Tackling air pollution from diesel cars through tax: options for the UK

Paul Drummond
Paul Ekins

University College London
Institute for Sustainable Resources (UCL ISR)

GreenBudgetEurope
EUROPEAN EXPERT PLATFORM ON ENVIRONMENTAL TAXATION AND GREEN FISCAL REFORM

Contents

Executive Summary

• Air pollution in the UK is a 'public health emergency'

Each year an estimated **40,000-52,500 premature deaths** result from outdoor air pollution in the UK. The House of Commons Environment, Food and Rural Affairs Committee (EFRAC) recognises this as a 'public health emergency', costing the economy up to £54 billion a year. A primary component of air pollution is nitrogen oxides (NO_x) from various sources, but particularly from road transport, with diesel cars a significant contributor.

The UK's car fleet experienced significant 'dieselisation' over the past 20 years, with **diesel cars now making up half of all new cars sold across the UK**. This was prompted in large part by policy seeking to take advantage of the lower CO_2 emissions once produced by diesel cars compared to their petrol equivalents. However, **diesel cars emit significantly higher levels of other air pollutants than petrol cars** (including NO_x), and CO_2 emissions from diesel and petrol cars are now approximately equal.

• Existing and proposed measures to tackle air pollution from diesel cars are insufficient at both the EU and UK level

Since 1992, successive European Emission ('Euro') Standards have sought to tackle the emission of air pollutants from cars. **Since 1996/97, diesel cars have been permitted to emit more NO_x than petrol cars**. A more problematic issue, as brought sharply into public focus since the Volkswagen 'Dieselgate' scandal in September 2015, is **the lack of practical achievement of these standards by diesel cars**. On average, **new diesel cars emit NO_x at 5-6 times the regulated level** in 'real-world' driving conditions. To tackle this, from September 2019, all new diesel cars sold in the EU must be subject to 'Real Driving Emission' (RDE) testing. However, 'conformity factors' will **initially allow cars to continue to emit NO_x at over twice the regulated limit**, reducing to 1.5 times in 2021. This means that NO_x emissions from new diesel cars sold between September 2014 (when 'Euro 6' regulations entered into force) and January 2021, may produce **additional costs to society of €12 billion in the UK** over the cars' lifetimes, compared to petrol equivalents.

For the purposes of air quality regulation, the UK is divided into 43 areas, **38 of which are currently in breach of NO_2 emission limits set by the EU Air Quality Directive**. In January 2016 the annual limit for London was breached within one week. Plans published by the UK Government in late 2015 to address this issue mean that **37 of these 38 areas would remain non-compliant until 2020, with London remaining so until 2025**. The initial deadline for compliance was 2010. As a result, the environmental law firm ClientEarth filed papers in March 2016 to pursue a Judicial Review to order the Government to draw up more rigorous plans. Regardless of the outcome of the case, **this public health emergency warrants further action to reduce NO_x emissions from diesel cars**.

• Tax instruments can complement existing measures

Tax instruments hold a number of benefits to complement the existing policy landscape. They may induce changes in consumer preferences through altering the economics to favour the purchase, ownership and use of cars or other modes of transport with lower NO_x emissions. Compared to regulatory approaches, taxes are often more flexible, better able to account for nuances in the objective/s, easier to implement, and simpler to adjust over time in response to new developments. They also generate a revenue stream, which may further promote the objective of the tax.

This report proposes the introduction in the UK of a graded **national supplementary NO_x Registration Tax** for new diesel cars, with the rate levied approximately proportional to real-world NO_x emissions of the vehicle, and the average additional damage such emissions cause over its life (against a chosen comparator – see table below). Real-world NO_x emissions may be determined either through existing data, or through mechanisms to encourage manufacturers to submit their vehicles for testing.

Four different options are presented in the table below. The adoption of Option 4, which is technologically-neutral and takes differences in average distances driven by diesel and petrol cars into account, would see new diesel cars charged between £170 and £4,950, applied at the point of registration or purchase. The upper band, at just under £5,000, reflects NO_x emissions around 17 - 20 times higher than a petrol equivalent. The **average diesel car currently sold would be charged £1,100 - £1,700,** depending on the Option chosen.

		OPTION 1	OPTION 2	OPTION 3	OPTION 4
		Equal average annual mileage		Actual average annual mileage	
Grade	NO_x emissions (mg/km)	Above Diesel Euro 6 Value (80mg/km)	Above Petrol Euro 6 Value (60mg/km)	Above Diesel Euro 6 Value (80mg/km)	Above Petrol Euro 6 Value (60mg/km)
A*	<60	-	-	-	-
A	60-80	-	£40	-	£170
B	80-120	£80	£150	£100	£320
C	120-180	£270	£340	£360	£580
D	180-250	£510	£560	£690	£910
E	250-500	£1,120	£1,200	£1,520	£1,740
F	500-750	£2,070	£2,150	£2,800	£3,020
G	750-1000	£3,020	£3,100	£4,090	£4,310
H	>1000	£3,490	£3,570	£4,730	£4,950

This supplementary levy can **be introduced and work alongside the reform of the CO_2-based Vehicle Excise Duty in April 2017**. Conformity factors with Real Driving Emissions testing means that from September 2019, only diesel cars that fall into Grades A*-C may be sold. From January 2021, this reduces to Grades A*-B. It may be preferable to redefine the remaining Grades further over time, to maintain a sufficient signal as the market begins to concentrate into these higher bands.

The proposed supplementary NO_x Registration Tax does not impact emissions from diesel cars already on the road, nor does it act to focus abatement efforts in densely populated urban areas, where the damage to human health and environment is greatest. This may be addressed through **the parallel introduction of city-level NOx-related road pricing**, options for which are also detailed in this report. In London, this could mean the **inclusion of diesel cars sold after September 2014 in the proposed Ultra Low Emission Zone (ULEZ) charge** (the inclusion of diesel cars sold before this date is already planned). **In other cities, the proposed Clean Air Zone charges can include all diesel cars** (existing proposals for Birmingham, Leeds, Southampton, Derby and Nottingham do not cover any cars). **Reform to company car taxation and 'benefit in kind' rules for diesel cars** are also proposed.

• The tax revenue generated may be used to reduce air pollution further, and contribute to other environmental and public health objectives

Using the revenue generated from these instruments to **increase investment in low- and ultra-low-emission public transport, along with active transport (walking and cycling) infrastructure, particularly in cities, should be a priority**. Such transport investment not only reduces NO_x emissions, it also serves other environmental and public health objectives (e.g. reducing greenhouse gas emissions and obesity), yielding further social and economic benefits. Other options, such as **low-emission car clubs** and **infrastructure to accelerate the deployment of low-emission cars**, may also be appropriate.

1 Introduction and Background

- **The level of air pollution in the UK is producing a 'public health emergency'**

Each year an estimated 40,000-52,500 premature deaths result from outdoor air pollution in the UK.[1] The House of Commons Environment, Food and Rural Affairs Committee (EFRAC), echoing the World Health Organisation (WHO), recognises this as a 'public health emergency' (EFRAC, 2016), producing an annual societal cost of £15-30 billion.[2] The cost to the UK's economy from air pollution may be up to £54 billion a year in total (The Scottish Government, 2015). Alongside particulate matter (PM), the emission of nitrogen oxides (NO_x) is a primary contributor to this[3], responsible for an estimated 23,500 of total air pollution-related deaths and a related societal cost of £13.3 billion each year (Defra, 2015a).

The problem is most acute in urban areas, with London particularly affected**.** Walton *et al* (2015) estimate that in 2010, the long-term effects on air pollution in London were responsible for up to 141,000 life-years lost (equivalent to 9,400 premature deaths), producing economic costs of up to £3.7 billion. NO_2 alone was estimated to be responsible for up to 88,100 life-years lost (equivalent to 5,900 premature deaths).

- **Road transport is the most prominent source of NO_x emissions, with diesel cars a significant contributor**

The European Union (EU) Air Quality Directive sets limits on the concentrations of key chemicals, including NO_2, in outdoor air.[4] In the 43 areas of the UK, 38 are in breach of these limits (EFRAC, 2015). One such zone is Greater London. Howard (2016) estimates that around 12.5% of London's area[5] exceeds the limit value for NO_2 (a total of 292 km^2), with around 5% of this area (0.5% of the total London region) experiencing NO_2 levels more than twice the legal limit. Some of the most polluted areas are estimated to be four times over the limit. In January 2016, in parts of London the annual limit was breached within one week.[6]

Excluding London, around two-thirds of NO_x emissions in areas exceeding annual NO_2 limits are from road transport.[7] Of this, diesel cars are responsible for over a third (Defra, 2015b). In Greater London, the contribution of road transport is 45%, with diesel cars responsible for 11% (the joint largest single contributor, alongside heavy goods vehicles (HGVs)). In Central London, these values are 48% and 5%, respectively (Howard, 2016a).

1 A recent study by the Royal College of Physicians (RCP) and Royal College of Paediatricians and Child Health (RCPCH) place this value at 40,000 (RCP & RCPCH, 2016), whilst the Department for Environment, Food and Rural Affairs (Defra) estimates values of 44,750 to 52,500) (Defra, 2015a)

2 The Scottish Government (2015) estimate a value of £15bn, whilst Defra (2015a) estimates £25.3 -29.7bn.

3 NO_x includes both nitric oxide (NO) and nitrogen dioxide (NO_2).

4 The Air Quality Directive (2008/50/EC) merges the majority of previous air quality-related legislation, with few changes to the limit values they set for different pollutants. For NO_2, the hourly limit value is a concentration of 200 µg/m^3 (with 18 permitted exceedances per year), with a yearly limit value of 40 µg/m^3. These limits entered into force on 1st January 2010.

5 All Greater London Boroughs, plus the remaining area within the M25 motorway.

6 See: http://www.theguardian.com/environment/2016/jan/08/london-takes-just-one-week-to-breach-annual-air-pollution-limits

7 Carslaw *et al* (2011) estimate from monitoring data that the fraction of primary NO_2 in NO_x emissions from all fuels in the UK was 15-16% in 2009, and around 21-22% in London.

Over the past 20 years the UK's car fleet has experienced significant 'dieselisation'. In 1994, diesel cars comprised 7% of the total fleet (with 1.6 million vehicles). This has increased to 36% (10.7 million vehicles), with around 50% of all new cars sold since 2011 being diesel-fuelled.[8] Although partially due to greater fuel efficiency providing an economic incentive for diesel over petrol, this 'dash for diesel' was driven to a large extent by policy seeking to take advantage of the lower CO_2 emissions produced by diesel cars. At the EU level, legally-binding CO_2 intensity targets require each car manufacturer to ensure the average CO_2 intensity of their annual sales across all Member States reached 130g CO_2/km by 2015, and will reach 95 gCO_2/km by 2021.[9] In the UK, efforts to reduce CO_2 emissions from the car fleet were advanced by the introduction in 2001 of the reformed Vehicle Excise Duty (VED), which applies an annual circulation (ownership) tax based on CO_2 intensity. Table 1 illustrates the rates applicable in 2016/17, for petrol and diesel cars[10]. In the 2015 Summer Budget plans were announced to reform the VED for cars registered on and after 1st April 2017. The proposed new rates and banding are also presented in Table 1. These policy instruments in particular have incentivised both manufacturers and consumers to favour diesel over petrol cars in the UK (and in the case of CO_2 intensity targets, around the EU).

Table 1 – Vehicle Excise Duty (VED) Rates[11]

	2016/17 RATES			APRIL 2017 ONWARDS		
Band	CO_2 Intensity (g/km)	First Year Rate[12]	Standard Rate	CO_2 Intensity (g/km)	First Year Rate	Standard Rate[13]
A	<100	£0	£0	0	£0	£0
B	101-110	£0	£20	1-50	£10	£140
C	111-120	£0	£30	51-75	£25	£140
D	121-130	£0	£110	76-90	£100	£140
E	131-140	£130	£130	91-100	£120	£140
F	141-150	£145	£145	101-110	£140	£140
G	151-165	£185	£185	111-130	£160	£140
H	166-175	£300	£210	131-150	£200	£140
I	176-185	£355	£230	151-170	£500	£140
J	186-200	£500	£270	171-190	£800	£140
K	201-225	£650	£295	191-225	£1,200	£140
L	226-255	£885	£500	226-255	£1,700	£140
M	>255	£1,120	£515	>255	£2,000	£140

8 See Department for Transport Vehicle Licensing Statistics, Table VEH0253.

9 As set by Regulation 443/2009. In 2015, the average reported CO_2 intensity of a new car sold in the EU was 119.6 gCO_2/km, 8% below the target, and down substantially from the 2007 value of 158.7 gCO_2/km (EEA, 2016). In the UK, this value was 121.4 gCO_2/km (SMMT, 2016). Whilst there are concerns regarding an increasing gap between the reported and real-world CO_2 emissions for new cars (up to 45% for some cars (ICCT, 2015)), this is beyond the scope of this paper.

10 Rates presented are those for a single annual payment. Rates for payment by instalments or by monthly direct debit are slightly higher. Rates for 'alternative fuel cars' are slightly lower.

11 Only for new cars registered on or after these dates.

12 Applicable the first year the car is registered.

13 Cars over £40,000 pay a £310 supplement for 5 years

Although the switch to diesel from petrol is estimated to have reduced CO_2 emissions[14], it is clear that the differential in CO_2 intensity between petrol and diesel cars has reduced substantially over time. In 2000, the average new petrol and diesel car sold in the UK had CO_2 intensities of 183.2 gCO_2/km and 167.7 gCO_2/km, respectively (a 15.5 gCO_2/km difference). By 2015, this had reduced to 124.2 gCO_2/km and 121.5 gCO_2/km, respectively (a 2.7 gCO_2/km difference) (SMMT, 2016)[15]. However, diesel cars continue to emit significantly higher levels of local air pollutants, including NO_x, than petrol cars.

- **The primary instrument for tackling non-CO_2 tailpipe emissions from cars in the EU, the 'Euro' Standards, have been relatively ineffective in reducing NO_x from diesel cars**

Since 1992, successive European Emission Standards (commonly known as the 'Euro' standards) have defined the maximum level of a range of different air pollutants permissible from passenger car exhausts. Table 2 illustrates how the limits for NO_x emissions from petrol and diesel cars have evolved over time.

Since the introduction of Euro 2, diesel cars have been permitted to emit more NO_x than petrol cars. From Euro 3 to Euro 5, new diesel cars could emit more than three times the level of NO_x than petrol cars. Whilst this differential reduced substantially with the introduction of the Euro 6 standard (from 300% to 33%), a gap still remains.

More problematic however, is lack of practical achievement of these limits for diesel cars. The current methodology for testing compliance with the regulations, the laboratory-based New European Driving Cycle (NEDC), does not accurately reflect emissions produced by a vehicle when under 'real-world' driving conditions.[16] Although the scientific community had been aware of this for some time[17], the issue came to widespread public attention through the 'Dieselgate' scandal, namely, the revelation that Volkswagen had calibrated emission control technology in its turbocharged direct injection (TDI) diesel engines so as to activate only under test conditions ('defeat devices'), therefore artificially supressing its real-world emissions. Recent investigations have found that real-world NO_x emissions for some

Table 2 - European Emission (Euro) Standards for NO_x Emissions

Euro Standard	DATE INTRODUCED		NO_x EMISSION LIMITS (mg/km)	
	New Model Approvals	All New Registrations	Petrol	Diesel
Euro 1	1st July 1992	31st December 1992	970	970
Euro 2	1st January 1996	1st January 1997	500	900
Euro 3	1st January 2000	1st January 2001	150	500
Euro 4	1st January 2005	1st January 2006	80	250
Euro 5	1st September 2009	1st January 2011	60	180
Euro 6	1st September 2014	1st September 2015	60	80

14 Mazzi and Dowlatabadi (2007) estimate that since 2001, switching from petrol to diesel cars has produced savings of 0.4 $MtCO_2$ and 1 million barrels of oil per year. However, when all greenhouse gas emissions from diesel cars are considered, it is unclear what the net climate-related effect has been. Compared to petrol, the combustion of diesel also produces significantly higher volumes of black carbon (a major component of soot), a short-lived greenhouse gas with substantially more global warming potential than CO_2. Such emissions may have greatly reduced the net climate-related benefit associated with diesel over petrol combustion, however more analysis is required to quantify this (Hodnebrog, Myhre and Samset, 2014; Schmidt, 2011).

15 However, see Footnote 9 regarding reported and real-world CO_2 emissions.

16 Amongst other issues, the test is a cycle of under 20 minutes, with low average speeds, low rates of acceleration and no gradients. It therefore tests the performance of the vehicle with the engine under relatively low load (Emissions Analytics, 2016).

17 For example, see Weiss *et al* (2011).

Euro 6 diesel cars are twelve times in excess of the regulatory limit, and 5-6 times on average.[18] By contrast, petrol cars have largely achieved compliance with their regulatory limits (Weiss *et al*, 2011).

This disparity between regulated and real-world NO_x emission levels from diesel cars purchased between September 2014 and April 2016 may produce an additional cost to society in the UK currently worth around £3.6 billion over their lifetimes. When compared to Euro 6 petrol cars, this rises to £4.1 billion.[19]

- **Measures to address these shortcomings have been adopted, but are insufficient**

In order to reduce the discrepancy between official and real-world NO_x emissions, it was decided that 'Real Driving Emission (RDE)' testing will be introduced across the EU, to be used alongside laboratory tests.[20] The use of RDE testing for compliance will be introduced in two steps, as summarised in Table 3. The first step is the requirement for RDE testing to be applied to all new diesel models from September 2017, and for all new registrations from September 2019. However, a 'conformity factor' of 2.1 will be applied. This means that new diesel cars will be able to emit 2.1 times the Euro 6 NO_x limit under RDE conditions for this phase (i.e. 168 $mgNO_x$/km). This is to allow manufacturers time to adapt to the new testing regime. The second step will see the conformity factor reduce to 1.5 for new models in January 2020, and all new diesel cars from January 2021 (i.e. 120 $mgNO_x$/km). This value is intended to reflect the Euro 6 level plus the error margin resulting from statistical and technical uncertainties surrounding the test procedure – currently set at 0.5 (i.e. a 50% error margin). Suggestions that this error margin is excessive[21] led to a commitment by the EU Commission to review it annually to take into account technical improvements to the test equipment.

Table 3 – Diesel Car Conformity Factors

APPLIES FROM	SCOPE OF APPLICATION	EURO 6 DIESEL LIMIT (mg NO_x)	CONFORMITY FACTOR	ON THE ROAD TEST - LIMIT VALUE (mg NO_x)
To Sept 2017	*N/A*	80	*N/A*	*N/A*
Sept 2017	New diesel models	80	2.1	168
Sept 2019	All new diesel cars	80	2.1	168
Jan 2020	New diesel models	80	1.5	120
Jan 2021	All new diesel cars	80	1.5	120

18 See DfT (2016a), the EQUA Air Quality Index (http://equa.emissionsanalytics.com/ - discussed further below), and: http://www.europarl.europa.eu/news/en/news-room/20160129IPR11905/Parliament-decides-not-to-veto-car-emissions-test-update

19 Based on new diesel car registrations in 2015 (1,276,871) (SMMT, 2016b), plus prorated sales for September-December 2014, and January-April 2016. Diesel cars sold since September 2014 assumed to emit an average of 400 gNO_x/km, whilst petrol vehicles emit 60 gNO_x/km. Annual diesel milage of 10,700 miles (17,220km) and petrol mileage of 6,700 miles (10,783km) assumed. Values are sourced from Table NTS0902 of the National Travel Survey Statistics. UK average damage cost of £25,252 /tNO_x from transport, as calculated by Defra (2015a). Average car lifetime of 15 years. Annual social discount rate of 3.5% applied as assumed by HM Treasury (2011).

20 RDE testing will 'means that the car will be driven outside and on a real road according to random acceleration and deceleration patterns. The pollutant emissions will be measured by portable emission measuring systems (PEMS) that will be attached to the car. RDE testing will reduce the currently observed differences between emissions measured in the laboratory, and those measured on road under real-world conditions, and to a great extent limit the risk of cheating with a defeat device' (European Commission, 2015). However, at the time of writing, the specific design of the RDE test procedure to be adopted is yet to be agreed.

21 As highlighted by Howard (2016a), the European Commission's Joint Research Centre estimate RDE uncertainty at between 20% and 30% (See: http://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/EMIS/DV/2016/04-19/EMIS_questions_JRC_responses_EN.pdf)

As a consequence, under these plans new diesel cars will be permitted to emit NO_x at rates significantly higher than the Euro 6 limit; more than double up to the end of 2020 – seven years after the regulation came into force. From 2021, diesel cars remain permitted to emit NO_x at double the rate of new petrol cars sold today (unless the review process outlined above reduces the conformity factor applied).

The presence of these compliance factors means that the diesel cars sold between September 2014 and December 2021 may produce an additional NO_x-related cost to society in the UK currently worth £10.3 billion over their lifetimes, compared to if these vehicles were required to meet Euro 6 limits in real-world emissions. When compared to Euro 6 petrol cars, this rises to £12.2 billion.[22]

- **The UK Government and other competent authorities must introduce additional measures to address NOx emissions from diesel cars**

It is projected that without additional measures, most English cities would not meet EU limits on NO_2 emissions until 2020, with five cities (Birmingham, Leeds, Southampton, Derby and Nottingham) not in compliance until 2025. London would not be compliant until 2030. The deadline set for reaching regulated levels was 2015 – itself an extension from 2010. In order to achieve compliance with NO_x limits for outdoor air across the country, in response to a ruling by the European Court of Justice (ECJ), the UK's Supreme Court ruled in April 2015 that the Government must, in the 'shortest time possible' and by 31st December 2015 at the latest, prepare and consult on new air quality plans for submission to the European Commission. Subsequently, in September 2015 Defra published draft plans for consultation, which were finalised in December 2015. The plans primarily consist of the introduction of 'Clean Air Zones' in the five cities listed above, which would charge vehicles entering the Zone a fee based on their Euro classification. However, no cars (petrol, diesel or alternatively fuelled) will be subject to these charges.[23] The existing Low Emission Zone (LEZ) in London also does not apply to cars (although, as discussed in Section 2, cars will be subject to the Ultra Low Emission Zone when it is introduced in 2019/20). As such, the measures set out in these plans mean that 37 of the 38 zones in breach would remain non-compliant until 2020, with London remaining non-compliant until 2025 (Defra, 2015c; EFRAC, 2016). As a result, the environmental law firm ClientEarth filed papers in March 2016 to pursue a Judicial Review to again order the Government to draw up more rigorous plans.[24] In April 2016, the High Court granted the request for a hearing.[25]

Regardless of whether the Government becomes legally obliged to produce a second, more effective national plan for reducing NO_x emissions, given the public health emergency such emissions (along with other air pollutants) is giving rise to, further action is warranted to reduce NO_x emissions from diesel cars at both the national and city levels.

22 Assumptions as per those detailed in Footnote 19. In addition for this calculation, it is assumed that diesel car sales remain static, and that all vehicles meet the relevant conformity factors by the dates required (presented in Table 3), and emit at those levels. New models are assumed to account for 10% of new sales in their first year, 30% in their second year, and 50% in their third year.

23 Specific designs for these Clean Air Zones are planned for consultation in 2016.

24 See: http://www.dev.clientearth.org/clientearth-takes-government-back-court-killer-air-pollution/

25 See: http://www.dev.clientearth.org/judge-decides-uk-government-will-face-legal-action-air-quality/

2 What Options Are Available?

This paper examines the options for taxation to encourage a reduction in NO_x emissions from diesel cars in the UK. Although not sufficient in isolation, taxation instruments hold a number of benefits that may complement the existing policy landscape. Whilst the Euro standards drive changes on the supply side (i.e. the manufacturers), taxation instruments may induce changes in consumer preferences through altering the economics to favour the purchase, ownership and use of cars (or other modes of transport) with lower NO_x emissions. Compared to regulatory approaches they are often more flexible, more able to account for nuances in the objective and implementation, and easier to adjust over time in response to new developments. They also generate a revenue stream, which may allow a reduction in other less socially desirable taxes, or the provision of a subsidy for a socially desirable good (either to offset the increased cost from the introduction of the new tax, to further promote the objective of the tax, or both). An environmental taxation[26] approach also broadly aligns with existing Defra plans to tackle NO_x emissions through charging[27] (non-car) vehicles to enter proposed Clean Air Zones, and other plans to invest in low-emission transport options.

The sections below provide an overview of the key characteristics of the main tax instruments available. In practice, each instrument may take a wide range of specific designs that must be assessed in detail to determine their particular impact. Similarly, whilst estimates of potential revenue are given for each option, these values must be seen as purely indicative.

2.1 Supplementary NO_x Tax on Diesel Fuel

Economic principles would suggest that the most efficient way of internalising the 'externalities'[28] associated with the combustion of fuel would be to levy a tax at the point of emission - ideally at a rate equal to the marginal costs produced. As such an approach for tackling externalities from the use of internal combustion vehicles has been historically (technically and administratively) impossible in practice, a common approach is to tax the purchase of the fuel to be combusted. This works well for a tax designed to tackle, for example, CO_2 emissions. The CO_2 emissions produced by a litre of diesel, and the marginal damage these emissions produce, are largely uniform[29], and thus amenable to upstream pricing of downstream emissions.

26 HM Treasury defines an environmental tax as that which is (a) explicitly linked to the government's environmental objectives, (b) the primary objective of the tax is to encourage environmentally positive behaviour change, and (c) the tax is structured in relation to environmental objectives, for example, the more polluting the behaviour, the greater the tax levied. However, this differs from the more widely accepted definition (as employed by the Office for National Statistics (ONS)), which defines an environmental tax as one whose base is a physical unit (for example, a litre of petrol or a passenger flight) that has a proven negative effect on the environment, are designed to promote environmentally positive behaviour and reduce damaging effects on the environment, and generate revenue that can potentially be used to promote further environmental protection (ONS, 2015).

27 'Taxes' are defined as 'compulsory, unrequited payments to general government levied on tax bases' (i.e. Benefits provided by government to taxpayers are not normally in proportion to their payments). By contrast, 'charges' are 'requited payments made by consumers to providers of…services' (i.e. levied approximately in proportion to services provided) (OECD, 2001). As such, charging a vehicle to enter a Clean Air Zone would normally be considered a tax, rather than a charge.

28 An 'externality' is a cost or benefit that results from an activity that affects a third party, who did not choose to incur it.

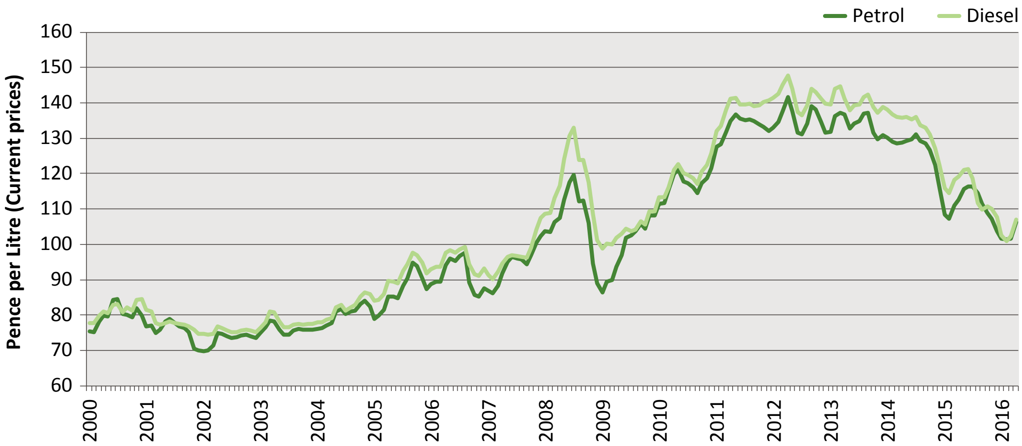
29 A unit of diesel produces a largely fixed unit of CO_2 (2.68 kg/litre), and a unit of CO_2 emitted in one place will have the same marginal damage cost as a unit of CO_2 emitted anywhere else.

This is much more difficult for NO_x (and other local air pollutants), for two reasons. Firstly, NO_x emissions from a litre of diesel vary according to the engine it is combusted in, how the vehicle is driven and in what conditions, and the presence of tailpipe technologies to remove NO_x from exhaust gasses. Secondly, the marginal damage caused by NO_x emissions depends on the circumstances in which they are emitted; NO_x emitted in a heavily populated urban environment will produce more health (and other) damage than the same unit of emissions in a sparsely populated rural environment.[30] An upstream tax on diesel fuel cannot account for these (spatial and temporal) differences.

However, it could be argued that a supplementary tax on diesel fuel set at perhaps the average marginal damage cost above petrol cars could be introduced. When comparing real-world NO_x emissions from Euro 6 diesel cars with real-world NO_x emissions Euro 6 petrol cars, the average additional damage cost is £0.19 per litre of diesel.[31] This represents an 18% increase in the current price of diesel, adding around £167 to the average annual cost of operating an average Euro 6 diesel car.[32] Whilst this is not an insubstantial increase, it would be unlikely to produce a substantial reduction in NO_x emissions and associated damage from diesel cars, for four key reasons.

1. A higher diesel price would in theory incentivise the more fuel-intensive diesel cars to reduce distance driven in the medium term, and to switch to a more fuel-efficient (or non-diesel) car (or transport mode) in the longer term. However, as discussed above, such vehicles are not necessarily the most NO_x intensive diesel cars, or driven in locations in which damages are greatest.
2. Even if fuel consumption and NO_x emissions from diesel cars were correlated, it is unlikely that any substantial shift in the vehicle fleet profile, particularly towards alternatively-fuelled vehicles, would result. Figure 1 illustrates the evolution of petrol and diesel retail prices in the UK from January 2000 to April 2016 (in current prices). It is clear there has been significant volatility, but with a steady increase in the diesel price of around 50p/litre in the three years between early 2009 and early 2012. A switch away from or the reduction in the use of diesel (or petrol) cars did not accompany such an increase in fuel prices, which was well over double the supplementary tax value discussed above. Additionally, underlying price volatility, driven by the oil markets, may swiftly counteract the value of such a tax.

Figure 1 - Monthly petrol and diesel retail prices in the UK (Current Prices) (Source: DECC Statistics)



30 For example, Defra (2015a) calculate damage costs from NO_x emitted from transport at £7,829 /tNO_x for rural areas, but £115,405 /tNO_x in Central London.

31 Assuming average diesel cars with NO_x emissions of 400 mg/km and fuel consumption of 4.7l /100km, and average petrol cars with NO_x emissions of 60 mg/km and fuel consumption of 5.5l/100km. Damage costs of £25,252 /tonne are assumed. (Defra, 2015a). Fuel consumption data sourced from Department for Transport Statistics Table TSGB0303 (ENV0103)

32 Based on the April 2016 average diesel price of 106.90 pence/litre (AA, 2016), and average annual fuel cost of £950 for a Euro 6 diesel car (adjusted from average running costs for 12,000 miles, based on data from the UK's vehicle Certification Agency (VCA), found at: http://carfueldata.direct.gov.uk/downloads/download.aspx?rg=aug2015

3. A supplementary tax on diesel would, however, provide a relatively steady differential with petrol prices (which as illustrated by Figure 1, track diesel prices closely). Despite this, at current prices and with a supplementary tax on diesel of £0.19 per litre, the average Euro 6 diesel car would retain a lower fuel bill per mile than the average Euro 6 petrol car.[33] Even if the supplementary tax (and therefore the differential with petrol prices) were high enough to reverse this[34], consumers tend to give more weight to short-term costs and benefits (e.g. vehicle purchase price), and 'discount' the value of costs and benefits yet to come. Studies suggest that the effects of a changing fuel price are only considered for about three years into the future.[35]
4. Although administratively very simple to introduce, such a supplementary tax could fall foul of public acceptability, and therefore political feasibility.[36] In Budget 2011 the 'Fuel Duty Escalator' was abolished, along with a 1p reduction in the existing rate. A 'Fair Fuel Stabiliser' was established in its place, in which Fuel Duty would rise in line with the Retail Price Index (RPI) when oil prices were high (above $75/bbl), and at RPI plus 1p when prices were below this for a sustained period. However, each planned increase in Fuel Duty, which applies equally to petrol and diesel, has been cancelled, leaving the rate frozen at 57.59p/litre since 2011 (despite steadily declining fuel retail prices), with its value decreasing in real terms.[37] A £0.19 per litre supplementary diesel tax would represent an equivalent Fuel Duty increase of 33% (perhaps initially producing up to the order of £4.5 billion additional annual revenue, but likely reducing with diesel consumption substantially thereafter[38]). Even if this were to be introduced in stages, at a lower (but still relatively high) annual rate of 3% on current levels, this would take 11 years for the full supplementary rate to materialise, further diluting any impact such a levy may have had. Additionally, such an increase in Fuel Duty would impact users of all (non-subsidised) diesel vehicles, regardless of type, age, emissions and usage profile, meaning that the addition of a supplementary tax may also be regressive[39], and produce substantial additional costs for commercial operations dependent on long distance road transport.

2.2 Supplementary NO_x Registration Tax

A common approach to encouraging a shift in the car fleet to a lower CO_2 intensity in many EU Member States is the use of registration taxes (a tax levied when a vehicle is first registered or purchased), linked (at least in part) to the CO_2 intensity of the vehicle.[40] In the UK, a flat rate Registration Tax of £55 is liable when a (petrol, diesel or alternatively-fuelled) car is registered and taxed for the first time. However, the CO_2-graded first-year rate of VED (sometimes known as a 'showroom tax') performs a function comparable to CO_2-graded registration taxes in other Member States (see Table 1).

33 Using April 2016 average petrol and diesel prices of 106.4p/litre and 106.9p/litre, respectively, and assuming average fuel cost for 12,000 miles driven of £1,444.77 and £1,066.17 for petrol and diesel respectively (Based on VCA data, see Footnote 32), the average fuel cost per mile is 3.2p higher for a petrol car. A 19p diesel supplement per litre would reduce this to 1.6p.

34 Using the assumptions outlined in Footnote 33, the diesel supplement would have to be 38p to achieve per mile fuel cost parity.

35 See, for example, Greene *et al* (2005) and Greene *et al* (2013).

36 However, in June 2016 the Secretary of State for Transport, Patrick McLoughlin, stated that Fuel Duty for diesel (along with Vehicle Excise Duty arrangements) were 'something the Chancellor will need to look at in due course'. See: http://www.standard.co.uk/news/politics/londons-diesel-car-owners-to-be-hit-by-tax-hike-to-tackle-air-pollution-a3265531.html

37 See Dempsey, Hough and Barton (2016) for a more in-depth discussion.

38 A 15-20% increase on 2015 Fuel Duty revenue (£27bn) (Data from HM Revenue and Customs receipts). Value assumes 2015 diesel sales of 27 billion litres (See: http://www.ukpia.com/industry_information/industry-overview.aspx), reduces initially by 10%.

39 Studies find that whilst fuel taxation is progressive if all households are considered, they are regressive when only car-owning households are considered. Additionally, due to the increased average travel distance, welfare losses are higher in rural areas. However, the effects depends to an extent on how revenue is recycled (Santos and Catchesises, 2005; Blow and Crawford, 1997)

40 In 2012, 14 Member States considered CO_2 emissions as part of the Registration Tax due, with 6 holding CO_2 as one of two parameters (with the other usually vehicle value) (Drummond, 2015).

Evidence suggests that such instruments have been generally effective in shifting purchase decisions to cars with lower CO_2 intensities.[41] As such, this approach may hold potential for tackling NO_x emissions (although, such an instrument is not able to influence emissions from existing vehicles, and as with fuel taxation, where and when emissions are produced). If applied as the only pricing instrument for addressing NO_x emissions from newly purchased and/or registered diesel cars, the 'optimal' rate to levy would equal to the net present value (NPV)[42] of the additional societal cost of the NO_x emissions produced by the vehicle over its lifetime, against a comparator. Although calculating such a value *ex-ante* for each vehicle individually is impossible in practice[43], estimations for the average vehicle may be reasonably calculated. Compared with an average Euro 6 petrol car, Howard (2016b) calculated that the average Euro 6 diesel car produces additional societal damage costs worth £800 over its lifetime. However, this is likely an underestimate. The two key assumptions behind this calculation are real-world NO_x emissions from the average Euro 6 diesel car of 270 $mgNO_x$/km (against the regulatory value of 80$mgNO_x$/km), and that both diesel and petrol cars exhibit the same average annual mileage.[44] However, recent studies show that Euro 6 vehicles likely exceed regulatory limits by 5-6 times in real-world conditions (as discussed in Section 1), and diesel cars travel significantly further each year on average.[45] When assuming a conformity factor of 5 (400 $mgNO_x$/km) and adjusting for mileage differences (whilst holding all else equal), this value would increase to £1,900. Regardless, this value represents an average for all Euro 6 diesel cars. If applied as an additional levy to a vehicle when registered and/or purchased, it would fail to distinguish between the most and least polluting diesel cars. As such, a graded approach, as per CO_2 emissions, would be preferable.

Table 4 presents estimated lifetime additional NO_x-related damage costs for average new diesel cars in the UK for different real-world emission Grades (as defined by the EQUA Air Quality Index, described below), against different comparators, and for different annual mileage assumptions.

Option 1 presents the average additional damage cost compared to a diesel car that meets the Euro 6 regulatory requirement in real-world conditions. Option 2 presents the average additional damage cost compared to a petrol car, which meets the relevant (more stringent) Euro 6 standards for NO_x. These values assume petrol and diesel cars travel the same average annual mileage. Option 3 and Option 4 repeat these calculations, but taking into account the difference in average annual mileage between petrol and diesel cars.

41 See, for example, Gerlagh *et al* (2015).

42 The current value of the sum of existing and future costs and benefits, with future costs and benefits discounted.

43 The factors that determine the damage costs of an individual car, such as the distance the car is driven, where and how, cannot be predicted.

44 See footnote 46 for values and sources (where appropriate), and other assumptions. A third key assumption is the use of an average UK damage cost of £25,252 /tNO_x from transport, as calculated by Defra (2015a). This represents a 'central' estimation for the emission of a tonne of NO_x averaged across different categories of urban and rural areas from transport. 'Low' and 'High' estimations are also available.

45 See Footnote 46 for values. This is likely due to the high proportion of diesel cars in the company car fleet (higher than that of the wider fleet), resulting from the financial incentives for the purchase of diesel, and the rapid turnover of the company car vehicles.

Table 4 – Average additional NO_x-related lifetime damage costs from new diesel cars[46]

		OPTION 1	OPTION 2	OPTION 3	OPTION 4
		Equal average annual mileage		Actual average annual mileage	
Grade	NO_x emissions (mg/km)	Above Diesel Euro 6 Value (80mg/km)	Above Petrol Euro 6 Value (60mg/km)	Above Diesel Euro 6 Value (80mg/km)	Above Petrol Euro 6 Value (60mg/km)
A*	<60	-	-	-	-
A	60-80	-	£40	-	£170
B	80-120	£80	£150	£100	£320
C	120-180	£270	£340	£360	£580
D	180-250	£510	£560	£690	£910
E	250-500	£1,120	£1,200	£1,520	£1,740
F	500-750	£2,070	£2,150	£2,800	£3,020
G	750-1000	£3,020	£3,100	£4,090	£4,310
H	>1000	£3,490	£3,570	£4,730	£4,950

Grades A-H, and associated NO_x emission ranges (in the second column), are those devised and by the EQUA Air Quality Index. Grade A vehicles meet the Euro 6 diesel standards in real-world emissions. Grade B and C vehicles meet the 1.5 and 2.1 conformity factor standards in real-world emissions, respectively. Grade D and E meet the Euro 4 and Euro 3 standards for diesel cars respectively, whilst cars in Grades F-H fail to meet even these standards (Emissions Analytics, 2016). In real-world testing of Euro 6 diesel vehicles by Emissions Analytics, only 10% fall into Grade A. Nearly a third are Grade E, whilst a further 20% are Grade D. 5% of those tested fell into Grade H (over 12.5 times the Euro 6 limit).[47] Grade A*, which has been added to the original EQUA grading system in this paper, corresponds to NO_x emissions at or below Euro 6 petrol standards.

A clear option might be the introduction of a tax, when a vehicle is registered and/or purchased, for each diesel car based on its Grade and associated additional damage costs, as presented in Table 4. However, two key issues arise. The first is the question of which of the four rate options should be applied. Given the difference in average annual mileage between petrol and diesel cars, it would be preferable to introduce Option 3 or 4, to more accurately reflect the additional social cost. Which of these remaining options is preferable depends on the objective of the tax. Option 4 is desirable from the perspective of economic efficiency and technological neutrality (amongst fossil fuel-propelled cars, at least). Option 3 is desirable if the objective is to penalise diesel cars with NO_x emissions that exceed their regulatory requirements in real-world conditions. However, given that the difference in value for bands between Options 3 and 4 is relatively small, the objective sought is likely to make relatively little difference in practice to the actual rates levied.

46 Based on the approach taken by Howard (2016b). UK average damage cost of £25,252/tNO_x from transport, as calculated by Defra (2015a). Average car lifetime of 15 years. Social discount rate of 3.5% applied as assumed by HM Treasury (2011). For 'equal annual average mileage', it is assumed all cars travel an average of 7,900 miles (12,714km) per year. For 'actual average annual mileage', these values are 6,700 miles (10,783km) and 10,700 miles (17,220km) for petrol and diesel cars, respectively. Values are sourced from Table NTS0902 of the National Travel Survey Statistics from DfT (2015a). It is assumed the average vehicle in each Grade emits at the central value (e.g. 100mg NO_x/km for grade B), except for Grade H, for which 1000 mgNO_x/km is assumed. All values are rounded to the nearest £10.

47 These values are based on the 62 Euro 6 diesel cars vehicles for which testing had been undertaken and results published, at the time of writing. More information, including on the test procedure, may be found at http://equa.emissionsanalytics.com/

The second issue is that of data availability and reliability. Existing data on real-world NO_x emissions for diesel cars are not yet comprehensive or produced by an agreed testing methodology. For example, although the EQUA index provides data for the majority of the Euro 6 diesel car market[48], it does not currently cover all models, and testing methodologies employed by different sources may yield different results. An approach to overcome this would be to set a default Grade to which all vehicles are assigned, with vehicles able to receive an improved grading and reduced tax rate if real-world emissions are found to be below that of the default Grade when voluntarily submitted to real-world testing by manufacturers (using a government-approved methodology).

To provide the greatest incentive for manufacturers to submit their vehicles for testing, the default Grade should be Grade H. However, it is possible that the imposition of a significant default levy associated with Grade H (between around £3,500 and £5,000) would prove politically unpalatable, with subsequent negotiations producing delays to the introduction of any mechanism to address NO_x emissions from diesel cars. Instead, given that the average Euro 6 diesel car would fall under Grade E for real-world emissions (around a third of the total, as discussed above), setting the default at this Grade may be an appropriate second-best choice. This provides an incentive for manufacturers with vehicles that may produce NO_x emissions at lower Grades to submit their vehicles for testing (although a third of tested for the EQUA index fall into Grade E, around half fall into Grades A-D[49]). However, it fails to directly target vehicles that may fall under Grades F-H. Given the relatively low proportion of vehicles on the market that fall into these Grades (the remaining 16% of the vehicles tested for the EQUA index), and the removal from the market of these vehicles entirely by September 2019, this may be a relatively minor issue.

To reduce conflict, the government-approved testing methodology should match the EU RDE testing methodology to be used for measuring compliance for new diesel car models from September 2017, and for all new diesel cars in September 2019. However, at the time of writing, the specific parameters for the new RDE test methodology have yet to be agreed upon. If delays in introducing a supplementary registration tax applied to all new diesel cars are to be minimised, then either such parameters must be agreed upon in short order, or another suitable (but likely similar) methodology should be used. The methodology employed by the EQUA Index may be an option. If so, then the vehicle grading already produced would significantly reduce any additional time and cost requirements.[50] It is likely that any difference between the results of the EU RDE methodology and another approved approach would be relatively small, and due to the broad width of the emission bands presented in Table 4, such differences are unlikely to result in different Grade assignments. In cases where this does occur, the results of one approach may take precedence, or an appeal procedure may be employed.

From September 2019 only diesel cars that fall into Grades A*-C may be sold. From January 2021, this reduces to Grades A*-B. As such, from September 2019 all diesel cars on the market must have been subject to EU RDE testing. If the same test methodology is employed unilaterally by the UK for the purposes of taxation, then additional testing would no longer be required, and values produced by EU testing would suffice for assigning vehicles to the appropriate (remaining) Grades. If an alternative methodology is used, then the Government may assess whether or not there is justification to continue with this testing in parallel (if, for example, there is evidence of deficiencies in the EU-approved test procedure). It may therefore be that Grades beyond A*-C remain,

48 At the time of writing, over 90% of all Euro 5 and Euro 6 car models.

49 As the EQUA Index does not consider Grade A*, it is not clear how many of these vehicles may fall into this category.

50 It may be that some form of compensation or cost-sharing mechanism is required in this case, to not penalise manufacturers of existing diesel models that have yet to be tested by the EQUA Index.

as appropriate. Whilst the presence of fewer Grades after September 2019 could be beneficial for administrative simplicity, it may be preferable to redefine and/or disaggregate the remaining Grades further over time to maintain a sufficient signal as the market begins to concentrate into these higher bands.[51] However, in the case of a parallel testing procedure, this may increase conflict as any differences between results become amplified.

There are two key channels for introducing a tax at the point a diesel car is registered and/or purchased:

- **Add a supplementary 'NO_x First Year Rate' for diesel cars** to operate alongside the existing CO_2-based First Year Rate and (flat-rate) Registration Tax. As CO_2 and NO_x emissions from a diesel car do not correlate, it is not possible to simply amend the existing First Year Rate to consider both objectives. Such separation also maintains clarity of the signal each rate produces, and allows for independent modification.
- **Revise the Registration Tax for diesel cars.** This option also maintains separation from the CO_2-related signal, but amends an existing levy rather than introducing another, with potentially positive (although given the scale of the modification, likely minor) consequences for public and political acceptability. Whether or not the rate is in addition to or displaces the current £55 rate will determine whether the (current) Registration Tax should remain applicable to other cars, or removed.

It would be appropriate to introduce either option to align with the changes to the VED planned for 1st April 2017 (discussed in Section 1). This may initially lead to additional annual revenue of the order of £650 million.[52] However, this value would be expected to reduce rapidly in following years as the NO_x emissions from the average diesel car declines (particularly as cars in above Grade C and subsequently Grade B become prohibited from sale), and as consumers switch to other fuels and transport modes.

2.3 Supplementary NO_x Circulation Tax

The use of circulation (or 'ownership') taxes (a tax levied, usually annually, to allow a vehicle to be used on public roads) is also an instrument often used to encourage a reduction in the CO_2 intensity of car fleets across EU Member States[53] – including the UK, where the VED Standard Rate is currently graded by CO_2 emissions (see Table 1). However, after the payment of the First Year Rate (which remains linked to CO_2 emissions), the Standard Rate will become a flat-rate £140 for all new vehicles registered on or after 1st April 2017 (with the current structure remaining applicable to all cars registered before this date).

If applied as the only pricing mechanism to tackle NO_x emissions from diesel cars, the 'optimal' rate to levy would be equal to the additional societal cost of the NO_x emissions produced by the vehicle in a single year (as a circulation tax is levied annually), against a comparator. Using the same structure and (relevant) assumptions used in the calculation of the values presented in Table 4, Table 5 presents options for a supplementary NO_x-related circulation tax.

51 This may be required by January 2021, if the 0.5 error margin/1.5 conformity factor is subject to alteration after review.

52 Total annual car sales are assumed to remain at around 2.7 million (following 2015 values), with the proportion of diesels reducing to 40% of sales (compared to over 48% in 2015) (SMMT, 2016b). It is also assumed that the average diesel car reduces from a Grade E to Grade C, and Option 4 in Table 4 is implemented. The resulting value is similar to the £500 million in revenue projected by Howard (2016b), based on a fixed £800 levy on sales of all new diesel cars (See: http://www.policyexchange.org.uk/media-centre/press-releases/category/item/raise-road-tax-on-new-diesel-cars-to-improve-air-quality-says-policy-exchange)

53 In 2012, 12 Member States considered CO_2 emissions as part of the Circulation Tax due (along with engine size/power), with 6 holding CO_2 as the sole parameter (Drummond, 2015).

Table 5 - Average additional NO_x-related annual damage costs from new diesel cars[54]

		OPTION 1	OPTION 2	OPTION 3	OPTION 4
		Equal average annual mileage		Different average annual mileage	
Grade	NO_x emissions (mg/km)	Above Diesel Euro 6 Value (80mg/km)	Above Petrol Euro 6 Value (60mg/km)	Above Diesel Euro 6 Value (80mg/km)	Above Petrol Euro 6 Value (60mg/km)
A*	<60	-	-	-	-
A	60-80	-	£0	-	£10
B	80-120	£10	£10	£10	£30
C	120-180	£20	£30	£30	£50
D	180-250	£40	£50	£60	£80
E	250-500	£100	£100	£130	£150
F	500-750	£180	£180	£240	£260
G	750-1000	£260	£260	£350	£360
H	>1000	£300	£300	£400	£420

If such values were to be introduced as a supplementary NO_x circulation tax, as with a supplementary registration tax, Options 3 and 4 in Table 5 would be those that most accurately reflects the (annual) social cost of NO_x emissions from the average new diesel car, with the appropriate choice depending on the specific objective (and again, as the difference in value for each band between Options 3 and 4 is relatively small, this would make little difference in practice). The values for Options 1 and 2 appear identical for most Grades due to rounding.

Issues discussed in relation to a supplementary NO_x Registration Tax/First Year Rate surrounding method of assigning vehicles to a NO_x emission Grade also apply here. The possible solutions are also the same. Again, entry into force on 1st April 2017 would also be appropriate to align with planned VED changes. As with a supplementary NO_x Registration Tax/First Year Rate, a supplementary NO_x Circulation Tax could not apply to and influence existing diesel cars (given the lack of and difficulty in obtaining real-world emissions data for such vehicles), nor can it target where and when emissions occur.

In addition, as opposed to registration taxes, the evidence suggests that circulation taxes have been ineffective in driving a reduction in CO_2 intensity of the car fleet, largely due to the discounting of future costs and benefits (discussed above in relation to fuel taxes).[55] As such, its potential for reducing NO_x emissions from diesel cars may also be limited. However, were it to be introduced, it may initially generate annual revenue of the order of £90 million (assuming it is introduced in addition to the £140 Standard Rate, applicable to all new cars).[56] This is substantially lower than the potential revenue generated by the instruments discussed above, although in this case, revenues are likely to rise rather than fall in the years following its introduction. Even if no new diesel cars were purchased after this first year, those that were purchased in previous years would continue to be

54 All assumptions as listed in Footnote 46 are applicable to these calculations, except for the 3.5% annual social discount rate and the assumed lifetime of the vehicle, which are not required. All values are rounded to the nearest £10.

55 See: Gerlagh *et al* (2015).

56 Total annual car sales are assumed to remain at around 2.7 million (following 2015 values), with the proportion of diesels reducing to 45% of sales (compared to over 48% in 2015) (SMMT, 2016b). It is also assumed that the average diesel car reduces from a Grade E to Grade D, and Option 4 in Table 5 is implemented.

charged annually at the rate appropriate to their Grade, producing relatively stable revenues. Although no new entrants to Grades D-H would be expected after September 2019, or to Grade C from January 2021, many diesel cars (or almost all, depending on the tax rate option chosen) that are purchased in the years following the instrument's first year would act to increase annual revenue (with revenue eventually decreasing as these vehicles begin to retire).

2.4 NO_x-related Road Pricing

The term 'road pricing' encompasses many specific instruments, however all require payment for the use of a road or roads. The payment due may be time-based, distance-based or zone-based, and be levied against different vehicle characteristics (e.g. vehicle type, size, emissions characteristics) for different objectives (e.g. congestion reduction, reduction of emissions, revenue raising). A single instrument may hold a combination of such elements.

Although other examples of road pricing exist in the UK,[57] those operating in London are the most prominent. Principal among these is the London Congestion Charge (LCC). The LCC, introduced in February 2003, applies to Central London on weekdays between 07:00 and 18:00. It charges £11.50 per day[58] for all vehicles entering the zone (except those eligible for discounts or exemptions), and is enforced through the use of automatic number plate recognition (APNR) technology. An Ultra Low Emission Discount (ULED) is available.[59] The ULED provides a 100% discount to all cars or vans that emit 75 gCO_2/km or less, and that meet the Euro 5 standards for their vehicle type. When combining these two criteria, no internal combustion-only vehicles currently qualify for the ULED.[60]

In line with other systems around the world[61], the evidence suggests that the LCC has been successful in reducing the use of private cars and encouraging a switch to public transport, contributing significantly to a 23% decline in vehicle-kilometres in Central London, and 11% in the wider London area, between 2000 and 2012.[62] Despite a reduction in traffic volume, traffic speeds have been reducing over the past decade due to reduced network capacity; a result of work to increase road safety, prioritise public transport, pedestrian and cycle traffic[63], and road works by utilities and general development activity. As such, overall congestion levels have remained largely stable since the introduction of the LCC, but are likely to have been higher without it (Transport for London, 2014). Between 2004 and 2009, trends in NO_x concentrations were 'weakly downwards'.[64] Operating in addition to the LCC is London's Low Emission Zone (LEZ). The LEZ, which covers most of Greater London and operates continuously, seeks to tackle tailpipe emissions from diesel-fuelled commercial vehicles through a charge of £100-£200 per day (depending on the vehicle[65]). The LEZ does not apply to cars (or other non-commercial vehicles).

57 Such as the Durham City Congestion Charge, and the M6 Toll (or Birmingham North Relief Road).

58 The charge may be paid online. However, the charge is £10.50 if using the 'CC Autopay' automated payment system, or £14 if paid by the end of the following day. A penalty charge of £130 is due for non-payment (reducing to £65 if paid within 14 days).

59 Cars belonging to residents of the LCC Zone are also eligible for a 90% discount. Vehicles exempt from the LCC include motorcycles, motor tricycles, mopeds, emergency service vehicles, taxi and private hire vehicles, and vehicles with nine or more seats (e.g. buses and coaches).

60 The ULED replaced the 'Greener Vehicle Discount' (GVD) in July 2013. The GVD provided a 100% discount to cars and vans with CO_2 emissions below 100 g/km. However, with no criteria for other air pollutants, the GVD favored small diesel engines over other low-carbon vehicles. The introduction of the ULED was in large part to remove this incentive. It also replaced the 'Electric Vehicle Discount'.

61 See Li and Hensher (2012) for a review 20 published studies examining the impact of congestion pricing around the world.

62 See Transport for London (2014). Such a result, as opposed to a switch to private cars that may be subject to reduced-rates or exemptions (such as electric cars), is common to the studies examined in Li and Hensher (2012). However, Börjesson *et al* (2012) found that the Stockholm congestion charge stimulated an increase in alternative-fuel vehicles, which are exempt from the charge.

63 Funded in part by the £1.2 billion spent on transport in London by revenues from the LCC (Transport for London, 2015a).

64 This trend is generally applicable across the country, although with significant variation at specific sites (Carslaw *et al*, 2011).

65 For a description of eligible and exempt vehicles, see: https://tfl.gov.uk/modes/driving/low-emission-zone/check-if-your-vehicle-is-affected

To help bring NO_x emissions in London within legal limits, an Ultra Low Emission Zone (ULEZ) is planned. The ULEZ is to be introduced in September 2020, and to cover the same area as the LCC (however in May 2016 it was announced that proposals for the ULEZ to extend to the North and South Circular roads, and to enter into force in 2019, would be put out to consultation). It will levy a daily charge for different vehicle types that do not meet certain exhaust emission standards. For cars (and small vans), these standards are Euro 4 for petrol and Euro 6 for diesel (thus, a common 80 $mgNO_x$/km standard – see Table 2). Cars that do not meet these standards must pay a £12.50 daily charge.[66] Vehicles that meet these standards will not be liable for any charge. The ULEZ will operate continuously, and in addition to the LCC and LEZ, and associated requirements and charges.[67] Modelling suggests that the ULEZ (as currently designed) could deliver a 51% reduction in NO_x emissions in Central London in its first year (along with a 64% reduction in PM emissions, and a 15% reduction in CO_2 emissions). This would be delivered through a combination of a switch from non-compliant to compliant vehicles, and a reduction in the number of vehicles entering the ULEZ. For cars, compliance rates are projected at 73% in the absence of the ULEZ. With the ULEZ, a ~5% reduction in vehicle-kilometres in Central London is projected, with the remaining cars reaching compliance at a rate of 93% (Transport for London, 2015a). Given that any non-compliant petrol car must be at least 14 years old by 2020, it is likely that the majority of this induced change would be through a reduced use and replacement of pre-Euro 6 diesel cars, with passengers switching to compliant cars or other modes of transport. For those that switch to compliant Euro 6 diesel cars, the gains in terms of NO_x emissions would be much reduced compared to those that switch to other compliant (petrol or alternatively-fuelled) cars, given the disparity in real-world and reported NO_x values.

The proposed ULEZ therefore does not adequately address NO_x emissions from the use of Euro 6 diesel cars in London. The introduction of Clean Air Zones to tackle NO_x emissions in other cities in England (as discussed in Section 1) would expand the use of road pricing in the UK, although such instruments currently plan to exclude cars from their scope. No other road pricing instruments (existing or proposed) seek to tackle NO_x emissions from cars.

As previously discussed, economic principles suggest that the most efficient way of internalising the externalities associated with the combustion of fuel would be to levy a tax at the point of emission (ideally at a rate equal to the marginal costs produced). Dynamic road pricing through the use of Global Navigation Satellite Systems (GNSSs) is a possible option to deliver this. A GNSS is able to track the movements of a vehicle including distance, location and time, data which may be used to levy an appropriate NO_x-related charge based on these variables, and the characteristics of the vehicle (determined either by real-world emissions testing, or through on-board diagnostics[68]). The vast majority of new cars are fitted with GNSS equipment that may be employed for this purpose, and from April 2018, all new cars in the EU must have such capability to some degree.[69] The introduction of such dynamic pricing would allow for other existing (and planned) taxes levied on cars and their use, such as the VED, the LCC (and planned ULEZ), and potentially Fuel Duty (if dynamic pricing

66 For an overview of the standards required of other vehicles, and the fees due for non-compliance, see: https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/check-your-vehicle?intcmp=32646#on-this-page-0

67 The ULEZ holds other requirements, including (a) all taxies and new private hire vehicles presented for licencing from 2018 must be 'zero emission capable', (b) a reduction in the age limit for non-zero emission capable taxis from 2020 from 15 to 10 years, and (c) all (TfL) double-deck buses operating in Central London must be hybrid, and all single-deck buses by zero emission, by 2020.

68 Directive 98/69/EC requires all new petrol and diesel cars (from 2001 and 2004, respectively), to be installed with on-board diagnostic systems (OBD). Amongst other things, OBD systems are able to (indirectly) monitor NO_x emissions. Existing legislation specifies that collected data must be made available for selected third party access for the purposes of engine maintenance and fault reporting. However, such data is not currently required to be available for regulatory compliance purposes (Lane & Loeliger, 2016).

69 The 'eCall Regulation' mandates that by April 2018, all new cars must be equipped with 'eCall' mobile data technology, which is able to contact emergency services and transmit the exact location of the vehicle in the event of an accident, independently of the driver. It may also be triggered manually.

is applied to all vehicles) to be removed, and their function transferred, merged and simplified (at least in part). It also allows for zone-based instruments, such as the ULEZ, to be expanded nationwide.

Although distance-based road pricing schemes measured by GNSS are used for levying charges for HGVs in some countries[70], and despite recommendations for its introduction in the UK and elsewhere[71], no such instrument for cars currently exists anywhere in the world.[72] The principal reason for this is a lack of public acceptability, particularly surrounding negative perceptions of the system and privacy issues.[73] Whilst this means that GNSS-based dynamic road pricing may be politically challenging to implement in the short term, reducing income from Fuel Duty and other externality-based tax instruments (such as VED) over time, resulting from a switch to hybrid and alternatively-fuelled cars (and other transport modes), is likely to mean that such an approach will become increasingly attractive (and necessary) in the medium to long term.

A more immediate option may be to alter the structure of existing and planned zone-based road pricing instruments in cities (where the impact of NO_x emissions is most acute), to address their current failings. For the ULEZ in London, the first option would be to remove the exemption for Euro 6 diesel cars that do not meet the regulatory limit in real-world emissions, and set a rate (approximately) equal to the marginal damage cost. However, again, two issues arise from this.

The first issue, as with instruments previously discussed, is differentiating between diesel cars with different NO_x emissions. If either of the two previous instruments discussed (supplementary NO_x Registration Tax/First Year Rate or Circulation Tax) have been introduced using real-world emission testing and grading, then such information would already be available for the majority of Euro 6 models. If not, an option may be to allow manufacturers to submit their vehicles to a test cycle approved by Transport for London (TfL)[74], to determine whether they fit into one of two categories, 'Euro 6 exempt', equivalent to Grades A* and A emissions according to the EQUA Index, and 'Euro 6 non-exempt', for vehicles that fall into all other Grades. The former may continue to receive a full exemption from the ULEZ charge. It may be possible to discourage speculative submissions by allowing TfL to absorb the cost of the test for cars that meet the Euro 6 exempt criteria, and charge the manufacturer for the cost of vehicles that do not. If this is introduced from the beginning of ULEZ in 2019 or 2020, it is possible that EU RDE test results from new models and new cars may be used. However, the charge should apply to all Euro 6 diesel cars, including those already sold, in order not to provide misaligned incentives.[75]

The second issue, again, is the level of the rate set (for Euro 6 non-exempt vehicles). Assuming a travel distance of 20km within the ULEZ in a day (in Central London, as currently planned), the value of the additional damage from NO_x emissions of an average Euro 6 diesel car compared to one that meets regulatory limits in real-world emissions is £0.92.[76] It is unlikely that charging the average Euro 6 diesel car at this rate per day would stimulate either a reduction in travel distance or the purchase of alternative vehicles.

For administrative simplicity, if comprehensive real-world emissions data is available by the time the ULEZ is introduced, a Euro 6 non-exempt diesel car

70 Germany, Hungary and Slovakia.

71 For example, the UK's Commission for Integrated Transport in 2002 recommended the use of a nationwide GNSS-based congestion charging system, alongside scrapping the VED and reducing Fuel Duty (Dodgson *et al*, 2002).

72 Such an instrument was planned for introduction in 2012 in the Netherlands, known as the 'Kilometre Charge', which would replace other vehicle taxes. However, its introduction was cancelled in 2010.

73 See Walker (2011) for an overview of public acceptability issues associated with road pricing.

74 TfL have developed their own drive cycle to test emissions from vehicles used on London's roads. For more information, see Transport for London (*undated*-a), and Transport for London (*undated*-b).

75 If not available from other sources, grading for Euro 6 vehicle models already sold may be determined through, for example, that assigned to the same or similar models available as new.

76 Assuming an average Euro 6 diesel car emits 400 $mgNO_x$/km compared to 80 $mgNO_x$/km regulatory limit. Damage costs for Central London of £115,405 /tNO_x are assumed, as calculated by Defra (2015a).

may be subject to one of two rates. Those falling into NO_x emission Grades B-E may be subject to a ‘reduced rate’, of perhaps £5. Although further investigation would be needed to determine its potential efficacy, such a value would act to provide a more substantive signal to the consumer, whilst remaining significantly below the rate that pre-Euro 6 diesel cars will be subject to (£12.50). It is also the rate levied when the LCC was first established. However, cars falling into Grades F-H, which do not meet regulatory requirements for even Euro 3 standards in real-world emissions, may be subject to the full £12.50 standard rate. This would incentivise against the use of the most polluting Euro 6 diesel cars to the same degree as pre-Euro 6 models. If comprehensive real-world emissions data is not available, but a mechanism is in place to determine which Euro 6 diesel cars are ‘exempt’ and ‘non-exempt’, then vehicles in the latter category may be charged the reduced rate only. Table 6 summarises these options.

Table 6 - Proposed Ultra Low Emission Zone charge rates for Euro 6 diesel cars

<table>
<tr><th colspan="3"></th><th colspan="3">ULTRA LOW EMISSION ZONE – EURO 6 DIESEL CAR RATE</th></tr>
<tr><th colspan="2">Grade</th><th>NO_x emissions (mg/km)</th><th>Currently Proposed</th><th>With Comprehensive Real-World Emissions Data</th><th>Without Comprehensive Real-World Emissions Data</th></tr>
<tr><td>A*</td><td rowspan="2">Exempt</td><td><60</td><td rowspan="9">£0</td><td rowspan="2">£0</td><td rowspan="2">£0</td></tr>
<tr><td>A</td><td>60-80</td></tr>
<tr><td>B</td><td rowspan="7">Non-exempt</td><td>80-120</td><td rowspan="3">£5</td><td rowspan="7">£5</td></tr>
<tr><td>C</td><td>120-180</td></tr>
<tr><td>D</td><td>180-250</td></tr>
<tr><td>E</td><td>250-500</td><td rowspan="4">£12.50</td></tr>
<tr><td>F</td><td>500-750</td></tr>
<tr><td>G</td><td>750-1000</td></tr>
<tr><td>H</td><td>>1000</td></tr>
</table>

Over time the instrument may be strengthened, with exemptions available only to ultra-low emission cars.[77] Transport for London (2015a) estimate that the ULEZ will generate approximately £12 million in revenue in its first year.[78] If the changes above are instituted, additional revenue in the region of £20-25 million may be generated (assuming the ULEZ mirrors the LCC area).[79] However, again, revenue would be expected to reduce as the market shifts towards exempt vehicles and alternative transport modes (in the absence of rate alterations). Such a design may be implemented in other cities around the UK, with perhaps differing charge rates and timeframes for implementation, reflecting local circumstances.

2.5 Diesel Company Car Taxation

The provision of a company car, where the employee is able to use the car for personal transport outside of their employment duties, is known as a ‘Benefit In

77 Aligning, to a large degree, with zero-emission requirements for new taxis and private hire vehicles entering into force from January 2018 and January 2020, respectively. For more information, see: https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/taxi-and-private-hire-requirements?intcmp=35073

78 However, it also notes that it expects operating costs of around £8 million, and a reduction in LCC income of around £4 million, making it essentially revenue neutral in its first year.

79 Assuming total number of vehicles (on a unique daily basis) entering the zone remains at 2015 levels (42.5 million)(See: http://data.london.gov.uk/dataset/vehicles-entering-c-charge-zone-month), 30% of these vehicles are cars, of with 40% of diesel. The value of 93% of compliance with Euro 6 is maintained, with 10% of these qualifying for ‘Euro 6 exempt’ status. This range holds for both implementation options.

Kind' (BIK), and forms part of the employee's taxable income. The BIK is formed of the list price of the car, plus VAT and delivery charges (but minus the First Year VED and Registration Tax), multiplied by an 'appropriate rate' set according to the CO_2 intensity of the vehicle. The result is then taxed at the individual's personal Income Tax rate.[80] Around 50% of vehicles purchased in the UK are for company car use, with this segment dominant in the larger, luxury diesel vehicle market. As diesel vehicles on average exhibit higher mileage than petrol equivalents, company cars therefore account for a significant proportion of the operational car fleet in the UK, and associated pollution (Conlan *et al*, 2016).

There are currently 30 CO_2 intensity bands, with BIK rates increasing incrementally from zero emissions (7% BIK rate) to >220 gCO_2/km (37% BIK rate). Rates in most bands are to increase by 2 or 3 percentage points annually to 2020, with an increasing number of bands falling into the 37% ceiling rate. For most of these bands diesel cars experience an additional 3% surcharge.[81] This rate was intended for removal in April 2016, but in the 2015 Autumn Statement it was announced that the surcharge was to be extended to 2021, 'in light of slower than expected introduction of more rigorous EU emissions testing', and will be removed thereafter, 'when EU-wide testing procedures will ensure new diesel cars meet air quality standards even under strict real-world driving conditions.'[82] However, as discussed in Section 1, these standards will still permit NO_x emissions from new diesel cars at double the rate of current Euro 6 petrol cars by this time. As such, reason remains to maintain an incentive to discourage their purchase. Two key options are available:

- **Maintain a flat-rate diesel surcharge**. Maintaining the 3% rate to all diesel cars beyond 2021 would appear to be the most direct option. However, as highlighted by Howard (2016b), it is unable to influence purchasing behaviour sufficiently. A solution may be to raise the surcharge rate. Although more administratively complex, the rate could rise for the purchase of new diesel company cars only, and be introduced as soon as possible. It may then be sufficient for the surcharge on existing diesel cars to continue at the current rate. However, regardless of the specific rate and whether it applies to new or existing cars, and although a flat rate may broadly stimulate a shift away from diesels, it fails to distinguish between the most and least NO_x-intensive diesel cars.
- **Differentiate diesel surcharge rate for new company cars according to real-world NO_x emissions.** This would particularly incentivise a shift away from the most NO_x-intensive diesel cars. As such an approach would require real-world NOx emission data, it would be most feasible to introduce in tandem with an instrument option above (such as a supplementary NO_x registration or circulation tax) that requires NO_x-related grading of diesel cars. As applying a revised rate to existing diesel company cars based on real-world emissions has been ruled out by the Government,[83] the existing surcharge rate could be maintained.

Although the additional revenue generated by these options depends very significantly on their specific design and implementation, such options may initially raise additional annual revenue of the order of £200 million.[84]

80 Petrol or diesel consumption, when paid for by the company, is also taxed as a benefit in kind. The taxable value is calculated as £22,000 (2016/17 rate), multiplied by the same 'appropriate rate'. The taxable value is reduced (or removed) according to the division between personal and private use, and whether the driver pays for a proportion (or all) of the fuel consumed. Electricity is not considered as a taxable benefit in kind.

81 However, the 37% BIK rate applies to both petrol and diesel cars. For the full list of annual BIK rates for each band to 2019/2020, see: https://www.theaa.com/resources/Documents/pdf/motoring-advice/company-car-tax-bik-2014to2020.pdf

82 See: https://www.gov.uk/government/speeches/chancellor-george-osbornes-spending-review-and-autumn-statement-2015-speech, and https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/479749/52229_Blue_Book_PU1865_Web_Accessible.pdf

83 See: http://www.parkers.co.uk/company-cars/news-and-advice/latest-news/2015/october/government-confirms-no-bik-changes-for-cars-fitted-with-defeat-devices/

84 Assuming an average additional new diesel car surcharge of 2% (i.e. total diesel surcharge of 5%), average combined list price and VAT value of £30,000, full taxation of all fuel (at the £22,200), a 30% income tax rate (assuming 50% of employees pay an income tax rate of 20%, and 50% pay a rate of 40%), and annual new company car registrations of 1.3 million (as per 2015 values (SMMT, 2016)), 50% of which are diesel.

3 Options for the Use of Revenue Generated

This section presents an overview of the key options available for the use of revenue generated by the instrument options outlined above. There are two key principles that should be applied when deciding how such revenue should be used:

- Any instrument should be **revenue neutral**. All revenue generated should be used either to offset the additional cost of the instrument by reducing taxes on socially desirable activities (such as labour), or to provide funds for other initiatives to further encourage a reduction in NO_x emissions from diesel cars.[85] Aside from the 'double dividend' this may produce[86], such ring-fencing of revenue increases the public acceptability of a tax compared to when revenue is 'lost' in broader government spending.[87]
- However allocated, the **use of revenue should not work against other environmental or public health objectives, and should ideally encourage their achievement**. If used to further the objective of reducing NO_x emissions, the manner through which this is achieved should not produce an increase in other pollutants, such as particulates or GHG emissions, and should encourage their reduction if possible.

It would therefore be inadvisable to use revenue generated to reduce other levies with an environmental or public health objective, such as the (current, or from April 2017, enhanced) CO_2-based First Year Rate for new registrations. The key options for the use of revenue are:

3.1 Reduce Taxation on Labour

Environmental Tax Reform' (ETR), commonly defined as 'reform of the national tax system where there is a shift in the burden of taxes, for example from labour to environmentally damaging activities, such as unsustainable resource use or pollution' (EEA, 2012), when well designed and implemented, is widely acknowledged to be broadly environmentally, economically and socially beneficial.[88] Although marginal, it has precedence in the UK, with the introduction of the Landfill Tax and Climate Change Levy (CCL) both accompanied by reductions in employer National Insurance Contributions (NIC).[89]

In 2015, Income Tax and NIC receipts totalled £168 billion and £113 billion, respectively. Using the indicative revenue estimations calculated for the four tax options that may be applied at the national level in this paper, Table 7 calculates the approximate proportion of annual Income Tax and NIC these instruments may displace.

Table 7 - Revenue Estimates as a Proportion of Income Tax and National Insurance Contribution Receipts

INSTRUMENT	PROPORTION OF INCOME TAX	PROPORTION OF NICS
Supplementary NO_x Tax on Diesel Fuel	2.42%	3.98%
Supplementary NO_x Registration Tax	0.39%	0.58%
Supplementary NO_x Circulation Tax	0.05%	0.08%
New Diesel Company Car Additional Surcharge	0.12%	0.18%

85 Once the administrative costs of the initial instrument, which would vary substantially between the options presented, have been covered.

86 The first 'dividend' is environmental improvement. The second 'dividend' is an improvement in economic efficiency through a shift in the tax burden. A broad overview of the double-dividend hypothesis may be found in Fullerton & Metcalfe (1997).

87 See, for example, Hsu, Walters and Purgas (2008) and Saelen & Kallbekken (2011).

88 For summary discussions see, for example, Withana *et al* (2014), EEA (2012a) and EEA (2012b).

89 The Landfill tax was accompanied by a reduction in employer's NIC of 0.2%, whilst the CCL was accompanied by a 0.3% reduction. Both were intended to compensate businesses for the cost burden associated with these two instruments.

A supplementary tax on diesel fuel would seem capable of displacing a substantial proportion of both Income Tax and NICs. Whilst the revenue from the remaining three instruments appears negligible in this context, they are of the order of (or higher than) the reduction in employer NICs introduced with the Landfill Tax and Climate Change Levy. However, the revenue estimates provided for these instruments are broad approximations, most of which would be expected to reduce rapidly and substantially even in the relative short term (except a supplementary NO_x Circulation Tax), as a shift to cars, fuels and transport modes with lower NO_x emissions gains pace. As such, their ability to offset other sources of taxation diminishes over time, potentially leading to income deficit.[90] Additionally, such use of revenue does not contribute to further reducing NO_x pollution (or aligned environmental or public health objectives). Given the 'public health emergency' such emissions are producing, the use of revenue for this purpose would seem preferable.[91]

3.2 Diesel Car Scrappage Scheme

Such a scheme would provide a capital grant for the purchase of a new car to individuals who choose to trade-in diesel cars to be scrapped, in order to encourage a shift in the car fleet to newer, less polluting vehicles. In 2009/10, the UK Government introduced a scrappage scheme as part of an economic stimulus package. The Government provided a capital grant of £1,000 for the purchase of any new car or van from participating manufacturers (who also agreed to provide a matched £1,000 discount on the list price), to UK citizens when scrapping a car or van that was over 10 years old, and which they had owned for 12 months or more. With a Government budget of £400 million, nearly 400,000 vehicles were scrapped and replaced over the duration of the scheme (around 20% of all new registrations during that time).[92] Despite the lack of environmental criteria for newly purchased vehicles, the Government estimates that the CO_2 intensity of new cars bought under the scheme were on average 25% lower than those scrapped.[93]

As such, the introduction of national scrappage scheme focussed on replacing diesel cars has been called for by a range of policy-making bodies in the UK (including the House of Commons' Environmental Audit Committee[94], the Environment, Food and Rural Affairs Select Committee[95], the London Assembly[96], and successive Mayors of London[97]), and enjoys support from other organisations.[98] However, the Government recently rejected a scrappage scheme for diesel cars as an option for tackling NO_x emissions.[99]

90 This was less of an issue for income from the Landfill Tax and Climate Change Levy, as opportunities (and the required incentive) to rapidly mitigate associated cost liabilities by reducing relevant types of waste and energy consumption were lacking (and in the case of the Landfill Tax, rates have increased substantially over time). However, from a broader perspective, could be argued that as NO_x-related social costs would be permanently reduced, reducing other public expenditure (e.g. healthcare) and increasing Government income through other channels (e.g. Proceeds from economic activity resulting from a larger, healthier workforce).

91 In addition, such use of revenues would be required if a tax is to meet the ONS definition of an environmental tax (See Footnote 26)

92 Although £300 million was initially provided when the scheme launched in May 2009, another £100 million was allocated in September 2009. The scheme concluded in March 2010. For more information on the vehicles scrapped, see: https://www.gov.uk/government/publications/car-scrappage-scheme-in-2009

93 The average CO_2 intensity for scrapped cars was estimated to be at least 179 gCO_2/km, compared to 133.9 gCO_2/km for new cars purchased under the scheme (Harari, 2009).

94 See: https://www.parliament.uk/documents/commons-committees/environmental-audit/Defra-air-quality-consultation-response.pdf

95 See: http://www.publications.parliament.uk/pa/cm201516/cmselect/cmenvfru/479/479.pdf

96 See: https://www.london.gov.uk/sites/default/files/Driving%20Away%20from%20Diesel%20final%20report.pdf

97 Former Mayor of London Boris Johnson called for such a scheme in 2014 (See: http://www.theguardian.com/environment/2014/sep/10/boris-johnsons-diesel-car-scrappage-scheme-could-cost-300m). The current Mayor of London, Sadiq Kahn, submitted to consultation in May 2016 plans to ask '*Transport for London (TfL) to start work on the costs and challenges of implementing a diesel scrappage scheme as part of a wider national scheme delivered by the Government'* (See: https://www.london.gov.uk/press-releases/mayoral/bold-plans-to-clean-up-londons-toxic-air)

98 For example, Howard (2016b) calls for a diesel scrappage scheme similar in design to the 2009/10 scheme, but not necessarily restricted to vehicles over 10 years old, with the grant to encourage purchase of low emission, but non-diesel cars.

99 See: http://www.telegraph.co.uk/news/2016/04/27/ministers-reject-diesel-scrappage-scheme-as-ineffective-and-expe/

There is evidence to suggest that a scrappage scheme may not be as environmentally effective as first appears. Despite the reduction in CO_2 intensity between new vehicles purchased and those scrapped under the 2009/10 scheme, analysis suggests that actual reductions in CO_2 were likely negligible, or perhaps even increased.[100] There are three key reasons for such an outcome: (a) as a result of increased fuel efficiency and thus reduced fuel costs, new cars tend to be driven further than older vehicles[101], (b) given the age of the cars scrapped, it is likely that such a scheme simply advances vehicle replacements that would have occurred in the near future anyway, meaning a large proportion of the gains sought from a scrappage scheme would be achieved without additional financial incentive, and (c) the manufacturing process of the new vehicles purchased, and the disposal process of the old vehicles scrapped also produces (directly or indirectly) various environmental emissions, which must be considered if a new vehicle was purchased and an old vehicle scrapped earlier than would otherwise have been the case.[102]

Analysis by Lawson & Gomm (2016) suggests that if the 2009/10 scrappage scheme were to be replicated with a focus on NO_x emissions, with 400,000 of the oldest diesel cars scrapped and replaced with Euro 6 equivalents, NO_x emissions may increase slightly, due to the increase in distance driven and the relatively small difference in average real-world emissions between new and scrapped vehicles.[103] Even if it were mandated that any new car purchased under the scheme must exhibit zero tailpipe emissions, a reduction of just 3.2% may be expected. Additionally, it is not clear whether such reductions would occur in areas where the damages from NO_x emissions are most pressing. As such, it is possible that using revenue generated from the instruments discussed above to fund a scrappage scheme for diesel cars may produce relatively small gains in terms of additional NO_x reduction, and may be counterproductive.

3.3 Capital Grants for Low-Emission Cars

Whilst the taxation instruments discussed above seek to make the purchase, ownership and use of NO_x-intensive diesel cars more expensive, a capital grant (provided independently or as part of a scrappage scheme discussed above) seeks to make the purchase of vehicles with low NO_x emissions less expensive. If coupled with a supplementary NO_x registration tax, a style of 'feebate' instrument would be formed.[104]

A nationwide 'Plug-in Car' Grant is available for the purchase of low CO_2 emission cars. The scheme was introduced in January 2011, and as of 1st March 2016 provides grants linked to three technology-neutral categories of low-emission cars, as defined by the Office for Low Emission Vehicles[105]:

- **Category 1** – CO_2 emissions less than 50 g/km, and a zero-emission range of at least 70 miles. Eligible for a grant of 35% of the purchase price, up to £4,500.
- **Category 2** – CO_2 emissions less than 50 g/km, and a zero-emission range of between 10 and 69 miles. Eligible for a grant of 35% of the purchase price, up to £2,500, for cars with a purchase price of less than £60,000. Cars above this value in this category are ineligible for a grant.

100 See, for example, Wadud (2014) and Brand *et al* (2013).

101 This is known as the 'rebound effect', and is borne out by the data. For all new cars (0-3 years), are driven an average distance of 10,400 miles per year. This reduces to 8,500 miles (3-6 years), 7,300 miles (6-13 years), and 5,600 miles (over 13 years). Values are sourced from Table NTS0903 of the National Travel Survey Statistics from DfT (2015a).

102 Such emissions are part of the wider 'lifecycle' emissions of a vehicle, include those produced (directly or indirectly) at all stages of the vehicles lifetime, including during its manufacture, use and disposal.

103 An increase in emissions of 0.2%. See Footnote 101 regarding the difference in mileage between old and new vehicles.

104 A 'feebate' is a combination and contraction of the words 'fee' and 'rebate'. An additional 'fee' is charged on the cost of a product activity with socially undesirable characteristics (e.g. diesel car with high NO_x emissions), with the revenue used to provide a 'rebate' (i.e. subsidy) for the cost of a similar product or activity with socially desirable (or less socially undesirable) characteristics (e.g. hybrid or electric car). 'Fees' and 'rebates' are usually proportional to the socially undesirable characteristic targeted, around a given 'pivot point' (e.g. a NO_x emission intensity).

105 Initially, the scheme provided a grant equal to 25% of the vehicle purchase price (capped at £5,000), and was available for any vehicle with CO_2 emissions of less than 75 g/km, with a zero-emission range of at least 10 miles (or 70 miles for all-electric vehicles).

- **Category 3** – CO_2 emissions of 50-75 g/km, and a zero-emission range of at least 20 miles. Eligible for a grant of 35% of the purchase price, up to £2,500, for cars with a purchase price of less than £60,000. Cars above this value in this category are ineligible for a grant.

Total (cumulative) funding of £400 million is available until March 2018, although the scheme will come under review once a total of 40,000 Category 1 claims, and 45,000 Category 2 and 3 combined claims, have been made. By the end of March 2015 more than 58,000 cars had been registered under the scheme since its inception, with uptake increasing rapidly since mid-2014.[106]

An option would be to use the revenue from a nationally applicable taxation instrument to support (and potentially enhance) this scheme beyond March 2018, in particular Category 1 vehicles, which in practice only ultra-low emission vehicles (fully electric and hydrogen cars) are currently eligible for.[107] However unlike a scrappage scheme, which encourages a one-for-one replacement of a vehicle, there is a risk that a direct capital cost grant encourages a net increase in the size of the vehicle fleet[108], with lifecycle damages associated with these net additions reducing the benefits of such an instrument.

3.4 Investment in Enabling Infrastructure for Low-Emission Cars

For the rapid increase in the sales of low and ultra-low emission cars to continue, remaining barriers to their uptake must be overcome. One such barrier is relatively high up-front capital cost, which the options above seek to address. Another is 'range anxiety'; the perception that the range of low and ultra-low emission vehicles (particularly electric) is not sufficient to travel between available charging or refuelling points. Although this issue is likely to progressively reduce over time (with increasing battery capacity, for example), providing sufficient infrastructure is essential to overcome this (both real and perceived) constraint.

Various national funding initiatives are currently in place to encourage the deployment of electric charging infrastructure across the UK, including the Electric Vehicle Homecharge Scheme[109], Plugged-in Places[110] and the Go Ultra Low City Scheme.[111] At present, around 4,000 charging locations are publically available around the country.[112] Revenue from national and/or city level NO_x-related taxation instruments may be used to extend or complement these initiatives, to accelerate the deployment of low-emission vehicle charging and refuelling infrastructure.[113]

106 Over 75% of ultra-low emissions cars in the UK were registered since mid-2014 (nearly 43,000 of the 58,000 total), with over 10,000 registered in the first three months of 2016 alone. See: DfT (2015b) and: https://www.goultralow.com/press-centre/releases/electric-car-registrations-reach-record-high-plug-popularity-continues-grow/.

107 See: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/502056/plug-in-grant-rate-changes-2016.pdf

108 This likely happened to some degree as a result of the French Bonus-Malus 'feebate' system (See: D'Haultfoeville *et al* (2013))

109 A grant of 75% of the cost of a residential electric car chargepoint (with a cap of £500) is available to individuals that purchase a new or used electric vehicle eligible for the Plug-In Car Grant, purchased after 1st April 2015.

110 In 2009, £30 million was made available under this scheme for eight locations (East of England, Greater Manchester, London, the Midlands, Milton Keynes, North East Northern Ireland and Scotland) for match-funding for consortia of business and public sector partners to support the installation of electric vehicle charging infrastructure.

111 In January 2016, it was announced that four cities (Nottingham, Bristol, Milton Keynes and London) would share a £35 million fund for specific initiatives (in large part surrounding the installation of charging points) to encourage the deployment of electric cars. A further £5 million has been allocated for smaller, more specific initiative in Dundee, Oxford, York and the North East region. For more information, see: https://www.goultralow.com/go-ultra-low-cities-winners-announced/

112 Across these locations are over 6,100 charging devices, and over 11,200 connectors (at the time of writing). For more information, see https://www.zap-map.com/statistics/.

113 The focus for the initiatives described above is electric car charging. As a result, at the time of writing, only 8 publically-available hydrogen refuelling points are present across the UK (See: http://www.carbuyer.co.uk/tips-and-advice/144957/hydrogen-cars-all-you-need-to-know)

3.5 Investment in Low Emission 'Car Clubs'

'Car clubs' provide access to shared vehicles, with users charged based on time, distance travelled, or both. Car clubs may function with different operational models[114], with vehicles commonly arranged in 'clusters' of dedicated parking bays. The operator of the club is responsible for purchasing, repairing, insuring and servicing the vehicle, with the cost recovered through the fees charged to members. The target membership is individuals and organisations that require occasional rather than frequent or continual use of a vehicle.[115] As such, car clubs hold particular potential in areas of high population density.

There are currently over 220,000 car club members across the UK, sharing 3,800 vehicles. Clubs in London are dominant, with 186,000 members sharing 2,800 cars. It is estimated that car club membership in London has led to the removal of 25,000 cars from the road, with an average annual mileage reduction of 750 miles per member, and an annual reduction in CO_2 emissions of 36,000 tonnes (with car club vehicles exhibiting a CO_2 intensity around 30% less than the national average car) (Carplus, 2016). NO_x and other local air pollutants will also have been reduced, along with indirect lifecycle emissions from new car purchases forgone. Congestion is also likely to have been eased.

Such benefits may be amplified and distributed more widely if revenue generated from the instruments discussed above were to be channelled towards expanding the presence and use of car clubs, both in London and (particularly in other cities) nationwide. This would be particularly the case if such car clubs employed ultra-low emission vehicles. Indeed, such investment would match with existing plans, such as the target of one million car club members in London by 2025.[116]

3.6 Investment in Public and Active Transport

The presence and use of public transport and active (i.e. walking and cycling) transport infrastructure may produce several benefits. Alongside reducing the emission of various pollutants (including NO_x and GHG emissions, particularly if the public transport concerned is low or ultra-low emissions), it may also relieve congestion, and in the case of active transport, serve to tackle other public health issues, producing additional social and economic benefit.[117]

Figure 2 illustrates that car and van passenger transport, in terms of both the average number of trips taken and average distance travelled per person per year, are dominant in England.[118] Active transport (walking and cycling) ranks higher than remaining modes in terms of trips taken, although distance travelled is lower than all other modes. The proportional split for all modes remained relatively stable between 2004 and 2014. However, this masks trends at the local level. For example, in London, journeys made by private transport reduced by 7% between these years (39% to 32%), whilst public and active transport increased (from 60% to 68%).[119]

114 'Round-trip' car clubs (vehicles picked up and returned to the same location), 'Fixed one-way' clubs (vehicles picked up and returned to different set locations), and 'Floating one-way' clubs (vehicles can be picked up from and returned to any location).

115 The five criteria that define a car club are: '(a) 24/7 on-demand access, (b) self service access, (c) cars located conveniently: normally local to home, workplace or transport hub, (d) ongoing access to the service following some form of sign-up and membership, and (e) members often feel mutually responsible for the shared resource, hence the term car 'club'. This also translates to loyalty to a brand and a desire to ensure that the service quality is maintained' (Car Club Coalition, 2015, p.8).

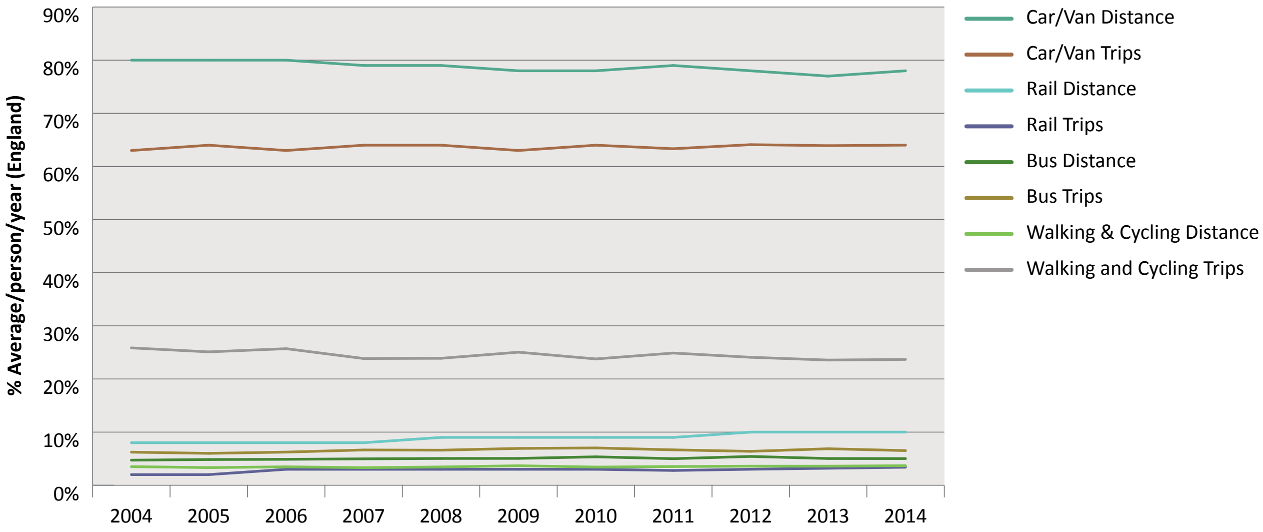
116 As presented by the 'Car Club Strategy for London. See: https://tfl.gov.uk/modes/driving/car-clubs/how-car-clubs-work

117 Active transport may lead to reductions in cardiovascular disease, dementia, diabetes and several cancers, along with reduced duration and severity of depressive episodes – all of which are linked to obesity and are costly to treat (Woodcock *et al*, 2009). Sustrans (2015) estimate that by doubling the number of local journeys already being made by foot, bike and public transport the economy would benefit by over £110 billion over the next 30 years, from the impact on health alone.

118 2004-2012 values closely mirror those for all Great Britain (see Department for Transport Statistics Tables NTS0303 and NTS0305). Values for 2013 and 2014 are not available at a national level.

119 Public transport increased from 38% to 45%, cycling increased from 1% to 2%, and walking remained largely stable at 21% (Transport for London, 2015b).

Figure 2 - Proportion of average annual distance and trips taken per person per mode in England[120]



Various initiatives are currently in place to promote the establishment and use of, and reduced pollution from, public and active transport options. At the national level this includes the Low Emission Bus Scheme[121], the Clean Bus Technology Fund[122], and various funds available for promoting walking and cycling.[123] Such initiatives are complemented at the local level through, for example, the creation of segregated cycle lanes and a bicycle hire network in London.[124] The use of revenue generated from tax instruments at the national and/or local level to tackle NO_x from diesel cars may be used to extend or complement these funds and initiatives, in order to accelerate the switch from private vehicles to (ultra-low emission) public and active transport happening in London, and to encourage other regions of the UK (particularly cities) to follow suit. Such use of revenues would contribute directly to declared aims, targets and strategies, such as those detailed in the Government's Walking and Cycling Investment Strategy and the Mayor of London's Transport Strategy.[125]

120 Data sourced from Department for Transport Statistics Tables NTS0303 and NTS0305. 'Rail' includes both surface rail and London Underground. 'Bus' includes local and non-local busses. 'Car/Van' includes trips as both as driver and passenger.

121 £30 million available for the purchase of low and ultra low emission busses by local authorities and transport operators across England and Wales. For more information, see: http://www.lowcvp.org.uk/initiatives/leb/Home.htm

122 For the 2015 round, £7 million was awarded to 18 local authorities to retrofit 439 buses with technology to reduce NO_x emissions.

123 Over £300 million has been made available to promote walking and cycling during the current Parliament. For more information on the specific funds that comprise this, along with broader funding initiatives, see DfT (2016c).

124 In 2015, over £145 million was earmarked for investment in cycling in London, with £913 million planned for investment in cycling in the ten years from 2013 (Mayor of London, 2013).

125 For more information see: DfT (2016c) and: https://www.london.gov.uk/what-we-do/transport/transport-publications/mayors-transport-strategy. Indeed, by law, and as with the LCC, any revenue raise from road user charging schemes (such as the ULEZ) must be spent on furthering the aims of the Mayor's Transport Strategy (Transport for London, 2015a, p.38).

4 Conclusions and Recommendations

The level of air pollution in the UK, including from nitrogen oxides (NO_x), is producing a 'public health emergency', leading to up to 52,500 premature deaths and a cost to the economy of up to £50 billion in the UK each year. Road transport is the single greatest source of NO_x emissions, with diesel cars a substantial contributor. The primary instrument for tackling NO_x (and other non-GHG) emissions from cars in the EU is the 'Euro' standards. However, they have been relatively ineffective in reducing NO_x emissions from diesel cars, for two reasons. First, successive standards have permitted diesel cars to emit more NO_x than petrol cars. Second, there is a substantial gap between reported and 'real-world' NO_x emission levels for many diesel cars (with real-world emissions exceeding regulated levels by 5-6 times on average, across the EU). Although measures to address these shortcomings have been adopted, including the use of 'Real Driving Emissions' (RDE) testing, they are insufficient. 'Conformity factors' mean that new diesel cars will be permitted to emit NO_x at rates significantly higher than their Euro 6 limit; more than double to the end of 2020 (seven years after the regulation came into force). From 2021, new diesel cars will still be permitted to emit NO_x at double the rate of new petrol cars sold today. This means that NO_x emissions from diesel cars sold in the UK between September 2014 and December 2021 may produce additional costs to society of around £12 billion over their lifetimes, compared to the purchase of petrol cars.

The EU's Air Quality Directive set limits on the concentrations of key chemicals, including NO_2, in outdoor air. In the 43 areas of the UK, 38 remain in breach of these limits. The original deadline for achieving compliance was 2010. In response to a Supreme Court ruling, the Government published plans for reducing air pollution towards regulatory requirements. However, the measures set out in these plans mean that 37 of the 38 zones in breach would remain non-compliant until 2020, with London remaining non-compliant until 2025. In response, further legal proceedings have been initiated against the Government. Regardless of whether the Government becomes legally obliged to produce a second, more effective national plan for reducing NO_x emissions, given the public health emergency such emissions (along with other air pollutants) is giving rise to, further action is warranted at the national level, city level, or both, to reduce NO_x emissions from diesel cars.

Although not sufficient in isolation, taxation instruments hold a number of benefits that may complement the existing policy landscape. They may induce changes in consumer preferences, they are often more flexible, more able to account for nuances in the objective and implementation, and easier to adjust over time in response to new developments. This paper presents and assesses five key tax options: a supplementary NO_x tax on diesel fuel, a supplementary NO_x registration tax, a supplementary NO_x circulation tax, NO_x-related road pricing, and a reform of company car taxation arrangements for diesel cars. Taxation instruments also generate a revenue stream, which may be used to further promote the objective of the tax. Six options for the use of revenue generated were assessed: reduce taxation on labour, a diesel car scrappage scheme, capital grants for low-emission cars, investment in enabling infrastructure for low-emission cars, investment in low-emission 'car clubs', and investment in public and active transport. From this assessment, key recommendations are:

- The introduction of a **national supplementary NO_x Registration Tax** for diesel cars. The tax due at the point of registration and/or purchase would be approximately proportionate to the real-world NO_x emission intensity of the vehicle, with the most polluting vehicles charged up to £3,500-£5,000 (based on their UK average additional lifetime NO_x-related damage costs, against a chosen comparator). Real-world NO_x emissions may be determined either through existing data, or though mechanisms to encourage manufacturers to submit their vehicles for testing. Such an instrument encourages consumers to purchase less polluting cars and use other transport options, and could be introduced (and work alongside) the reform of the CO_2-based Vehicle Excise Duty in April 2017. However, a supplementary NO_x registration tax does not impact emissions from diesel cars already on the road, nor does it act to focus a reduction in NO_x emissions from diesel cars in densely populated urban areas, where the damage to human health and environment is greatest.

- This may be addressed through the parallel introduction of **city-level NO_x-related road pricing** for diesel cars. In London, the Ultra-Low Emission Zone (ULEZ) charge planned for introduction in 2019/20 may be amended to include diesel cars purchased after September 2014 (Euro 6 vehicles), which are currently excluded from the proposed levy. The rate due on these vehicles would depend on their real-world emissions reported as part of the national supplementary NO_x Registration Tax, or if this has not been introduced, determined by an independent mechanism. Such an instrument may be emulated in other key cities around the UK, broadly in line with plans for Clean Air Zones for cities in England.

- Company cars account for approximately half of all new car sales. As registration tax and First Year Vehicle Excise Duty do not form the taxable 'benefit in kind' received by a company employee in receipt of a company car, additional measures to prevent the purchase of highly-polluting diesel cars for this purpose is required. Therefore, the **diesel surcharge for new company cars may be increased, or graded according to NO_x emission intensity**.

- For both national and city-level instruments, using revenue generated for **investment in low-emission public and active transport infrastructure should be a priority**. Such transport investment not only reduces NO_x emissions (by providing an alternative to private (and motorised) transport), it acts to serve other environmental and public health objectives (e.g. reducing greenhouse gas emissions and obesity), conferring further social and economic benefits. Other options, such as investment in **low-emission car clubs** or **infrastructure to accelerate the deployment of low-emission cars**, may also be appropriate.

References

AA (2016) *Fuel Price Report: UK & Overseas Petrol and Diesel Prices – April 2016*, [Online] Available at: http://www.theaa.com/motoring_advice/fuel/ [Accessed 18th May 2016]

Blow, L and Crawford, I. (1997) *The Distributional Effects of Taxes on Private Motoring*, The Institute for Fiscal Studies, London

Börjesson, M., Eliasson, J., Hugosson, M.B., Brundell-Freij, K. (2012) The Stockholm congestion charges – 5 years on. Effects, acceptability and lessons learnt, *Transport Policy*, 20, 1-12

Brand, C., Anable, J., Tran, M. (2013) Accelerating the transformation to a low carbon passenger transport system: The role of car purchase taxes, feebates, road taxes and scrappage incentives in the UK, *Transportation Research Part A: Policy and Practice*, 40, 132-148

Car Club Coalition (2015) *A Car Club Strategy for London: Growing car clubs to support London's transport future*, [Online] Available at: http://content.tfl.gov.uk/tfl-car-club-strategy.pdf [Accessed 30th May 2016]

Carplus (2016) *Car clubs in London: Changing the way Londoners Travel*, [Online] Available at: http://www.carplus.org.uk/wp-content/uploads/2016/04/Carplus-Annual-Survey-of-Car-Clubs-in-London-A4-AW.pdf [Accessed 30th May 2016]

Carslaw, D.C., Beevers, S.D., Westmoreland, E., Williams, M.L., Tate, J.E., Murrells, T., Stedman, J., Li, Y., Grice, S., Kent, A. Tsagatakis, I. (2011) *Trends in NO_x and NO2 emissions and ambient measurements in the UK*, Department for Environment, Food and Rural Affairs, London

Conlan, B., Fraser, A., Vedrenne, M., Tate, J., Whittles, A. (2016) *Evidence review on effectiveness of transport measures in reducing nitrogen dioxide*, Department for Environment, Food and Rural Affairs, London

D'Haultfoeville, X., Givord, P., Boutin, X. (2013) The Environmental Effect of Green Taxation: The Case of the French Bonus/Malus, *The Economic Journal*, 124, p444-480

Defra (2015a) *Valuing Impacts on air quality: updates in valuing changes in emissions of Oxides of Nitrogen (NO_x) and concentrations of Nitrogen Dioxide (NO2)*, UK Department for Environment, Food and Rural Affairs, London

Defra (2015b) *Draft plans to improve air quality in the UK: Tackling nitrogen dioxide in our towns and cities*, Department for Environment, Food and Rural Affairs, London

Defra (2015c) *Improving air quality in the UK: Tackling nitrogen dioxide in our towns and cities – UK overview document,* Department for Environment, Food and Rural Affairs, London

Dempsey, N., Hough, D. Barton, C. (2016) *Petrol and Diesel Prices*, Briefing Paper Number 04712, House of Commons Library, London

DfT (2016a) *Vehicle Emissions Testing Programme: Moving Britain Ahead*, UK Department for Transport, London

DfT (2016b) *Traffic counts*, [Online] Available at: http://www.dft.gov.uk/traffic-counts/download.php [Accessed 14th June 2016]

DfT (2016c) *Cycling and Walking Investment Strategy*, UK Department for Transport, HM Government, London

DfT (2015a) *Vehicle milage and occupancy (NTS09)*, [Online] Available at: https://www.gov.uk/government/statistical-data-sets/nts09-vehicle-mileage-and-occupancy [Accessed 5th May 2016]

DfT (2015b) *Number of newly registered ultra low emissions vehicles*, [Online] Available at: https://www.gov.uk/government/publications/number-of-newly-registered-ultra-low-emissions-vehicles [Accessed 30th May 2016]

Dodgson, J., Young, J and van der Veer, J.P. (2002) *Paying for Road Use: Technical Report – A Report for the Commission for Integrated Transport*, Commission for Integrated Transport, London

Drummond, P. (2015) *Policies to Deliver a Low-Carbon Energy System in Europe: Examining Different Policy Pathways*, University College London, London

EEA (2016) *Reported CO_2 emissions from new cars continue to fall*, [Online] Available at: http://www.eea.europa.eu/highlights/reported-co2-emissions-from-new [Accessed 2nd May 2016]

EEA (2011a) *Environmental tax reform in Europe: Implications for income distribution*, EEA Technical Report No 16/2011, European Environment Agency, Copenhagen

EEA (2011b) *Environmental tax reform in Europe: Opportunities for eco-innovation*, EEA Technical Report No 17/2011, European Environment Agency, Copenhagen

EFRAC (2016) *Air Quality: Fourth Report of Session 2015-16*, HC479, UK House of Commons Environment, Food and Rural Affairs Committee

Emissions Analytics (2016) *EQUA Air Quality Index Technical FAQ*, [Online] Available at: http://emissionsanalytics.com/equa-air-quality-index-technical-qa/ [Accessed 5th May 2016]

European Commission (2015) *FAQ – Air pollutant emissions standards*, [Online] Available at: http://europa.eu/rapid/press-release_MEMO-15-5705_en.htm [Accessed 15th June 2016]

Fullerton, D. and Metcalfe, G.E. (1997) *Environmental Taxes and the Double Dividend: Did You Really Expect Something for Nothing?*, NBER Working Paper No. 6199, National Bureau of Economic Research, Cambridge, M.A.

Gerlagh, R., van den Bijgaart, I., Nijland, H., Michielsen, T. (2015) *Fiscal policy and CO_2 emissions of new passenger cars in the EU*, CPB Discussion Paper 302, CPB Netherlands Bureau for Economic Policy Analysis,

Greene, D.L., Evans, D.H., Hiestand, J. (2013) Survey evidence on the willingness of U.S. consumers to pay for automotive fuel economy, *Energy Policy*, 61, 1539-1150

Greene, D.L, Patterson, P.D., Singh, M., Li, J. (2005) Feebates, rebates and gas-guzzler taxes: a study of incentives for increased fuel economy, *Energy Policy*, 33, 757-775

Harari, D. (2009) *Vehicle scrappage scheme*, Standard Note SN/EP/5177, House of Commons Library, London

HM Treasury (2011) *The Green Book: Appraisal and Evaluation in Central Government*, HM Treasury

Hodenbrog, Ø., Myhre, G., Samset, B.H. (2014) How shorter black carbon lifetime alters its climate effect, *Nature Communications*, 5, doi:10.1038/ncomms6065

Howard, R. (2016a) *Up in the Air – How to Solve London's Air Quality Crisis: Part 1*, Policy Exchange, London

Howard, R. (2016b) Up in the Air - How to Solve London's Air Quality Crisis: Part 2, Policy Exchange, London

Hsu, S-L., Walters, J., Purgas, A. (2008) Pollution tax heuristics: An empirical study of willingness to pay higher gasoline taxes, *Energy Policy*, 36(9), 3612-3619

ICCT (2015) *Real-World Fuel Consumption and CO_2 Emissions of New Passenger Cars in Europe*, The International Council on Clean Transportation

Mazzi, E.A. (2007) Air Quality Impacts of Climate Mitigation: UK Policy and Passenger Vehicle Choice, *Environmental Science and Technology*, 41, 387-392

Lane, B. and Loeliger, J. (2016) *An alternative to vehicle type approval regulation: Continuous Vehicle Emissions Monitoring (CVEM)*, Next Green Car and NXP Semiconductors

Lawson, A. and Gomm, P. (2016) *Would a diesel car scrappage scheme improve air quality?*, RAC Foundation

Li, Z. and Hensher, D.A. (2012) Congestion charging and car use: A review of stated preference and opinion studies and market monitoring evidence, *Transport Policy*, 20, 47-61

Mayor of London (2013) *The Mayor's Vision for Cycling in London: An Olympic Legacy for all Londoners*, Greater London Authority, London

OECD (2001) *Environmentally Related Taxes in OECD Countries: Issues and Strategies*, Organisation of Economic Cooperation and Development, Paris

ONS (2015) *Environmental Taxes – 2014*, Office for National Statistics

RCP & RCPCH (2016) *Every breath we take: the lifelong impact of air pollution*, Royal College of Physicians, London

Saelen, H. and Kallbekken, S. (2011) A choice experiment on fuel taxation and earmarking in Norway, *Ecological Economics*, 70(11), 2181-2190

Santos, G. and Catchesides, T. (2005) Distributional Consequences of Gasoline Taxation in the United Kingdom, *Transportation Research Record: Journal of the Transportation Research Board*, 1924, 103-111

Schmidt, C.W. (2011) Black Carbon: The Dark Horse of Climate Change Drivers, *Environmental Health Perspectives*, 119 (4), 172-175

SMMT (2016) *New Car CO_2 Report 2016*, The Society of Motor Manufacturers and Traders Limited, London

SMMT (2016b) *Record year for new car market as registrations hit 2.6 million in 2015*, [Online] Available at: http://www.smmt.co.uk/2016/01/record-year-for-new-car-market-as-registrations-hit-2-6-million-in-2015/ [Accessed 31st May 2016]

Sustrans (2015) *Cycling and walking routes save the economy £1 million a day*, [Online] Available at: http://www.sustrans.org.uk/press-releases/cycling-and-walking-routes-save-uk-economy-%C2%A31-million-day#_edn4 [Accessed 13th June 2016]

The Scottish Government (2015) *Cleaner Air for Scotland: The Road to a Healthier Future*, The Scottish Government, Edinburgh

Transport for London (2015a) *Ultra Low Emission Zone: Report to the Mayor*, Transport for London

Transport for London (2015b) *Travel in London: Report 8*, Transport for London

Transport for London (2014) *Public and stakeholder consultation on a Variation Order to modify the Congestion Charging scheme: Impact Assessment*, Transport for London

Transport for London (*undated*-a) *London Exhaust Emissions Study: A summary of the drive cycle development, test programme and comparison of test data compared with Type Approval data*, Transport for London, London

Transport for London (*undated*-b) *London Exhaust Emissions Study: Developing a test programme and analysis of emissions data from passenger cars in London*, Transport for London, London

Wadud, Z. (2014) New vehicle fuel economy in the UK: Impact of the recession and recent policies, *Energy Policy*, 74, 215-223

Walker, J. (2011) *The Acceptability of Road Pricing*, RAC Foundation

Walton, H., Dajnak, D., Beevers, S., Williams, M., Watkiss, P., Hunt, A. (2015) *Understanding the Health Impacts of Air Pollution in London*, Kings College London, London

Weiss, M., Bonnel, P., Hummel, R., Manfredi, U., Colombo, R., Lanappe, G., Le Lijour, P., Sculati, M. (2011) *Analyzing on-read emissions of light-duty vehicles with Portable Emission Measurement Systems (PEMS)*, European Commission Joint Research Centre Institute for Energy, Ispra

Withana, S, ten Brink, P., Illes, A., Nanni, S., Watkins, E. (2014) *Environmental Tax Reform in Europe: Opportunities for the Future*, Institute for European Environmental Policy, Brussels

Woodcock, J., Edwards, P., Tonne, C., Armstrong, B.G., Ashiru, O., Bannister, D., Beevers, S., Chalabi, Z., Chowdhury, Z., Cohen, A., Franco, O.H., Haines, A., Hickman, R., Lindsay, G., Mittal, I., Mohan, D., Tiwari, G., Woodward, A., Roberts, I. (2009) Public health benefits of strategies to reduce greenhouse gas emissions: urban land transport, *The Lancet*, 374, 1930-1943.

Green Budget Europe (GBE) is a non-profit organisation advocating a shift in tax from labour and on to pollution and non-renewables. Based in Brussels, GBE has members and / or partner organisations in 22 Member States, including the UK, and is supported by economists and fiscal experts across Europe and beyond. We achieve our goals through research, knowledge exchange and advocacy work both at EU level and within EU Member States. Ultimately, GBE works to foster a broad-based, cross-party consensus in favour of environmental fiscal reform with the support of a wide range of stakeholders.

UCL Institute for Sustainable Resources (UCL ISR) was established as an academic department at University College London in 2011. It is a cross-disciplinary institute set up to carry out research, teaching and enterprise work in the sustainable use of resources and the environment. The UCL Institute for Sustainable Resources is part of The Bartlett School of Environment Energy and Resources, along with the UCL Energy Institute, the UCL Institute for Environmental Design and Engineering and the UCL Institute for Sustainable Heritage.

For any questions please contact:

Rozan Consten rozan.consten@green-budget.eu
Paul Drummond p.drummond@ucl.ac.uk

Green Budget Europe (GBE)
Rue du Trône 4
Visitors entrance: Avenue Marnix 28
B-1000 Brussels
T: +32 2 588 57 65
www.green-budget.eu

Printed on 100% recycled, chlorine-free paper using vegetable ink. Design: www.beelzepub.com

GreenBudgetEurope