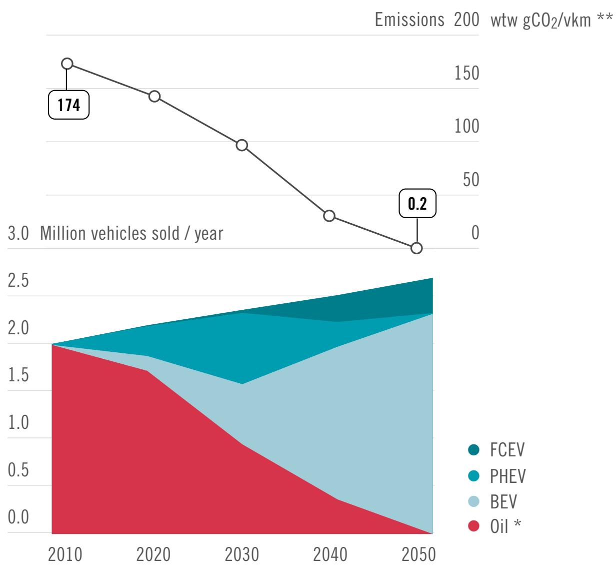

*Constrained mobility budget and total mobility budget have not been studied in detail yet and will need further research*

## A6. Car mobility

**6.a** Car stock




**6.b** Car sales and related emissions




** "Oil" means thermal motorization fueled by liquids (gasoline, diesel, liquid biofuels)*

*** Emissions of average car sales is expressed in "well-to-wheel" $gCO_2$ per vehicle-km travelled*

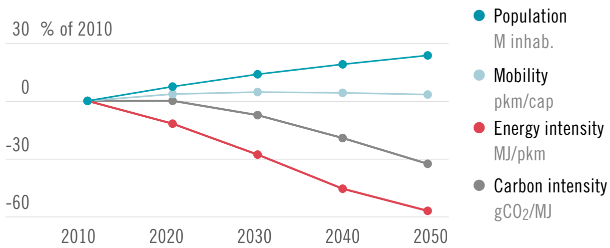
# UK - No Place Like Home (NPLH) Scenario



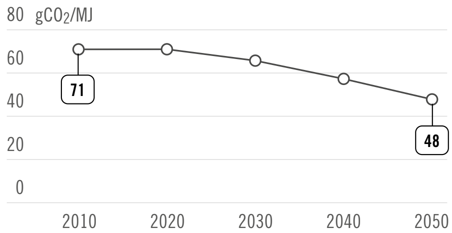
The projections of international aviation demand are based on estimates of the distance travelled by passengers on departing flights from the UK. In 2010, the UK estimate of total international passenger demand was 565 bpkm, of which approximately half were from departing flights. The UK projections are therefore based from an activity number of 283 bpkm in 2010. It is important that the analysis uses this accounting basis, as it is the one recommended by the CCC in view of the UK's LT legislated targets. However, it must be stressed that these activity estimates obviously include mobility demand of non-UK residents. For all other modes in this analysis, only the passenger demand for UK residents are reflected.

## A1. National energy consumption and related emissions

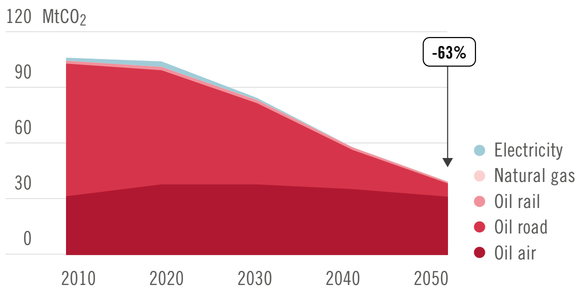
**1.a** Emission drivers



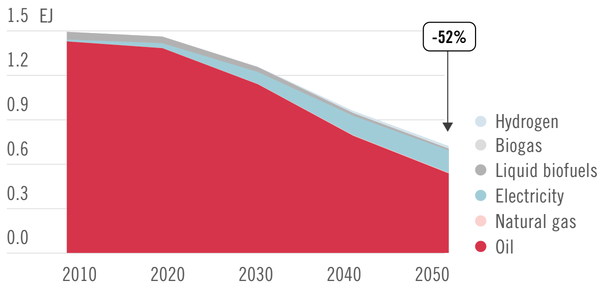

**1.c** Carbon content of energy




**1.b** $CO_2$ emissions




**1.d** Final energy consumption

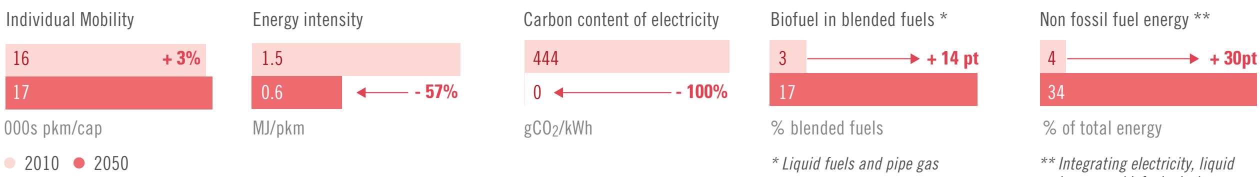



## A2. The pillars of decarbonization

**Pillar 1**
Energy efficiency

**Pillar 2**
Decarbonization of electricity and fuels

**Pillar 3**
Shifting to low carbon fuels

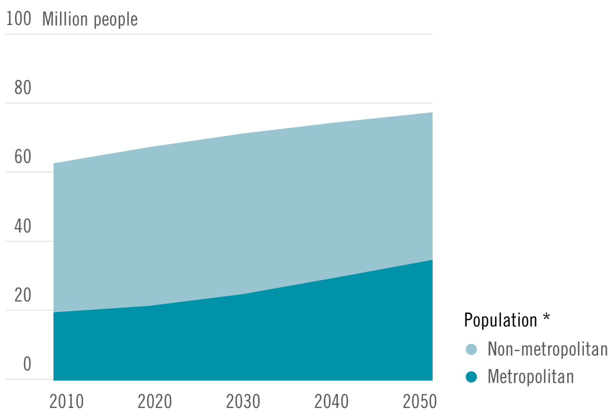



** Liquid fuels and pipe gas*

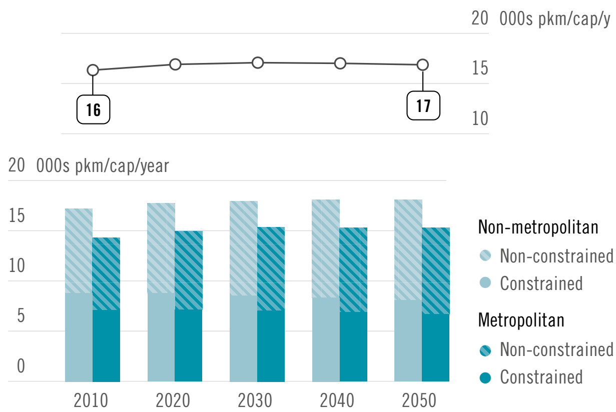
*** Integrating electricity, liquid and gaseous biofuels, hydrogen*

## A3. Population and mobility

**3.a** Metropolitan and non-metropolitan population



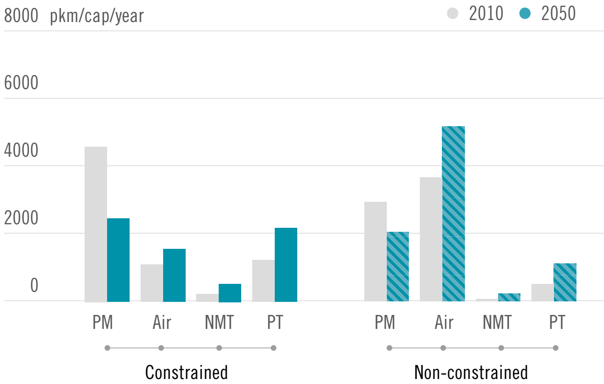

**3.b** Constrained and non-constrained mobility



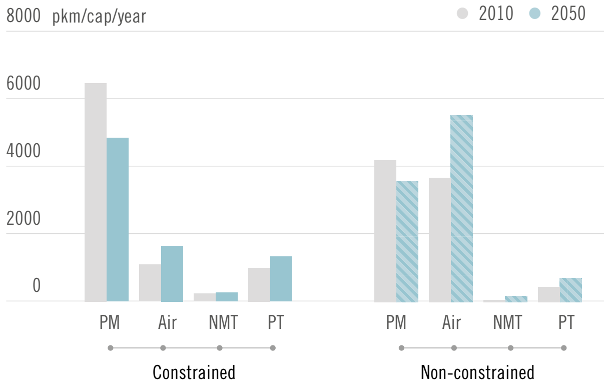

** The "metropolitan areas" category integrates data for the Greater London area with the Former Metropolitan County (FMC) regions of Greater Manchester (City of Manchester, City of Salford, Bolton, Bury, Oldham, Rochdale, Stockport, Tameside, Trafford, Wigan), Merseyside (City of Liverpool, Knowsley, St Helens, Sefton, Wirral), South Yorkshire (City of Sheffield, Barnsley, Doncaster, Rotherham), Tyne and Wear (City of Newcastle upon Tyne, City of Sunderland, Gateshead, South Tyneside, North Tyneside), West Midlands (City of Birmingham, City of Coventry, City of Wolverhampton, Dudley, Sandwell, Solihull, Walsall), and West Yorkshire (City of Leeds, City of Bradford, City of Wakefield, Calderdale, Kirklees).*

## A4. Modal structure

**4.a** Metropolitan



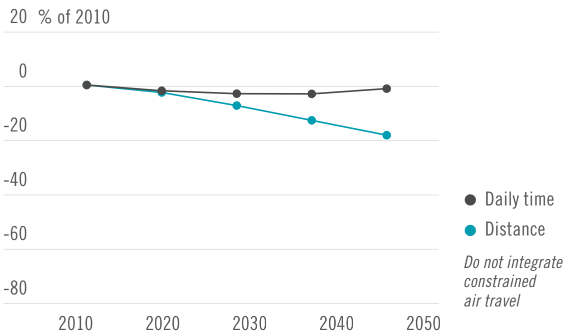

**4.b** Non-metropolitan



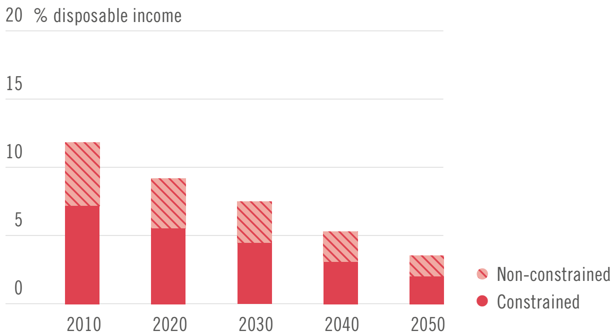

*PM = Private Mobility (car and 2W), NMT = Non-motorized transport (walking, biking…), PT = Public transport (bus and rail)*

## A5. Mobility indicators

**5.a** Indicators for constrained mobility



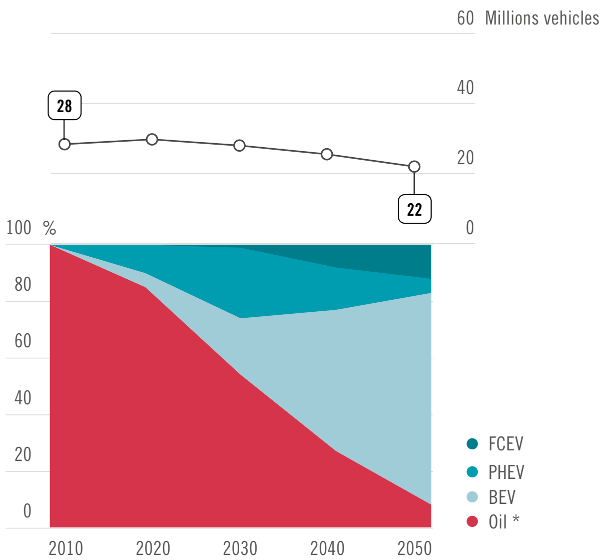

**5.b** Transport budget, car only



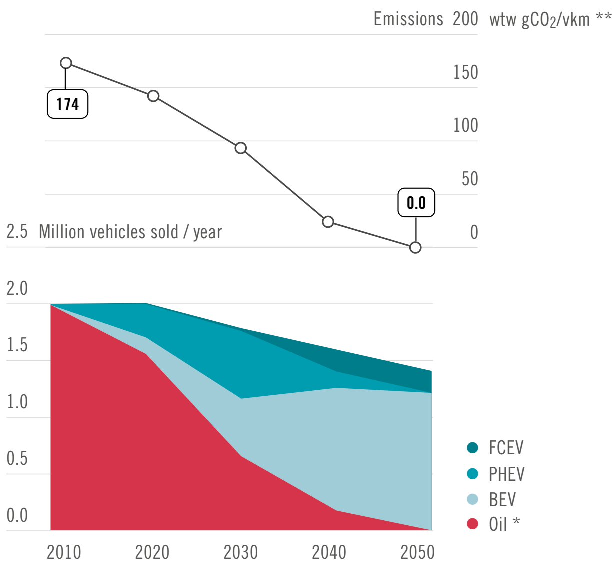

*Constrained mobility budget and total mobility budget have not been studied in detail yet and will need further research*

## A6. Car mobility

**6.a** Car stock




**6.b** Car sales and related emissions




* "Oil" means thermal motorization fueled by liquids (gasoline, diesel, liquid biofuels)

** Emissions of average car sales is expressed in "well-to-wheel" $gCO_2$ per vehicle-km travelled

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