transport for quality of life

Friends of the Earth

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Briefing

More than electric cars

Why we need to reduce traffic to reach carbon targets

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Summary

The Intergovernmental Panel on Climate Change has in its recent report identified the significant danger to ecological systems and human wellbeing of allowing global temperatures to increase by 2 degrees compared to pre-industrial levels. The UK government has responded by asking the Committee on Climate Change to identify what additional effort is needed to reduce emissions above that already agreed through the UK's Climate Change Act. Friends of the Earth suggests that the UK should achieve net zero emissions by 2045 at the latest, with a steeper emissions reduction curve before then.

Transport is now the UK's largest source of greenhouse gases. Friends of the Earth asked the transport consultancy Transport for Quality of Life to produce a series of papers on what changes are needed in transportation and transport policy if the UK is to deliver its fair share of global emissions reduction.

This first paper sets the context for future papers by showing why a switch to electric cars is not enough, and why traffic reduction is also needed. Transport for Quality of Life suggests that the level of traffic reduction needed by 2030 could be anywhere between 20% and 60%, depending on factors including the speed of the switch to electric vehicles and how fast the electricity powering them is decarbonised. It also identifies the numerous benefits from traffic reduction, for example to health and wellbeing. It provides a number of important policy recommendations in the final section, which Friends of the Earth is happy to endorse.

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1. Introduction

This is the first of eight papers commissioned by Friends of the Earth on the transport policies that are needed to cut carbon emissions in line with the Paris Agreement on climate change. The papers will focus on emissions from cars in urban areas, as this is where significant and rapid carbon savings can be made, while improving quality of life for the 80% of people living in towns and cities[1].

Government policy on reducing carbon from cars is mainly focussed on vehicle electrification. While this is essential, the scale and speed of carbon saving that is needed means that electrification is insufficient on its own, and demand management to reduce traffic volumes will also be necessary. Politicians are nervous of action to reduce traffic because it has (wrongly) come to be seen as 'anti-motorist'. However, policies to reduce traffic have multiple benefits, and can and should be designed so that there are more winners than losers.

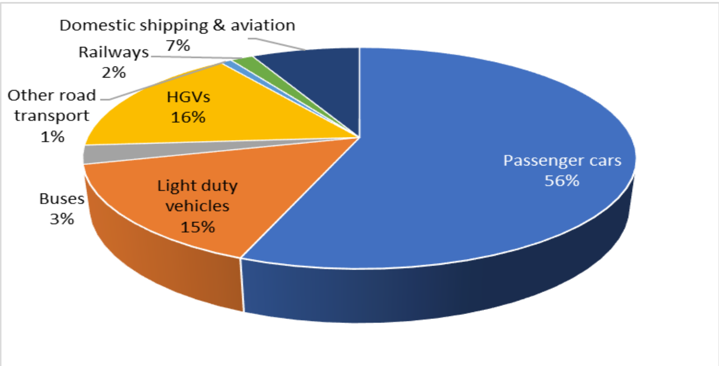
This first paper looks at the shift from fossil fuel to electric cars and argues for a faster transition than currently planned. It also makes the case for action to manage traffic volumes. Future papers will go further into the policy areas that we believe offer the most potential to achieve this[2].

In the rest of this paper, section 2 summarises the national and global context for policy on transport and carbon, and section 3 explains the wider benefits of decarbonising transport. Sections 4-6 explore the three main ways to reduce carbon emissions from the transport sector: improving vehicle and fuel technology, driving more efficiently, and driving less. Section 7 summarises the high-level policy changes we believe are needed to achieve sufficient emissions savings from the transport sector.

2. The national and global context

Transport is now the single largest source of greenhouse gas emissions in the UK, accounting for 27% of domestic emissions[3]. While annual emissions have fallen steadily in some other sectors, notably the power sector, emissions from transport are flat-lining or even increasing. As Figure 1 shows, emissions from cars account for more than half of domestic transport emissions, with most of the remainder coming from lorries and vans (HGVs and light duty vehicles). Emissions from public transport (rail and bus) account for just 5%[4].

Figure 1: UK domestic transport greenhouse gas emissions in 2016[5]



The Committee on Climate Change (CCC) has highlighted the lack of progress in the transport sector, and made clear that without rapid action, the 4th and 5th carbon budgets (covering the periods 2023-27 and 2028-32 respectively) will be missed [6,7].

Under the terms of the Paris Agreement on climate change, the UK is committed to limit global warming to well below 2°C above pre-industrial levels, with an aspirational aim to stay below 1.5°C[8]. This is more ambitious than current UK targets and budgets[9]. A recent Special Report from the Intergovernmental Panel on Climate Change (IPCC) concluded that in order for warming to stay below 1.5°C, human-caused carbon dioxide (CO_2) emissions must fall to net zero by around 2050 or preferably earlier[10,11]. The IPCC report says that this will require "*rapid and far reaching transitions*" that are "*unprecedented in scale…and imply deep emissions reductions in all sectors*"[12].

The reductions needed from the UK transport sector in order to stay below 1.5°C are still to be determined by the CCC[13]. However, analyses by climate researchers suggest that UK transport carbon emissions will need to be reduced by around 80% by 2030, which is greater than the current CCC target[14,15,16]. Global temperature rise is determined by cumulative carbon dioxide emissions, and this means that measures that achieve early emissions cuts offer greater benefits than measures that are implemented later[17].

3. Co-benefits of decarbonising transport

There are three broad ways to reduce carbon (and pollutant) emissions from road transport, in order of decreasing cost-effectiveness[18]:

- Demand management: reducing the number of miles driven overall.
- More efficient driving: using less fossil fuel energy per mile.
- Making vehicles and fuels less carbon-intensive over their whole life-cycle: by improving vehicle technology and using low or zero carbon energy to power them[19].

Failure to stay below 1.5°C of warming will have enormous social and economic costs[20]. In contrast, the health and economic benefits of fewer and cleaner vehicles are sufficient to justify these policies in their own right, regardless of carbon reduction. The benefits include:

- **Better air quality**: air pollution leads to around 28,000 to 36,000 early deaths per year[21] at a cost of £20 billion or more[22], and road traffic is a major source of pollution[23]. Meeting the Climate Change Act targets could cut NO2 and particulate matter ($PM_{2.5}$) significantly, with significant public health benefits[24].
- **Safer roads**: less traffic and lower speeds would reduce road deaths and injuries, estimated to cost society £31 billion a year [25,26].
- **Healthier population**: more active travel would reduce levels of obesity-related diseases[27,28]. Shifting less than 2% of car miles to walking and cycling has been estimated to provide health benefits worth over £2.5 billion per year in 2030[29].
- **Quieter neighbourhoods**: less traffic would reduce noise. At low speeds (<20 mph), electric vehicles are quieter than petrol and diesel vehicles[30].

- **More convivial public spaces**: demand management would reduce the space needed for parking and multi-lane roads in towns and cities, enabling creation of high-quality public realm.
- **A fairer transport system**: nearly a quarter of households (and nearly half of low income households) don't have access to a car[31]. These low-income households would benefit the most from measures to provide affordable good quality alternatives to driving.
- **Benefits to drivers**: less traffic would mean fewer delays from congestion for essential road users. Nearly half of motorists find driving stressful, and more than half would like to reduce their car use, but feel constrained by the lack of alternative ways to meet their transport needs[32]. An RAC survey found the majority of drivers would swap to public transport if the services were better[33].

4. Making vehicles and fuels less carbon-intensive

4.1 More ambitious targets for ULEV and zero-emission vehicles

The government's strategy to reduce carbon emissions from road transport was set out in *Road to Zero*, published in July 2018[34]. It lists 46 actions, of which 44 are intended to change the vehicle fleet from petrol and diesel, first to Ultra Low Emission Vehicles (ULEVs, which include both plug-in hybrid and battery electric vehicles)[35], and then to zero emission[36].

The strategy sets out the following aims:

- By 2030, at least 50% (and up to 70%) of new cars and up to 40% of new vans will be ULEVs.
- By 2040, all new cars and vans will have "*significant zero emission capability*" and the majority will be 100% "*zero emission*".

The main measures to stimulate the purchase of new ULEVs are grants towards the cost of plug-in cars and vans, and reform of vehicle excise duty (VED) for the cleanest vans. There is also investment in electric vehicle charging infrastructure[37], and measures to increase use of low-carbon fuels (including hydrogen and biofuels).

The targets and actions outlined in *Road to Zero* fall significantly short of what the CCC considers to be required[38]. The CCC has identified a transport policy gap of 14 $MtCO_2e$ (million tonnes of CO_2 equivalent) for which there are no policies and a further 42 $MtCO_2e$ for policies that are either not firm or at risk of delivery[39]. This compares with a reduction target of 63 $MtCO_2e$ by 2030 for road transport in the 5th carbon budget. In effect, this means that almost 90% of the road transport emission reductions that are required are uncertain and 'at risk'. The Chair of the Committee has urged the government "*to implement policies with greater ambition to reduce emissions even further*"[40]. This is simply to achieve carbon budgets that predate the Paris Agreement.

The CCC previously recommended 60% of new cars and vans should be ULEV by 2030[41]. Its recent report reiterates the need to end sales of conventional petrol and diesel vehicles by 2035[42]. A growing number of other countries have set more challenging targets: Norway aims for all new car sales to be ULEV by 2025[43]; and the Netherlands, Denmark, Ireland, Austria, Slovenia, Israel, India and China aim for all new car sales to be ULEV by 2030[44,45,46].

Even if all new cars are ULEVs by 2030, transport emissions are still likely to exceed what is needed to meet a 1.5°C target, as we discuss in section 6.1. If the transition is slower than this, more action will be required in other areas – for example, substantial reductions in traffic (possibly unfeasibly large) will become necessary. This means that it is important to make the transition to an electric car fleet as soon as possible.

4.2 Policies for a faster transition: subsidy, regulation, or both?

The CCC has called for a number of policies to achieve a faster transition to ULEVs, including grants towards the higher purchase cost of ULEVs beyond 2020, changes to VED and company car tax to make ULEV purchase more attractive, and more ULEV charging infrastructure[47]. They have also suggested that vehicle manufacturers need to address supply issues and long waiting times.

While all these measures are required, there are risks associated with an approach which focuses mainly on incentives. These risks are exemplified by the Norwegian experience.

Norway is seen as a big success story in encouraging a rapid increase in the purchase of electric cars: ULEVs will account for over 45% of new vehicle sales in Norway in 2018, and at the current growth rate, ULEV market share will reach 100% by 2025[48]. The rapid take-up of ULEVs is due to attractive incentives, including no import or purchase taxes or VAT, lower company car tax and annual road tax, free parking, no charges on toll roads, and access to bus lanes[49]. This has made electric cars both cheaper to buy than equivalent conventionally-fuelled vehicles and cheaper to run[50].

However, some Norwegian policy experts argue that there is a need for more balance between ‘pull’ measures (ie, incentives) and ‘push’ measures (ie, measures to discourage ownership and use of conventional vehicles). They point out that the very low cost of electric car use as a result of incentives appears to have encouraged more driving, and less use of public transport and cycling. One study found that among purchasers of electric cars, public transport-mode share for commuting had fallen from about 23% to less than 6%, while car-mode share had increased from 65% to 83%[51]. Modelling suggests that each 1%-point increase in electric car registrations leads to a 0.63% increase in average car kilometres in the short term, and a 0.78% increase in the long run[52]. Finally, the availability of electric cars has resulted in an increase in multiple car ownership, such that 15-20% of electric vehicles represent cars that would not have been purchased if there were no electric vehicles on the market[53].

These unintended consequences have led experts from a Norwegian government agency to comment:

‘If this is the trend that stays in the future transport market, it will produce results that are very adverse for public transport. There is good reason to question whether it is desirable for the urban transport situation and land use in the long term, to maintain these incentives in the form they have today”[54].

Norway's experience offers some important lessons for policy in the UK. It suggests that incentives must be carefully designed so as not to stimulate unwanted increases in vehicle ownership. One way to achieve this would be for grants only to be offered to purchasers of electric vehicles who are replacing an existing petrol or diesel car or van – in other words, grants should be replaced by trade-in rebates[55,56]. The rebate should be additional to any trade-in or scrappage discount, and should only continue until electric vehicles reach cost parity with conventional vehicles[57]. In parallel, the government should offer the same or higher level of financial support for public transport season tickets, electric car club membership or e-bikes in exchange for scrappage of an old, high-emission car.

Alongside incentives for faster take-up of ULEVs, regulatory measures are needed to ensure sufficient supply of electric vehicles and to progressively reduce the number of conventionally-fuelled vehicles that are sold between now and 2030[58]. One option is a binding mandate for ULEV sales, similar to that adopted by California but as a percentage (rather than absolute number) of new cars and vans sold[59]. This would increase market certainty as well as the prospect of meeting carbon targets[60]. Manufacturers would be required to sell a fixed percentage of ULEVs, rising steadily to 100% by 2030, with penalties for non-compliance[61]. Such a mandate could also specify the split between plug-in hybrid and battery electric vehicles, to encourage a much faster transition to the latter. This is important because emissions from plug-in hybrids under real-world driving conditions are much poorer than test results suggest[62,63]. Alternatively, the mandate might be framed as an absolute cap on the number of new petrol or diesel cars and vans that can be sold each year in the UK, falling steadily to zero by 2030. This would avoid the risk with the 'percentage approach' that increased sales of ULEVs would enable manufacturers to also increase sales of conventional vehicles.

While a 100% market share for ULEVs by 2030 is ambitious, it is achievable, as the evidence from Norway shows. In September 2018, 8% of new cars bought in the UK were ULEV[64]. A linear trajectory towards 100% by 2030 would require a similar annual growth rate to that in Norway, leading to around 25% of new cars being ULEV by 2020 and 60% by 2025.

4.3 Reducing emissions from conventional vehicles

Even if all new car sales are ULEVs in 2030, around 40% of the fleet will still be conventional petrol and diesel vehicles. The CCC has called for more action to reduce emissions from these vehicles, including:

- More demanding CO_2 limits for new cars and vans beyond 2020, with a 50% reduction in new car emission limits between 2021 and 2030 to meet the 5th carbon budget[65,66].
- Introduction of a real-world driving test to avoid cheating by manufacturers[67]. A new test was introduced this year to replace the previous discredited one, but this is still open to manipulation and does not fully reflect real-world emissions[68]. The old test is estimated to have cost British motorists around £21 billion in additional fuel burnt since 2000[69].

- Reintroduction of VED graduated by CO_2 emissions[70,71]. Since the VED CO_2 differentials were much reduced in 2017, emissions from the average new car sold in the UK have increased for the first time since 1997[72,73]. This is partly due to a move away from smaller, lower-CO_2 vehicles, with power-hungry SUVs the only segment to record growth in registrations in 2017[74].

- Increases in fuel duty and company car tax.

All of these measures are necessary and important.

5. More efficient driving

There are immediate opportunities to reduce emissions through more efficient driving, which can benefit all drivers. Although the absolute amount of carbon saved each year is relatively small, it is worthwhile because the cumulative saving over the period from now to 2030 will be significant.

Eco-driving (eg, smooth driving, correct tyre pressure) is estimated to increase fuel efficiency (mpg) by 6% long term and prolongs the range and reduces electricity consumption for battery electric vehicles[75,76]. This could save around 1% of road transport emissions a year with only a small percentage of drivers trained[77]. The *Road to Zero* strategy proposes support for driver training, focusing on novice and fleet drivers. Yet there is evidence that the potential for improvement among average drivers is significant[78]. Opportunities to increase the use of eco-driving techniques include:

- Requiring driving instructors to undertake a high quality eco-driving course so they are equipped to teach these techniques to a high standard to learner drivers and other trainees[79].

- Teaching eco-driving as part of speed awareness courses[80]. This training could save the average driver over £100 a year at today's petrol prices[81].

Reduced speeds can also help meet carbon targets. The most efficient speed for petrol and diesel cars is around 50 mph and fuel consumption for a typical car increases by around 15% between 60 and 75 mph[82]. Nearly half of cars on motorways are exceeding the 70 mph limit[83], so simply enforcing the existing speed limit on motorways would reduce annual emissions by an estimated 1.3 $MtCO_2$ in 2020[84]. This is about 1% of annual road transport emissions. Reducing motorway speed limits would deliver further carbon reductions. Better enforcement or reductions in speed limits would also have benefits for air quality[85], noise, congestion and safety[86].

6. Reducing miles driven

6.1 How much traffic reduction is needed?

The government's *Road to Zero* strategy failed to include any measures to reduce traffic, and the CCC subsequently stated there is an "*urgent need for stronger policies to reduce growth in demand for travel*"[87]. Even if there is an early transition to an all-electric vehicle fleet and effective action to reduce emissions from conventional vehicles, it is highly likely we will also need to reduce miles driven by all vehicles.

The scale of traffic reduction required is uncertain until the CCC has modelled the least-cost pathway to a 1.5°C target[88]. However, provisional work carried out by the Tyndall Centre has found that even if all new cars were ULEVs by 2035 (80% battery electric, 20% plug-in hybrids), a 58% reduction in car mileage between 2016 and 2035 would be needed for car CO_2 emissions to be in line with a 'well below 2°C' pathway[89,90].

Assuming transport takes its fair share of emission cuts, a separate study by UCL implies car CO_2 emissions would need to be cut to around 17 $MtCO_2$ by 2030[91]. Indicatively, we estimate that this would require reductions in car mileage of around 35-45% between 2017 and 2030 based on the *Road to Zero* target for uptake of electric cars[92]. These estimates are highly dependent on a host of factors including the rate of uptake of ULEVs in the car fleet, improvements in conventional car efficiency, size of the fleet, and reductions in grid carbon-intensity, as well as the assumptions used to estimate the carbon budget[93,94]. This means that the necessary mileage reduction could be as low as 20% or as high as 60%.

Based on these two studies, and acknowledging the large uncertainties, we suggest that it is necessary for the government to investigate policy options for traffic reduction in the order of 20-60% between now and 2030. The least-cost pathway would need to be confirmed through detailed modelling by the CCC and others. Traffic reductions of this magnitude may sound an impossible challenge, but to avoid the worst impacts of climate change demands action on this scale. And although the challenge is huge, there are some grounds for believing that substantial reductions in traffic would go with the grain of societal shifts in travel behaviour.

6.2 The potential for change

Evidence of changing travel patterns among young people suggests that a shift towards less car-dependent lifestyles is happening already. For example, the proportions of 17-20 and 21-29 year olds in England who have a driving licence are now nearly 20 and 10%-points lower respectively than in the 1990s[95]. Car distance travelled by the same age groups is 32% and 14% less respectively than ten years ago[96]. As these young adults get older, the amount they drive increases, but there is a general decline in driving across all age groups (with the exception of the over-70s) compared with previous cohorts of the same age[97]. There is also evidence of a shift in attitudes, with many young people saying they would never be interested in driving[98]. There is an opportunity to build on this trend by improving alternative ways of travel, while addressing the difficulties and high costs that many young people without a car experience in accessing jobs and services.

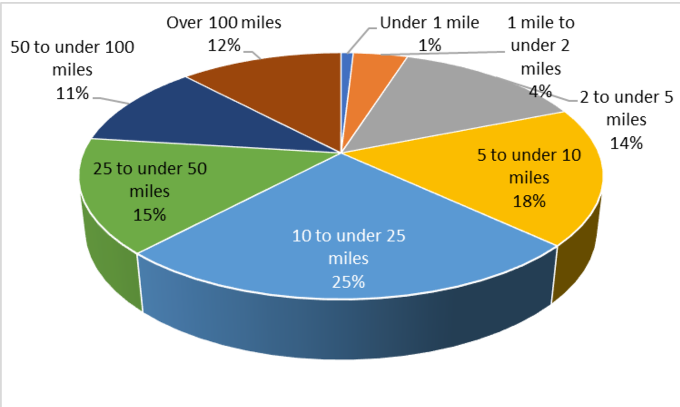
As recently argued by the Commission on Travel Demand, "*demand is not just 'out there' waiting to be fulfilled or not by policies. It is shaped by policy"*[99]. Instead of the old model of "*predict and provide*" we need a shift to "*decide and provide*"[100]. This means that rather than treating forecast traffic growth as inevitable, and building more road capacity to accommodate it, we should put carbon reduction and other key policy goals, such as public health and fairness, at the heart of transport planning. This implies a change away from traffic forecasting towards scenario planning, in which policy options to achieve a range of changes in traffic volume are assessed.

The CCC's 5th carbon budget included small reductions in transport carbon from demand management, based on shifting 5% or 10% of personal mileage to bus, walking and cycling by 2030[101]. The CCC partly based these reductions on the evidence from past behaviour-change programmes such as Sustainable Travel Towns and the Local Sustainable Transport Fund. Yet these programmes, while positive, were short-term and limited in what they could do, involved little or no traffic restraint, and had funding levels that were a fraction of investment in road-building[102]. Large cuts in vehicle mileage will need much more funding, major improvements in public transport and provision for walking and cycling, effective traffic restraint policies, and a consistent long-term approach.

While a large proportion of car journeys are short distance (<5 miles), these represent less than one-fifth of carbon emissions (19% – see Figure 2). More than half (57%) of carbon emissions from cars are from short-to-medium length journeys (under 25 miles)[103]. Significant mileage and carbon reduction requires these medium length journeys to be targeted too.

Many car journeys under 10 miles (the average car commute distance) should be possible to switch to alternatives, particularly in urban areas. The percentage of car commuters who could switch to other modes increases with city size[104]. This explains why the biggest reductions in car mileage in recent years have been in London, core cities and conurbations, and other large towns[105]. Yet regardless of whether they live in urban or rural areas, more than half of people report that they have alternatives (public transport, walking, cycling or other) to get to work[106]. Switching longer journeys of 10-25 miles will be more challenging and will need a package of carrots and sticks involving land-use planning, improved public transport and restraints on car travel[107, 108]. In particular, changes in land use have the potential to reduce journey lengths, replacing medium-length car trips with short trips by public transport or cycling.

Figure 2: Estimated CO_2 emissions from cars by journey distance[109]



6.3 Counterproductive policies and forecasts

Despite the potential for change, UK transport policy is heading in the wrong direction. One recent analysis suggests the freeze on fuel duty since 2001 has directly caused a 4% growth in traffic, emission of an additional 4.5 million tonnes of CO_2 and increased emissions of health-damaging pollutants such as NOx and PM_{10}[110]. The freeze is set to continue for a ninth year in a row. Although average car mileage per person has fallen[111], the number of vehicles has increased over the last ten years, and as noted earlier, abolition of graduated VED has encouraged a shift to purchase of larger less-efficient vehicles. The growth in traffic and the shift to larger vehicles has cancelled out the effect of any improvements in vehicle fuel efficiency.

The government forecasts that traffic in England and Wales will increase by up to 51% between 2015 and 2050 in a 'high electric vehicle' scenario[112]. Light goods vehicle (LGV) traffic has grown by nearly 70% over the last 20 years, and is forecast to more than double by 2050[113,114]. None of the government's forecast scenarios are compatible with the carbon emission reductions in the 5th carbon budget, let alone the more stringent Paris Agreement needs[115].

Government forecasts consistently overestimate traffic growth, and so in practice it is likely that actual growth will be less than predicted. However, high forecasts lead to a systematic overestimation of the 'benefits' of new road construction[116]. This in turn leads to more road building, which generates more traffic[117,118]. The policy bias towards road building and underfunding of alternatives have the effect of increasing car-dependency, with people forced to drive in order to access employment and services[119]. The National Infrastructure Commission has called for more investment in mass rapid transit in recognition that new roads only lead to new car journeys[120].

Planned funding for the trunk road network of £30 billion is the highest ever, of which £1 billion will go towards the creation of a Major Road Network[121]. This high funding for more road capacity will drive emissions higher, making it more difficult to achieve future carbon budgets. We therefore believe that all new road construction should be halted immediately, and not resumed unless and until it can be demonstrated that transport carbon emissions are safely below the level consistent with a 1.5°C limit. Money no longer required for road schemes should be invested in sustainable transport infrastructure and services.

7. Conclusions

In addition to implementing the priority actions identified by the CCC in their ***2018 Progress Report*** and response to ***Road to Zero***, the following are 'must do' actions to get transport on a 1.5°C track:

- Regulate the number of new fossil fuel cars and vans that can be sold, so that by 2030 all new car and van sales will be ULEVs, and nearly all will be zero-emission battery electric vehicles.
- Reform the grant scheme for electric cars to a trade-in rebate system, with grants only for trading in or scrapping an existing vehicle.
- Offer similar or higher financial support for electric car clubs, public transport or e-bikes in exchange for scrappage of an old, high-emission car.
- Develop and assess policy scenarios to reduce car mileage by 20-60% between now and 2030.

- Cancel all new road schemes and use the funding for public transport, walking and cycling.
- Enforce speed limits and consider further measures, including speed limit reduction, if scenario planning shows additional carbon savings are needed.

The transport sector is lagging in terms of carbon reductions and more action is needed beyond the measures set out in the 5th carbon budget. The IPCC has set out the scale and urgency of the challenge. To limit global temperature rise to 1.5°C will need deep emission cuts from all sectors as quickly as possible. The government should ask the CCC to determine the additional sector reductions that are needed between now and 2032, not just after 2032.

It is likely that transport carbon emissions will need to be reduced by around 80% by 2030. To achieve this we need to electrify the car and van fleet as soon as possible. This cannot be achieved through incentives alone, and will also require regulation to limit sales of conventional cars and vans, and increase sales of electric cars and vans, between now and 2030. Incentives to encourage purchase of electric vehicles must be designed to avoid increasing car ownership. One way of doing this would be to replace the current grants for electric vehicles with a trade-in rebate scheme.

Even if all new cars and vans are zero-emission by 2030, which will reduce emissions significantly, it will still be necessary to reduce miles driven. The scale of traffic reduction required may be in the order of 20-60% by 2030, depending upon the implementation of other policy measures. We therefore need to develop and assess policy scenarios that could achieve large reductions in traffic volume.

There is significant scope to shift car journeys (and mileage) to other modes. There is most potential for change in urban areas, but we will need to reduce traffic elsewhere too. The current focus of transport policy on building new roads will make matters worse, because it will increase car dependency and traffic. The government should therefore cancel all new road construction until transport carbon emissions are in line with carbon budgets, and use the money to invest in sustainable transport infrastructure and services. This will not only help us work towards net zero emissions by 2050, but will also result in better air quality, safer roads, healthier lifestyles and more vibrant and convivial towns and cities. How we do this will be outlined in future papers.

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References

[1] Urban areas are settlements with population over 10,000 people. Defra (2016) Rural Urban Classification. https://www.gov.uk/government/collections/rural-urban-classification, accessed 07.11.2018.
[2] The policy areas that will be covered by future papers are: better and more integrated public transport; land-use planning; walking and cycling; low-carbon freight (tbc); financial mechanisms to encourage mode shift; governance changes; new funding sources to pay for the necessary changes and to offset lost revenue from fuel duty following the shift to electric vehicles.
[3] Transport is now responsible for 126 $MtCO_{2e}$ or 27% of total UK domestic emissions (468 $MtCO_{2e}$). This increases to 168 $MtCO_{2e}$ (33%) if international aviation and shipping (43 $MtCO_{2e}$) are included in the total (511 $MtCO_{2e}$). Department for Business, Energy and Industrial Strategy (BEIS) (2018a) Final UK greenhouse gas emissions national statistics 1990-2016. https://www.gov.uk/government/collections/final-uk-greenhouse-gas-emissions-national-statistics
[4] Road transport emissions were 114 $MtCO_{2e}$ or 91% of domestic transport emissions in 2016. Car and LGV emissions were 70 and 19 $MtCO_{2e}$ respectively. Department BEIS (2018a) Ibid. Note that the majority (around 99%) of transport greenhouse gas emissions, CO_{2e}, are carbon dioxide, CO_2.
[5] Department for BEIS (2018a) Ibid.
[6] Committee on Climate Change (2018a) Reducing UK emissions – 2018 Progress Report to Parliament. 28 June 2018. https://www.theccc.org.uk/publication/reducing-uk-emissions-2018-progress-report-to-parliament/
[7] Committee on Climate Change (2018b) Letter from Lord Deben to Chris Grayling on the Government's Road to Zero Strategy. 11/10/18. https://www.theccc.org.uk/publication/letter-to-chris-grayling-and-greg-clark-assessment-of-the-road-to-zero-strategy/lord-deben-to-chris-grayling-greg-clark-on-road-to-zero/
[8] The Paris Climate agreement is based on a 66% chance of keeping average global temperature rise well below 2°C above pre-industrial levels with a goal to "*pursue efforts to limit the temperature increase even further to 1.5C*". UNFCCC (2015) Paris Agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[9] The Climate Change Act mandates at least an 80% reduction of greenhouse gas emissions by 2050, which is based on a 50% chance of keeping global temperatures below 2°C. Committee on Climate Change (2016) UK climate action following the Paris Agreement. https://www.theccc.org.uk/wp-content/uploads/2016/10/UK-climate-action-following-the-Paris-Agreement-Committee-on-Climate-Change-October-2016.pdf
[10] Global net human-caused emissions of CO_2 would need to fall by about 45% from 2010 levels by 2030, reaching net zero around 2050. This means that any remaining emissions would need to be balanced by removing CO_2 from the air using negative emissions strategies. The IPCC proposed a carbon dioxide budget of 420 Gt (based on surface air temperature) or 570 Gt (based on observed global mean surface temperature) for a 66% chance of keeping global temperatures no more than 1.5°C above pre-industrial levels. IPCC (2018) Global Warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. October 2018. http://www.ipcc.ch/report/sr15/
[11] There are many uncertainties and sensitivities in the IPCC assessment, such as the risk of feedback mechanisms, and the assessment relies heavily on the efficacy of negative emissions strategies. Regardless of the precise budget levels, the importance of reducing cumulative emissions and the risks of overshooting the budget mean it is better to adopt a precautionary approach and cut emissions as quickly as possible.
[12] IPCC (2018) *op. cit.*
[13] The government has requested the CCC to provide options on the range of greenhouse gas reductions required to contribute to global efforts to limit warming to 1.5°C and how these can be delivered across sectors. Department for BEIS (2018b) Letter from Claire Perry, Minister for Energy, to Lord Deben, Chair of the Committee on Climate Change. 15 October 2018

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[14] There is no consensus within the Paris Agreement on the probability for a 1.5°C target, but for the purposes of this paper we have adopted a precautionary approach and assumed the less risky 66% chance of limiting warming to 1.5°C.

[15] Provisional analysis by the Tyndall Centre for Climate Research suggests that we need an 80% reduction in CO_2 emissions between now and 2030, and zero emissions from all energy sources (including transport) by 2035-2040, to be compliant with the Paris 'well below 2°C' pathway. Anderson, K. (2018). Personal Communication 5 November 2018 about the Rapid Acceleration of Car Emission Reductions (RACER) project, a project led by the Tyndall Centre, University of Manchester and the Institute of Transport Studies, University of Leeds. https://tyndall.ac.uk/RACER

[16] Another study by researchers from UCL, using a global carbon budget (equivalent to around 470 $GtCO_2$ from 2018) very similar to the IPCC 1.5°C budgets, suggests net zero emissions by 2045 in the UK, requiring cuts to CO_2 of 9% per year. Assuming domestic transport takes its fair share of UK emission cuts, this would suggest transport emissions would need to be around 30 $MtCO_2$, half of what the CCC's 5th carbon budget is targeting for 2030. Pye S. et al. (2017) Achieving net-zero emissions through the reframing of UK national targets in the post-Paris Agreement era. *Nature Energy*, 2, 17024. DOI: 10.1038/nenergy.2017.24

[17] Warming from emissions from pre-industrial times to the present can persist for hundreds of thousands of years. Faster and more immediate carbon dioxide reductions can limit cumulative emissions. IPCC (2018) *op. cit.*

[18] When the many other impacts of road traffic are taken into account, including air pollution, congestion, road deaths and injuries, noise and community severance, demand management measures are highly cost effective.

[19] This includes: reducing vehicle weight; tightening emissions standards for conventional vehicles; using non-fossil fuels in conventional vehicles (eg, hydrogen, synthetic hydrocarbons and some biofuels); changing the vehicle drive-train from internal combustion engines to ULEV (battery electric and plug-in hybrid vehicles), and ultimately to zero-emission vehicles (battery electric run on 'green' electricity). Note that not all biofuels are necessarily low carbon. In particular, long-distance transport of imported feedstocks leads to significant greenhouse gas emissions, and conversion of natural vegetation or forest to cultivate biofuel feedstocks releases carbon from soil and plant biomass. See Royal Academy of Engineering (2017) Sustainability of liquid biofuels https://www.raeng.org.uk/publications/reports/biofuels

[20] Climate-related risks to species, health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and increase further with 2°C. IPCC (2018) *op. cit.* Additional impacts not in the IPCC summary include risks of human displacement leading to the possibility of war, and tipping points such as the melting of ice-sheets or a halt to the Gulf Stream. Ward B. (2018) The IPCC global warming report spares politicians the worst details. Article in The Guardian by the policy and communications director at the ESRC Centre for Climate Change Economics and Policy at the London School of Economics and Political Science, 8 October 2018. https://www.theguardian.com/commentisfree/2018/oct/08/world-leaders-climate-change-ipcc-report

[21] COMEAP, 2018, Associations of long-term average concentrations of nitrogen dioxide with mortality, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf

[22] Royal College of Physicians et al (2016) Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP, 2016. https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution

[23] Road traffic is responsible for 34% of emissions of NOx (which includes NO_2) and 80% of NOx concentrations at roadside. National Atmospheric Emissions Inventory (2018a). About Nitrogen Oxides. Webpage. http://naei.beis.gov.uk/overview/pollutants?pollutant_id=6, accessed 25.10.18. Defra and DfT (2017) UK plan for tackling roadside nitrogen dioxide concentrations. Detailed plan. July 2017, https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017.

[24] A scenario which met the CCA targets by 2050 reduced NO_2 concentrations by 60% and $PM_{2.5}$ concentrations by 44% compared to 2011. Williams M. L. et al. (2018) The Lancet Countdown on health benefits from the UK Climate Change Act: a modelling study for Great Britain. Lancet Planet Health, 2: e202–13 https://www.thelancet.com/action/showPdf?pii=S2542-5196%2818%2930067-6

[25] In 2017 there were 27,010 people killed and seriously injured on Britain's roads, of which 2,230 were children. Department for Transport (2018a) Reported road casualties Great Britain, provisional estimates: July to September 2017. www.gov.uk/government/statistics/reported-road-casualties-great-britain-provisional-estimates-july-to-september-2017

[26] The total value of prevention of all reported road injury accidents and non-fatal injury accidents reported to the police in 2017. Department for Transport (2017a). Table RAS60004. Total value of prevention of accidents by severity and road type. Great Britain 2017. https://www.gov.uk/government/statistical-data-sets/ras60-average-value-of-preventing-road-accidents#table-ras60003

[27] Public Health England and Local Government Association (2013) Obesity and the environment: increasing physical activity and active travel. Briefing, November 2013. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/256796/Briefing_Obesity_and_active_travel_final.pdf
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[31] 24% of all households or 44% of the lowest income households do not have access to a car or van. Department for Transport (2018b). National Travel Survey Table NTS0703. Household car availability by household income quintile: England, 2017. www.gov.uk/government/statistical-data-sets/nts07-car-ownership-and-access
[32] Dudleston A. et al. (2005) Public Perceptions of Travel Awareness – Phase 3 Report for the Scottish Executive https://www2.gov.scot/Publications/2005/08/0193550/35595
[33] RAC (2018) 6 in 10 drivers would switch to public transport. News item, 20 September 2018. https://www.rac.co.uk/drive/news/motoring-news/6-in-10-drivers-would-switch-to-public-transport/
[34] Department for Transport (2018c) Road to Zero. July 2018 https://www.gov.uk/government/news/government-launches-road-to-zero-strategy-to-lead-the-world-in-zero-emission-vehicle-technology
[35] ULEVs produce less than 75 g/km CO_2 under the existing test cycle. They include battery electric vehicles, which are pure electric vehicles charged from the grid, and plug-in hybrid electric vehicles, which are a combination of an internal combustion engine and plug-in battery. Department for Transport (2018c) *op. cit.*
[36] Zero-emission vehicles emit no carbon or pollution from the tailpipe and include battery electric vehicles and fuel cell vehicles. Ibid. Strictly these are only zero emission when powered by renewable or zero-emission electricity.
[37] This includes £400 million for installation of charging points; a £40 million programme to develop and trial low cost wireless and on-street charging technology; and grants of up to £500 for home charging points. Ibid.
[38] Committee on Climate Change (2018b) *op. cit.*
[39] Ibid.
[40] Ibid.
[41] Committee on Climate Change (2015a) The Fifth Carbon Budget. The next steps towards a low-carbon economy. November 2015. https://www.theccc.org.uk/publication/the-fifth-carbon-budget-the-next-step-towards-a-low-carbon-economy/
[42] Committee on Climate Change (2018b) *op. cit.*
[43] Website of the Norwegian Electric Vehicle Association https://elbil.no/english/norwegian-ev-policy/ accessed 25.09.2018
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[46] Committee on Climate Change (2018a) *op. cit.*
[47] Committee on Climate Change (2018b) *op. cit.*
[48] Website of the European Alternative Fuels Observatory http://www.eafo.eu/content/norway accessed 25.09.2018
[49] Website of the Norwegian Electric Vehicle Association https://elbil.no/english/norwegian-ev-market/ accessed 25.09.2018
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[51] Halvorsen B. and Frøyen Y. (2009) Trafikk i kollektivfelt.Kapasitet og avvikling. Elbilens rolle. Rapport fra AsplanViak (with English summary) https://www.vegvesen.no/_attachment/120733/binary/225415?fast_title=Trafikk+i+kollektivfelt+%28pdf%29

[52] Højklint R. and Hansen C. (2017) The Adverse Effects of the Norwegian Electric Vehicle Incentive Scheme with emphasis on congestion and public funding. Norwegian School of Economics MSc thesis in Economics and Business Administration, https://brage.bibsys.no/xmlui/bitstream/handle/11250/2454238/masterthesis.PDF?sequence=1

[53] Bauer G. (2018) The impact of battery electric vehicles on vehicle purchase and driving behaviour in Norway Transportation Research Part D, pp. 239-258 https://www.sciencedirect.com/science/article/pii/S1361920916305235?via%3Dihub

[54] Aasness M. and Odeck J. (2014) The explosion of electric vehicle use in Norway – environmental consciousness or economic incentives? Association for European Transport 2014 European Transport Conference, https://aetransport.org/public/downloads/8tuFk/4400-5400a2876cd3d.pdf

[55] Bauer G. (2018) *op. cit.*

[56] The rebate for electric cars should be offered only on condition that a car has been traded in or scrapped. Many car manufacturers run or have run part-exchange or scrappage schemes. These provide substantial discounts on new cars in exchange for old, typically Euro 1-4 petrol and diesel cars registered before 2010. Newer cars would be traded by dealers, helping to drive up average car efficiency in the second hand market, while older cars would be scrapped.

[57] With the current subsidy, the cost of running and owning a battery electric car in the UK is already cheaper than a petrol car. The total cost of ownership (TCO) in the UK for a typical petrol car (Ford Focus) was compared with a battery electric car (Nissan Leaf) as well as hybrid models, for a period of 3 years and an annual mileage of 10,400 miles. The battery electric car, with plug-in grant, had the lowest TCO at £10,787 compared to £12,285 for the petrol car. Palmer K. et al. (2018) Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. *Applied Energy*, 209, pp. 108-119.

[58] The current EU policy provides only a weak incentive for electric vehicle uptake. There is evidence that car-makers are not choosing a linear trajectory to achieve the EU car CO_2 targets but are holding back sales of plug-in vehicles. Transport & Environment (2018) CO_2 emissions from cars: the facts. April 2018. https://www.transportenvironment.org/publications/co2-emissions-cars-facts

[59] California and China introduced binding mandates for the number of electric vehicles sold by 2020 and 2025 as a way to address the supply shortage. Kasten P. The Way Forward: The Future of Electric Vehicles. In European Parliament (2018a) Post 2020 CO_2 emission targets for cars and vans: the right level of ambition? Workshop Proceedings, 18 April 2018. http://www.europarl.europa.eu/thinktank/en/document.html?reference=IPOL_STU(2018)618992

[60] Smokers R. The Way Forward: Possible Steps for Further Improvement. In European Parliament (2018a) *op. cit*.

[61] Up until 2030, one possibility to provide manufacturers with more flexibility is to allow trading of credits, which would allow industry laggards to buy electric-vehicle credits from electric-only manufacturers and would reward the more forward-planning manufacturers. European Parliament (2018a) *op. cit*.

[62] Studies have shown that real-world emissions of plug-in hybrid cars and vans could be 100-150% higher than testing suggests, partly due to much lower levels of driving in electric mode. Element Energy (2015) Quantifying the impact of real-world driving on total CO_2 emissions from UK cars and vans. Report for the Committee on Climate Change. September 2015. https://www.theccc.org.uk/publication/impact-of-real-world-driving-emissions/

[63] A study of company car emissions found that plug-in hybrids were the most polluting, with equivalent CO_2 emissions of 168 g/km. compared with advertised emissions of 55 g/km. The Miles Consultancy (2017) New Analysis of Plug-in Hybrid Car MPG and Emissions is Expected to Spark Debate on their Suitability for Fleet Operation. Blog 19 September 2018. https://themilesconsultancy.com/new-analysis-plug-hybrid-car-mpg-emissions-expected-spark-debate-suitability-fleet-operation/

[64] SMMT (2018a) UK new car market rises in August as one in 12 buyers goes electric. News article, 5 September 2018. https://www.smmt.co.uk/2018/09/uk-new-car-market-rises-in-august-as-one-in-12-buyers-goes-electric/, accessed 06.11.18.

[65] EU Regulations set a CO_2 emissions standard at 95 g/km for the new EU fleet average, phased in for 95% of vehicles in 2020, with 100% compliance in 2021. Individual manufacturers are allowed higher or lower average CO_2 emissions, depending on the average vehicle weight of their vehicle fleet, according to a limit value curve that is adjusted in such a way that the EU targets for fleet average emissions are achieved. Every manufacturer must ensure that the average CO_2 emissions from its fleet of newly registered vehicles in a calendar year do not exceed its specific annual emissions target, otherwise they pay a premium. European Parliament (2018b) CO_2 standards for new cars and vans. Briefing. February 2018. http://www.europarl.europa.eu/RegData/etudes/BRIE/2018/614689/EPRS_BRI(2018)614689_EN.pdf This actually incentivises heavier cars, as the heavier the average weight of the cars sold by a manufacturer, the higher the permitted CO_2 emissions. Some have therefore suggested that a system based on vehicle size or footprint would have greater impact.

[66] The new EU car and van post-2020 CO_2 targets are expressed as a percentage reduction in emissions. The European Commission has proposed that average CO_2 levels from new cars and vans need to be 15% lower by 2025 and 30% lower by 2030 compared to their 2021 sales average values. The European Parliament voted for a higher level of ambition of 40% by 2030, with a final decision expected in early 2019. Committee on Climate Change (2018b) *op. cit*.
[67] A 'real driving emissions' test measures emissions of NOx and ultrafine particles from vehicles on the road, and is mandatory for all new cars sold from September 2019 (complementing the WLTP test). The European Parliament has called for a similar real-driving emissions test for CO_2 to be up and running from 2023. European Parliament (2018c) Parliament pushes for cleaner cars on EU roads by 2030. Press Release, 3 October 2018. http://www.europarl.europa.eu/news/en/press-room/20180925IPR14306/parliament-pushes-for-cleaner-cars-on-eu-roads-by-2030 , accessed 05.10.2018
[68] The previous test cycle, NEDC, was manipulated by manufacturers, for example by removing parts to lightweight a car prior to testing and overinflating tyres, through to illegal practices of detecting test cycles, exposed by the Dieselgate scandal. The new Worldwide Harmonized Light Vehicle Test Procedure (WLTP) applies to all new cars sold from September 2018. However, there are still ways manufacturers can exploit it to make emissions appear lower. Because the CO_2 standards after 2020 are based on a percentage reduction, there is a potential loophole that artificially increasing the starting point will make hitting the targets easier. There is evidence to suggest that most manufacturers intend to make use of this loophole when setting their baseline. Transport & Environment (2018) Ending the cheating: using real-world CO_2 measurements within the post-2020 CO_2 standard. August 2018.
https://www.transportenvironment.org/sites/te/files/Ending%20the%20CO2%20cheating_FINAL%20290818.pdf
[69] Transport & Environment (2018) *op. cit*.
[70] Since the 2000 budget, VED has been graduated according to CO_2 emissions, as an incentive to drivers to purchase vehicles with lower emission ratings. Over time, more bands were introduced to increase the differential between the lowest and highest bands. In 2010 a 'first-year' rate was introduced for new cars, with zero VED in the first year for cars with CO_2 emissions of 130 g/km or less (VED bands A–D). Butcher L. (2017) Vehicle Excise Duty (VED) House of Commons Briefing Paper. SN01482. November 2017.
https://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN01482
[71] SMMT (2018b) *op. cit.*
[72] Butcher L. (2017) *op. cit.*
[73] SMMT (2018b) *op. cit.*
[74] SUVs (dual-purpose cars such as Kia Sportage) had an average emission of 141.3 g/km in 2017 compared to cars in the Mini segment (eg Hyundai i10) with an average emission of 105.9 g/km. SMMT (2018b) *op. cit.*
[75] Energy Saving Trust (undated) Subsidised eco-driving webpage.
http://www.energysavingtrust.org.uk/transport/subsidised-ecodriving-training, accessed 24.10.18.
[76] Energy Saving Trust (2017) Advising Fuel Efficient Driving Techniques for your Fleet.
http://www.energysavingtrust.org.uk/sites/default/files/reports/5984%20EST%20A4%20ecodriving%20guide_v6.pdf
[77] Eco-driver training for 10% of car and van drivers and all HGV drivers could save 0.9 $MtCO_2$ in 2020. Committee on Climate Change (2010) The Fourth Carbon Budget – Reducing Emissions through the 2020s. December 2010. https://www.theccc.org.uk/publication/the-fourth-carbon-budget-reducing-emissions-through-the-2020s-2/w Annual savings would be lower as the efficiency of the vehicle fleet improves.
[78] UK private drivers average "6 out of 10" on an efficient driving scale. Brook Lyndhurst (2016) Efficient Driving. A Rapid Evidence Assessment for the Department for Transport. Jan 2016.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/509972/efficient-driving-rapid-evidence-assessment.pdf
[79] Such as 'train the trainer' courses. Energy Saving Trust (undated) Subsidised Ecodriving Training webpage. http://www.energysavingtrust.org.uk/transport/subsidised-ecodriving-training, accessed 24.10.2018
[80] In 2017 nearly 2 million people attended a National Speed Awareness Course. NDORS (undated) Trends and Statistics webpage. https://www.ndors.org.uk/scheme/trends-statistics/, accessed 10.10.2018
[81] Based on an average 8 year-old car fuel consumption of 6.3 L/100km (44.6 mpg), an average household car mileage in 2017 of 12,553 km, a petrol pump price in October 2018 of 130 p/L and assuming a 10% fuel saving.
[82] Simple unweighted average of petrol and diesel car 1400-2200cc with Euro 5 engine. Energy Saving Trust and Department for Transport (2016) Advising fuel efficient driving techniques for your fleet.
http://www.energysavingtrust.org.uk/sites/default/files/reports/5984%20EST%20A4%20ecodriving%20guide_v6.pdf
[83] 25% travelling over 75 mph and 11% over 80 mph. Department for Transport (2017b) Road Statistics Great Britain. Table TSGB0714 (SPE0111) Vehicle speed compliance by road type and vehicle type in Great

Britain: 2016. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664323/tsgb-2017-print-ready-version.pdf

[84] Committee on Climate Change (2010) *op. cit.*

[85] Lower average speeds tend to reduce NOx emissions. Air quality monitoring is being undertaken along the M1 to evaluate the impact of 60 mph speed limits. Defra and DfT (2017) UK Plan for tackling roadside nitrogen dioxide concentrations. Technical Report. June 2017. https://www.gov.uk/government/publications/air-quality-plan-for-nitrogen-dioxide-no2-in-uk-2017

[86] RAC Foundation (2012) Speed limits: a review of evidence https://www.racfoundation.org/wp-content/uploads/2017/11/speed_limits-box_bayliss-aug2012.pdf

[87] Committee on Climate Change (2018b) *op. cit.*

[88] In the UK carbon budgets, emission cuts are allocated across sectors on a least-cost basis. The 5th carbon budget involves a reduction in gross emissions of 61% by 2030 relative to 1990, but domestic transport emissions are only required to fall by around 44% by 2030. While reducing carbon from vehicles has been found to be generally less cost effective than from other sectors this is largely because the technological solutions considered are much more costly than behavioural solutions such as reducing car mileage. When the benefits of reducing pollutant emissions from road transport are factored in, encouraging switching to cleaner and healthier ways of travelling is generally highly cost effective.

[89] Freeman, R. (2018) Personal communication, 6 November 2018. Provisional analysis from the Rapid Acceleration of Car Emission Reductions (RACER) project, a project led by the Tyndall Centre, University of Manchester and the Institute of Transport Studies, University of Leeds. https://tyndall.ac.uk/RACER.

[90] Anderson, K. (2018). Personal Communication, 5 November 2018. Provisional analysis from the Rapid Acceleration of Car Emission Reductions (RACER) project, a project led by the Tyndall Centre, University of Manchester and the Institute of Transport Studies, University of Leeds. https://tyndall.ac.uk/RACER.

[91] Pye et al. (2017) *op. cit.*

[92] This indicative range is based on a 2030 emissions target derived from the study by Pye et al. (2017) and the Road to Zero upper and lower targets for electric car uptake by 2030 under two highly simplified scenarios: (1) 70% new cars in 2030 are ULEV (50% battery, 50% plug-in hybrid) and the CCC target for emissions from conventional cars; (2) 50% new cars in 2030 are ULEV (50% battery electric, 50% plug-in hybrid) and a slower rate of improvement in emissions from conventional cars. Both assume no growth in the overall car fleet, an even split of mileage between new and old cars, and the CCC target for electricity grid carbon-intensity by 2030. If the uptake of ULEVs is more rapid than projected in Road to Zero, such that 100% of new cars are EVs by 2030, the degree of car mileage reduction that could be necessary is estimated to be 10-20% relative to 2017.

[93] The CCC is targeting a grid carbon-intensity of under 100 gCO_2/kWh by 2030, but warns of risks this may not be delivered. Committee on Climate Change (2018a) *op. cit*.

[94] The scale of emissions reduction required also depends on the assumptions used to determine the 2030 target, which in turn depends on how the global carbon budget is allocated to the UK, and the role of negative emissions strategies.

[95] In 2017 30% of 17-20 year olds held driving licences compared with 48% in 1992/94, while the proportion of 21-29 year olds fell from 75% to 67% over the same period. Department for Transport (2018d) National Travel Survey. Table NTS0201: Full car driving licence holders by age and gender: England; and Table NTS0204: Likelihood of non-licence holders learning to drive by age: England. https://www.gov.uk/government/statistical-data-sets/nts02-driving-licence-holders

[96] Car driver distance travelled per year in England fell from 1,828 miles per person to 1,248 miles per person for 17-20 year olds and from 4,235 miles per person to 3,626 miles per person for 21-29 year olds in England between 2007 and 2017. Department for Transport (2018e) National Travel Survey. Table NTS0605. Average distance travelled by age, gender and mode: England. https://www.gov.uk/government/statistical-data-sets/nts03-modal-comparisons

[97] Chatterjee, K. et al. (2018). Young People's Travel – What's Changed and Why? Review and Analysis. Department for Transport. www.gov.uk/government/publications/young-peoples-travel-whats-changed-and-why

[98] In 2017 8% of 17-20 year olds and 17% of 21-29 year olds said they were never interested in driving. Department for Transport (2018f) National Travel Survey. Table NTS0201: Full car driving licence holders by age and gender: England; and Table NTS0204: Likelihood of non-licence holders learning to drive by age: England. https://www.gov.uk/government/statistical-data-sets/nts02-driving-licence-holders

[99] Marsden G. et al. (2018) All Change? The future of travel demand and the implications for policy and planning. May 2018. The First Report of the Commission on Travel Demand. http://www.demand.ac.uk/commission-on-travel-demand/

[100] Marsden G. et al. (2018) *op. cit.*

[101] The 5th carbon budget suggests a 4 $MtCO_2$ reduction by shifting 5% car km (24% trips) of the shortest length (<4 miles for bus, <2 miles for cycling and <1 mile for walking) to bus, cycling and walking. Reducing distance by 10% could lower emissions by 6 $MtCO_2$ by 2030. Committee on Climate Change (2015a) *op. cit*.
[102] The Local Sustainable Travel Fund supported investment in 96 local sustainable transport projects between July 2011 and March 2015 with funding of around £600 million over 4 years from government. https://www.gov.uk/government/collections/local-sustainable-transport-fund, accessed 07.11.2018. This is half the £1.5 billion cost of a single highways project such as the A14 Cambridge to Huntingdon bypass. https://highwaysengland.co.uk/a14-cambridge-to-huntingdon-improvement-scheme-home/, accessed 07.11.2018.
[103] Department for Transport (2008) Carbon Pathways Analysis. Informing Development of a Carbon Reduction Strategy for the Transport Sector. July 2008. http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/pgr/sustainable/analysis.pdf
[104] Le Vine S., Polak J. and Humphrey A. (2017) Commuting trends in England 1988 – 2015. Report for Department for Transport. November 2017. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/657839/commuting-in-england-1988-2015.pdf
[105] Headicar P. (2018) Variations in travel between different locations. Analyses from the National Travel Survey. January 2018. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/674568/analysis-from-the-national-travel-survey.pdf
[106] Based on the National Travel Survey dataset. See Figures 44 and 45. Le Vine et al. (2017) *op. cit.*
[107] Almost half of these journeys in 2006 were commuting/business travel. Many of these can potentially be switched to public transport, although this will require much better and more integrated public transport and restraint measures such as road pricing and workplace parking charges to provide less incentive to travel by car.
[108] Cass N. and Faulconbridge J. (2016) Commuting practices: New insights into modal shift from theories of social practice. *Transport Policy*, 45, pp. 1–14
[109] Department for Transport (2008) *op. cit*. While there are no updated figures available, the breakdown of CO_2 by trip length in 2006 (62% <25 miles) is very similar to the breakdown of average distance travelled by trip length for car/van drivers in 2006 (58% <25 miles) and 2017 (59% <25 miles). Department for Transport (2018g) National Travel Survey. Table NTS0309. Average distance travelled by trip length and mode: England, 2006. Therefore it is reasonable to assume that these older CO_2 figures are broadly similar in 2017.
[110] Begg D. and Haigh C. (2018) The Unintended Consequences of Freezing Fuel Duty. Report for Greener Journeys, June 2018. https://greenerjourneys.com/wp-content/uploads/2018/06/THE-UNINTENDED-CONSEQUENCES-OF-FREEZING-FUEL-DUTY-JUNE-2018.pdf
[111] While the average distance travelled by car/van per person has reduced from 3,479 miles in 2008 to 3,269 miles in 2017, the total car/van mileage has increased from 287 billion vehicle miles to 305 billion vehicle miles over the same period. Department for Transport (2018h) National Travel Survey Table NTS0410 Average distance travelled by main mode and purpose. Department for Transport (2018i) Road Traffic Statistics. Table TRA0101 Road traffic by vehicle type in Great Britain, annual from 1949.
[112] Department for Transport (2018j) Road Traffic Forecasts 2018. https://www.gov.uk/government/publications/road-traffic-forecasts-2018
[113] Department for Transport (2018j) Ibid.
[114] While traffic is forecast to grow under all scenarios by between 17% and 51% between 2015 and 2050, the highest growth rates are for the high ULEV scenario, driven by the lower operating costs of electric vehicles. Department for Transport (2018j) Ibid.
[115] CO_2 emissions for England and Wales alone are forecast to be 67.9 MtCO2 by 2030 for the high electric vehicle scenario, which exceeds the 5th carbon budget target of 62 $MtCO_2$ for the UK. Department for Transport (2018j) Ibid.
[116] Nicolaisen M. S. and Næss P. (2015) Roads to nowhere: The accuracy of travel demand forecasts for do-nothing alternatives. Transport Policy, Volume 37, pp. 57-63.
[117] Wood, D. A. (1994). Trunk Roads and the Generation of Traffic. The Standing Advisory Committee on Trunk Road Assessment, report to DfT, December 1994. http://www.bettertransport.org.uk/sites/default/files/trunk-roads-traffic-report.pdf
[118] Evaluation of 13 major road schemes after completion showed that traffic growth was generally higher than forecast, and significantly higher than increases in background levels of traffic and population. Sloman, L., Hopkinson, L. and Taylor, I. (2017). The Impact of Road Projects in England. Report for CPRE. https://www.cpre.org.uk/resources/transport/roads/item/4542-the-impact-of-road-projects-in-england
[119] Around 80% of the working age population can (theoretically) reach 7 or more large employment centres by car compared with 20% by public transport within 45 minutes. Department for Transport (2016). Road Use Statistics. www.gov.uk/government/statistics/road-use-statistics-2016

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[121] Department for Transport (2017) Proposals for the Creation of a Major Road Network Consultation. https://www.gov.uk/government/consultations/proposals-for-the-creation-of-a-major-road-network