Readdressing the balance between petrol and diesel demand

Nick Vandervell
September 2015

RAC Foundation

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

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About the Author

Nick worked in the oil industry since the early 1980s, both in the exploration side of the business, as well as ‘downstream’ refining and marketing. He has a keen interest in energy issues and the motor industry, the latter inherited from his family’s past involvement in the industry.

He was Communications Director of the UK Petroleum Industry Association, which represents the eight main oil refining and marketing companies, between 2004 and the end of 2013.

During that time he was responsible for developing and implementing a communications strategy that encompassed government and media relations, issues management and the writing of a wide range of articles and briefing papers, as well as co-authoring or authoring major publications such as ‘Meeting our energy needs – the Future of UK Oil Refining’ and ‘Fuelling the UK’s future – the role of our refining and downstream oil industry’.

Acknowledgements

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Disclaimer

This report has been prepared for the RAC Foundation by Nick Vandervell. Any errors or omissions are the author’s sole responsibility. The report content reflects the views of the author and not necessarily those of the RAC Foundation.

Contents

List of Abbreviations and Terms

CCT	company car tax
CDU	crude distillation unit
CNG	compressed natural gas
CO_2	carbon dioxide
CONCAWE	CONservation of Clean Air and Water in Europe: oil industry research body
DECC	Department of Energy & Climate Change
DfT	Department for Transport
E5	petrol with up to 5% ethanol by volume
EC	European Commission
ETBE	ethyl-tertiary butyl ether
EUCAR	European Council for Automotive Research and Development
FCC	fluid catalytic cracker: unit that converts high-boiling-point crude feed to petrol/gasoline
FQD	Fuel Quality Directive (EC)
gCO_2/km	gram of CO_2 per kilometre
GHG	greenhouse gas
GPSS	Government Pipeline and Storage System
HGV	heavy goods vehicle
Hydrocracker	process unit within a refinery which increases yields of diesel
Hydrotreater	process in a refinery using hydrogen to remove sulphur
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
JRC-IET	Joint Research Centre – Institute for Energy and Transport
LCV	light commercial vehicle (sometimes known as light goods vehicle, LGV)

LEZ	Low Emission Zone
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MOSES	IEA's Model Of Short-term Energy Security
NEDC	New European Driving Cycle
NO_2	nitrogen dioxide
NO_x	nitrogen oxide
NTM	DfT's National Transport Model
PM	particulate matter
PM_{10}	particulate matter of median diameter 10 microns or less: coarse particulate matter
RED	Renewable Energy Directive (EC)
ROACE	return on average capital employed
RTFO	Renewable Transport Fuel Obligation
Tonne	metric tonne
UKPIA	UK Petroleum Industry Association: oil industry trade body
ULEZ	Ultra-Low Emission Zone
VDU	vacuum distillation unit
VED	Vehicle Excise Duty
WLTP	Worldwide harmonized Light vehicles Test Procedure
WTW	well-to-wheel; calculation of emissions from production through to combustion of a fuel

Between 1994 and 2014 diesel demand has increased by 76%, from **12.9** to **22.7 billion litres**. During this time petrol demand decreased by 46%.

Each year close to

65 million tonnes

of petroleum products are moved around the UK refineries to inland storage locations, nearly half by pipelines and the balance by rail and sea.

Diesel engines are around **33%** more efficient than petrol in converting fuel to energy.

In 2000, petrol cars accounted for **85%** of new car registrations. In 2014 new diesel registrations hit **51.9%**.

Typically a barrel of North Sea crude oil will yield
3% liquefied petroleum gas,
37% petrol,
25% diesel,
20% kerosene and
12% fuel oil.

The number of diesel cars in the UK has risen from **1.6 million** in 1994 to **11 million** in 2014.

Foreword

This report by Nick Vandervell explores the changing pattern of demand for, and the changing sources of supply of, the two fuels that have dominated motoring from its very early days – petrol and diesel.

The report tells an interesting story, plotting the dramatic rise of diesel consumption and the fall in petrol sales in the UK since the 1980s, while at the same time noting that investment in domestic refinery capacity has fallen away, making us particularly reliant on imports of diesel.

The mismatch of domestic supply and demand would be notable of itself, but the report comes at a time when a question mark is already hanging over our growing affection for diesel engines – prompted largely by concerns over air quality and emissions of particulates and NO_x.

This was the subject of a major report commissioned by the RAC Foundation and published in June last year.

It would be all too easy to demonise the diesel engine in the search for swift and simple solutions. But this is a complex issue. And the fact of the matter is that with nearly 11 million diesel cars on our roads we have to recognise that these are vehicles many of us are relying on to get to work, education, health and other services, and to carry home the weekly shop.

The Foundation will continue to explore this issue, engaging with the policy makers who are wrestling with the UK's EU air quality infraction proceedings, looking at the scope for technological solutions to come forward from the UK's brightest automotive engineers, considering the design of local authority low emission zones, as well as hopefully shedding more light on the factors that motorists should take into account when they are making their purchase decisions and influences on their driving styles.

Steve Gooding

Director, RAC Foundation

1. Introduction

1.1 Objective of this report

Research published by the RAC Foundation (Hitchcock et al., 2014) indicates that the switch by motorists in the UK from petrol- to diesel-fuelled cars has had unfortunate and unintended consequences for air quality. This report will recount how, quite separately from the issue of air quality, this switch has also caused considerable problems for the oil refining and fuel supply industries.

While diesel demand has increased in recent decades, overall demand for road transport fuels is forecast to remain broadly flat over the next 15 years, with a continuing decline in petrol usage. In recent years, these changes in the pattern of demand have led to the UK exporting a growing surplus of petrol and at the same time importing ever-increasing volumes of diesel from around the globe, to meet the deficit in UK diesel production.

This report analyses the growing demand imbalance between these two products; its causes; the limited ability of UK refineries to boost diesel output; the risks and implications of this imbalance; its wider potential impacts upon consumers; and the policy measures that could be applied to address the imbalance.

1.2 Demand for road fuels: changes and forecasts

Cars fuelled by diesel have become increasingly popular in the UK, and now account for over half of new car registrations in 2012 (SMMT, 2014a). This trend has accelerated rapidly since 2000, when petrol cars accounted for 85% of new car registrations, until sales of diesel cars overtook those of petrol in 2011 gaining a 50.3% market share (DfT, 2015a).

Although that share dipped temporarily to just under 50% in 2013, the upward trend resumed in 2014, with new diesel car registrations increasing to 51.9% in October 2014 (SMMT, 2014b). The resultant fundamental shift in the UK's road fuel mix to diesel has had some unintended consequences both for air quality and the oil refining industry in the UK (and indeed in most of the EU).

The UK refining industry continues to face a challenging commercial environment, one that is exacerbated by stricter legislation than that faced by non-EU competitors. It has been unable to make a commercial case for the massive investment in the new refinery process plant that would be required to enable it to adapt fully to the comparatively rapid changes in the type of fuel the market requires. This growing mismatch in output in comparison with demand has prompted restructuring which has resulted in refinery closures and permanent reductions in output capacity.

The UK became a net importer of diesel in 2006, and in 2013 imported over 45% of its requirements (IHS, 2013). The closure of Milford Haven Refinery in 2014 and the planned halving of Lindsey Refinery's capacity in 2015 are likely to increase diesel import dependency even further in the near future. Conversely, UK refineries' net exports of petrol equated to around 26% of total petrol production in 2013 (DECC, 2014a); these capacity adjustments may reduce future petrol output but not to an extent that would eliminate the continued need for substantial petrol exports.

The reasons for, and implications and risks of, this growing dependence upon diesel are examined in more detail in Sections 2 and 3 respectively.

The growth in demand for diesel for use in cars has been driven by a number of factors:

- UK and EU policy initiatives to reduce the carbon emissions impacts of burning fossil fuels (road transport accounted for 25% of UK CO_2 emissions in 2013 (CCC, 2014);
- fiscal policy, particularly CO_2-related Vehicle Excise Duty and company car tax; and
- better fuel efficiency of diesel cars combined with technological, performance and refinement improvements that have won over consumers.

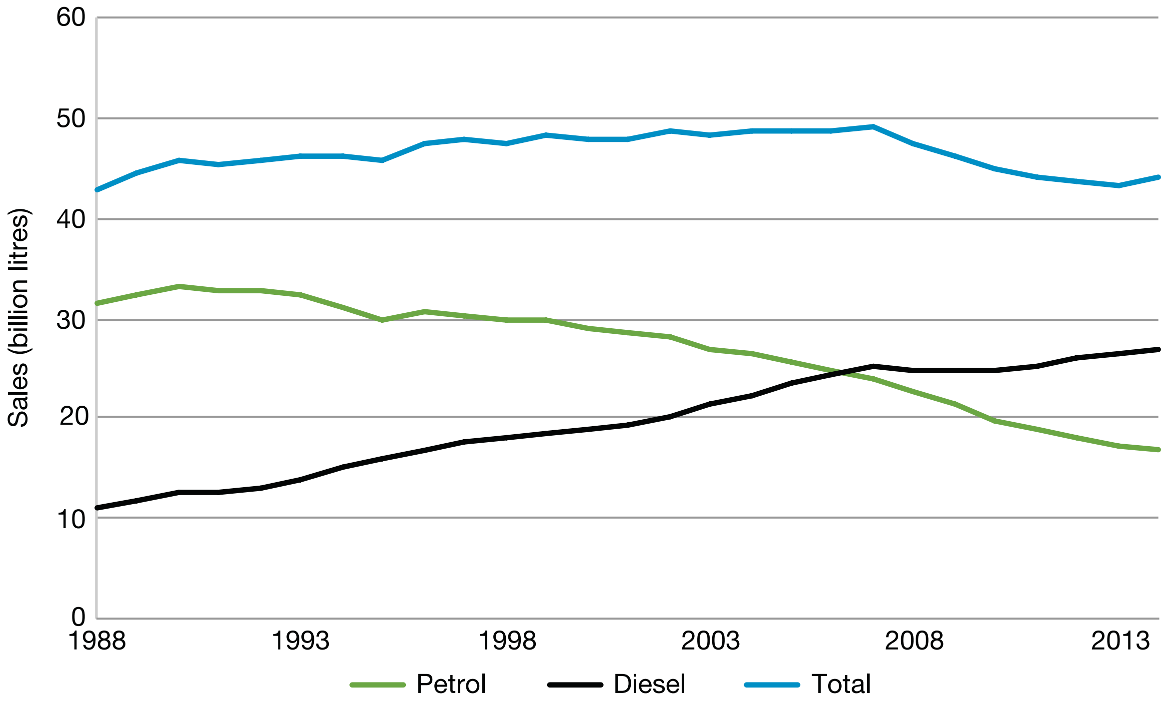
1.2.1 Evolution of changes in demand for road fuels

Historically, UK road fuel demand has been biased towards petrol. UK refineries, largely constructed in the 1950s/60s and expanded/modified from the 1960s through to the 1980s, were configured to meet this need. However, UK petrol demand peaked in 1990 with a 73% share of the total road fuels market and has been in steady decline ever since.

Diesel demand has been increasing consistently for over 20 years at an annual average rate of 3%, barring a short decline in the recession of 2008-10, a trend that has accelerated since the late 1990s. This is a reflection mainly of the shift towards diesel cars over this period, coupled with increased movement of goods by road. Indeed without this shift to diesel-powered cars, combined with efficiency improvements in petrol cars, it is unlikely that average new car CO_2 emissions in 2013 could have been reduced by 29% since 2000 (SMMT, 2014a).

Overall road fuel demand in the UK, which had been on an upward trend for decades, peaked in 2007 at close to 50 billion litres. By the end of 2014 it had declined to 44 billion litres, split 62% diesel and 38% petrol (see Figure 1.1), and with a year-on-year increase being recorded in 2014 for the first time since 2008. Some of this recent decline has been attributable to the effects of the recession and higher fuel prices, but is also linked to the continuing improvement in the fuel economy of both petrol and diesel vehicles.

Figure 1.1: UK road fuel sales



Source: UKPIA (2015b) using DECC data

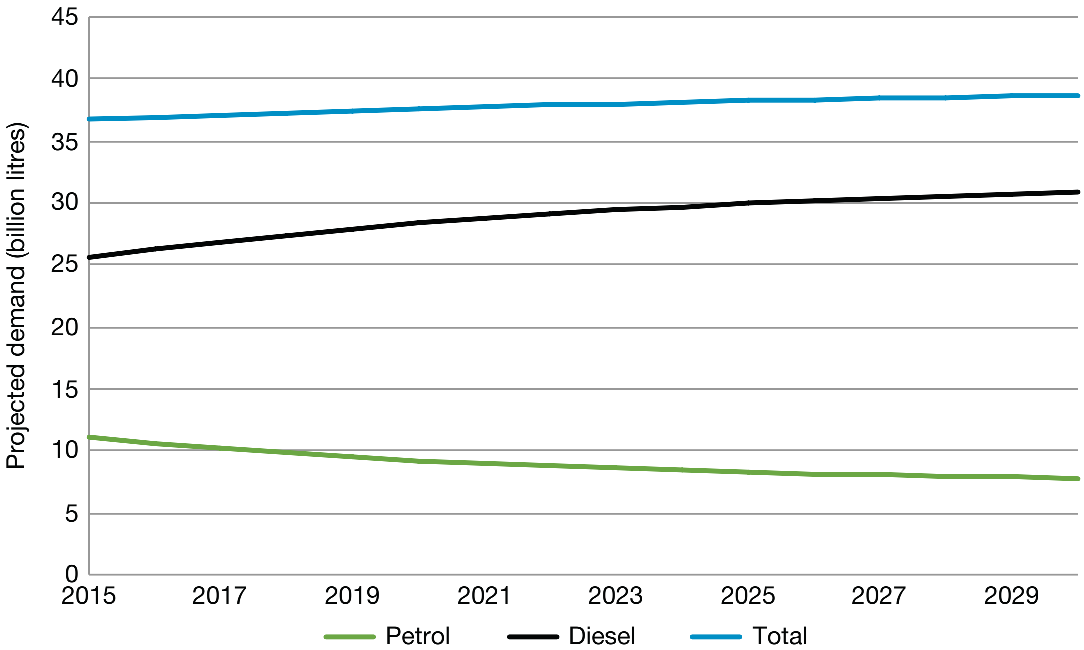
1.2.2 Forecasts

Forecasts of future conventional road transport fuel demand to 2030 are highly dependent upon a number of variables, especially growth in Gross Domestic Product (GDP) and population (which impact upon new car sales), the price of fuel relative to disposable income of consumers, further improvements in vehicle efficiency and the rate of growth in non-fossil alternative fuels. However, allowing that these factors introduce a measure of uncertainty, current forecasts are for relatively modest overall demand growth to 2030 (IHS, 2013).

The total number of cars in the United Kingdom is currently about 29.7 million (DfT, 2014), an average of 460 per thousand people. Of these, 11 million are diesel-powered whereas in 1994 there were just 1.6 million (DfT, 2015b). The variables referred to above will influence the number of cars on the road in the future. However, over the period to 2030, energy analysts forecast that diesel demand will continue to grow and petrol demand to decline, albeit both at a much slower rate than that seen in the last decade (IHS, 2013). But overall conventional road fuel demand is estimated to remain broadly flat at 0.2% above the 2010 level – see Figure 1.2.

An additional caveat in forecasting the future demand split between petrol and diesel could be the price premium of diesel fuel over petrol (which has been anything up to 12p per litre at times (DECC, 2014b)). The higher purchase price of a diesel car compared with its petrol equivalent means a motorist typically needs to drive 11,000 miles annually for 7.8 years to recover the additional purchase cost of a diesel car over the equivalent petrol model (Which?, 2015). If the price premium of diesel fuel became significantly greater than its recent levels, this could partially negate the advantage of diesel and increase the attractiveness of petrol cars. The growing tightness in the diesel market in the UK and the rest of Europe has an influence on the price, an issue that is explored in more detail in Section 3.

Figure 1.2: UK petrol and diesel demand to 2030



Source: IHS (2013)

1.3 Technological influences on petrol and diesel demand

Technological factors that have influenced motorists to buy diesel cars include better fuel economy than petrol cars, greatly improved performance (particularly at low engine revolutions), and the refinement of modern diesel cars.

Diesel engines have an inherent efficiency advantage over petrol cars because the compression-ignition combustion process helps make them about 45% efficient in converting fuel energy to mechanical energy (this figure is their ‘fuel conversion efficiency’) (Roberts et al., 2014). Most modern petrol engines are around 30% efficient, but the recent advent of small-capacity three-cylinder compound-turbocharged petrol engines has narrowed the gap slightly (SMMT, 2013a).

In addition, although the calorific value (the energy content) of diesel fuel is roughly 43 megajoules per kilogram (MJ/kg), slightly lower than that of petrol, diesel fuel is denser than petrol and contains about 11% more energy by volume (roughly 36 MJ/litre compared to 32 MJ/litre) (EC, 2009b). This greater efficiency more than offsets the added weight of a diesel engine that is necessary to enable it to withstand the higher combustion pressures.

Over the coming decades there is scope for further reducing fuel consumption as a result of general gains in vehicle efficiency through powertrain improvements; reduction in vehicle weight, drag and rolling resistance; and energy recovery/storage systems such as hybrid drives. These improvements will also be augmented and facilitated by a combination of alternative fuels and energy sources such as electricity.

However, it remains to be seen to what extent further technological improvements to petrol engines (for example ‘hybrid’ petrol/diesel homogeneous charge compression ignition or similar), particularly those of smaller capacity, can close the efficiency gap on the equivalent diesel engines. What is apparent is that small-capacity petrol engines at the moment are the preferred choice as a ‘range extender’ or auxiliary power source for electric vehicles because of their lighter weight and compact dimensions.

A continuing concern for consumers in making informed choices about a new car is that the validity of manufacturers’ official fuel economy figures, produced on a rolling road under laboratory conditions, has been questioned. A report by Transport & Environment (2014a) indicates that the official fuel consumption figures cited by car manufacturers are on average almost 25% lower than that achieved in reality. Furthermore, Department for Transport (DfT) data indicates that of all private car trips made in 2013, 18% were less than 1 mile in length, 67% less than 5 miles and 95% less than 25 miles (DfT, 2014a). Despite quicker warm-up of modern engines, this means that many of these journeys will be undertaken when the engine (or exhaust catalyst / particulate filter) hasn’t reached optimum working temperature, and fuel consumption as a result is higher than it would be at optimum operating temperature (Roberts et al., 2014).

Analysis of data for the years 2007 to 2012, in a report by ICCT, the International Council on Clean Transportation (Mock et al., 2014), indicates that the widening of the discrepancy between manufacturers’ fuel consumption figures and those achieved by motorists has increased to over 30% for all types of passenger car.

The European Commission (EC) has proposed that the current drive cycle (the ‘New European Driving Cycle’, NEDC) and test procedure be replaced by the ‘Worldwide harmonized Light vehicles Test Procedure’ (WLTP) by 2017. The WLTP is expected to be more representative of real-life driving conditions.

1.4 Policy influences on demand for petrol and diesel

Over recent decades a number of legislative and policy measures, both at the EU and UK level, have been introduced to reduce carbon emissions and pollutants from road transport. There has been a major focus upon CO_2 reduction with the introduction of mandatory CO_2 targets for new cars, which may have been a driver of the switch to diesel cars.

1.4.1 Carbon and CO_2 reduction

A significant milestone in 2009 was the introduction of a mandatory target (EU Regulation No 443/2009) setting an average CO_2 emissions target for new passenger cars of 130 gCO_2/km. It has been gradually phased in between 2012 and 2015 but was in fact achieved in the UK by the end of 2013 when average new car emissions were 127 gCO_2/km.

A new target of 95 gCO_2/km (147 gCO_2/km for vans) will apply from 2021, phased in from 2020 (EC 333/2014) (EC, 2014). The legislation is likely to be reviewed by the EC post-2015 with a view to framing proposals for CO_2 emission targets for the period beyond 2020, including possibly setting a 2025 target.

The EU has also framed carbon reduction targets affecting road transport, as part of climate change policy, in a number of other pieces of legislation, including the Renewable Energy Directive (RED) (2009/28/EC) (EC, 2009b) and Fuel Quality Directive (FQD) (2009/30/EC) (EC, 2009c). The UK's Renewable Transport Fuel Obligation (RTFO) (DfT, 2012) aims to achieve the requirements of the RED by mandating the addition of biofuels to conventional road fuels to achieve 4.75% on a volume basis by 2013/14 (this target was achieved). The RTFO has also been extended to include non-road machinery using diesel.

The FQD requires suppliers to reduce as gradually as possible the life-cycle greenhouse gas (GHG) 'intensity' of transport fuel by 6% by 31 December 2020 compared with a 2010 baseline. The 6% reduction may be achieved through the use of biofuels, renewable electricity and reduction measures in other parts of the fuel supply chain. The most common biofuels added to diesel and petrol are, respectively, fatty acid methyl esters and ethanol. Both these additives have less energy content than conventional diesel or petrol and result in a marginal reduction in fuel efficiency.

The road transport sector is also affected by the Climate Change Act 2008, which established a long-term framework and targets to reduce the UK's GHG emissions by at least 80%, compared to 1990 levels, by 2050 (CCA, 2008). This is underpinned by the Carbon Plan 2011, establishing a series of four legally binding carbon budgets up to 2027, which outlines delivery measures and targets across all sectors of the economy, including transport (CCA, 2008). For road transport, the Carbon Plan envisages targets being met by a combination of more efficient conventionally fuelled vehicles, sustainable biofuels, and ultra-low-emission technologies such as battery electric, hydrogen fuel cells and plug-in hybrid technology.

1.4.2 Emissions

Although key pollutants from vehicles have reduced substantially over the last two decades, it has become apparent that an unintended consequence of the growing market share of diesel cars has been the adverse impact upon air quality, especially in urban areas or those with heavy traffic concentrations. Breaches of the limits for nitrogen dioxide (NO_2) and in some instances particulate matter (PM), associated mainly with diesel engines, have become more widespread in these areas (Hitchcock et al., 2014).

In the early 1990s, a key EU policy measure was the establishment of tighter exhaust emissions limits for road vehicles under the Euro 1-6 framework, to improve air quality. The key pollutants targeted were hydrocarbons, nitrogen oxide (NO_x) and PM. These limits have become progressively tighter, with the most recent standards (Euro 5-6 for cars and light vans, and Euro V-VI for buses and trucks, from September 2009 and September 2014 respectively), setting levels that are some 80-90% lower than those introduced in 1992 (EC, 2014).

On a like-for-like basis, diesels produce fewer CO_2 emissions. However, diesel cars emit more PM and NO_x than petrol cars, and both of these are linked to poor air quality and health issues that can reduce life expectancy. Ongoing analysis of air quality points towards real-world emissions performance of diesel vehicles, particularly in urban areas, being below expectations. This could be due to a combination of the performance of vehicle abatement equipment not matching results obtained under test conditions, and buildings in urban areas impeding the dispersal of pollutants.

Whatever the reasons, the issue requires tackling; and, whilst compliance tests under the latest Euro 6 standard aim to better replicate real-world conditions, a specific limit for NO_2 may be necessary to reduce emissions.

A more drastic approach would be one involving measures implemented through the duty or tax system so as to reflect the economic cost of pollution from diesel engines. This is considered in more detail in section 4.3.

1.4.3 Taxation

Taxation in various forms, backing the focus on climate change and reducing carbon emissions, may have also played a crucial role in driving

the switch to diesel cars. Rates of Vehicle Excise Duty (VED), company car tax (CCT) and capital allowances for business users linked to CO_2, have all incentivised low-CO_2 vehicles and encouraged fleet buyers/users particularly to opt for diesel vehicles.

VED rates are currently banded according to CO_2, with those vehicles in Band A emitting below 100 gCO_2/km attracting a zero rate, while a vehicle meeting the level of the EU average new car CO_2 limit of 130 gCO_2/km falls in the Band D range of 121–130 gCO_2/km, paying £110 per year (DVLA, 2015). 'Gas guzzlers' emitting above 255 gCO_2/km fall into the top Band M and pay £500 per year. In addition, for vehicles registered after April 2010, a first-year registration rate is applicable. Vehicles up to 130 gCO_2/km are rated at zero, with chargeable rates rising rapidly thereafter up to the top Band M, which pays £1,090 in year one.

CCT is a benefit-in-kind tax upon employees provided with a car by their employer, and from 2002 has been based on CO_2 emissions (HMRC, 2014a). Since 2012 diesel cars have been subject to a 3% surcharge over petrol models within the same CO_2 emissions band, to reflect the greater amounts of harmful particulate matter. However the Government reconfirmed in Budget 2014 that this surcharge would be removed from 2016/17 (HM Treasury, 2014).

The amount of the charge payable is dependent upon the benefit value of the car (based on the manufacturer's list price) multiplied by the appropriate banded percentage rates. These bands are based on the CO_2 emissions of the vehicle, with the resultant sum taxed at the individual's personal tax rate. For 2016/17 the starting band is 0 to 50 gCO_2/km which attracts a 7% rate, rising to 37% for cars emitting the highest levels of CO_2.

Capital allowances for companies that buy or lease their vehicles have also moved towards allowance rates that are linked to CO_2 (HMRC, 2013). All cars that have CO_2 emissions up to 110 gCO_2/km qualify for full first-year writing-down allowances and cars between 96-130 gCO_2/km qualify for an 18% annual writing-down allowance.

Fuel duty is currently charged at 57.95 pence per litre on the majority of road fuel, with 20% VAT charged on the total fuel price and duty (HMRC, 2014b). Thus diesel cars, with their inherent fuel-efficiency advantage, are the obvious choice for those doing higher annual mileage. Other than Switzerland, which levies a higher rate of duty on diesel, the UK is the only European country to apply as high a rate to diesel as to petrol. Many EU members apply a substantially lower rate of duty on diesel than petrol (EC, 2015a).

The history of fuel duty in recent decades has been complex, inconsistent and confusing, giving mixed messages to motorists. Ultimately, the total pump price payable has been a significant influence upon motorists, and although the duty element accounts for the greater part of the total, the proportion varies with changes in underlying fuel cost.

From 1994, the duty rate on unleaded petrol and diesel has been aligned at the same rate, diesel having previously been taxed at a lower rate. The biggest change came in 1993 when a ‘duty escalator’ was introduced, partly as a step towards meeting carbon reduction targets. The effect was that by 1998 duty had risen by over 70% and accounted for about 80% of the pump price of fuel (UKPIA, 2015a). The escalator policy was unpopular with the electorate and was abandoned in 1999, even before the widespread fuel tax protests of autumn 2000. Since then, successive Chancellors have tinkered with rates, especially when oil prices have been high, and inflation linkage has come and gone at times, to be replaced by a ‘fair fuel stabiliser’ linked to oil prices (see Kay et al., 2013 for further information on road taxes). A move to fuel duty based on the energy content of the fuel, as proposed by the EC in 2012 but rejected by member states, would mean diesel attracting a higher rate of duty.

1.4.4 Congestion zones and Low Emission Zones

The London Congestion Charge (the only one in the UK) was introduced in February 2003, and is payable by motorists who wish to drive within the central London congestion zone between 7 a.m. and 6 p.m. on a weekday (TfL, 2015a). Exemptions from the scheme exist for a number of vehicles, including taxis, motorcycles, buses, disabled badge holders and emergency vehicles, although previously available discounts have been greatly tightened. An ‘Ultra Low Emission Discount’ (ULED) of 100% applies to electric vehicles or cars and light vans which emit 75 gCO_2/km or less and which meet the Euro 5 air quality standard.

A Low Emission Zone (LEZ) is a geographically defined area which the most polluting vehicles are restricted, or discouraged, from using. The aim is to improve air quality by setting an emissions-based standard for the vehicles within the area. There are two LEZs in the UK – the largest scheme is in London and restricts diesel engine vehicles over 3.5 tonnes, buses, coaches, large vans and minibuses (TfL, 2015b). The Norwich LEZ restricts buses only (DEFRA, undated).

In October 2014, the Mayor of London announced a consultation on proposals to charge the most polluting vehicles for driving in central London (the same area covered as by the congestion charge) by introducing an Ultra-Low Emission Zone. The zone will come into effect in September 2020 and will require vehicles entering it to comply with new emission standards for NO_x and coarse particulate matter (PM_{10} – particulate matter of median diameter 10 microns or less), based on Euro 6 standards, or pay a daily charge (TfL, 2015b).

2. Oil Refining and Supply

Many of the refineries in the United Kingdom came on stream in the late 1950s and early 1960s, reflecting the post-war demand for petroleum products as the economy recovered, road transport expanded and car ownership took off. Up until the early 1990s, they were configured largely to meet the preponderance of demand for petrol. Since that time, although refineries have evolved to meet the growing demand for more complex and environmentally friendlier fuels, they have been unable in recent years to adapt to the rapid increase in diesel demand. As a result the UK now imports 45% of its requirements for diesel.

In response to refining overcapacity and poor financial returns, three UK refineries have closed since 2009, a situation mirrored across the EU.

2.1 Making petrol and diesel from crude oil

The starting point in the manufacture of petroleum products is crude oil. In its natural state, crude oil has little practical use, but by refining it can be turned into liquid petroleum gas, petrol, diesel, jet fuel, gas oil, heating oil and residues such as bitumen. Refining also provides the by-products, or 'feedstocks', for lubricants and petrochemicals.

Crude oil contains hundreds of different types of hydrocarbons mixed together and these all have different chemical composition, density and impurities, depending on the source of the crude (EU refineries typically process oil from over 140 different sources).

The type of crude oil processed – for example lighter and 'sweeter' North Sea Brent blends, or Arabian heavy – has an influence upon the final mix of products that a refinery produces. UK refineries process a range of crude oils, but those from the North Sea predominate (about 46% of the total) (UKPIA, 2015b). This helps refineries produce a higher proportion of lighter products such as the high-quality, sulphur-free road fuels that modern vehicles require to deliver low exhaust emissions.

Typically, depending upon the configuration and complexity of the refinery, a barrel of North Sea crude oil will yield 3% liquefied petroleum gas, 37% petrol, 25% diesel, 20% kerosene (jet fuel/heating oil) and 12% fuel oil – a heavy residue previously used for power generation or in ships, but with fewer applications these days owing to recent legislative changes (2012/33/EU) (EC, 2012a). A heavy crude oil will yield a much smaller proportion of petrol, diesel and kerosene – perhaps 50% – and the balance as fuel oil residue, which requires further processing to transform it into lighter and more useful fuels.

In order to produce petrol, diesel or any other oil-based products, hydrocarbons in the crude oil require separating in a sequence of processes, which can be broken down into four main categories.

2.1.1 Distillation

Increasing hydrocarbon chain lengths all have progressively higher boiling points, and they can all be separated by a process known as fractional distillation. During the process, crude oil is heated at high temperature in a column called a crude distillation unit (CDU). The different hydrocarbon chains are extracted as a vapour according to their vaporisation temperatures and then recondensed into liquid form (see Figure 2.1). The lighter fractions, such as petrol or gases, rise higher up the column, with heavier ones such as diesel settling lower down.

The liquid residue of heavy fuel oil left over at the bottom of the column requires further processing to be turned into more valuable, lighter products or blending components. This residue is first sent to a second stage of fractional distillation in the vacuum distillation unit (VDU). This unit performs the distillation under reduced pressure and at lower temperatures. Using the same approach as before, the VDU separates streams into different components from gas oil to a heavy liquid residue. The streams from the CDU and VDU are then processed further by the remaining refinery units as explained in the following paragraphs and Figure 2.2.

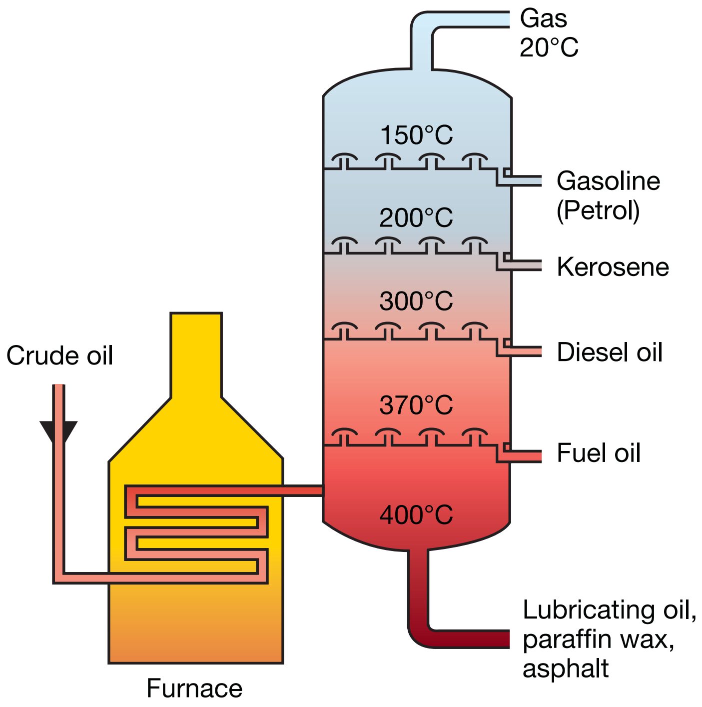
Petrol in the UK is manufactured to the current standard, which is BS (British Standard) EN 228 (BSI, 2013a). The seasonal composition of petrol is modified in winter and summer to adjust for the different requirements for cold- and hot-weather starting.

Petrol is made up of a mix of alkanes and cycloalkanes with a chain length of between 5 and 12 carbon atoms. These have a boiling point of between 40°C and 205°C.

Diesel in the UK is manufactured to the current standard, which is BS EN 590 (BSI, 2013b); as with petrol, the seasonal composition is modified in winter and summer to adjust for the different requirements for cold- and hot-weather flow characteristics and starting. These complex standards are designed to meet the requirements of modern higher-speed engines to aid cold starting, and deliver low noise, good lubricity, fuel stability and cleanliness, as well as help deliver low emissions.

Diesel, and its close relative gas oil, is a ‘middle distillate’ made up of alkanes containing 12 or more carbon atoms. These heavier components boil at between 250°C and 350°C, the middle temperature range in the CDU, considerably higher than that of petrol.

Figure 2.1: Crude oil primary distillation process



Source: Author

2.1.2 Conversion, cracking and reforming

Merely distilling crude oil does not produce sufficient petrol or diesel. Therefore conversion units, such as a fluid catalytic cracker (FCC), isomerisation unit and alkylation unit, are used to treat some of the streams from the VDU to turn the heavy components into lighter transport fuels such as petrol. Reforming units are used to upgrade the octane rating of the petrol components produced from the CDU – typically 95 RON (research octane number) for unleaded and 97 RON or higher for super unleaded.

2.1.3 Desulphurisation

Desulphurisation units are then used to remove sulphur from the products. This enables them to meet today's tighter fuel specifications and allows the refinery additional flexibility to process higher-sulphur 'sourer' crude oils. Reliance on more expensive low-sulphur crude oils alone would limit the flexibility of a refinery.

The level of sulphur in petrol and diesel has progressively been reduced and since well before the end of 2009 all petrol in the UK has been manufactured to a sulphur-free level of less than 10 parts per million (ppm) (UKPIA, 2015b). Refineries have achieved this by a combination of using more-expensive low-sulphur crude oils, or the physical removal of the sulphur from blending components. This latter option has required substantial investment in hydrodesulphurisation (HDS) plants. In addition to capital costs of new plant, the removal of sulphur also requires more energy and other materials (primarily hydrogen), thus increasing refinery operating costs and CO_2 emissions.

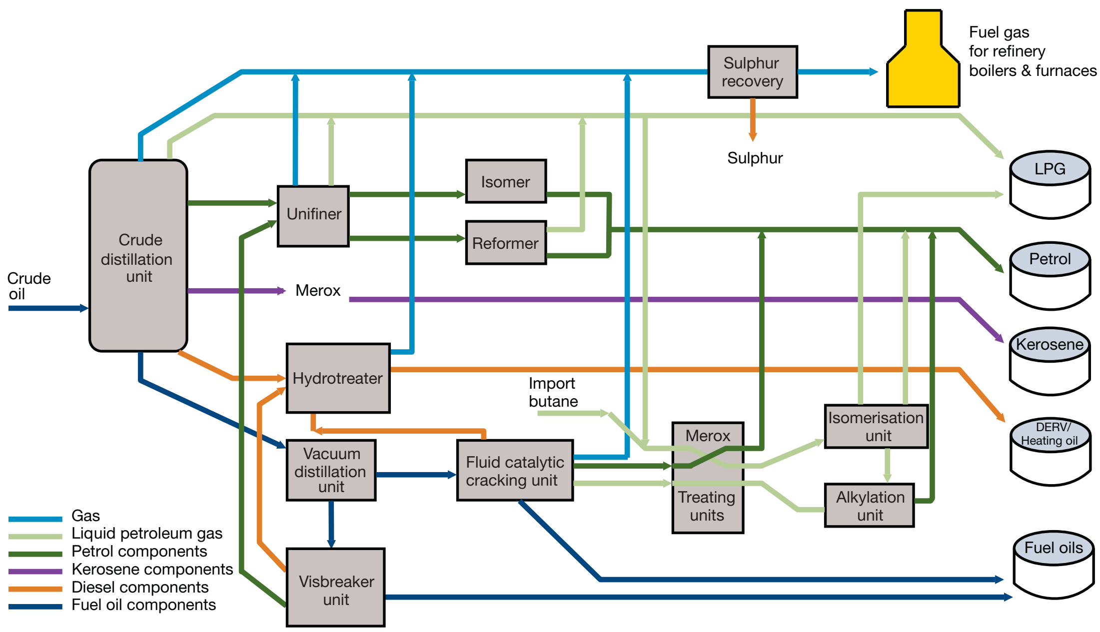
Diesel/gas oil streams from the CDU and VDU are processed in a hydrotreater, which cleans them by removing sulphur and other unwanted compounds using hydrogen and a catalyst, prior to final blending.

Driven by EU Directives, there has been a major move to reduce sulphur, initially from 500 ppm to 150 ppm from 1 January 2000, and again to 50 ppm by 2005. A further EU Directive (EC, 1998) required that sulphur-free fuels (10 ppm or less) be made available on a "*balanced geographic basis*" starting in 2005. Diesel in the UK met this specification by December 2007 as a result of substantial early investment by UK refineries in hydrotreater technology (UKPIA, 2015b).

2.1.4 Blending

The final step is blending, whereby the petrol streams from the FCC, the reformer, the isomerisation unit and the alkylation unit are blended to meet fuel specifications and current regulations. In the case of petrol, the addition of bio-components commonly in the form of ethanol, required to meet current EU/UK targets, is usually carried out at the terminals, where road delivery tankers are filled. However, some refiners blend ethyl-tertiary butyl ether (ETBE) with petrol at the refinery, as it is more compatible with pipeline and storage distribution systems than ethanol. It should be noted that the energy content of ethanol is lower than that of petrol, but at the levels permitted under current fuel standard BS EN 228 (BSI, 2013a) of 5-10% maximum by volume, the effect upon fuel consumption is not easily discernible.

Figure 2.2: Typical refinery process units



Source: UKPIA (2015b)

The petrol and diesel fuels produced by this process differ in terms of their energy content. The energy content of petrol is 45.8 MJ/kg, very slightly higher than the 45.5 MJ/kg of diesel, but being a ‘lighter’ fuel the overall density is about 11% lower than diesel so the energy content in a litre of fuel is 32 MJ in comparison with 36 MJ for diesel.

There have been a number of significant changes to petrol specifications in recent decades to comply with legislative requirements and developments in vehicle technology. The UK started to move to unleaded petrol in the late 1980s to early 1990s, enabling the introduction of three-way exhaust catalysts. Leaded petrol was largely withdrawn from sale across the EU from 1 January 2000.

As with petrol, there have been significant changes to the specification of diesel in recent years to comply with legislation aimed at reducing harmful exhaust emissions such as NO_x, particulates and poly-aromatic compounds. These changes have had an impact on the whole refining process of diesel, in some cases constraining output.

Additional changes in both legislation and engine technology have required an increase in the minimum cetane number of diesel (higher cetane delivers shorter ignition delays and more complete combustion), a reduction in the density of diesel, and tighter limits on the distillation temperature range.

2.2 Ability to address the shortfall in diesel production

The fundamental problem for UK refineries (and for those in the rest of the EU) is that refinery output is mismatched with market demand – there is too much petrol being produced, and too little diesel. As a result, the UK became a net importer of diesel in 2006 (DECC, 2013). In 2013, it imported over 45% of its needs, a figure that is likely to increase further following a recent refinery closure and permanent capacity reductions at other refineries. Weak commercial conditions for refining mean that there is little prospect of a major increase in domestic diesel production.

The reasons for this are discussed below.

2.2.1 Historic configuration

The UK currently has six major oil refineries (see Figure 2.3), down from nine in 2009. The most recent closures or changes have been as follows:

- **2012**: Coryton Refinery, Thames Estuary closed. Plans for conversion to fuel import and storage facility announced by new owners in late 2013, but work yet to start.

- **Autumn 2014**: capacity reduction implemented at Stanlow Refinery, Ellesmere Port, to reduce gasoline and increase diesel output.
- **Late 2014**: Milford Haven Refinery, Wales closed. In early 2015, the site was acquired by a new owner for conversion into crude oil storage, fuel import and product storage.
- **Early 2015**: Lindsey Refinery announced a planned permanent capacity reduction of 50%.

Milford Haven Refinery had the disadvantage of being the smallest in the UK but was well configured to maximise diesel and middle distillate production, so loss of this facility will further increase import dependence for these products. The capacity reduction at Lindsey Refinery could help reduce the petrol surplus, but may increase the UK's diesel imports.

Figure 2.3: Map of UK refineries

Source: UKPIA (2015b)

The oil refining industry in the UK, and the associated supply and distribution network, has evolved over many years. Much of the expansion in refining capacity took place between the mid-1950s and the early 1970s, with the bias being towards provision of petrol for cars and fuel oil for power generation. Further major additions of distillation and FCC capacity were made in the 1970s and 1980s. Since then most investment has been focused on environmental, safety, and product quality improvements, with additional diesel and gasoline desulphurisation capacity.

In the last two decades demand for middle distillates, such as diesel and jet fuel, has increased to the point that it greatly exceeds the supply capacity of UK refineries, and petrol demand has steadily declined since the peak reached in 1990. The configuration of most UK refineries thus remains today more suitable, generally speaking, for supplying the UK demand profile of the late 1990s.

Construction of major refinery plant, often with a designed lifespan of 25 years or more, is complex and highly expensive – a hydrocracking unit to boost diesel / middle distillate production typically costs upwards of £856 million to construct (IHS, 2013), depending upon the size, complexity and level of integration with existing refinery units. In addition, design and construction usually takes around four to five years.

However, more modest refinery upgrade investment is taking place in the UK, albeit not at a level sufficient to make a substantial difference to the diesel deficit. An example of a recent major UK refinery investment (estimated to cost close to £300 million) was by Total at its Lindsey Refinery (IHS, 2013). A project was started in 2007 to build a distillate hydrotreater (HDS-3) and a hydrogen production unit. Delayed by labour disputes, the units eventually came on stream in late 2010, boosting production of sulphur-free diesel and giving greater flexibility in the type of crude oils that can be processed.

However, given the combination of the current commercial climate and the outlook for refining in the UK and the rest of the EU, it seems inconceivable that large investments in hydrocracking, to substantially boost diesel output, will be made at UK refineries. A cost-effective and thus more likely outcome is that additional import facilities will be constructed to increase fuel storage capacity, both at former refinery sites and elsewhere.

This more modest investment scenario is reinforced by Total's announcement in early 2015 of plans to halve Lindsey's capacity, to reduce petrol output, and to invest £150 million to reconfigure the plant to increase diesel yield (Adams, 2015). This follows similar capacity reduction and reconfiguration at Stanlow Refinery.

2.2.2 Changing demand and specification convergence

As explained earlier in this section, a major challenge for the refining industry is that petrol/diesel output has been misaligned with the increasing volumes of diesel that consumers need. Moreover, the consensus of projections by the government, oil industry and energy analysts is that diesel demand will increase in the coming decades.

The petrol surplus is expected to be exacerbated further by some ethanol substitution of petrol under the RTFO and RED legislation that mandates use of biofuels (IHS, 2013).

An additional factor is that the convergence of specifications for other middle distillate products with those of diesel, linked to the legislative requirement to desulphurise fuel for off-road applications and marine fuels, is likely to constrain refinery output of diesel unless there is substantial investment in hydrotreating capacity.

2.2.3 Legislation

Another challenge for the UK refining and fuel supply sector as a whole is the legislative environment under which it operates. Many non-EU competitors do not face the same burdens.

As explained in Section 1, the recent focus of legislation in the EU and the UK has been on climate change and reducing carbon emissions. At the EU level, a target of a 20% reduction in GHG emissions by 2020 (in comparison with 1990 levels) has been set (EC, 2014). The UK is pursuing a challenging target for a 34% reduction by 2020, rising to 80% by 2050, underpinned by carbon budgets within the statutory framework of the Climate Change Act 2008 (CCA, 2008). However, the problem for the downstream oil sector is the increasing complexity and overlap in a range of policies designed to reduce GHG emissions such as the EU Emissions Trading System Phase III (EC, 2015b), Fuel Quality Directive Article 7a (EC, 2009c), Industrial Emissions Directive (EC, 2010), Renewable Energy Directive and Energy Efficiency Directive (EC, 2012b).

2.2.4 Low level of financial return on refining

The financial returns on UK oil refining and fuel supply have usually been low, certainly in comparison with profit levels in upstream crude oil and gas production, the manufacturing sector as a whole, and the retail/consumer sectors.

Profit margins on refining in Europe have also been volatile over the last decade. Low returns and competitive market conditions have focused companies on making their refining and marketing operations as efficient as possible, but have also triggered other responses, including withdrawal from refining in the UK (in the case, for example, of BP, Murco and Shell) and closure of refineries as referred to in section 2.3.1.

The stark reality of the squeeze facing UK oil refining is summarised by the UK Petroleum Industry Association (UKPIA) in a report (IHS, 2013) commissioned to help inform a study by the Department of Energy & Climate Change (DECC) into the refining and fuel import sectors. The UKPIA observed that a broad-brush projection of 'return on average capital employed' (ROACE) for the UK refining industry for the period 2013 to 2030 indicated that it could expect an average simple return on investment of around 4.1% (not including impending compliance costs of two key pieces of EU legislation). Applying a low discount rate of 3.5%, this ROACE falls to 3.2%. The UKPIA estimated that "*to simply keep pace with current demand trends, UK refineries would need to invest some £1.5 to £2.3 billion over the next 20 years… projected [refining] margins would allow some level of reinvestment if there are no other cost burdens on the industry*", but the UKPIA also estimated that in the period 2013–30, refineries would need £11.4 billion of capital and operating expenditure simply to meet UK and EU legislative measures.

It concluded that "*such a low return is also very likely to make refiners conclude that operating in the UK (or Europe) would not provide adequate return on investment compared to other regions or businesses, and therefore voluntarily decide to close UK and European refining operations" (IHS, 2013).*

2.2.5 Overseas competition

The UKPIA report observed that, assuming a level playing field with other refiners across the EU and the rest of the world in respect of legislative compliance investment, UK refineries would be considered to be competitive. However, competition from overseas sources – such as the USA, the Middle East, India and Russia – has intensified recently.

A significant development is the emergence of the USA as a major oil producer with a growing production output which in 2014 reached 8.7 million barrels per day (US EIA, 2015), close to that of Saudi Arabia, the world's largest producer. This has been a major factor in the collapse of crude oil prices in late 2014 to early 2015.

Legislation in the USA currently only permits minimal quantities of crude oil to be exported, and the development of light shale oil has precipitated a substantial expansion in the utilisation of domestic US refining capacity and a transformation of the economics of many refineries there. This has resulted in a significant reduction in exports of surplus petrol produced by UK and EU refineries to the USA, traditionally one of the biggest markets. Aside from growing volumes of product, especially diesel, available to Europe from the US market, the USA is also exporting petrol to Africa, which hitherto has been an important destination for surplus European petrol (US EIA, 2015).

Most of the recent growth in global refining capacity has come from countries outside the OECD (Organisation for Economic Co-operation and Development), in particular India and the Middle East. Refineries in these areas are large-scale and have been designed at the outset to maximise output of middle distillates such as diesel and jet fuel. Moreover, they do not generally bear the same level of regulatory costs as those in the EU.

Furthermore, Russian refineries are a major source, for both UK refineries and importers, of diesel and gas oil imports (which are then reprocessed into road diesel meeting EU standards). Government incentives in Russia to upgrade domestic refineries to produce higher-quality road fuels to EU specifications and capture more value from each barrel of domestic oil production, has resulted in a near doubling of diesel/gasoil output since 2012 (Raval, 2014). Although this is likely to help meet the deficit in UK and EU diesel output, it poses yet another threat to UK refineries.

2.3 Supply infrastructure and import sources

2.3.1 Supply infrastructure

UK oil refineries are supplied with crude oil via a combination of pipelines from the North Sea and by large crude oil tankers. Of the crude oil processed by refineries, 46% originates from the North Sea (8% from the UK and 38% from Norway), 28% from Africa, 7% from Russia and 1% from the Middle East, with the balance of 18% from coming from other sources (UKPIA, 2015b).

The infrastructure that supplies the UK with oil products is extensive, comprising six main refineries, 31 coastal supply terminals, 14 inland terminals and a range of other facilities, including pipelines (UKPIA, 2015b). To date, this infrastructure has generally ensured that the UK has secure and reliable sources for the fuels it needs, even during disruptions.

UK refineries all have substantial storage capacity for crude oil and the finished products that they produce, and are augmented by other large storage terminals around the country, generally near major population conurbations. Each year close to 65 million tonnes of petroleum products is moved around the UK from refineries to inland storage locations, nearly half by pipelines and the balance by rail or sea (UKPIA, 2015b).

Joint ventures or product exchange agreements between oil-supplying companies are commonplace, as a means of increasing efficiency, reducing costs and avoiding the necessity to transport products over long distances from one terminal to another.

Despite high initial capital costs, pipelines are an efficient means of moving large volumes of product, and they have comparatively low operating costs. The pipeline network (see Figure 2.4) in the UK comprises a mix of privately owned and formerly government-owned facilities, the latter being known as GPSS (Government Pipeline and Storage System) and originally constructed during the Second World War to supply fuel to defence bases. The GPSS is interconnected with several oil industry private pipeline networks, playing an important role in supplying aviation fuel to major airports. Only 10% of the fuel is for military purposes, hence the Government's decision in March 2015 to sell the GPSS to a private buyer (Ministry of Defence, 2011).

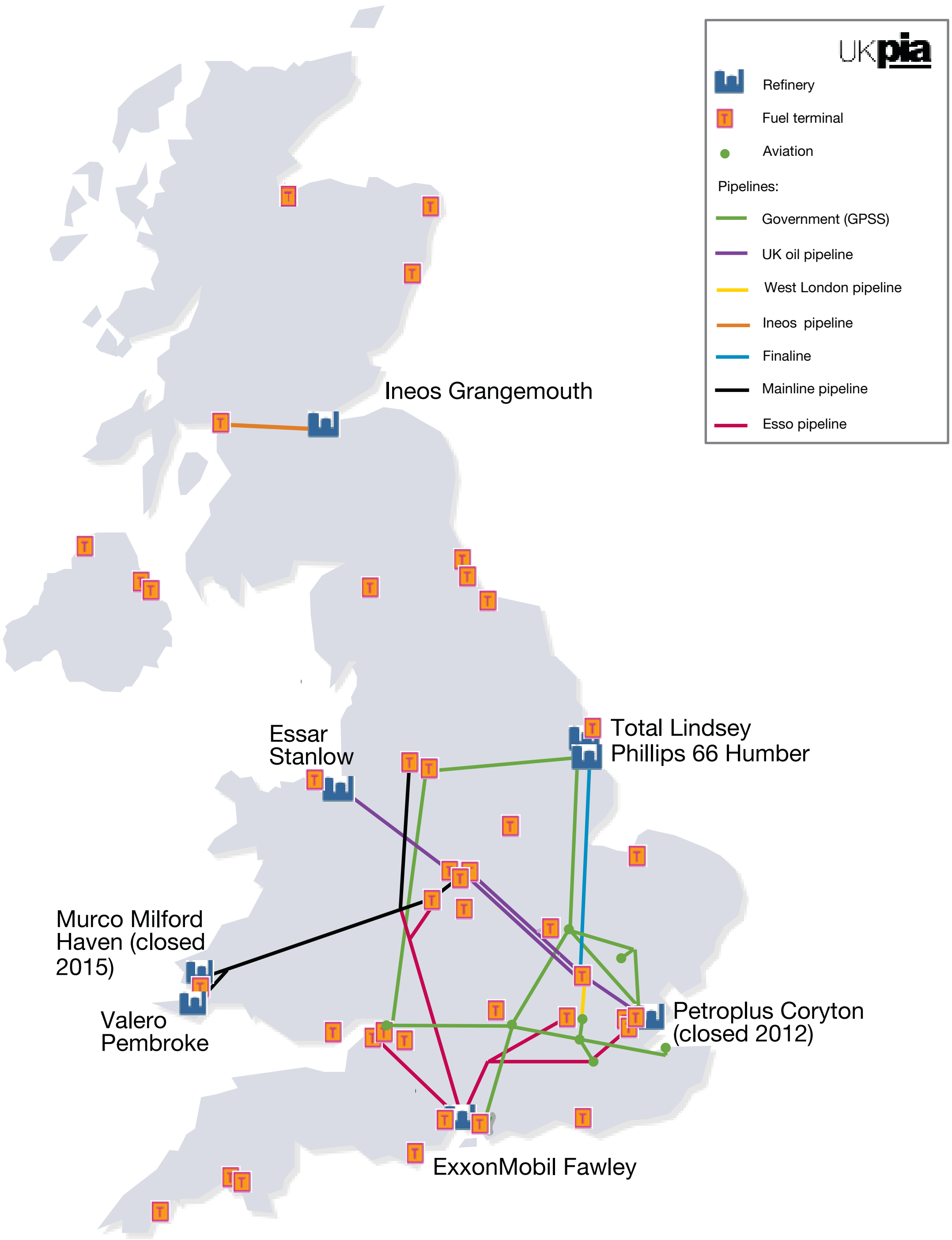
Most of these pipelines cover England and Wales. In Scotland, a pipeline conveying crude oil and products links the Finnart Ocean Terminal on the west coast near Helensburgh to Ineos's Grangemouth Refinery and petrochemical complex near Edinburgh.

The last major private oil pipeline constructed in the UK was the Fina-Line, which links Total's Lindsey Refinery on the Humber to Hertfordshire Oil Storage terminal (HOSL) at Buncefield, near Hemel Hempstead. Since a major accident at HOSL in December 2005, this line has been dedicated to transporting jet fuel rather than road fuels (IHS, 2013).

All the UK refinery locations are capable of receiving finished product imports. There are also finished product storage facilities independent of refineries, the major ones being situated along the estuaries of the Thames, Humber, Mersey, and Tees.

The final link in the supply infrastructure is road transport of fuels to commercial users, agriculture and petrol filling stations. This is carried out by a mix of transport contractors working for oil companies, wholesale suppliers and independent distributors.

Figure 2.4: Map of main UK pipelines and terminals



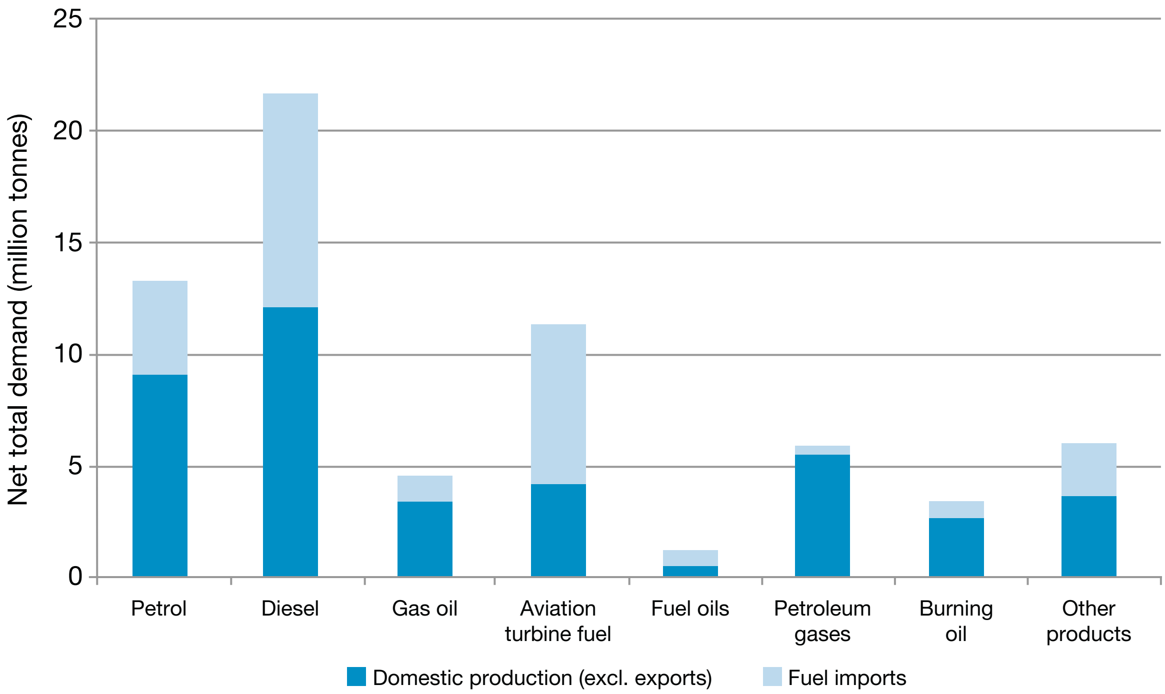
Source: IHS (2013)

2.3.2 Import sources

Net imports to the UK of diesel in 2012 amounted to over 9 million tonnes, equivalent to over 45% of the UK's needs (DECC, 2014a). The UK is well situated to source diesel supplies from major near-continent production/import/

trading hubs such as Amsterdam/Rotterdam/Antwerp, as well as from Russia. In addition, diesel is also imported from the USA, the Middle East and Asia (see figure 2.5).

Figure 2.5: 2012 UK demand by product and source of supply



Source: DECC (2014a)

Given the limited capability of UK refineries to expand diesel production to bridge the supply shortfall, the UKPIA report (IHS, 2013) forecasted that the combined UK gasoil and diesel net imports would rise further, to 54 million tonnes by 2030. Of these import sources, Russia is expected to remain the most significant, but there is likely to be an increasing diversity of supply from the other areas cited above.

The implications of this growing import dependence are analysed in Section 3.

3. Impacts of and Risk Posed by the Growing Fuel Deficit

Taken together, the growing demand for diesel (met by increased imports), the imbalance with petrol demand, and the loss of UK refining capacity, have implications and risks for the UK. Some of these impacts and risks are outlined in this section. There are also geopolitical risks associated with some of the countries upon which the UK has growing reliance for diesel supply, but this is an issue outside the scope of this report.

In response to independent studies commissioned by the oil industry, and concerns voiced by the Energy & Climate Change Committee's report in July 2013 (House of Commons, 2013), DECC carried out a public consultation in 2013 (DECC, 2014c), its response to which was issued in April 2014. It concluded that:

"Resilience and security of supply is supported by retaining a mix of domestic refining and imported product. This is consistent with the government's energy security of supply strategy which recognises the benefits of supply diversity" (DECC, 2014c).

The robustness and resilience of the UK's fuel distribution system is critical for all consumers and, as has been demonstrated by disruptions attributable to a variety of causes in recent years, there are regional variations in the ability of supply networks to respond to disruption.

3.1 Import reliance

By 2030, it is forecast that diesel will account for 42% of the UK's total transport fuel demand (DECC, 2014c). Currently the UK imports 45% of its diesel requirements, a figure that is likely to increase in the near future, taking account of the UK refinery reductions, as outlined in Section 2.

Currently the domestic UK oil refining industry, with its good links to other European refiners, access to North Sea, and other crude oil supply, provides the UK with a generally secure, reliable and economic source of transport fuels and other petroleum products.

The market for crude oil and refined petroleum products is, by nature, global. Access to these global markets has become more significant for the UK in meeting its growing deficit in diesel and also aviation jet fuel. However, domestic refinery production of key fuels gives added flexibility in the event of external disruptions or emergencies.

3.2 Security of supply

The UKPIA report (2013) also analysed security of supply on the basis of the International Energy Agency's (IEA's) approach used in its 'Model Of Short-term

Energy Security' (MOSES), which considers imports compared to demand. Under that methodology, the UK is already at the high-risk level for supply of diesel and jet fuel. Projected future demand trends and any further closure of UK refineries would substantially increase this risk.

Crude oil and oil products, which can be easily stored, deliver excellent security of supply in a wide range of scenarios. At the moment, the UK's comprehensive infrastructure of refineries, pipelines, storage terminals, delivery logistics and service stations ensures a robust and dependable supply for the country. This infrastructure can provide a quick and flexible response to maintaining energy supplies in the event of disruption or emergencies. Increased reliance upon imported products is a feasible strategy for meeting the product imbalances from external sources that the UK faces; many other EU countries are in a similar position of increased import reliance. However, the extent to which this may compromise the UK's security of energy supply and resilience remains uncertain, and is highly dependent upon the accuracy of assumptions about global future demand increases, product mix and surplus refining capacity.

To address issues raised in the UKPIA report in 2013, DECC, working with other departments and agencies, launched a review and consultation of the refining and product import sector as outlined above.

It is worth repeating a consultation response published in April 2014 (DECC, 2014c), the Energy Minister and DECC which concluded that "*resilience and security of supply is supported by retaining a mix of domestic refining and imported product. This is consistent with the government's energy security of supply strategy which recognises the benefits of supply diversity*."

As regards some of the investment challenges faced by industry, and concerns about both energy costs and the regulatory burden hindering the competitiveness of UK refining, the Government considered that existing policies and actions address some of these concerns. However, since the UKPIA report and the DECC response in 2014, a further UK refinery has closed, and capacity reductions have been either implemented or announced at two others (see Section 2).

Closed refineries may, in suitable locations, be modified to become import and storage terminals. One example is the proposed Thames Oilport at the former Coryton Refinery in Essex, announced in 2012 as a joint venture of Vopak, Greenergy and Shell (Platts, 2014). However, construction of new facilities is yet to commence.

An increase in seaborne product imports and exports of excess petrol at existing refineries, as well as terminals, has implications for jetty and storage capacity. There are implications, too, for the volume of shipping movements, particularly in already congested shipping lanes in areas such as the English Channel and Thames Estuary.

3.3 Supply robustness and resilience

The UKPIA report (2013) also examined UK regional product supply robustness and resilience. It defined **robustness** as the availability of supply in a region compared to demand, and **resilience** as the diversity of sources of supply to a region. To analyse this, the UKPIA used the official government definition of regions and then placed them in one of four 'supply envelopes' as follows:

3.3.1 Central regions that are all interconnected by the existing main fuel distribution infrastructure. This is both the most robust and the most resilient region in the UK, with surplus petrol, a modest diesel deficit, and access to multiple suppliers that provides resilience to a short-term disruption centred on a single supplier. This region comprises:

- North-East & North-West England
- Yorkshire and Humber
- East Midlands, West Midlands
- Wales

3.3.2 South regions with limited connections into this envelope from other envelopes. This region is particularly at risk, with low levels of supply cover for all fuels including petrol, and no spare import logistics capacity to meet a shortfall if existing production were to be interrupted. This region comprises:

- Greater London
- East, South, South-East and South-West England

3.3.3 Northern Ireland is defined as an individual supply envelope. It has very poor robustness (with 100% import dependency on the rest of the UK) but many potential suppliers, meaning that supply is resilient, with disruption to one supply source readily replaceable by another.

3.3.4 Scotland is defined as an individual supply envelope. It has good robustness, with surplus supply of petrol and a modest diesel deficit, but poor resilience, with very high dependency on Grangemouth Refinery and few alternative import routes.

The differences in supply robustness and resilience across the UK are outlined in Table 3.1.

Table 3.1: Regional supply robustness and resilience

	Robustness	Resilience
Central	Good	Good
South	Poor	Poor
Northern Ireland	Very poor	Good
Scotland	Good	Poor

Source: IHS (2013)

In the South, although there are multiple importers, the import infrastructure has no spare capacity. The closure of Coryton Refinery in 2012 has exacerbated the situation, and the planned development of an import facility at the Thames Oil Port at the former Coryton site is behind schedule (Platts, 2014). The loss of Coryton came on top of the closure of HOSL Buncefield for road fuels following the 2005 accident, with the Fina-Line pipeline from the Humber now dedicated to jet fuel (IHS, 2013). As a result, there is heavy reliance on the region's remaining refinery, Fawley on Southampton Water, both as a supplying refinery and an import route with excellent cross-country pipeline links.

Within the Central region, the closure of Milford Haven Refinery in late 2014 will affect supply in Wales and South-West England, particularly of diesel, and will increase import dependence slightly (IHS, 2013). Likewise, the impact upon the same region of the planned capacity reductions at Stanlow Refinery and Lindsey Refinery is not accounted for in the IHS assessment for UKPIA; these reductions are likely to reduce the petrol surplus.

3.4 Consumer impacts

3.4.1 Diesel/petrol price differential

A feature of the growing demand for diesel in the UK and across Europe, and tightness in supply, is that a significant pump price differential has opened up at times between diesel and petrol. This can be especially pronounced in winter when demand increases in Europe for heating gas oil, a product that is similar to diesel.

The UKPIA (2014b), in its briefing paper *Petrol and Diesel Price Differential*, cites a number of factors for this, including:

Market factors:

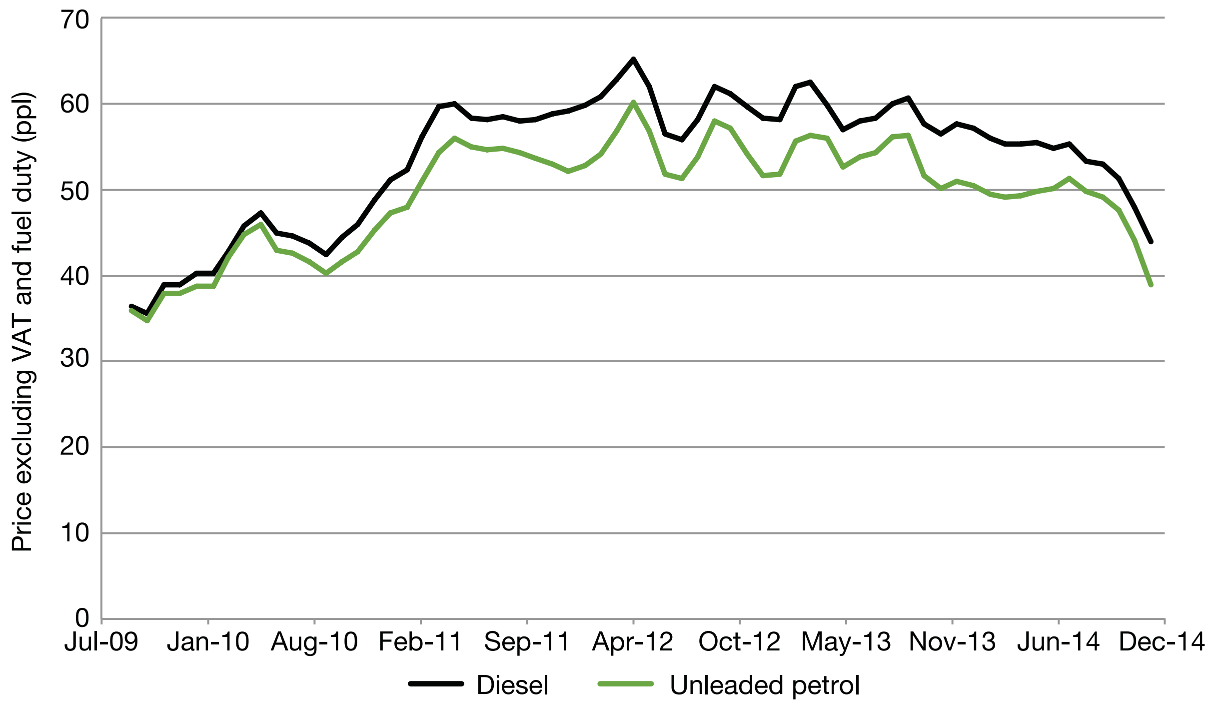
- crude oil prices, with particular demand for 'sweeter' lower-sulphur crudes such as those from the North Sea
- increased global demand for transport fuels, particularly diesel, that is reflected in wholesale prices

- seasonal winter demand for heating gas oil, which is similar to diesel and made from the same basic refinery components
- short-term market factors reflecting fuel specification changes, extreme cold weather or temporary supply problems

Structural influences:
- a growing imbalance in the UK and in most other EU countries between petrol and diesel production and demand
- diesel fuel specification changes, combined with off-road diesel and marine fuels moving to a specification closer to that of diesel

Data on the price differential from DECC (2014a) (Quarterly Energy Prices) indicates a clear winter trend, with a maximum diesel differential of 12 pence per litre over petrol opening up in winter 2008/9; since then it has fluctuated between 5 and 8 pence per litre, with the largest differentials during winter months (see Figure 3.1).

Figure 3.1: Price of unleaded petrol and diesel excluding taxes, September 2009 to December 2014



Source: DECC (2015)

Pump prices broadly track the changes in underlying NW Europe wholesale prices for petrol and diesel (UKPIA, 2015a). Future demand forecasts all point towards continued diesel demand growth in the UK, Europe and worldwide until a 2030 forecasting horizon (IHS, 2013). However, the number of factors affecting future prices makes it difficult to predict whether the price differential between diesel and petrol will continue in the range of 5 to 8 pence per litre experienced in recent years or be significantly above or below it.

3.4.2 Price speculation

The role of speculation in driving up crude oil and product prices for consumers has long been a subject of continuous debate, especially in the period 2008 to 2014 when prices have been high. There have been numerous studies on this complex issue, most of which have concluded that short-term speculation both in physical and 'paper' markets, has been a factor in driving up prices (Vansteenkiste, 2011; Beidas-Strom & Pescatori, 2014).

The use of futures[1] is a well-established method whereby traders or businesses who have exposure to future changes in the physical price of oil or oil products can hedge some of their risk exposure. This activity can have a smoothing effect on market prices.

These studies indicate that the growth in the use of derivative products and the activities of commodity index funds appears to have a link to those engaged in the paper market, and could be a factor in increasing price volatility.

However, it is difficult to discern the relative impact of fundamental factors and speculation-driven demand on oil futures price levels and volatility, and the link between underlying physical markets and paper ones. A study by the European Central Bank (Vansteenkiste, 2011) sought to do so by identifying the main drivers of oil futures trends between 1992 and 2011. The study found that up to 2004, movements in oil futures prices were best explained by underlying fundamentals. However it found that since 2004 it has been during periods of higher fundamental volatility, combined with uncertainty about future oil demand and low deviation from oil price fundamentals, that commercial traders have been the biggest participants in the market. On the other hand, if a large unexpected shock to the oil spot price occurs, then all traders will enter the market.

The International Monetary Fund has also revisited the topic in a study published in December 2014 (Beidas-Strom & Pescatori, 2014). One of its key findings was that typical speculative demand shocks in the crude oil market may increase or decrease the real oil price by between 10% to 35%, contributing to short-run oil price volatility. As an example, the study highlighted that the run up in crude prices between 2003 to 2008 was largely demand-driven but was influenced strongly by speculative demand after 2005. The same drivers were seen to re-emerge in the years 2011 to 2012.

1 A future is a contract binding the parties to buy or sell specified product volumes at a predetermined price.

3.5 Environmental and air quality impacts

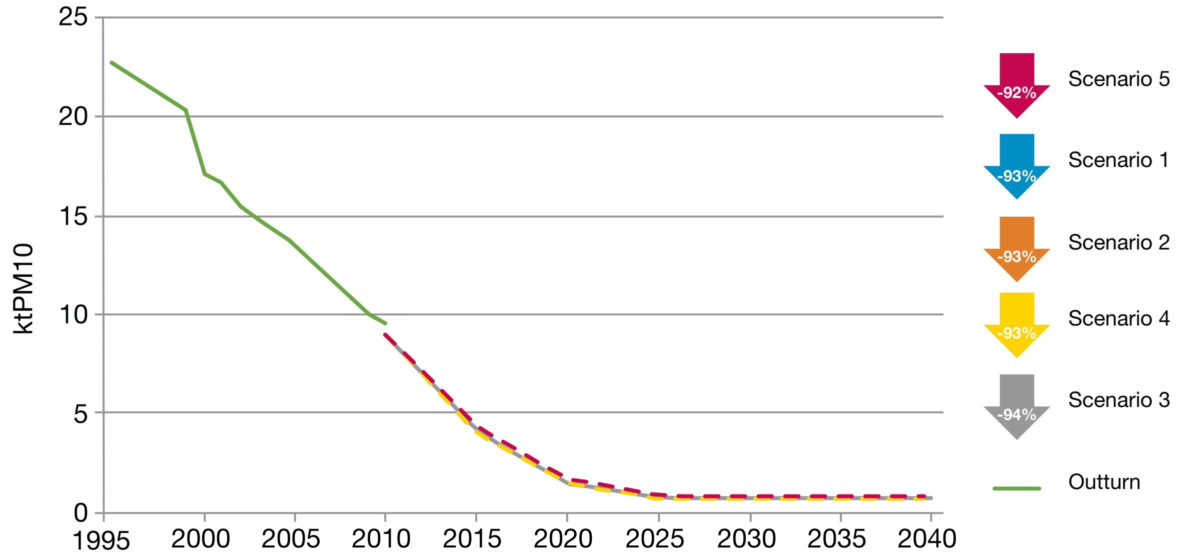
3.5.1 Air quality impacts

Research published by the RAC Foundation (Hitchcock et al., 2014) indicates that the switch by motorists in the UK from petrol- to diesel-fuelled cars has had unfortunate, unintended consequences for air quality and may be contributing to health impacts on those living in urban areas and beside busy roads. These consequences may have been unintended, but were perhaps not altogether unforeseen – particularly the impacts on air quality and the domestic oil refining industry.

Government policy focus on reducing CO_2 emissions from road transport may have been a dominant factor in driving the switch to diesel. But clearly consumer choice has been almost as important, whether that choice be influenced by the better fuel consumption of diesel cars, lower VED and CCT rates, or indeed the refined driving experience offered by most modern diesel cars.

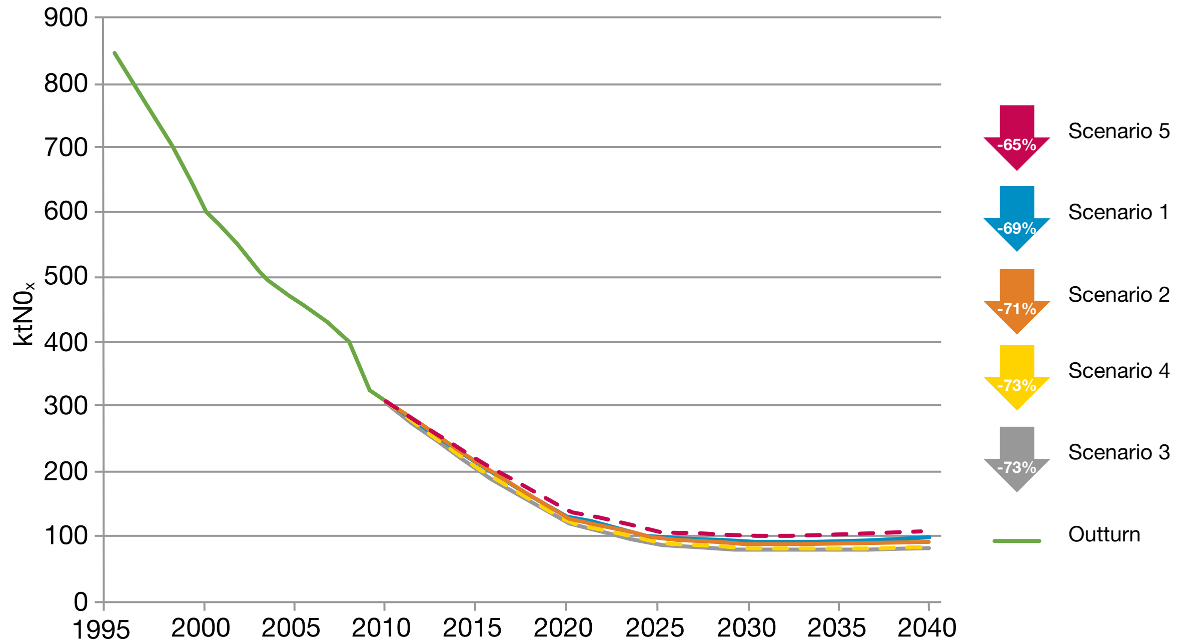
Although concentrations of some air pollutants – carbon monoxide and sulphur dioxide for example – have come down significantly over recent decades, current regulatory breaches relate to NO_2, generated from emissions of NO_x, and PM (AEA Group, 2009). Road traffic accounts for around 30% of total UK NO_x emissions and 20% of total PM emissions (diesel cars being the second largest source within the road transport sector, following diesel light commercial vehicles (LCVs)) (AEA Group, 2009). Airborne PM emissions originate from a variety of sources aside from transport, including industry, agriculture, household and other dust-generating activities. Although most road transport PM is generated by diesel vehicles, dust from brakes and tyre wear is produced by all vehicles. The impact of these emissions is greatest in urban, town centre and other locations bordering busy roads.

Figure 3.2: PM_{10} emissions in England, 1995-2040 (historical and projected)



Source: DfT (2013)

Figure 3.3: NO_x emissions in England, 1995-2040 (historical and projected)



Source: DfT (2013)

DfT's National Travel Model indicates that road transport PM_{10} and NO_x emissions are forecast to continue on a downward trend until 2025, in line with reductions to date and due to gradual fleet replacement by new Euro 6-compliant cars. After 2025, PM_{10} and NO_x emissions are projected to plateau (see Figures 3.2 and 3.3 respectively), but at significantly lower levels than those observed in 2010 (DfT, 2013).

The modelling scenarios in Figures 3.2 and 3.3 include various assumptions for factors such as population growth, per capita GDP fuel prices, the number of journeys made by individuals and the relationship between car ownership and the amount of use.

However, as the RAC Foundation report observed, reductions in vehicle emissions have not delivered the expected improvement in local air quality, which points to a discrepancy between the official emissions test results of new cars and what they deliver in real-world conditions, especially in relation to NO_x and the roadside NO_2 levels. The continued growth in market share of diesel vehicles will likely make matters worse.

3.5.2 Environmental impacts

Aside from effects on air quality, the wider environmental impacts of the UK's growing demand for diesel are difficult to separate from those of using other transport fossil fuels. In terms of GHG emissions, the most common analytical method of comparing these emissions is on a 'well-to-wheel' (WTW) basis.

Comparison of the GHG savings from different energy sources and vehicle technologies is a highly complex but vital process, and entails analysis of whole-life-cycle emissions associated with producing the fuel and its use in a vehicle, rather than the emissions solely at point of use – tailpipe emissions. This enables a whole range of fuels and energy sources – whether fossil, biofuel, hydrogen or electric – to be compared.

The EC's JRC-IET, together with CONCAWE and EUCAR, conducted a major study (Edwards et al., 2011) of WTW emissions testing a variety of engine and vehicle technologies, and fuel combinations, including conventional fossil-based and alternatives. One conclusion of this study was that the production of additional diesel fuel in Europe (using hydrocracking technology and requiring more refinery hydrogen capacity) is more energy-intensive than that of gasoline. On a WTW basis the impact is modest, and is compensated by the superior efficiency of modern diesel engines compared with petrol engines, although a fuel consumption penalty of 2.5% was assigned to diesel engines which used diesel particulate traps with regeneration (Edwards et al., 2011).

4. Addressing the Issues, Conclusions and Recommendations

The growing demand for diesel has had an impact upon meeting air quality targets; this demand cannot be met by UK refineries, with the result that the UK is increasingly reliant on imported diesel from across the globe.

Government policy should be based on sound science and seek to maintain a level playing field between different fuels and technologies to avoid unintended consequences. Incentives aimed at changing behaviour can be valuable, but need to be carefully framed to avoid distortions and kept under regular review to assess their effectiveness.

The present policy emphasis based almost exclusively upon reducing CO_2 emissions needs to be reassessed to address the problem of air quality targets not being met.

4.1 Rebalancing demand and supply

The demand balance between diesel and petrol largely has been, and will be in the future, driven by legislative policy, vehicle technology change, relative fuel costs and consumer preferences/choices. Without policy intervention or a major change in petrol vehicle technology, there seems little scope for a rebalancing of demand between the two fuels. Demand for diesel, in line with forecasts, will continue to increase over the next decade, albeit at a slower rate than in the past, before levelling off by 2030. Petrol demand is also forecast to decline over the same period, again at a slower rate than in recent years.

On the supply side, UK refineries are being forced by commercial pressures to address excess petrol production and plan modest investment to boost diesel output.

4.2 Reducing dependence upon diesel

Overall road fuel usage is forecast to decline in the coming decades as a result of continued improvements in vehicle fuel efficiency. Average new car CO_2 emissions in 2013 were 29% lower than in 2000; a higher proportion of diesel cars, alongside petrol-engine efficiency improvements, has helped achieve this reduction (SMMT, 2014a). New petrol cars in 2013 had average CO_2 emissions of 128.8 gCO_2/km and diesel cars 129 gCO_2/km. Within the medium-to-large class of cars, a higher proportion are diesel-fuelled, which affects the overall diesel fleet average CO_2.

The EU target for new cars of 95 gCO_2/km by 2020 implies potentially further inroads by diesel cars, as well as more ultra-low-emission cars (defined as emitting less than 70 gCO_2/km) employing hybrid drive or range extender electric technology; small conventional drive petrol-powered cars may be able to achieve this target but it would be a greater challenge for petrol cars of medium size or larger (SMMT, 2013b).

DfT's Road Transport Forecasts 2013 (DfT, 2013), based on its National Transport Model (NTM), indicate that, despite a 46% road traffic increase over 2010, by 2040 CO_2 emissions from road transport will decline by around 15% from 2010 levels, reflecting fleet fuel-efficiency improvements and use of biofuels. It should be noted that the model assumes no further vehicle fuel-efficiency improvements after 2020, in the absence (at the moment) of mandatory targets beyond that date, but that further improvements will continue to be delivered through turnover of the car fleet.

The forecast indicates that a combination of mandatory and voluntary measures could produce a fuel use reduction of 47% for cars, 34% for LCVs and 14% for heavy goods vehicles (HGVs) (DfT, 2013).

There appears to be limited scope for significantly reducing dependence upon diesel for HGVs, but perhaps a greater potential for LCVs. However, there are many other options for cars.

Another factor limiting any short-term change in the fuel mix is the turnover time in the make-up of the car fleet on the road. DfT data for 2013 (DfT, 2013) shows that there were around 30 million cars registered, with cars over six years old accounting for over 19 million of this total, meaning that many of these predate Euro 5 standards. Scrappage incentives are one way of speeding up the turnover rate.

4.2.1 Cars

Given the health concerns associated with urban air quality, there is a case for encouraging a switch from diesel fuel to petrol/alternative fuels, or applying tighter limits on NO_x and PM, particularly for those vehicles used in an urban environment which do not comply with the latest Euro 6 standards.

Cars and taxis accounted for around 40% of road transport CO_2 emissions in 2013 (DfT, 2013) but experience in Scandinavia and the Netherlands indicates that reducing the proportion of diesel-powered cars need not jeopardise achievement of future CO_2 reduction targets.

A review of fiscal policy, which currently has a strong bias towards CO_2-based limits and emission limits within LEZs, could also help.

4.2.2 Heavy goods vehicles / light commercial vehicles

HGVs account for around 24% of road transport CO_2 emissions (DfT, 2013) and, along with vans/LCVs, have been a growth area. The fuel they use is predominantly diesel.

A shift of goods to other transport modes offers limited scope to reduce HGV/LCV fuel demand, given the complexities of modern distribution and freight movements. For this reason, emphasis has to be upon reducing the emissions of these vehicles. Areas of focus are aerodynamics, engine efficiency, tyres with low rolling resistance, transmission systems and hybrid drive systems, as well as energy recovery/storage systems.

A Ricardo-AEA 2012 study for the Low Carbon Vehicle Partnership (Kay & Hill, 2012), based on a 1,500 km UK test route, concluded that 52% of HGV vehicle energy consumption is used in overcoming rolling resistance and 35% to overcome aerodynamic drag, so action to improve these aspects of performance could have a significant effect upon fuel consumption.

Similar technology is applicable to buses, and in addition buses may be more appropriate for introduction of hybrid drive where they are operating in an urban environment.

LPG (liquefied petroleum gas – propane and butane gases derived from refining), LNG (liquefied natural gas) and CNG (compressed natural gas – mainly methane) have been used to a limited extent in internal-combustion engines for some years. They have advantages in terms of improved local air quality, but their use to date has been based largely upon fiscal incentives. For gas-fuelled vehicles, dedicated storage and refuelling facilities are required, combined with onboard fuel tanks that are heavier and larger than those required for conventional petrol or diesel. Taken with fuel economy that is inferior to diesel's, this has tended to limit uptake. However, the Chancellor of the Exchequer's Autumn 2013 statement that the 50% fuel duty differential between gas and diesel will be held at the current level until to 2024 may give sufficient longer-term investment certainty to the market to encourage greater uptake of these gaseous fuels (HM Treasury, 2013).

For LCVs in an urban environment, hybrid/electric technology has scope to reduce use of, or substitute for, diesel fuel.

4.3 Role of policy

Policy areas which influence consumer choice, including new registration taxes, VED, fuel duty and CCT, are the obvious starting point for bringing about a more balanced demand mix between petrol and diesel. Such a rebalancing need may not necessarily lead to a slowdown in achieving targeted CO_2 reductions, as experience in Denmark and the Netherlands indicates.

An indication of the possible effects of rebalancing upon CO_2 emissions and air quality can be found in DfT's Road Transport Forecasts 2013 (DfT, 2013), which contains the latest results from the NTM projections for traffic demand, congestion and emissions in England up to 2040. It employs a complex set of assumptions and scenarios covering all the aforementioned parameters, also drawing upon input from a report by the AEA Group (2009) modelling total UK emissions of NO_x, PM_{10}, fuel consumption and CO_2 according to vehicle type, fuel and speed curves. The NTM forecasts a continuing overall downward trend in NO_x and PM_{10} until 2025, in line with historical precedent and rollout of the new Euro 6 vehicle emission standards. Post-2025, PM_{10} and NO_x emissions are projected to plateau, although at significantly lower levels than those observed in 2010. Clearly, new policy measures to promote petrol cars would have a beneficial impact on the level of these specific pollutants.

Across Europe a range of different policy approaches are in place, as outlined in the report by Transport & Environment (2014b). The report shows that taxes are generally graduated according to CO_2 and/or vehicle weight and power, which has had the effect of accelerating the move towards diesel cars. Furthermore, most countries other than the UK and Switzerland levy a lower rate of fuel duty on diesel, although the report highlights the fact that in Denmark and the Netherlands sales of new diesel cars, at 30% and 25% respectively, comprise a significantly lower proportion than the EU average. In these countries purchase of new diesel cars is discouraged through the tax system, but this has not affected overall car fleet fuel-efficiency improvements because of heavily graduated taxes incentivising the purchase of small cars with low CO_2 emissions.

UK policy is correct to focus upon tighter exhaust emission standards and reducing carbon emissions from road transport, and to some extent letting the market decide upon the best fuel/vehicle technology combinations to meet these limits. However, some of the consequences of the ensuing rapid switch to diesel-powered cars may have been unintended, but were perhaps not altogether unforeseen. This underlines the importance of keeping policy under review and changing it if it ceases to deliver what was intended by its creation. The downside is that businesses and consumers need an element of policy security to underpin decisions.

CCT rates are linked to CO_2 emissions through a banding system which is gradually being tightened. Currently diesel cars attract a 3% surcharge on top of the band rate but this will be removed in tax year 2016/17.

It was announced in the Summer Budget 2015 that there would be a reform to **VED** rates and bands for those cars registered from 1 April 2017. The first year rate for these cars will be based on CO_2 emissions. However from the second year onwards all cars will attract a standard flat rate of £140, except those with zero emissions, which will pay nothing. There will also be a supplement of £310 per year for the first five years of the standard rate for cars with a list price above £40,000.

Fuel Duty is currently charged at the same rate for petrol and diesel (HMRC, 2014b), although indirectly it has an influence since it forms part of total fuel cost, meaning that less fuel-efficient cars have higher fuel cost. A possible change could be to tax fuel on an energy basis, and indeed the EC put forward proposals in a draft Directive in 2011 (EC, 2012b) for setting minimum levels of tax by energy content on all energy sources, amending Directive 2003/96/EC (EC, 2003). The UK is already applying fuel duty tax rates on road fuels well above the EC's proposed rates, but the UK – along with many other member states – is not in favour of the proposals as tax rates are considered as a matter for the government to decide.

Applying fuel duty on an energy basis has merits, since it treats all energy sources for road transport on an equal basis, including biofuels and possibly electric. On the basis of there being a similar level of petrol and diesel fuel consumption to 2014, the current fuel duty rate of 57.95 pence per litre, equivalent to 1.63 pence per megajoule, duty on an energy basis indicates petrol duty at 55 pence per litre and diesel at 60 pence per litre to give the same overall revenue yield to government. On the basis of average UK pump prices for June 2015, this this would more than double the petrol/diesel differential from approximately 4 pence per litre to 10 pence per litre.

Such a change might influence the balance between petrol and diesel demand, but would have serious implications for the HGV sector, which has limited alternative fuel choices, unless an administratively simple and ring-fenced duty rebate scheme could be devised.

Low Emission Zones could be another effective means of addressing local air quality within a defined area, as applied to central London for example. Currently the London Congestion Zone charge is mainly CO_2-based, with an exemption for vehicles that emit 75 gCO_2/km or less and meet the Euro 5 air quality standard (TfL, 2015b).

Following a consultation, an Ultra-Low Emission Zone will come into effect in London from September 2020. A daily fine will be levied on vehicles entering the zone that do not comply with new emission standards for NO_x and PM_{10} (see section 1.3).

The downside to LEZs is that while improving air quality locally, the resultant pollution is not entirely eliminated unless vehicles are scrapped – it is simply moved to adjacent areas.

Scrappage schemes can be effective in bringing about a more rapid turnover in the vehicle fleet and taking older less fuel-efficient, more-polluting vehicles off the road. The Government introduced a Vehicle Scrappage Scheme in May 2009 which ran until the end of March 2010, to help the motor industry during the depths of the recession (SMMT, 2010). The scheme offered a £2,000 incentive, equally split between government and industry, to new car or van buyers scrapping a ten-year-old vehicle with a current MOT certificate. The cost of the scheme was estimated at £400 million and may have triggered the sales of 396,000 new vehicles, many of them smaller more fuel-efficient and cleaner than the ones scrapped (Williams, 2010).

However, applying such a scheme to diesel cars to address the problem of NO_x and PM emissions could be expensive, since to be effective it would have to apply to comparatively newer early Euro 5 cars little more than six years old.

4.4 Conclusions and recommendations

The main conclusions are as follows:

1. Government policy is a driver of change which should be based on sound science and seek to maintain a level playing field between different fuels and technologies, to avoid unintended consequences and distortions.

2. The focus of government policy in recent years upon CO_2 reduction has been successful in bringing about improvements in vehicle fuel efficiency but, combined with consumers' choices, has also driven a rapid switch to diesel cars from petrol.

3. This rapid growth in diesel cars has been a major factor in the failure of emissions from diesel vehicles of all types to deliver a significant reduction in nitrogen oxide (NO_x) over the past two decades, while the proportion of nitrogen dioxide (associated with smog and breathing difficulties) has actually increased.

4. The failure of Euro 5 diesel car technology to deliver the expected reductions in NO_x and particulate matter (PM) emissions has been a factor in targets not being reached; this is related in part to real-life driving conditions, in which many journeys are of comparatively short duration.

5. The imbalance between demand for diesel and petrol has caused major problems for UK refineries (and those across Europe), which have been unable to adapt output sufficiently; a substantial deficit in diesel is now met by imports and a growing surplus of petrol requires export.

6. Any rebalancing of demand will be driven by a range of factors, including policy, technological change and consumer choice; but without such changes, diesel demand is forecast to grow to 2030, albeit at a slower rate than that seen in recent years.

7. The financial squeeze taken together with structural changes in refining means there is little prospect of major investment being made to boost domestic diesel production substantially.

8. The UK will become increasingly reliant upon imported diesel (currently accounting for 45% of the UK's needs), which poses risks associated with disruptions along a long supply chain.

9. The closure of a further UK refinery could have serious implications for security of supply generally, as well as for the robustness and resilience of regional supply, which is already strained in most regions of the UK.

10. The ability of the UK's storage and distribution infrastructure to be expanded in a timely manner to cope with both the growing volumes of imported diesel and increased petrol exports remains unclear.

11. The growing demand for diesel in Europe and across the globe continues to result in seasonal variations in the price of diesel, but the price premium over petrol is difficult to forecast since much depends upon the future diesel supply/demand balance.

The following recommendations are made as suggestions to stimulate debate on the issues raised in this report. Overall policy should be reviewed by government to reduce the negative impacts of the rapid switch to diesel-powered cars caused by the emphasis of policy being largely upon CO_2 reduction, with the aim of achieving a more even balance between demand for petrol and that for diesel:

1. **Incentives** to change behaviour can be valuable, but need to be framed carefully to avoid distortions, and should be kept under regular review to assess their effectiveness.

2. Changes to **Vehicle Excise Duty (annual and/or first-year) and company car tax** should be considered, to introduce limits on pollutants such as NO_x and PM alongside those for CO_2 for all vehicles, with the caveat that the changes are framed in such a way as not to be unduly complex for consumers.

3. Applying **fuel duty** on an energy basis has merit since it treats all energy sources for road transport on an equal footing. Such a change would have serious implications for the heavy goods vehicle sector, so an administratively simple and ring-fenced duty rebate scheme would have to be devised if such a change were implemented.

4. **Scrappage schemes** can be effective in bringing about a more rapid turnover in the vehicle fleet and taking older, less fuel-efficient, more-polluting vehicles off the road. The Government should examine applying such a scheme to diesel cars to address the problem of NO_x and PM emissions, but to be effective the starting point would ideally have to be comparatively newer early Euro 5 cars of six years old.

5. The current **drive cycle and test procedure** should be replaced by the Worldwide harmonized Light vehicles Test Procedure by 2017, which is expected to be more representative of real-life driving conditions.

6. **Security of supply** and the **robustness/resilience of the UK's fuel storage and distribution infrastructure** is a major concern for all consumers, given the uncertain future facing the domestic oil refining industry. The Department of Energy & Climate Change's consultation response in April 2014 (DECC, 2014c) stated "*Resilience and security of supply is supported by retaining a mix of domestic refining and imported product. This is consistent with the government's energy security of supply strategy which recognises the benefits of supply diversity*."

Diversity of supply is important but there is also a shared concern with the refining industry that the closure of another UK refinery could pose very serious risks to security of supply and regional robustness/resilience, unless there is investment in additional storage capacity and import infrastructure. Government must address the policy issues identified in the UK Petroleum Industry Association report (IHS, 2013) and referred to in the consultation response (DECC, 2014c) that would help the domestic refining industry to compete on a more level playing with international competition. Further, it must keep under close review all the issues affecting the robustness and resilience of the fuel supply chain, and the pace at which it is adapting to market changes.

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