DIESEL
The true (dirty) story

a study by TRANSPORT & ENVIRONMENT

In house analysis by Transport & Environment
Published by Transport & Environment

For more information, contact:

Julia Poliscanova
Clean Vehicles Manager
Transport & Environment
julia.poliscanova@transportenvironment.org
Tel: +32(0)2 851 02 18

Acknowledgements:

This report is a labour of love and collective effort by many current and past T&E staff including: Nusa Urbancic; Nina Renshaw; Greg Archer; Francois Cuenot; Malcolm Fergusson; Laura Buffet; Thomas Earl; Carlos Calvo Ambel; Florent Grelier; Lisa Allegretta. The conclusions reached however remain exclusively those of T&E.

Diesel: the true (dirty) story

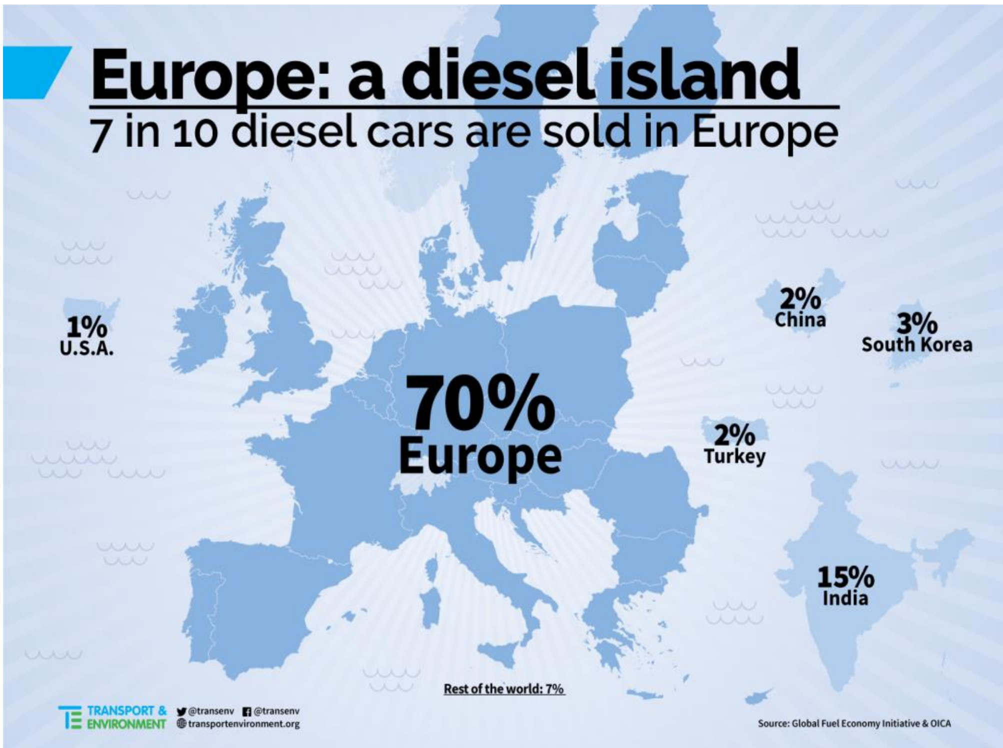
Why Europe's obsession with diesel cars is bad for its economy, its drivers & the environment

September 2017

Executive summary

Two years after the Dieselgate scandal first broke the full scale of the cheating and deception by carmakers is still emerging. There are now 37 million dirty diesel cars and vans on the EU's roads. But whilst the way carmakers have cheated emissions rules is becoming clearer the response from carmakers and Governments is derisory with only a tiny fraction of these diesels cleaned up. This report draws on a wide range of data and analysis to examine the underlying reasons for Europe's diesel addiction, i.e. the biased regulations and taxes that have artificially created the bloated sales of diesel cars in Europe that until recently represented over half of the new car market. It also examines the consequences for health and the environment and wider economic effects of dieselisation. Contrary to perceived wisdom it shows that diesel cars are not actually lower carbon than gasoline versions if emissions are considered across the full lifecycle of the vehicle.

One of the key reasons for Europe's higher share of diesel cars has been the laxer air pollution emission limits that have allowed diesels to spew more toxic NOx emissions than petrol-fuelled vehicles. The lax tests allowed cheap after-treatment systems to be installed that are at the heart of the dieselgate scandal and save the car industry over Euro 500 per vehicle that would otherwise make diesel cars prohibitively expensive. The introduction of the new real-world emissions (RDE) tests are a step forward but perpetuate the bias by allowing future diesel engines to emit 2-3 times more NOx than gasoline. Similarly, the EU car CO_2 regulations were designed to favour heavier vehicles by raising carmakers targets by 3.3 g CO_2/km for every additional 100kg, thus favouring diesel vehicles.

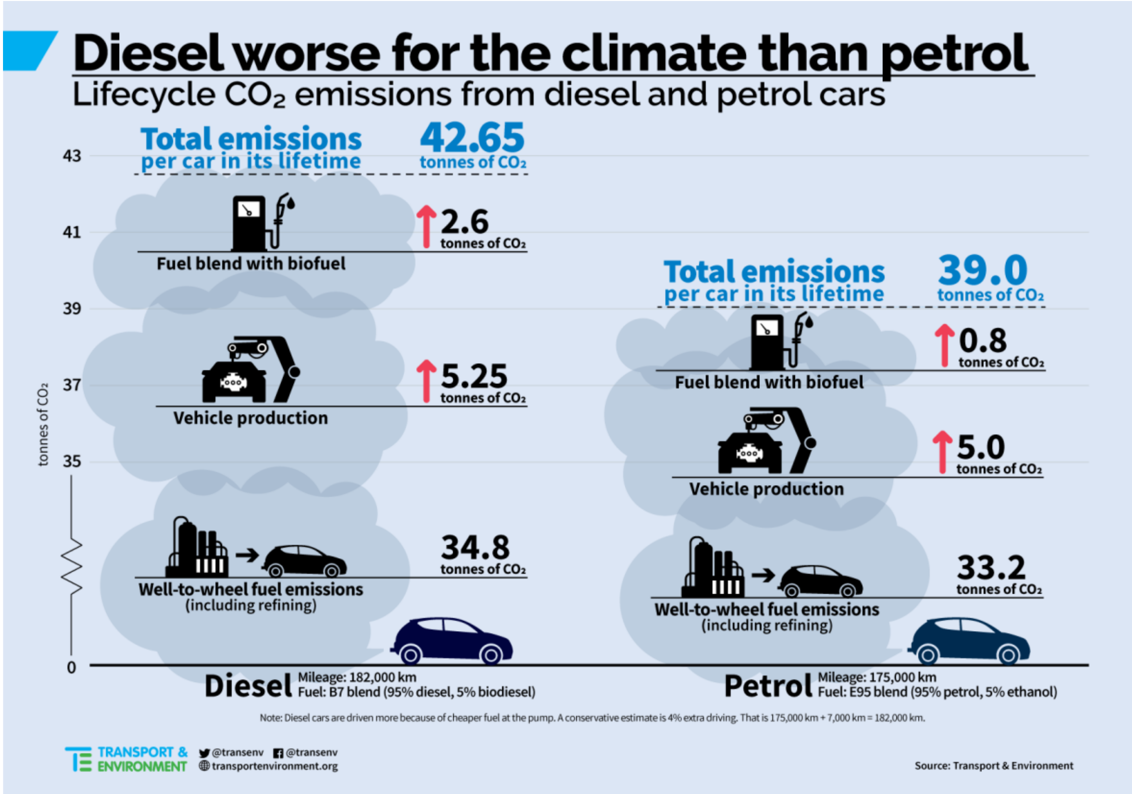


Whilst EU regulations create an uneven playing field for diesel, fuel and vehicle taxes set at a member state level incentive their purchase. Diesel fuel is taxed significantly less than petrol in most countries, making it 10% to 40% cheaper at the pump. This 'diesel bonus' has also resulted in a drop in real income from fuel taxes and cost national budgets almost EUR 32 billion in lost tax revenue last year alone.

Together these regulatory and financial distortions have skewed the vehicle market in favour of diesels and raised its sales share to above 50%. This is in stark contrast to other global markets where in the absence of biased regulation diesel's share is consistently below 5%; in the USA and China it is 1% and 2% respectively. Europe is now a diesel car island, accounting for 70% of world's sales of diesel cars and vans. This share is set to grow in the future as light-duty diesel becomes the technology of the past that no one else in the world wants to use or develop.

The main argument of the car industry to continue with diesel is its lower CO2 emissions. But the report analyses evidence and concludes an average diesel car produces over 3 tonnes more CO2 than petrol over its lifetime. This is due to:

- higher mileage (4% more due to cheaper diesel fuel, or rebound effect)
- More intensive refinery processes for diesel fuel
- larger amounts of manufacturing material due to diesel's weight and complexity
- High GHG emissions of biodiesel substitutes when ILUC emissions are factored in.



This analysis does NOT take into account all of the additional km's diesels are driven.

New direct injection gasoline engines are now significantly more efficient closing the gap with diesel. The average CO2 emissions of new diesel cars (119g/km) are only a few grams/km lower than an average (often less powerful) petrol car (123g/km). If the Euro 2,000 cost premium of diesel over petrol car is taken into account gasoline cars already outstrip their diesel counterparts. For example hybrid systems are now no more expensive than diesels (and cheaper in some markets) but average 89g/km. In the medium term the opportunities to lower CO2 emissions from cars are primarily from gasoline and electric solutions. To 2050 electric is the most cost effective technology. Since diesel is not better for the climate than petrol there is no justification for its preferential treatment.

Is diesel worth the cost?

Same power, same CO_2, €2,750 more expensive

	Volkswagen Golf VII	Volkswagen Golf VII
Trim level	Highline	Highline
Gearbox	Automatic 7	Automatic 7
Fuel type	Petrol	Diesel
Engine power	110 kW - 150 hp	110 kW - 150 hp
CO_2 emissions (NEDC)	114 gCO_2/km	114 gCO_2/km
Weight	1,317 kg	1,391 kg
Price	**€28,075**	**€30,825**

TRANSPORT & ENVIRONMENT @transenv @transenv transportenvironment.org

Source: www.volkswagen.de - checked on 12/09/2017

Since Dieselgate erupted in September 2015 diesel vehicles have been shown to be the dominant reason for the high levels of toxic nitrogen dioxide pollution across European cities and the resulting death toll of 68,000 Europeans from breathing air with high levels of nitrogen dioxide. The hundreds of real-world emission tests carried out in the aftermath show that around 80% of all cars and vans sold in Europe since 2010 (37 million) are grossly polluting, exceeding the NOx emission limits by over 300%. Almost every European carmaker - including Daimler, Renault and Fiat - has now been engulfed by the scandal amidst allegations of rigging emissions tests. The new Real Driving Emissions (RDE) regulations, based on on-road PEMS testing, have entered into force in September 2017 and are expected to bring down NOx emissions from new vehicles after 2019. However, recent tests carried out by ICCT point to some new diesel cars specifically designed and calibrated to pass the new stricter tests while NOx emissions outside of RDE test conditions in the order of 26-40 times over the limits undermining any air quality benefits, in particular in urban areas.

There is a vicious circle now revolving around diesel cars. New emissions tests and regulations are finally requiring better after-treatment systems raising manufacturing costs. Diesel cars are in the cross-wires of concern about our toxic air and legal pressure to enforce air pollution limits with diesel bans now proposed in many cities. Increasingly attractive competing technologies are eroding its market share in Europe, notably more efficient gasoline cars and in the future electric. Beyond Europe the hoped for growth of diesel in emerging markets has stalled so diesel remains a niche global powertrain for cars. With so many demands on research and development funds, further diesel development is becoming a low priority. All of these factors were inevitably going to dismantle the dominance of diesel in Europe. However, the Dieselgate scandal has trashed its reputation as a clean solution but probably accelerated rather than initiated its decline.

Most European car manufacturers seem to be in denial about the inevitable trend of a declining diesel share. Like King Canute, they demand the sea retreats and are calling on their friends in Government to ease the pressure on diesel cars by preventing diesel car bans and retaining the tax and regulatory biases that have created the European diesel market; their mantra of technology neutrality suddenly forgotten. Instead of trying to preserve diesel in Europe carmakers and Governments must focus on producing clean electric vehicles that are now being recognised as the future – notably in China which is gearing up to supply both its own huge market and export to the rest of the world. If Europe creates a significant home market for electric cars, the cars will be made here along with the battery packs and cells. If the European market remains niche the likelihood is that the cars will be largely imported from China. Whether or not the European car industry avoids a Nokia moment will to a large extent depend upon whether it invests heavily in new solutions or seeks to perpetuate the market for diesel for as long as possible by retaining tax and regulatory biases. We now need the dash for diesel to be replaced by one for electric motors and batteries.

From an environmental perspective there is no justification to continue the preferential treatment diesel currently enjoys that has created the bloated European diesel market - now is the time to support and incentivise the shift to clean electric solutions. Specifically to create fair competition between technologies EU policy needs to:

1. End biased vehicle emissions standards and propose a technology neutral Euro 7 emission standard that would allow new diesel cars to emit no more NOx than state-of-the-art petrols
2. Reform EU car CO2 regulations by getting rid of distortions in favour of heavier diesels, including accounting for vehicle km and introducing a zero emission vehicles sales target to incentivise industry to increase supply of electric vehicles and market them effectively
3. Remove the diesel bonus and other biases in national tax regimes, and introduce fair fuel and vehicle taxes based on real-world CO2 emissions with an air quality increment.

Specifically in response to the dieselgate crisis:

4. Regulators must ensure there is a harmonised and effective approach to clean up 37 million dirty diesel cars and vans already on the road that is offered to all consumers EU-wide
5. Cities must put in place effective vehicle circulation restrictions when air pollution is above the recommended limits and ensure future low emission zones are designed based on vehicles real-world performance.

The true story behind diesel is that it has enabled the industry to sell larger, more powerful and more profitable cars - but at a cost for Europe's economy, energy security, climate and environment. It is time Europe stopped pouring money and energy into a globally niche 20th Century technology. The future is electric with Europe either joining the flow or drowning in diesel's dirt.

Table of Contents

This report 9

1. **The dieselisation of Europe's car fleet** 10

1.1. The trend in diesel cars in Europe and beyond 10
1.2. Why Europe developed its market for diesel cars 11
1.3. The diesel car market 12
1.4. The usage patterns of diesel cars 14
1.5. The diesel fuel market 15
The products of refining crude oil 16

2. Pro-diesel biases in EU policies 17

2.1. The 'diesel bonus' 17
2.2. The diesel bias in the EU Energy Tax Directive 19
2.3. CO_2-based vehicle taxes 19
2.4. The design of the EU Cars and CO_2 Regulations 22
2.5. Biased air pollution regulations 23
2.6. Obsolete and inaccurate vehicle emissions tests 25
2.7. The Dieselgate scandal 28
2.8. Cartel investigation 30

3. Impact of dieselisation and pro-diesel policies 31

3.1. Air pollution and human health 31
3.1.1. Nitrogen oxides 31
3.1.2. Particulate matter 34
3.1.3. City diesel bans and the "Diesel Summit" 35
3.2. Land use change through use of biodiesel 36
3.3. High demand for diesel in Europe creates a market for (Canadian) tar sands diesel 37
3.4. Climate effects 38
3.4.1. Upstream 'well-to-tank' refinery emissions 38
3.4.2. Embedded emissions in vehicle production 40
3.4.3. Diesel cars are driven further 41
3.4.4. First generation biodiesels are more CO_2-intensive than bioethanols 41
3.4.5. Lifetime CO2 emissions of a diesel compared to a petrol car 43
3.4.6. Lifecycle comparison with other fuels and powertrains 44
3.4.7. Diesel is not needed to meet EU climate targets 45
3.5. Effects on the balance of trade and energy dependence 48
3.6. Declining fuel tax revenues 49

4. Global Diesel market outlook 51

4.1. Worldwide diesel sales of Light-Duty Vehicles (LDVs) 51
4.2. Low- and zero emission alternatives to diesel 52

5. The road ahead: recommendations for fair clean car policies 57

5.1. Diesel is not worth Europe's money or effort 57
5.2. Ending EU regulatory biases in favour of diesel 59
5.2.1. Euro Standards 59
5.2.2. Car CO2 regulations 59
5.2.3. Renewable Energy Directive 59
5.2.4. Type Approval 60
5.2.5. An end of diesel 60

5.3. National and local policies 61
5.3.1. Abolishing the diesel tax bonus 61
5.3.2. Rebalancing vehicle taxation 61
5.3.3. Local air quality measures 61
5.4. Europe's next 'Nokia moment'? 62

This report

Over the past 15 years there has been a rapid growth in the sale and use of diesel cars in Europe. Although the trend finally peaked in 2014, and somewhat reversed following the pan-industry Dieselgate emissions scandal, an appalling legacy of damage to the environment and harm to the competitiveness of the European automotive industry persists. Despite this, there are desperate attempts by some premium carmakers and governments (notably Germany) to preserve diesel as the premier powertrain in Europe and to prevent cities' plans for diesel bans that are the inevitable consequence of the toxic air in our cities the diesel cars have largely caused. Around half of the new cars sold in Europe in 2015 were diesels (more than 5 times the figure in 1990). Consequently, just a third of the road fuel used is now petrol, a reversal of the pre-1990 share when just a third of road fuel was diesel, and most of this was used by vans, trucks and buses. The demand for diesel is projected to decrease, albeit very slowly, such that by 2020 it will continue to make up a significant share of road transport fuel.

The dieselisation of the car fleet has profound implications for air quality and public health, energy security, technological innovation and national transport tax revenues. It has also accelerated unsustainable trends for larger and higher performance cars in Europe. It risks damaging the global competitiveness of EU carmakers at a time when the rest of the world is deploying more and more hybrid and electric powertrain technology whilst Europe is a diesel island.

The growth in diesel has not been stimulated by superior engine technology, nor has it been observed in other major car markets. In global markets, such as US and China, where diesel is not favoured by lower taxes and weaker environmental standards, its market share is consistently below 5%. In Europe, the use of diesel has been stimulated by regulations on vehicle emissions and fuel taxation, which predisposes the market in its favour. Europe's dieselisation is therefore the result of years of technology-biased regulations. Despite the ongoing diesel scandal and new pressures from cities, consumers and NGOs, the pro-diesel bias continues in many Member States – although some, like France, are now raising diesel fuel and vehicle taxes. Manufacturers are fighting back wrongly arguing that new Euro 6 cars are clean and that Europe cannot reach its climate targets for transport without diesel. Behind this argument hides a desperate attempt to keep selling diesel cars in Europe, as sales decline or remain a niche in most other markets. The pro-diesel bias is also being maintained by many national governments (notably Germany), who are reluctant to adopt a tough stance on national champions. The current mood can be best summarised in the words of Daimler CEO Dieter Zetsche, who announced that 'Diesel is worth fighting for!', presumably because the company reportedly spent 3 billion euros developing its new diesel engine.

This report assembles data and evidence to show that, in fact, diesel forms part of the dirty history of the car industry and that new clean technologies, like battery electric cars, represent the future:

- Section 1 of this report examines the origins and nature of the growth in diesel cars in Europe.
- Section 2 explains why dieselisation has happened and highlights the biases in policy that favour diesel.
- Section 3 looks at the environmental and economic implications and examines whether diesel cars are really lower carbon than petrol and represent the best route to transport decarbonisation, as claimed.
- Section 4 looks at the vehicle market developments and wider competitiveness aspects
- Sections 5 propose policy recommendations to rebalance the vehicle fleet and end the pro-diesel bias in favour of low and zero emissions technology.

1. The dieselisation of Europe’s car fleet

1.1. The trend in diesel cars in Europe and beyond

Twenty years ago, almost all private cars were powered by petrol (or gasoline) engines. Diesel was used primarily in vans and trucks (Heavy-Duty Vehicles or HDVs), plus a relatively small share of cars that were driven over very long distances, such as taxis and the cars of sales representatives, maintenance engineers, etc.

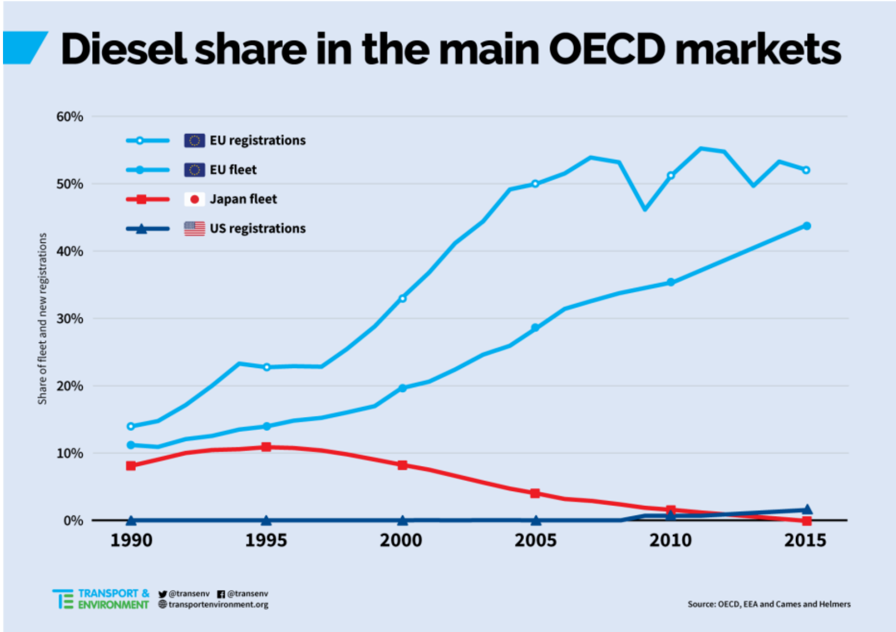


Figure 1

Over the past two decades, the process of ‘dieselisation’ has transformed the car fleet in Europe. The share of new diesel registrations has increased from 15% in 1990 to 52% in 2015. It fell back briefly to 45% in 2009, as buyers delayed buying new diesel cars in the recession, but have since steadily grown to slightly above half of all new cars sold.[1] As a result, over a third of all cars on Europe’s roads are now diesels (Figure 1), and the diesel share hovered around 50% in 2016, as more new diesels entered the fleet. It is only very recently that the Dieselgate emissions scandal (Section 2.7) and the resulting loss of consumer confidence have slightly damaged the diesel car market share, although it is too soon to determine with confidence its long-term effect on the market.

This high share of diesel cars in Europe is unique around the world. In the other major car markets — US, Japan and China — almost all new cars have petrol or hybrid engines. In the US, diesel cars have always been rare; and, even in Japan, where in the early 1990s the diesel share of new cars exceeded 10% and looked set on a similar trend to that in Europe, diesel car sales fell back again, being currently close to zero.[2] Only the emerging car market in India has a significant diesel share (50%), because of a substantial tax bonus for

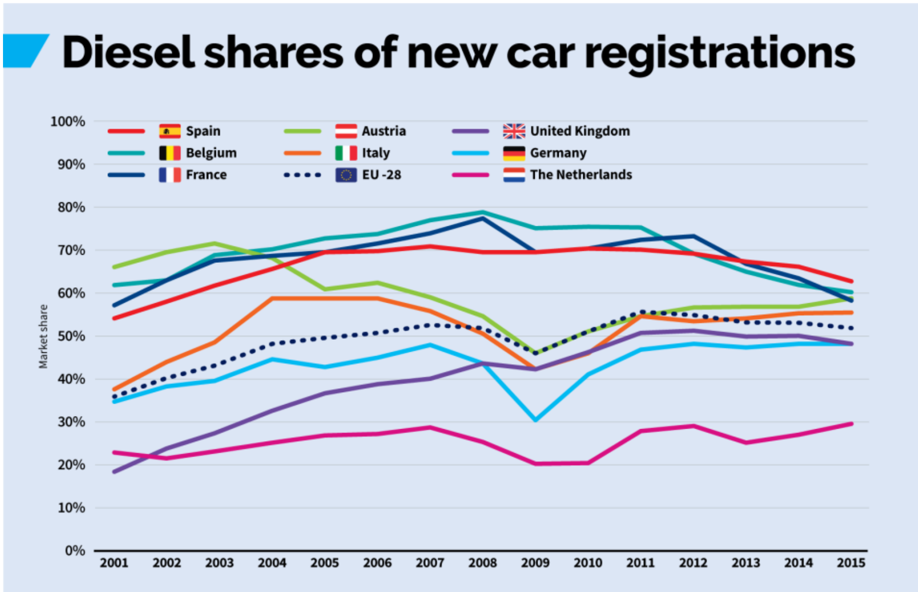


Figure 2

[1] ICCT, 2016, Pocketbook, http://www.theicct.org/sites/default/files/publications/EU_vehiclemarket_pocketbook_2015_Web.pdf

[2] Cames and Helmers, *Critical evaluation of the European diesel car boom – global comparison, environmental effects and various national strategies*, 2013. http://www.enveurope.com/content/25/1/15

diesel use at around 30%.[3] In Korea, the diesel share is around 30% of new cars, a percentage partly achieved as a result of the EU-Republic of Korea Trade Agreement. But the shares in both countries are likely to fall in coming years following the diesel emissions scandal and ensuing regulatory reforms.

Dieselisation trends are fairly consistent across the major EU Member States (Figure 2), with almost all countries increasing their diesel share of new cars from the mid-1990s or before. Spain, France and Belgium have consistently had the highest diesel share (close to 60% each), while other Member States seem to be levelling out at around 50%. Only the Netherlands amongst the major EU markets has a new car market share of diesels significantly below 50% (29% in 2015)[4] and this reflects a deliberate policy choice, as explained below.

Nearly all the major European car brands now sell at least half of their diesel cars in Europe[5] except Fiat (35%), Opel (37%) and Ford (45%). The premium German car brands (BMW, Audi and Mercedes) each sell presently over 70% diesel cars, and Volvo has reached 88% (though the carmaker has subsequently announced that it will phase out diesel engines by 2025). In contrast, Toyota, one of the world's largest car companies, sells only 23% diesel cars in Europe, and fewer still elsewhere.

1.2. Why Europe developed its market for diesel cars

Diesel has for a long time been used in heavy-duty applications including lorries, buses, trains, ships and boats, tractors and mobile machinery such as construction equipment. In these applications diesel has significant technical advantages, as a litre of diesel contains around 15% more energy than petrol (approx. 36.9MJ/l vs. 33.7MJ/l for petrol), so more work output can be extracted from a litre of diesel than of petrol. Beyond this, diesel engines are also more efficient, robust and reliable, and have greater longevity in demanding applications. This makes them the natural choice for heavy-duty purposes.

For passenger cars, however, the picture was historically rather different. Petrol engines tended to operate at higher engine speeds and were more responsive across the range of typical driving conditions and were therefore regarded as being more easily driveable. Virtually all high-performance cars were petrol-driven up to the end of the twentieth century. Because petrol engines operate at lower engine compressions, they do not need to be as robustly constructed as diesel engines and are therefore cheaper to manufacture. Today, a typical diesel car costs around €2,000 more than its gasoline equivalent. This makes any CO_2 savings in the tailpipe emissions of diesel engines very expensive to achieve.

Diesel was first used in cars by Citroën in 1933, but it remained a niche product until the first oil crisis of the early 1970s. Since then, the diesel engine market share in vehicles grew to around 10% by 1980 and remained at that level over the following decade. This early growth was in part a response to the declining heating oil market brought on by the introduction of natural gas in Europe and nuclear energy in France. A growing market for middle distillates from diesel cars was able to offset the declining fuel oil market and enabled European refineries to find local markets for all the crude oil fractions that they produced. There was also now a financial incentive for people who drove very long distances – such as taxi drivers – to choose a diesel car, as the higher up-front cost of a diesel car was offset by lower fuel costs per kilometre (described in greater detail below).

Diesel technology progressively improved over time with the introduction of turbochargers and, subsequently, common rail fuel management systems, while petrol engines had to deal with the additional costs and complexity of a shift to unleaded petrol and the requirement for three-way catalysts to deal with emissions of regulated pollutants. Emissions standards for nitrogen oxides (NOx) were also kept less stringent for diesel than petrol cars, making their emissions control requirements less demanding and

---

[3] Deutsche Gesellschaft für Internationale Zusammenarbeit, *International Fuel Prices 2012/2013*, 2013. http://www.giz.de/expertise/downloads/giz2014-en-international-fuel-prices-2013.pdf
[4] ICCT, 2016, Pocketbook, Figure 4.1, http://www.theicct.org/sites/default/files/publications/ICCT_Pocketbook_2016.pdf
[5] Ibid.

cheaper. In contrast, other regions set the same limits for diesel and petrol engine exhaust emissions making diesel cars unattractively expensive.

In the 1990s, concerns over climate change created pressure on carmakers to improve the fuel-efficiency (and hence CO_2 emissions) of the cars they sold. This worry was reflected in the voluntary agreement between the European Automobile Manufacturers' Association (ACEA) and the European Commission in 1998. The lower tax on diesel (and hence lower pump prices) provided an incentive to use diesel in high-mileage applications, but some countries, such as France and Spain, went further, also offering lower vehicle taxes on diesel cars. The car industry itself was also quick to advocate a switch to diesels as an essential component of any strategy to cut CO_2 emissions.

Environmentalists, in contrast, were far less enthusiastic about this further shift to diesel. In particular, there were concerns over the health effects of particulates, nitrogen oxides and the carcinogenicity of diesel exhaust fumes. However, the increasingly strict Euro standards to control exhaust emissions *should* have ensured that the shift to diesel did not result in high emissions and air pollution levels. In practice, due to weak testing regimes, diesel cars produced many times the Euro standard limits on the road and the anticipated improvements in air pollution levels failed to materialise. By the early 2000s, it had become clear that car emissions were not being adequately controlled, and Euro 5 and 6 standards were agreed. However, test cheating and extensive delays to the introduction of real-world tests meant that the problems of high real-world emissions still persist today.

1.3. The diesel car market

Diesel cars tend to have much higher power output than their petrol equivalents. As the left hand panel of Figure 3 illustrates, the average power of new cars has risen fairly steadily from around 75kW in 2001 to more than 90kW now. Back in 2001, the power difference between petrol and diesel cars was quite small, but it has steadily increased as diesels have become commoner, to the point where the average petrol/gasoline car is just above 80kW, while a typical diesel is only slightly short of 100kW.This difference offsets most of the efficiency benefits of diesel, to the point that the average CO_2 emissions from a typical petrol or diesel car are now virtually identical (see section 3.4). Had dieselisation not occurred, it is highly unlikely the same growth in power and performance would have happened as the fuel costs would have been prohibitive. The growth in power and performance has been highly beneficial for the carmakers, who earn significantly higher profits on these engines.

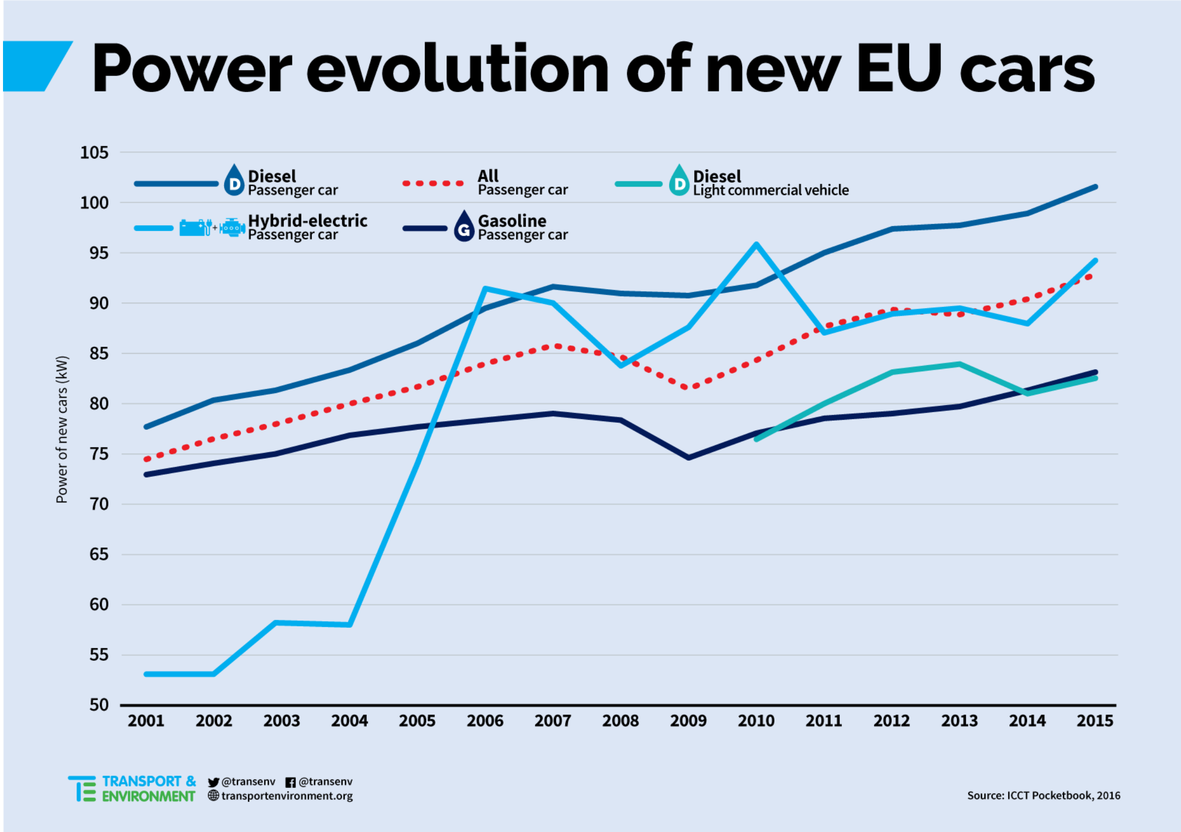


Figure 3

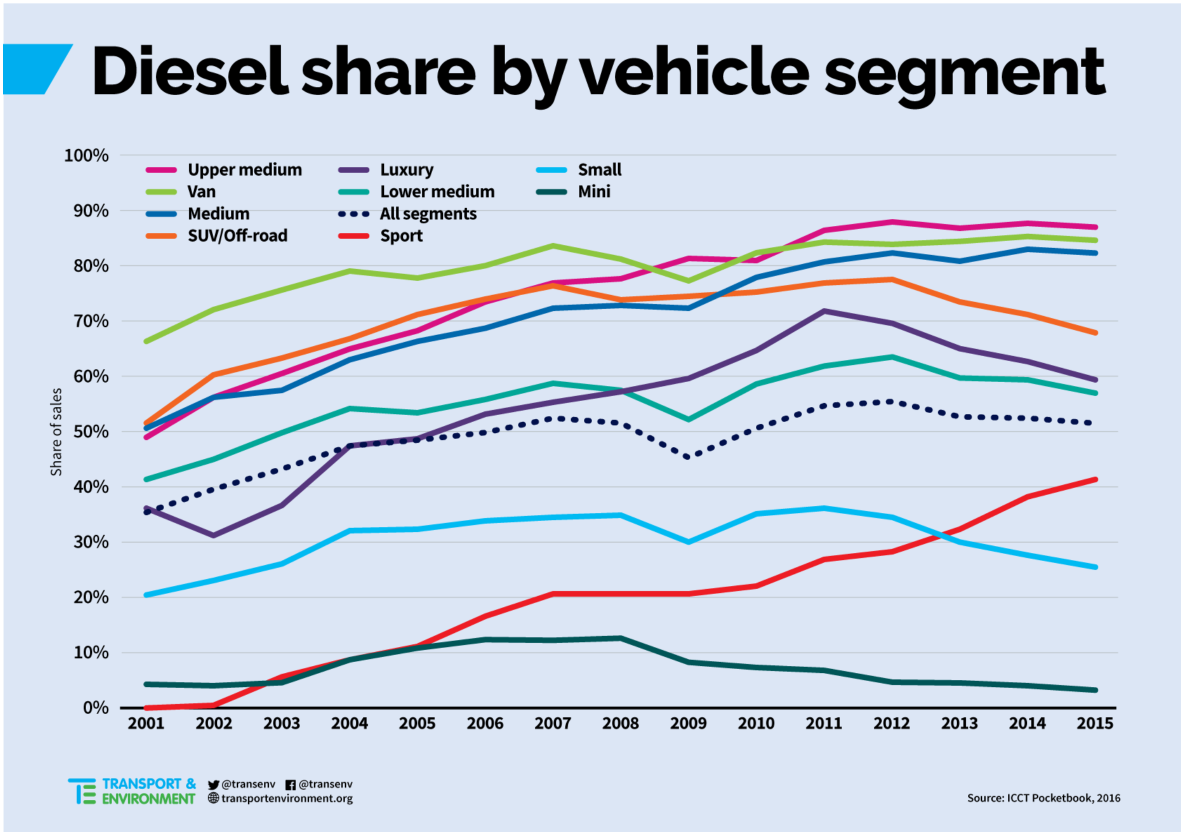


Figure 4

As Figure 4 illustrates, the diesel share has increased from around 35% at the start of the century to above 50% today. However, the picture varies significantly in different market segments. More than 80% of new

Medium cars (e.g., VW Golf), Upper Medium cars (e.g. Ford Mondeo), plus vans, are now diesel; this high proportion has been sustained in recent years. The sport segment has risen from virtually all petrol to over 40% diesel today and it is the only segment where diesel as a proportion is still growing, which reflects the improving performance of diesel engines.

In contrast, the diesel share of Sport Utility Vehicles (SUVs) (e.g. BMW X series), Luxury (e.g. the Mercedes S-Series) and Lower Medium (e.g. the Ford Focus or Fiat Bravo/Brava) segments appears to have peaked and is now in modest decline with market shares falling to 60% or 70%. The Small (e.g. Citroën C3 or VW Polo) and Mini (e.g. Fiat Cinquecento) segments, have never moved to very high diesel market shares (due to the €2,000 diesel premium) and even this small market is now declining.

1.4. The usage patterns of diesel cars

As noted above, diesel engines tend to be more durable than petrol ones and, historically at least, they have tended to be chosen for applications that require long distances to be driven. As a result, it has long been known that diesel cars are driven farther on average in a year and over their useful lifetimes than petrol cars.

In 2014, the consultancy Ricardo AEA illustrated the size of this effect for the UK through a detailed analysis of returns from individual cars for their annual safety and environmental tests (Periodic Technical Inspection). The results[6] are summarised in Figure 5.

Lifetime distance driven and average mass

Mass system (with mileage)	Petrol (small)	Petrol (medium)	Petrol (large)	Diesel (small)	Diesel (medium)	Diesel (large)
Lifetime mileage (km)	150,000	169,000	186,000	222,000	230,000	238,000
Mass in running order (kg)	1084	1422	1700	1242	1579	1898

TRANSPORT & ENVIRONMENT @transenv @transenv transportenvironment.org

Source: Ricardo AEA 2014

Figure 5

Figure 5 illustrates, firstly, that larger cars are on average driven much farther than smaller ones and in each size class, diesel cars are driven substantially farther than their petrol equivalents. The latter is the larger effect, amounting to around 30% for large- and medium-sized cars, but nearly 50% for the smaller models. Petrol cars have an average lifetime marginally longer than diesel cars (14.4 years compared to 14 years) and the additional mileage is therefore a result of greater usage.[7] Around 4% of this result is likely to arise exclusively because diesel fuel is less expensive.

Within each size class, diesel cars are on average substantially heavier (by around 200kg) than their petrol equivalents, reflecting in part the heavier construction of the engines themselves. The difference in weight and distance driven is more than enough to counteract the natural fuel economy benefits of diesel cars and, consequently, a typical diesel consumes more fuel and emits more CO_2 over its lifetime than a petrol equivalent. There is no mileage weighting in the current EU Car CO_2 law, and such a weighting should be introduced into the forthcoming post-2020 regulation.

---

[6] Ricardo-AEA, *Data gathering and analysis to improve understanding of the impact of mileage on the cost-effectiveness of Light-Duty Vehicles CO_2 Regulation*, 2014. https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/ldv_mileage_en.pdf

[7] Ibid.

1.5. The diesel fuel market

Twenty years ago most cars were fuelled by petrol and most heavy goods vehicles and vans by diesel. This division was important in maintaining the right balance between the middle and light distillates refined from a typical barrel of oil. A small switch from petrol to diesel for cars in the last decades of the twentieth century (to about 10% market share) was actually helpful in maintaining this balance, but the steady growth in diesel car sales since then has upset that balance. Today, cars represent around half of Europe's diesel use; vans consume around one-eighth and the rest goes to trucks and buses. As a result, as shown in Figure 6, the ratio of diesel to petrol and of total middle distillates to petrol is changing rapidly.

The increasing demand for diesel is expected to continue, according to projections from Conservation of Clean Air and Water in Europe (Concawe).[8] By 2030, petrol demand is projected to have declined from around the current 20% to just 13% of total fuel demand, whereas middle distillate fuels, including diesel, will grow to more than 60%. The ratio of diesel to petrol and of total middle distillates to petrol is projected to virtually double between 2008 and 2030 (from 2.1 to 3.7 and from 3.5 to 6.5, respectively). As yet, this change is less than halfway complete, but the ratios have already gone much beyond what traditional European refineries can provide. This necessitates massive global movements of refined fuels and raises major energy security concerns for Europe.

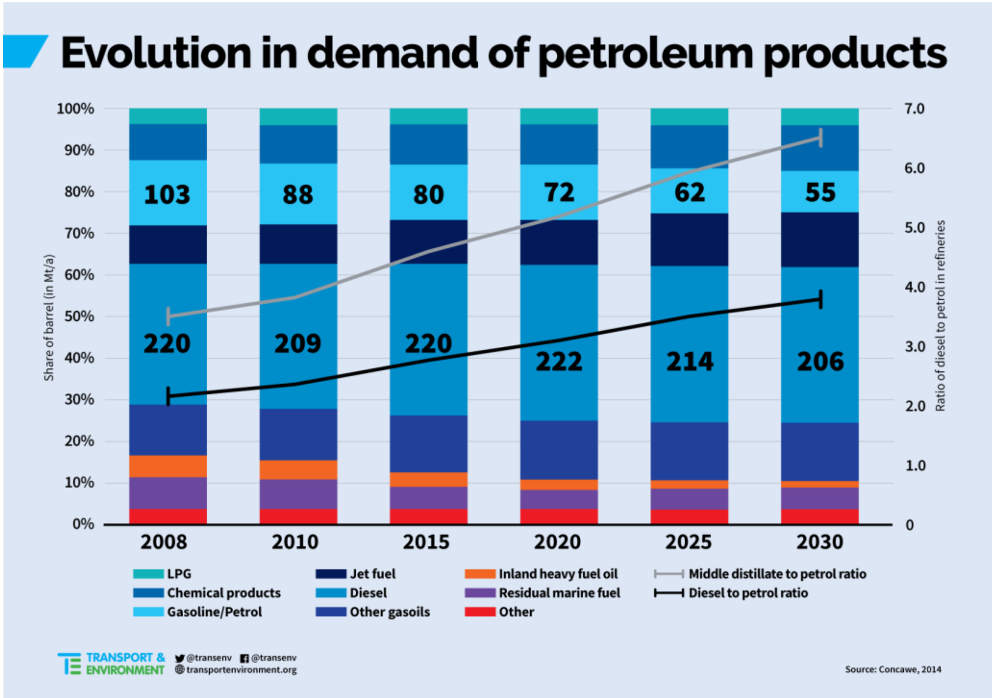


Figure 6

[8] Concawe, *Oil refining in the EU in 2020, with perspectives to 2030*, Appendix 7, 2013. https://www.concawe.eu/wp-content/uploads/2017/01/rpt_13-1r-2013-01142-01-e.pdf

The products of refining crude oil

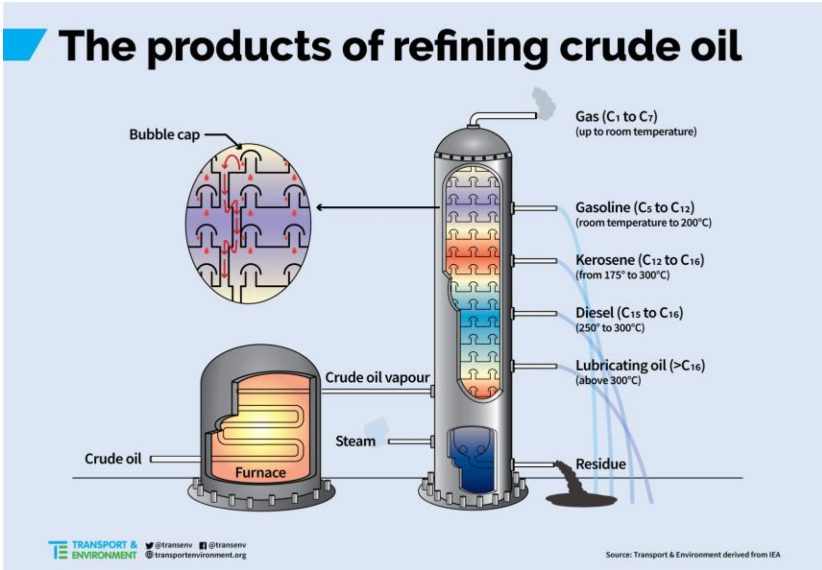


Figure 7

When crude oil is refined, it is separated into a range of different products, most of which are used as fuels – heavy oil, diesel, kerosene, petrol, LPG, etc. The residue from this process is bitumen, used primarily as a road surface. A typical barrel of conventional oil yields a broad range of final product, although the exact proportions and technical specifications of each fraction of the final output depends on the nature of the crude oil used and the technical specifications of the refinery.

Refineries have some flexibility in determining what proportion of each product they will produce, but not very much; more important for the oil industry is ensuring that there are stable markets for each of the products that they produce. In particular, this includes maintaining the correct balance between the 'middle distillates' (principally diesel and jet fuel, plus gasoil for heating) and the 'light distillates' of which petrol or gasoline are the most important and useful components).

2. Pro-diesel biases in EU policies

The growth of diesel cars in Europe has not been replicated in other car markets around the world. This suggests that unique conditions beyond market forces exist in Europe that favour diesel over gasoline cars. This section examines what these are.

2.1. The 'diesel bonus'

In most countries diesel fuel has always been taxed at a lower rate since it was predominantly used by commercial vehicles. By applying two different tax rates for diesel and petrol, governments have maximised stable fuel tax revenues from petrol car drivers whilst protecting the commercial road haulage sector from excessive costs and from competition from neighbouring countries with a lower diesel rate. When the share of diesel passenger cars remained low, this taxation framework worked effectively; but this is no longer the case.

Across most European countries, diesel taxes are currently 10%-40% per litre lower than petrol taxes, with the biggest diesel bonuses in the Netherlands (37%) and Greece (41%). The UK is notable as the only EU country with no diesel bonus, while non-EU Switzerland levies slightly higher taxes on diesel than petrol.[9] In both cases, this results in diesel actually being slightly more expensive to buy on station forecourts than petrol. Elsewhere, the lower tax rate for diesel shields consumers and drivers from the fact that diesel costs more per litre than petrol pre-tax.[10] While the world market price for diesel is consistently higher than for petrol, consumers see the opposite at the pump almost everywhere in Europe. This disparity is even more important when tax rates are considered relative to energy content or CO_2 emissions per litre, which are around 10% and 16% higher, respectively, for diesel than petrol.

In general, the diesel bonus decreased from the mid-1990s to the mid-2000s, but overall it has remained largely constant for the last decade. However, this masks quite large recent changes in individual countries, including following the diesel emissions scandal. For example, in the last two years the diesel bonus has been reduced in France, Belgium and Portugal. Some of these countries were obliged under the terms of their IMF/ECB bailout programmes to review fuel taxes. It is notable that Slovakia cut diesel tax dramatically (in parallel to the introduction of km-charges for lorries) and that Greece, whilst raising fuel taxes significantly, has actually increased the gap and the relative diesel bonus. Overall, the trend heads in the right direction, but the absolute progress is painfully slow.

[9] Swiss fuel taxes October 2013: Petrol 731.20 CHF (≈592 €) per 1000 l, diesel 758.70 CHF (≈614 €) per 1000 l.
[10] However, per unit of energy (GJ) diesel is generally slightly cheaper before tax because of its higher energy density.

The diesel tax bonus in the EU

Country	Diesel tax bonus* 1994	Diesel tax bonus* 2017	Change 1994-2017	Total Change
France	36.4%	17.1%	↓	-53%
Germany	36.7%	28.1%	↓	-23%
Austria	25.9%	17%	↓	-34%
Belgium	30.1%	12.4%	↓	-59%
Denmark	20.8%	31.8%	↑	53%
Spain	27.4%	20.4%	↓	-26%
Finland	39.1%	23.6%	↓	-40%
Greece	34.6%	40.9%	↑	18%
Ireland	14.6%	17.9%	↑	23%
Italy	22.2%	15.2%	↓	-32%
Luxembourg	22.5%	27.5%	↑	22%
Netherlands	39.8%	36.7%	↓	-8%
Portugal	27.5%	28.4%	↑	3%
Sweden	27.9%	11.6%	↓	-58%
UK	2.2%	0%	↓	-100%

* Diesel tax bonus = 100x (petrol tax per litre – diesel tax per litre)/petrol tax per litre

TRANSPORT & ENVIRONMENT @transenv @transenv transportenvironment.org

Source: EC Oil Bulletin, 2017

Figure 8

When diesel engines' better fuel efficiency and their higher energy content are taken into account, the tax rates are even more favourable to diesel cars in most EU countries. On a per km basis, tax rates per litre would need to be at least 20% higher for diesel, just to equalise taxation rates on an energy content basis per litre. The Organisation for Economic Co-operation and Development (OECD)[11] recently argued that there is no justification for diesel to be less heavily taxed, as the efficiency gains should be a big enough incentive to save on fuel costs.

Transport & Environment has attempted to quantify the result of such an EU-wide diesel bonus. The indirect fuel subsidy for a diesel car using the average excise duties in the EU in 2016, assuming 15,000 litres fuel consumption over its lifetime, and including 21% average VAT, currently amounts to €2,400 (compared to the price for equivalent petrol use).

[11] Harding, *The diesel differential: differences in the tax treatment of gasoline and diesel for road use*, p.17, OECD 2014. http://dx.doi.org/10.1787/5jz14cd7hk6b-en

2.2. The diesel bias in the EU Energy Tax Directive

The EU's energy taxation legislation, the Energy Tax Directive (ETD), also reflects and perpetuates the diesel bonus. The Directive sets minimum fuel tax rates per litre that must be levied by the Member States for a range of different fuels, and the specified minimum is considerably lower (by 9%) for diesel than for petrol. Various attempts to update this legislation have been blocked by some Member States, so the minimum levels specified remain very low by most modern standards.

The ETD also makes provision for diesel tax rebates for truck operators, in order to allow Member States to in effect differentiate diesel tax rates for commercial and non-commercial use. As a result, trucks paid on average €0.44/l diesel tax in the EU in 2014, which is €0.04 below the rate levied on cars, and 15% below the inflation-corrected €0.52/l which they paid in 2000. Truck diesel tax rebates totalled around €4.5bn in 2014, up from €0 in 1999[12]. Several countries in Southern Europe make use of this option. [13]

2.3. CO_2-based vehicle taxes

Lower diesel excise duty is an important underlying reason for the dieselisation of the European car fleet, but it is not the only cause. If it was, rates of dieselisation in different countries would correlate closely with their diesel tax bonus, but they do not. For example, in the UK (48% diesel cars in 2015 are new car sales) there is no diesel tax bonus, but the rate of dieselisation is similar to the EU average of 52%. In two EU Member States with the highest diesel tax bonus, Greece and the Netherlands, the share of diesel cars in the fleet has been lower than anywhere else in Europe for years (in Greece it rose sharply very recently).

- In Greece, dieselisation started only in 2012, when new diesel car models (Euro 5/6 compliant) became widely available. Diesel cars had previously been banned from entering the two largest cities, Athens and Thessaloniki, representing almost 40% of the country's total population, because of dangerous levels of air pollution. Since May 2012, the ban has been lifted, and Greece has seen a dramatic surge in diesel car sales to profit from the huge diesel tax bonus (41% in 2017). In 2012, over 40% of the new cars sold had diesel engines; by 2015 this had risen to 63%.
- In the Netherlands, diesels represented over 20% of new car sales before 2000. Since then, growth has been marginal in spite of the large diesel tax bonus (almost 40%) because of high fixed taxes (sales tax and annual circulation tax) on diesel cars. Both the sales tax and the annual circulation tax are almost twice as high for diesel cars as for equivalent petrol models. These taxes in effect limit the market for diesel cars to drivers of over 35,000 km per year.

These two examples show different ways in which other policies can override the influence of fuel tax rates alone. The main drivers of the disparity between dieselisation rates in different countries are in fact the systems of national vehicle taxation. In the last years, these rates were changed in many countries to promote more fuel-efficient, lower CO_2 cars, which has further biased the market in favour of diesel cars. Prior to 2007, fixed taxes (sales, circulation road and company car taxes) on cars were largely based on the purchase price, weight and/or engine size, which effectively penalised diesel cars relative to petrol cars, since diesel cars tend to be heavier and more expensive. Many national governments also levied an additional 'diesel factor' to increase the fixed taxes, usually to offset lower fuel taxes or to reflect the higher air pollution emissions of diesel cars. High, fixed taxes thus made it expensive for most owners driving less than around 15,000 km per year to own a diesel car, in spite of the lower price at the pump. Under this tax regime, diesel cars were primarily used for professional purposes (taxis, distribution, sales representatives, etc.) and company vehicles with a high annual mileage.

Since this time, many Member States have amended some or all of their vehicle-related tax regimes (registration or sales tax, annual circulation tax and company car tax) in order to encourage cars with better fuel consumption or lower CO_2. As Figure 9 illustrates, most countries have at least some vehicle-related taxation linked to the CO_2 emissions of their vehicles, although these differ in extent and degree.

[12] Transport & Environment, *Europe's tax deals for diesel*, 2015. https://www.transportenvironment.org/publications/europes-tax-deals-diesel
[13] Ibid., p.10

Rating of national car tax and CO_2 policies

Rank	Country	CO_2 g/km	Registration Tax	Circulation Tax	Company Car Tax	Fuel Tax	Green car tax rating
1	Netherlands	109	✓✓		✓✓	✓✓	★★★
2	Greece	112		✓		✓	★
3	Portugal	112	✓✓	✓			★★
4	Denmark	112	✓✓	✓✓		✓	★★
5	France	117	✓✓	✓	✓✓	✓	★★★
6	Italy	121				✓✓	★
7	Spain	122		✓			★★
8	Belgium	124	✓		✓	✓	★★
9	UK	128		✓	✓✓	✓✓	★★
10	Austria	131	✓✓				★
11	Finland	132	✓	✓		✓	★
12	Sweden	133		✓		✓✓	★
13	Czech Republc	135					★
14	Germany	136		✓		✓	★
15	Poland	138					★

Vehicle Tax: ✓ Tax relates to CO_2 but only to a limited extent; ✓✓ Tax strongly graduated according to CO_2

Fuel Tax: ✓ Intermediate fuel tax rates; ✓✓ Highest fuel tax rates

Green car rating: ★ Weak policies; ★★ Average policies; ★★★ Best policies

TRANSPORT & ENVIRONMENT @transenv @transenv transportenvironment.org

Source: Transport & Environment

Figure 9

This analysis found a significant, but far from perfect, correlation between strong vehicle-related CO_2 policies and CO_2. To a first approximation, it also found that these policies tended to favour diesel vehicles over petrol cars amongst new car purchases, owing to the lower CO_2 of the latter and the consequently lower taxes that helped to offset the higher purchase costs. The air pollutant component has been largely ignored in most current national vehicle tax regimes.

It should be stressed, however, that following the diesel emissions scandal and the new evidence on NOx emissions exceedances of diesel cars, some countries announced a reform of their vehicle taxes. For instance, France announced in 2016 that it will close the tax gap between diesel and gasoline vehicles of company fleets, while Belgium promised to get its diesel bonus to almost zero as from 2018. However, it is not yet clear how exactly these announcements will be implemented in practice, and their effect on future diesel shares is too early to analyse. Once again, there are some steps in the right direction, but these are not widely followed and are still too limited.

A case study of dieselisation: Dutch and Danish tax policies compared

The car and fuel markets in Denmark and the Netherlands illustrate the ways different drivers of dieselisation operate. These two relatively small, high-income countries were less affected by the economic crisis of 2007/8 than most of the EU, but they still saw changes in their new car markets. In both countries CO_2 emissions from road transport peaked in 2006-2007, and have subsequently fallen slightly as a result of improving new car average CO_2 emissions.

- The Netherlands has long had amongst the highest petrol tax in EU (0.755 €/litre in December 2013) and the highest diesel bonus with petrol tax per litre, typically 75%-80% higher than diesel. It is also the only EU member where the diesel share of new cars has increased very little over the last 10 years.
- Denmark, in contrast, has amongst the lowest fuel taxes in north-west Europe (with petrol tax at 0.591 €/litre in December 2013) and a gap of 45-50% between petrol and diesel taxes. However, here the diesel car share of new car market has grown 2-3 times over the last 10 years and the diesel share of the car fleet has almost quadrupled.

Figure 10 shows how the percentage of new diesel cars has changed in both countries over time.

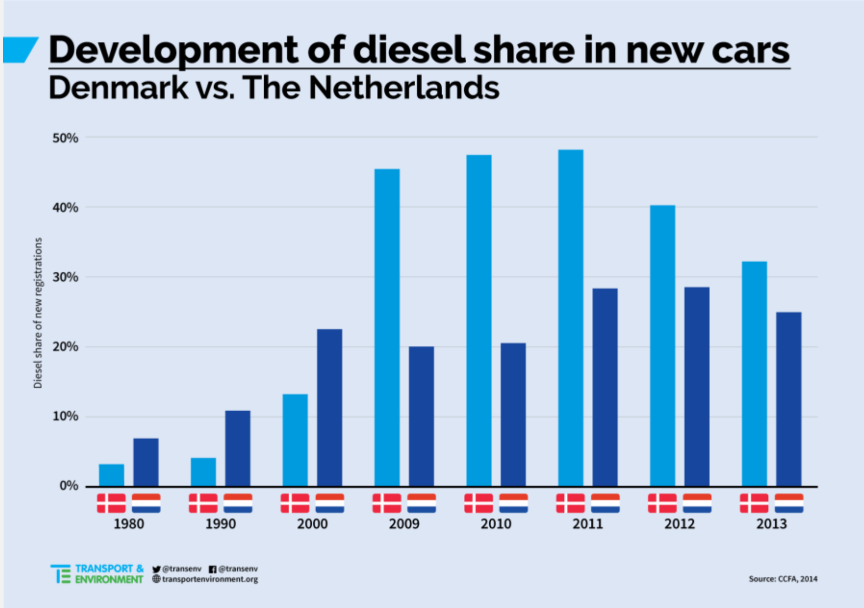


Figure 10

The explanation for the different developments in the two countries is that while the fixed taxes (sales tax, circulation tax) in Denmark since 2005/6 have strongly rewarded cars with low CO_2 emissions directly, the equivalent Dutch taxes (although also strongly linked to CO_2 emissions) are levied in a way that strongly discourages the average car customer from buying a diesel car. This diesel penalty is sufficiently large in most cases to counterbalance the fuel tax bonus to diesel.

The growing diesel car share in Denmark does not mean the Danish car fleet is more fuel-efficient than the Dutch fleet. On the contrary, the development towards more fuel-efficient vehicles is more or less identical in the two countries – indeed, the Netherlands have caught up with, and slightly overtaken, Denmark in CO_2 reductions in recent years. This is illustrated by Figure 11, which shows the CO_2 emissions per km from new cars in Denmark and the Netherlands (2001-2013).

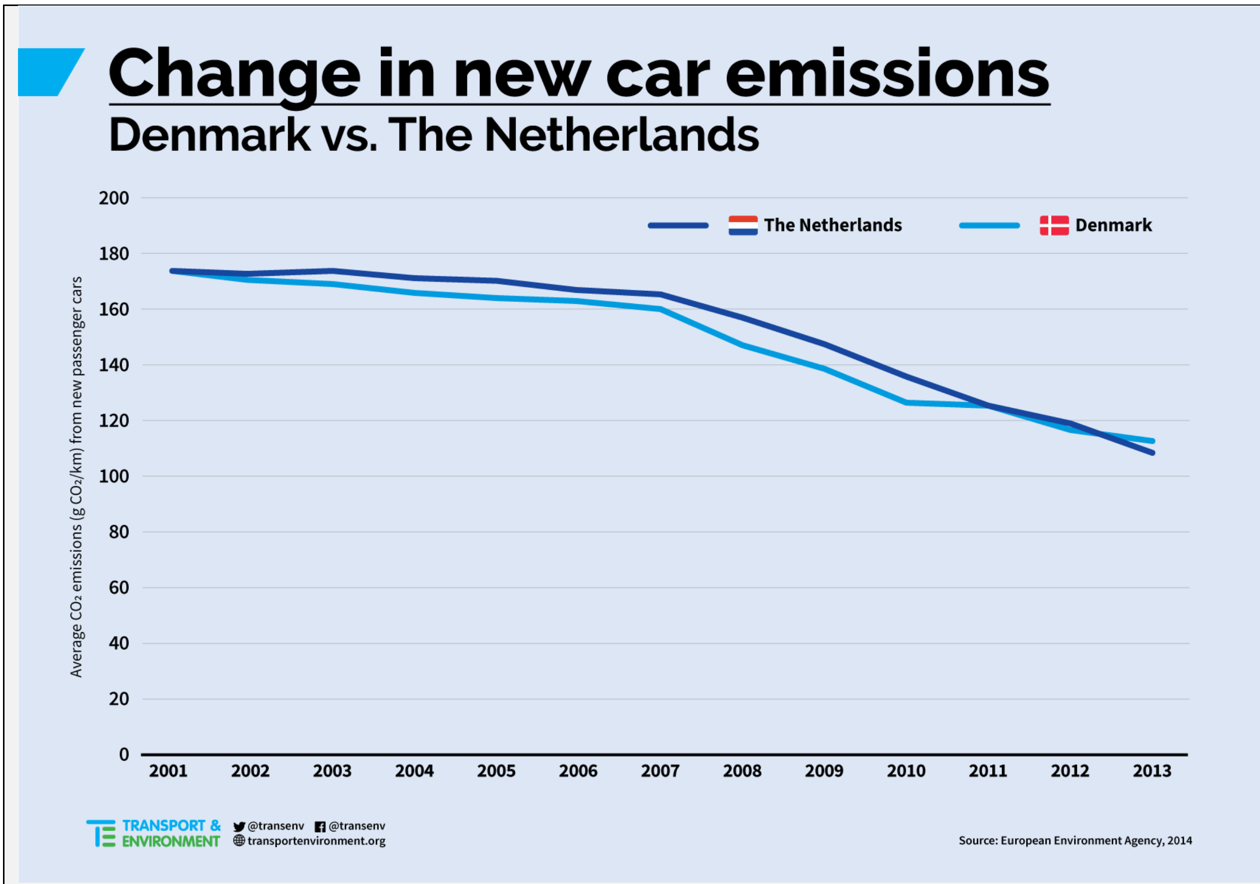


Figure 11

Several conclusions can be drawn from this case study:

1. It is possible to even maintain a substantial diesel tax bonus, but a major shift to diesel cars provided that the bonus is adequately compensated for in the structure of vehicle taxes.
2. CO_2-based vehicle taxes on their own have a strong effect in encouraging diesel cars, as they help to reduce the additional up-front costs while still offering the diesel bonus and other benefits of diesel cars.
3. High taxes on car ownership and low taxes on car use do not lead to low transport emissions, but rather to fewer cars driving further.

2.4. The design of the EU Cars and CO_2 Regulations

The Cars and CO_2 Regulation,[14] agreed in 2008 and confirmed in 2013, required carmakers to reduce fleet average CO_2 emissions from new cars to 130g/km by 2015 and 95g/km by 2021. The regulations are largely technology-neutral, at least in that they do not discriminate explicitly between the use of petrol and diesel technology and that both count in the same way towards the weighted fleet average CO_2 target. However, it is arguable that they have indirectly discriminated in favour of diesel cars in at least two ways.

First, since tailpipe CO_2 emissions per km from a diesel car are typically 15-20% lower than from an equivalent petrol car, increasing the share of diesel sales enables carmakers to make rapid progress towards their targets at relatively low cost. Unsurprisingly, the automotive sector continuously resists any change to the diesel tax bonus through revisions of the Energy Tax Directive, citing climate grounds and risks to meeting the targets.

[14] Regulation (EC) No 443/2009 and 333/2014 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles

Secondly, this trend was further encouraged by a feature of the design of the Regulation whereby each manufacturer's average CO_2 target is a direct function of the average weight of the vehicles sold. For each additional 100kg of weight the carmaker's target is increased by 3.3g/km. Selling only diesel cars therefore offers a benefit by 2020 (compared to selling solely gasoline cars) of around 20g/km from lower CO_2, but also a further 5-7g/km bonus in a higher target from raising the average weight.

The Regulation does include a modality to ensure that any overall increase in the weight of all vehicles sold does not weaken the overall target. However, this is done by lowering the targets of all companies uniformly, so that the penalty of increasing mass is shared across all carmakers, whether or not they sell heavier cars. In this sense, manufacturers with a higher share of heavier diesel cars (premium manufacturers) act as 'free riders' and impose an additional burden on those making small, light (and often petrol-engined) cars.

2.5. Biased air pollution regulations

During the 2000s, diesel engines had improved appreciably whilst investment in gasoline engines was lower and improvements were more incremental. This widened the efficiency benefit of diesel cars, combined with better driveability and increased sales. However, these advantages were exaggerated by a succession of air pollution regulations that were significantly less demanding for diesel vehicles and, therefore, they artificially reduced the costs of diesel cars relative to petrol vehicles by requiring less advanced exhaust after-treatment systems.

Air pollution emissions from cars and vans have been regulated through a sequence of tightening limit values, from Euro 1 beginning in 1991, through to Euro 6 which came into force for all models in 2015. These Euro standards limit all the main pollutants from vehicle exhausts – carbon monoxide, nitrogen oxides, particulates and volatile organic compounds. These are summarised (in a slightly simplified format) in Figure 12.

Euro emission standards: passenger cars

Euro stage	Year of entry into force for new models*	CO g/km	HC	HC+NOx	NOx	PM	PN number/km
Compression ignition (diesel)							
Euro 1	1992	2.72	-	0.97	-	0.14	-
Euro2	1996	1.0	-	0.7	-	0.08	-
Euro 3	2000	0.64	-	0.56	0.50	0.05	-
Euro 4	2005	0.50	-	0.30	0.25	0.025	-
Euro 5a	2009	0.50	-	0.23	0.18	0.005	-
Euro 5b	2011	0.50	-	0.23	0.18	0.005	$6.0x10^{11}$
Euro 6	2014	0.50	-	0.17	0.08	0.005	$6.0x10^{11}$
Positive ignition (petrol/gasoline/LPG/CNG)							
Euro	1992	2.72	-	0.97	-	-	-
Euro 2	1996	2.2	-	0.5	-	-	-
Euro 3	2000	2.3	0.20	-	0.15	-	-
Euro 4	2005	1.0	0.10	-	0.08	-	-
Euro 5	2009	1.0	0.10	-	0.06	0.005[a]	-
Euro 6	2014	1.0	0.10	-	0.06	0.005[a]	$6.0x10^{11}$ **

* models already in production must comply typically around one year later

** applicable only to direct injection engines

TRANSPORT & ENVIRONMENT @transenv @transenv transportenvironment.org

Source: European Commission

Figure 12

Euro 1 standards set in 1992 applied the same air pollution limits for diesel and gasoline cars, but Euro 2 in 1996 set differential limits in recognition that diesels emitted significantly more particulates (that needed to be controlled). Gasoline exhausts contained more carbon monoxide and hydrocarbons that needed to be tackled, which was done in practice by adding 3-way catalytic converters. Thus, the precedent of different limit values for diesel and petrol was established. Euro 3 in 2000 introduced separate limits for nitrogen oxides (NOx) and hydrocarbons for the first time, but crucially, diesels were permitted to have much laxer limits (0.5 g/km NOx in diesel compared to 0.15 g/km for gasoline vehicles). This continued for more recent Euro standards, including Euro 6, that commenced in September 2014. As a sort of trade-off, diesels have since Euro 2 had much tighter carbon monoxide limits, but these have been easy to meet without any after-treatment, owing to the combustion conditions in a diesel engine.

The 'double standards' applied to European cars contrasts with the US, where limits are strictly technology-neutral and no attempt was made to accommodate diesel through special measures. As a result, diesels with anything less than the most sophisticated after-treatment equipment have struggled to meet the US NOx standards, so diesel sales are a niche market as a result.

Figure 13 shows the share of different after-treatment systems used in new cars sold in the EU and the US in 2014, based upon data from the ICCT.[15] Notably, for the same model years' car manufacturers in the US (Audi, Daimler, VW) use significantly higher shares of Selective Catalytic Reduction (SCR) than in Europe, which is a far more effective and expensive after-treatment technology. In Europe, cheaper Lean NOx Traps (LNT) are more prevalent on the latest Euro 6 vehicles resulting in failure of diesels in Europe to achieve emission limits in real use on the road. BMW stands out by equipping all of its diesel vehicles in the US with a combination of SCR and LNT technology, whereas in Europe less than 30% of its diesel cars have state-of-the-art emission controls.

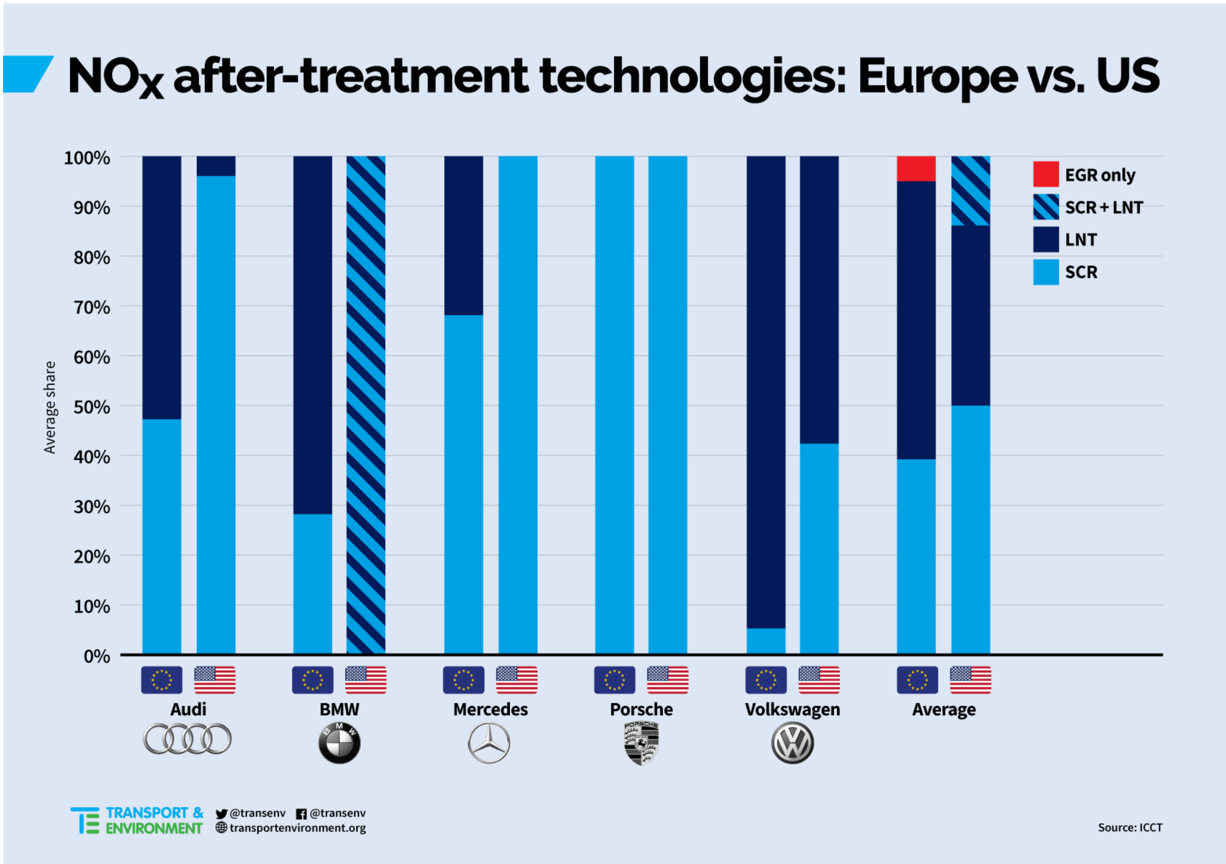


Figure 13

[15] ICCT, *Real-world exhaust emissions from modern diesel cars - White Paper*, 2014. http://www.theicct.org/sites/default/files/publications/ICCT_PEMS-study_diesel-cars_20141010.pdf

As will be discussed later, the 2015 VW emission scandal in the US and the ensuing industry-wide Dieselgate in Europe have brought stricter emission regulations. This will result in the vast majority of new diesel models in Europe fitting SCR in the coming years. However, the regulatory bias of Euro emission limits allows diesel cars to have a laxer limit by 20mg of NOx per km more than equivalent gasoline vehicles – and, in fact, much more in practice.

2.6. Obsolete and inaccurate vehicle emissions tests

Not only are regulatory limits for diesel engines weaker, but the loopholes of the test procedures (known as the New European Drive Cycle or NEDC) – in place until September 2017 – allow diesel vehicles to emit significantly higher emissions in real life. For CO_2 emissions, the gap between laboratory and real-world testing has continuously grown since the introduction of mandatory fleet average CO_2 targets in 2008 (Figure 14). According to the latest data for 2016, the average car emits 42% more CO_2 emissions on the road than its declared type approval values. The gap is higher for company cars (54%), most of which are diesel cars. Manufacturers optimise their models to achieve low results on the outdated NEDC test, instead of fitting technology that would achieve reductions on the road.

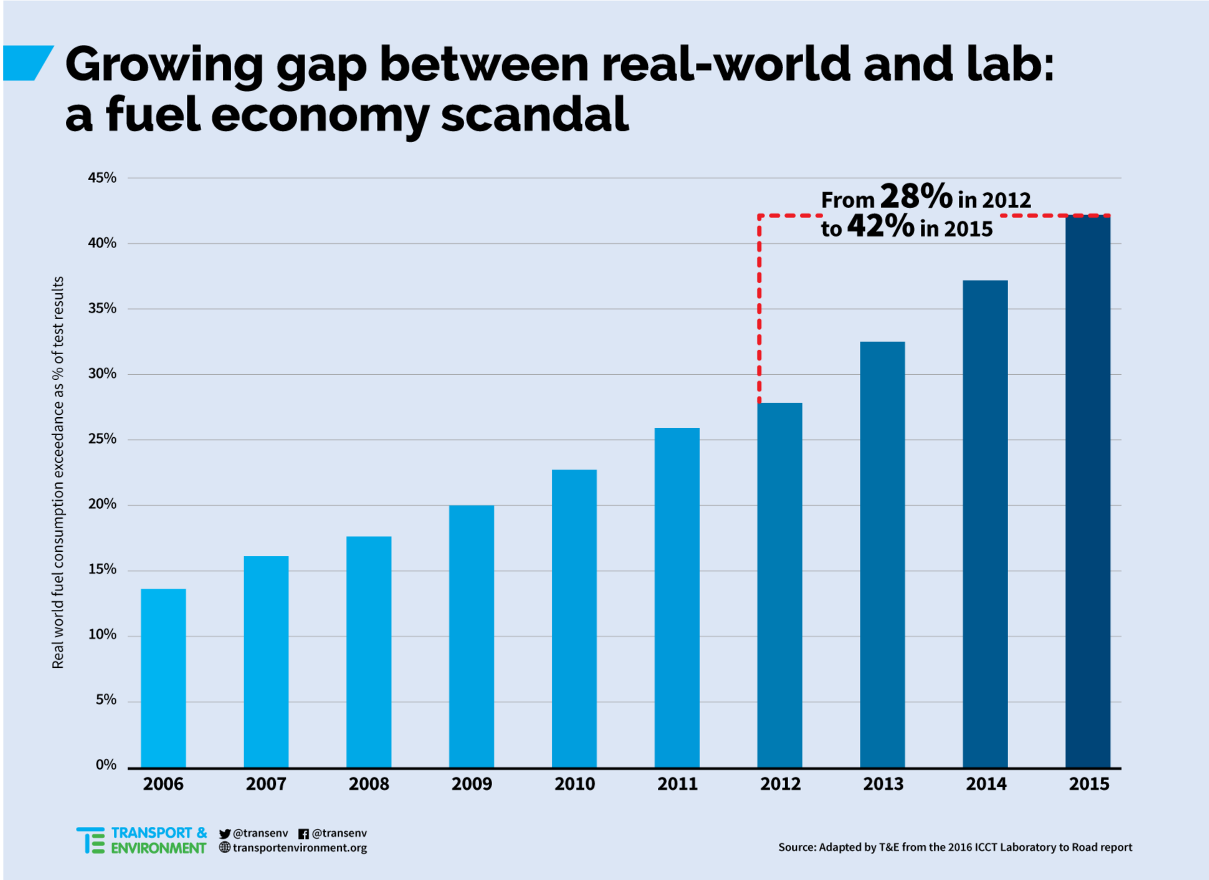


Figure 14

The situation is much worse with regard to air pollution. This is because the laboratory test was so inadequate that relatively cheap after-treatment methods, such as exhaust gas recirculation, de-NOx catalysts and adjusting the engine tuning, were capable of meeting limit values, but were largely ineffective over the range of driving conditions experienced in real life. In contrast, three-way catalytic converters used for exhaust after-treatment on petrol/gasoline cars generally reduced most pollutants to very low levels in both tests and on the road – although one recent study has highlighted issues with NOx and carbon monoxide emissions in some cars.[16] High-particle number emissions from gasoline direct-injection cars

[16] Which, 2016, *Car emissions: is nobody clean?* http://www.which.co.uk/news/2016/01/car-emissions-is-nobody-clean-430938/

should be resolved by 2017, once limits are lowered and real-world tests are introduced, so long as manufacturers respond by fitting gasoline particulate filters. Cycle-beating (and outright test manipulation uncovered by the Dieselgate investigations) by diesel cars means that real-world on-the-road emissions are even higher. In 2014, NOx emissions were typically 7-10 times higher[17] on the road than in tests (Figure 15). This gap had fallen in 2015/16, as newer Euro 6 diesels entered the market. T&E analysis of the real-world results available to date estimated the average gap to be on average 5.4 times, or 540% over the Euro 5 & 6 NOx emission limits. The most recent data by the ICCT show the average gap is falling, but it is still 4.5 times the legal limit.[18]

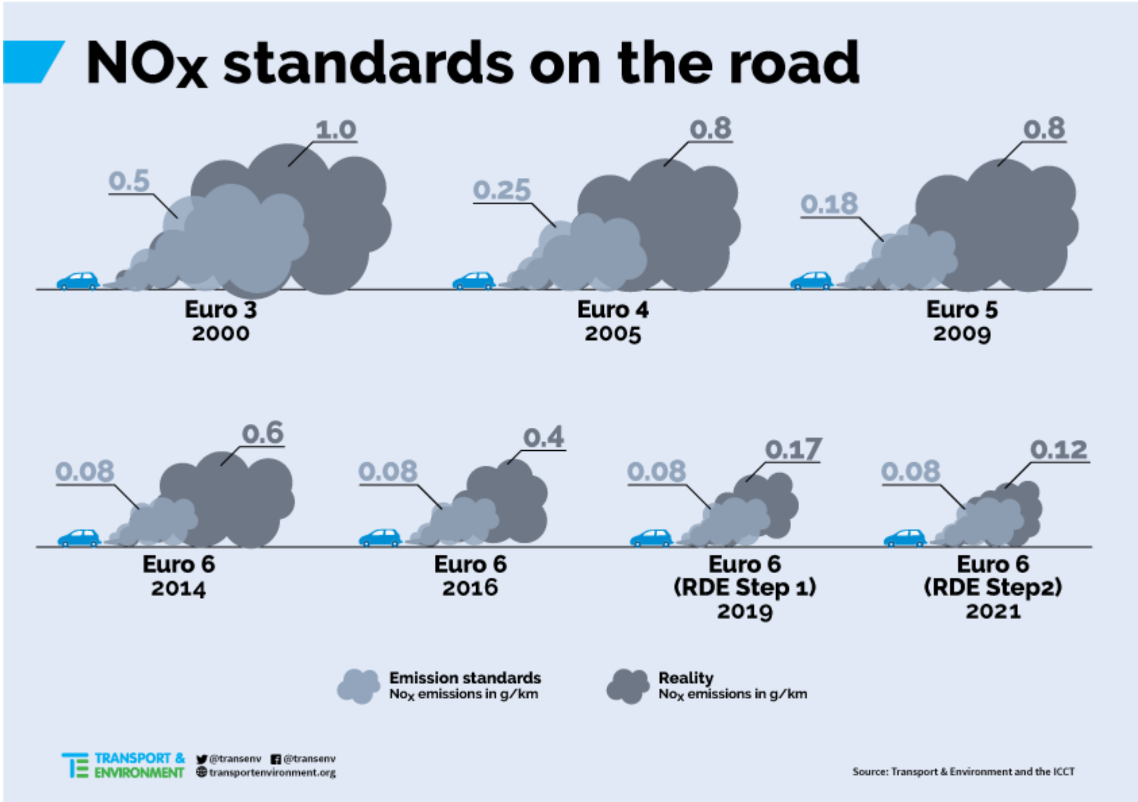


Figure 15

NOx after-treatment for diesel cars
Historically, diesel cars were fitted with a simple *oxidation catalyst* to treat emissions of carbon monoxide and hydrocarbons. NOx emissions were not stringent and could often be dealt with simply by tuning the engine appropriately. The introduction of Euro 5 standards required the use of *exhaust gas recirculation* (EGR) to lower the oxygen content and temperature in the cylinder and thereby reduce NO_x formation. But EGR systems have been unreliable and particularly prone to valve sticking and consequently, manufacturers have chosen to switch them off for the majority of the time the car is in use, claiming that this is allowed to protect the engine from damage.[19]

[17] ICCT, *Real-world exhaust emissions from modern diesel cars – White Paper*, 2014. http://www.theicct.org/sites/default/files/publications/ICCT_PEMS-study_diesel-cars_20141010.pdf
[18] ICCT, 2017, *ROAD TESTED: COMPARATIVE OVERVIEW OF REAL-WORLD VERSUS TYPE-APPROVAL NOX AND CO2 EMISSIONS FROM DIESEL CARS IN EUROPE*. http://theicct.org/sites/default/files/publications/ICCT_RoadTested_201709.pdf
[19] Transport & Environment, 2016, *Dieselgate continues: new cheating techniques*. https://www.transportenvironment.org/publications/dieselgate-continues-new-cheating-techniques

Euro 6 limits introduced in 2014 imposed even tougher NO_x limits. To achieve these limits, some systems use a *lean NO_x trap* (LNT) to retain the NO_x molecules which are subsequently desorbed and destroyed by a conventional three-way catalyst mounted downstream.

A supplementary system (which on many vehicles is used in combination with an LNT) is *selective catalytic reduction* (SCR). SCR also uses a diesel exhaust fluid (DEF), usually urea, marketed in Europe as AdBlue, which is injected into the exhaust. The DEF reduces NO_x to nitrogen, water and CO_2, achieving NO_x reductions of up to 90% and simultaneously reducing hydrocarbon and carbon monoxide emissions by 50-90%.

All of these options have some degree of fuel economy penalty that militates against the high efficiency of the diesel engine. Also, the DEF in an SCR system requires replenishing, adding to operating costs and causing some inconvenience for motorists. For this reason, car manufacturers have been accused of under-dosing the DEF, thereby reducing the effectiveness of the SCR system when the vehicle is driven on the road rather than in a test. This is to ensure that the DEF does not run out between service intervals, leaving the car to "limp home" until it is refilled.

The emerging evidence from a range of sources shows diesel NOx emissions of Euro 3, 4, and 5 vehicles did not differ greatly and the tighter limits achieved in tests are widely breached on the road. Similarly, while the latest Euro 6 emissions are low on paper – these are still significantly above the required on-road emissions. The gross failure to meet limits on the road, combined with the dieselisation of the car fleet, has been the principal reason why EU ambient air pollution standards are not being met in urban areas. Had the same Euro limits been applied equally to diesel and gasoline vehicles (and these limits been effectively enforced through robust testing), more advanced and expensive exhaust treatment systems would have been required for diesel vehicles. This would have increased the relative price of diesels and reduced their competitive advantage over petrol cars, and it might in itself have at least slowed down the rate of dieselisation in Europe.

The pro-diesel bias in the market should have been reduced through the earlier introduction of real-world driving emissions (RDE) tests, but it continues through *de facto* weakening of limits through higher conformity factors. In spite of being promised since 2012, the first set of RDE tests for NOx emissions to be conducted on public roads using PEMS equipment was agreed by national governments in October 2015. As summarised in Figure 15, it has been introduced in two stages. First, car manufacturers will be allowed to exceed the Euro 6 limit by 210% (i.e. conformity factors of 2.1), being mandatory for all models from September 2019 (and new type approvals from September 2017 already). Then the stricter Euro 6d will enter into force in January 2021 for all vehicles, still allowing a 50% flexibility above the limit and resulting in NOx emission of up to 120 mg/km, instead of the regulatory limit of 80. This was a political decision reached following the Dieselgate scandal, and perpetuates a continuing pro-diesel bias in emission policies. Stricter RDE tests will also apply to particle emissions in the same timeframe, but without the 210% initial flexibility, given that their purpose is to improve emission controls used on direct injection gasoline engines. Independent third-party RDE checks on vehicles in service should be agreed imminently.

Whilst it is more representative and robust than today's NEDC cycle, the RDE test protocol still does not capture the real-world performance of diesels. Together with PSA, Transport & Environment have carried out an RDE-like testing programme[20] involving 60 vehicles and over 400 tests that demonstrates that the regulatory boundary conditions for on-road tests are still less dynamic compared to how the diesel vehicles are driven in practice, notably as regards motorway driving where many emissions occur. This may result in manufacturers optimising engines to meet the inadequately demanding future tests at the expense of higher emission spikes outside of the boundary conditions and continuing air pollution exceedances.

[20] Transport & Environment, Press release, 2015. https://www.transportenvironment.org/press/psa-peugeot-citro%C3%ABn-and-transport-environment-will-cooperate-publish-real-world-fuel-economy

More worrying are the findings of the recent tests commissioned by ICCT[21] on four vehicles. These tests compare the vehicles' NOx emissions when driven within the RDE boundaries and outside of those (more dynamic driving, higher altitude, etc.). In all cases the emissions increase significantly when the vehicles are driven outside the RDE boundaries, to 26-40 times the Euro 6 NOx limits. The case of BMW's 520d diesel is particularly suspicious; while the NOx emissions are 5 times the Euro 6 limit in RDE-compliant conditions, this jumps up to 40 times when driven more dynamically than the regulation requires. This risks undermining the emission improvements expected from the new on-road tests and points to deliberate design and optimisation of vehicles to pass the test, rather than to reduce emissions.

Overall, the new real-world driving emissions (RDE) regulations, or Euro 6d, are expected to exert growing pressure on diesel NOx emissions, and to require all diesel cars to be fitted with SCR by 2019/2020. For smaller diesel cars, this requirement will add to the existing price premium in market segments where profit margins are already very tight, encouraging a shift to efficient gasoline and hybrid engines. Some small diesel models may simply not have space available for the new SCR equipment, and will therefore need to be extensively upgraded or withdrawn from the market. The premium car sector is relatively price-insensitive, and those diesel models not already fitted with SCR will be upgraded relatively easily with a cost increase of around €100-300 for most models. However, in this sector these cars will increasingly compete with hybrid, plug-in, range-extender cars and battery electric cars, driven by both CO_2 regulations and the enhanced performance of vehicles using electric motors.

2.7. The Dieselgate scandal

In 2013, emissions tests conducted on behalf of the International Council on Clean Transportation (ICCT) in the US found that some diesel-engined Volkswagen Group vehicles were emitting substantially more NOx pollution than in laboratory tests. The results were passed on to the California Air Resources Board and, subsequently, to the US Environmental Protection Agency (US EPA). After a period of investigation, the US EPA issued a Notice of Violation of the Clean Air Act to Volkswagen Group on 18 September 2015. Soon after, VW admitted that almost 500,000 of its vehicles in the US – including the VW-manufactured Audi A3, and some VW diesel versions of the Jetta, Beetle, Golf and Passat – were equipped with illegal emissions software designed to detect the regulatory test and lower emissions accordingly (while emitting up to 40 times the US NOx limits when on the road).

The emissions scandal that erupted in the US quickly spread to Europe and the rest of the world, with the US revelation being a mere tip of the iceberg amid years of industry-wide circumvention of emissions tests. The original 500,000 VW vehicles in violation of rules in the US has grown to about 11 million cars worldwide, including 8.5 million in Europe, all fitted with the same test detection equipment.

Since 2015, many more diesel manufacturers have been implicated in Europe with what is currently the biggest emissions cheating scandal in auto history. A number of national emissions investigations, notably in Germany, France and the UK, concluded that a vast majority of diesel cars sold and driven across Europe grossly exceed the NOx pollution limits in real world, with on average worst performing vehicles produced by Fiat, Renault and Opel (Figure 16). Transport & Environment's analysis[22] estimates the figure of grossly polluting Euro 5 and 6 diesels as at least 37 million cars and vans sold between 2010 and 2016, or around 80% of all diesel vehicles registered in that period. At least 4 millions of these vehicles are diesel vans, whose use is increasing rapidly due to online commerce and laxer rules on their use, compared to the rules for trucks.

[21] ICCT, 2017, *Real-world emissions testing on four vehicles*. http://theicct.org/real-world-emissions-testing-four-vehicles

[22] For original methodology, see The Dieselgate report and its subsequent updates, found at : https://www.transportenvironment.org/sites/te/files/publications/2016_09_Dieselgate_report_who_what_how_FINAL_0.pdf

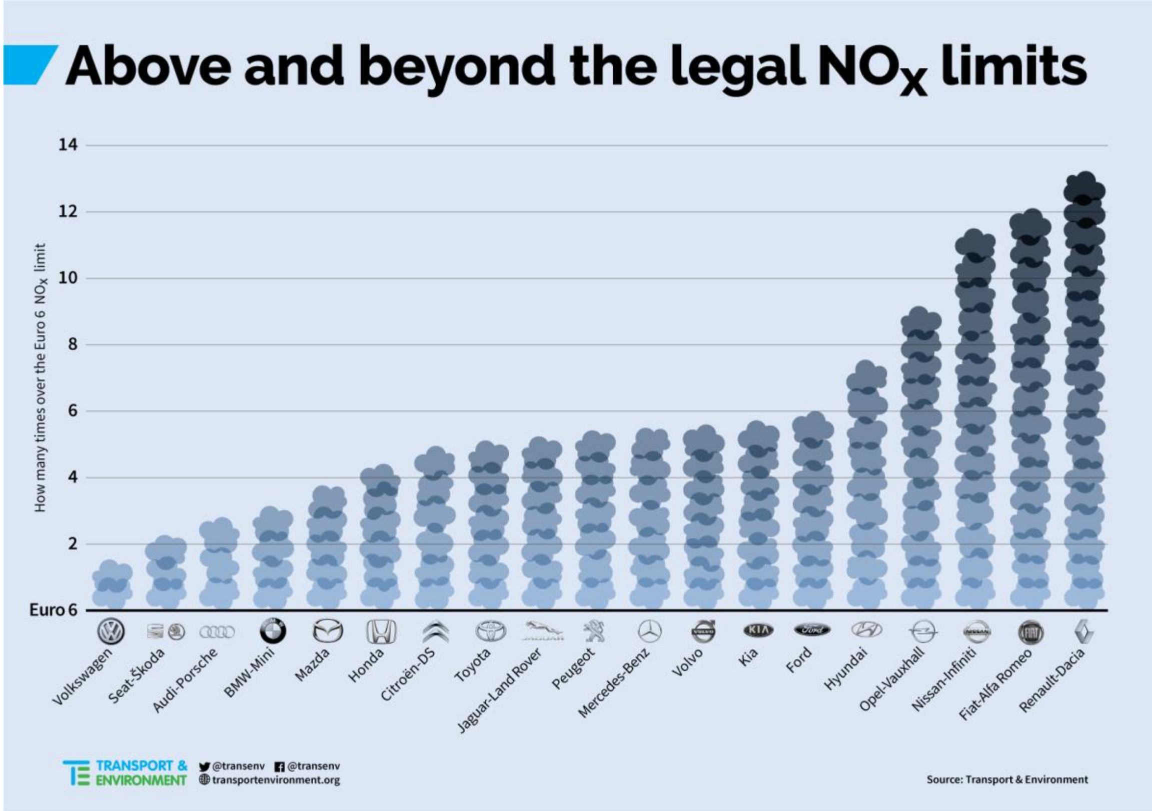


Figure 16

At the heart of the emissions scandal is the widespread use of defeat devices that switch off or down NOx after-treatment exhaust systems when diesel vehicles are on the road, thus saving carmakers having to fit expensive technology. This is a result of carmakers abusing the legal loophole in EU air pollution legislation made possible through frail enforcement by national vehicle regulators. To date, at least four different defeat strategies used by European carmakers have been uncovered, namely:

- Test detection devices, used by the VW Group
- Thermal window defeat devices that switch off or down emission controls when vehicles are outside the ambient temperatures of the regulatory test cycle (examples include those used by Renault, Opel and Daimler vehicles)
- Hot restart defeat devices (in contrast with EU tests conducted with a cold engine start)
- Defeat devices based on a timer (which disable emission controls after the time equivalent to the regulatory test cycle), e.g. the ones found in Europe and in the US on some of the FCA vehicles.

Under EU law[23], defeat devices (defined as any sensor or equipment that detects different parameters to alter the operation of emission control systems) are banned, apart from a few exemptions, including to protect the engine against damage and to ensure safe operation. This is almost a 'copy-paste' of the US legislation that led to the lawsuit against VW. While the disclosure provisions are not specified, it is the responsibility of the 28 national type approval agencies to enforce the defeat device ban and verify the legitimacy of the exemptions used. The Dieselgate scandal has shown that the national authorities have largely failed to enforce the ban or prosecute non-compliance with emission limits. The new RDE law, taking effect in September 2017, will require car manufacturers to systematically disclose all defeat devices used and justify the need for the exemptions, while national approval authorities will have to approve or reject those based on technical guidance.

In contrast to the action against VW by the US EPA – forcing carmakers to buy back the faulty vehicles and pay the penalty amounting to USD14.7 billions – no fines have been levied in Europe by any national

[23] EU Regulation 715/2007, Article 5.2

approval authorities in charge of certifying illegal cars for circulation. The German regulator (KBA) has approved fixes to the majority of the VW group vehicles affected by the scandal, but has not ordered any penalties or consumer compensation. Neither Spain, in the case of Seat vehicles, nor the UK with Skoda (part of the 8.5 million vehicles affected in Europe) took any action to remove the illegal emissions software or penalise the carmakers. As well as the ongoing case against the VW Group, legal investigations into potential emissions cheating have been opened against the Fiat Chrysler Group, Renault-Nissan Group and Peugeot-Citroën; their resolution is still pending at the time of writing. Earlier in 2017, the German authorities have similarly accused Porsche for alleged cheating on its 3l Cayenne diesel engines, refusing to register the affected vehicles until they have been fixed.

The aftermath of the scandal saw a raft of often voluntary emission recalls and upgrade programmes offered by most diesel carmakers in Europe, including Daimler, Renault, Fiat, Audi, Opel and others in 2016/17. The biggest effort took place in Germany, where some 12 million diesel vehicles[24] of VW, Audi, Porsche, Daimler and Opel were subject to emissions fixes agreed with the government authorities. The detail of the upgrades or independent verification of its effectiveness is still lacking, but reports in the media suggest that it would largely rely on software updates and cost less than €100 per vehicle.

2.8. Cartel investigation

July 2017 brought new allegations of illegal practices in diesel emissions control with allegation of a potential cartel case exposed by *Der Spiegel*. The alleged cartel included Daimler, VW, BMW, Audi and Porsche, and dates back all the way to the 1990s. The evidence obtained by *Der Spiegel* explains in great detail how senior representatives from Volkswagen, Audi, Daimler, BMW and Porsche met regularly to agree joint approaches to the development of cars as well as costs, suppliers and markets. Some 60 working groups discussed technologies ranging from convertibles to diesel cars' after-treatment systems. The cartel case is particularly explosive because of its link to Dieselgate. The starkest and most incriminating allegation is related to AdBlue, which is used in selective catalytic reduction (SCR) systems to reduce NOx from diesel engines. Volkswagen and the above listed manufacturers discussed what size of AdBlue tank would be appropriate. They agreed that they would need at least 19 litres to enable the SCR to function properly, but they then proceeded to agree that none of the partners would fit tanks bigger than 8 litres. That would save space and money, but it would never reduce NOx emissions to the level that the Euro 6 standard required.

The investigation into market collusion and cartel is currently ongoing, led by the EU Anti-Trust watchdog, and the verdict is not expected for some years to come.

[24] Reuters, *Germany demands costly recall of 12 million diesel cars*, 2017. http://uk.reuters.com/article/uk-volkswagen-emissions-germany-recall-idUKKBN19H1CT

3. Impact of dieselisation and pro-diesel policies

The previous section has clearly demonstrated that policy biases favouring diesel cars were the principal cause of shift in the car market in Europe, a shift not replicated in other major car markets. This section examines the implications of dieselisation for the economy, health, climate and the environment.

3.1. Air pollution and human health

Despite considerable reductions in emissions for some pollutants, air pollution remains a huge problem in Europe. In recent publications[25], the European Environment Agency (EEA) estimates that it is still responsible for over 450,000 premature deaths in Europe each year. The economic and human costs to Europe's cities and society are huge, at over €1tn per year.[26]

3.1.1. Nitrogen oxides

Sections 2.5 and 2.6 explained how the growth in the use of diesel cars combined with lax air pollution limits and inadequate tests for car air pollution emissions have meant that exhaust emissions from diesel cars for key pollutants are significantly higher than from equivalent gasoline vehicles, notably nitrogen oxides (NOx). NOx is a combination of nitric oxide (NO) and nitrogen dioxide (NO_2). In the air, NO is rapidly converted into NO_2 adding to the NO_2 directly emitted in diesel exhaust gases. However, a further problem is that diesel cars emit more of the NO_x emissions that they produce as primary nitrogen dioxide (NO_2). The EU Joint Research Centre (JRC)[27] found that the share of NO_2 in the total NOx emissions reached 60% for diesel vehicles, but was substantially lower for gasoline vehicles (0-30%). This is an issue, as NO_2 is the toxic form of nitrogen oxides. As a result, the toxic NO_2 levels in streets with a high penetration of diesel vehicles are especially high.

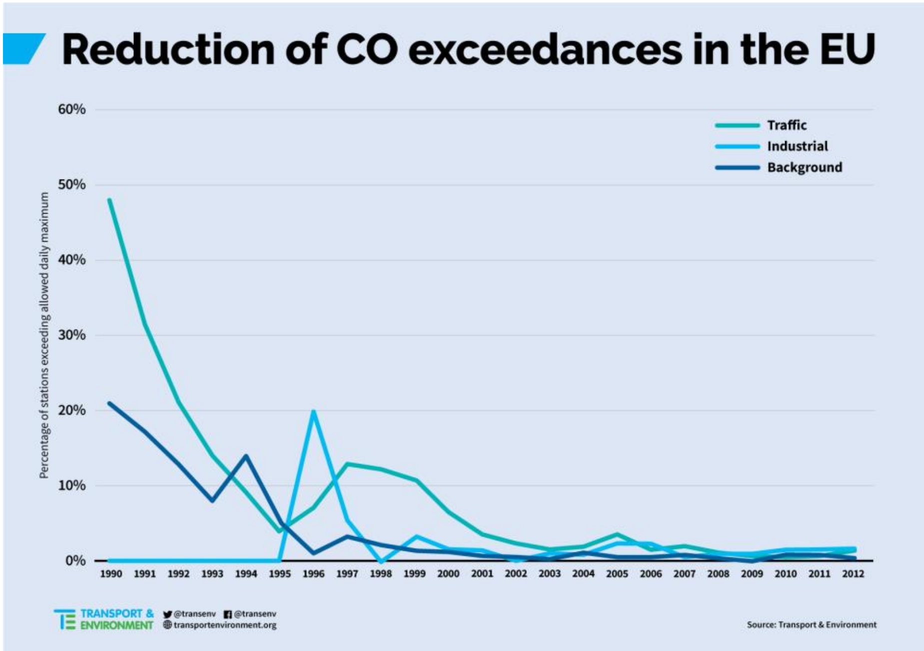


Figure 17

Concentrations of NO_2 are above World Health Organisation (WHO) health guidelines across much of Europe, with 94% of exceedances observed at traffic stations. The European Environment Agency estimates 7% of EU urban citizens live in areas where NO_2 pollution is damaging their health, causing 68,000 premature deaths annually.[28]

The data from the EEA's database on air pollution (Figure 17 and 18) illustrates the impact of traffic on overall air pollution – in this instance, it compares progress made in cutting carbon monoxide (Figure 17 – mainly from petrol engines) with NOx (Figure 18 – mainly from diesel cars) across Europe.

[25] EEA, 2016, *Air quality in Europe – 2016 report*, https://www.eea.europa.eu/publications/air-quality-in-europe-2016
[26] World Health Organisation, *Economic cost of the health impact of air pollution in Europe*, 2015 http://www.euro.who.int/__data/assets/pdf_file/0004/276772/Economic-cost-health-impact-air-pollution-en.pdf
[27] JRC, *Analyzing on-road emissions of light duty vehicles with Portable Emissions Measurement Systems*, p.47, 2011, https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/2011_pems_jrc_62639_en.pdf
[28] EEA, 2016, *Air quality in Europe – 2016 report*

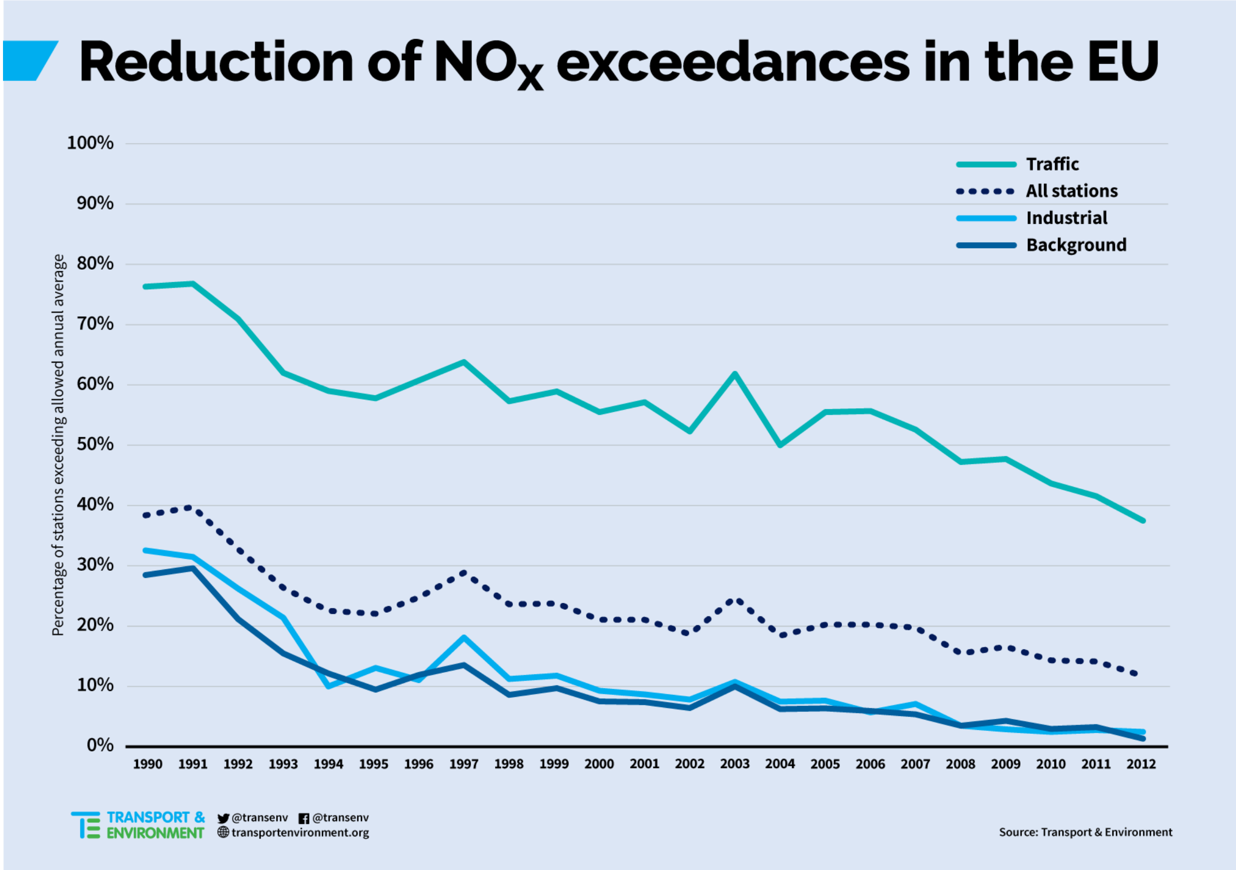


Figure 18

Figure 17 illustrates a clear 'success story' for vehicle emissions controls of carbon monoxide. Back in 1990, nearly half of all traffic-related monitoring stations registered exceedances of the currently allowed daily maximum value. However, the introduction of the three-way catalytic converter to spark-ignition engines led to a clear and rapid improvement through the 1990s. This improvement has been maintained since, with only occasional weather-related spikes. Non-attainment has now been virtually eliminated at all station types, including at the roadside.

As Figure 18 shows, it is a very different story for NO_2. Background and industrial stations have improved steadily over time (much as they did for CO_2) and exceedances have now almost been eliminated. Traffic stations start from a much higher level (nearly 80% of all stations reaching the limits) and have improved fairly steadily, but only slowly since the mid-1990s. In 1990, around three-quarters of all traffic stations registered exceedances, but still today more than one in three stations are not attaining the annual average limit value. Overall, EEA concludes that road transport is the biggest contributor to Europe's NOx emissions, accounting for almost half of the emissions, while in cities the proportion is typically three-quarters. As a result, many EU Member States remain in non-attainment of the EU Air Quality Directives, and see little prospect of remedying the problem. As from 2017, twelve Member States have been subject to EU infringement proceedings and face the threat of multi-billion fines for failing to meet the EU NO_2 limit values. These include Austria, Belgium, the Czech Republic, Denmark, France, Germany, Hungary, Italy, Poland, Portugal, Spain and the UK.

Short-term exposure to elevated levels of nitrogen dioxide (NO_2), ranging from 30 minutes to one day, causes respiratory effects inflaming the airways of healthy people and causing increased symptoms in people with asthma. There are increased visits to hospital emergency departments and hospital admissions for respiratory issues, especially asthma, during periods of high nitrogen dioxide levels, which are usually also associated with peaks in levels of fine particulate matter. Evidence of chronic health effects from long-term exposure to elevated levels of nitrogen dioxide have been significantly strengthened in the past 5 years. [29] For example, it has been associated with both low birth weights and small head circumferences. [30] It has also been associated with increased mental illness in children,[31] autism spectrum disorders[32] and slow overall development in children.[33] The EEA calculated that in 2016, nitrogen dioxide pollution was responsible for an estimated 71,000 premature deaths across wider Europe. [34] This pollution is largely attributable to road traffic.

In addition to the direct health effects, NOx in the atmosphere:

- Contributes to high levels of secondary fine particles in the air created by photochemical oxidation of nitrogen oxide to nitric acid and nitrate particles. This is a significant component of the total $PM_{2.5}$ in the atmosphere, which is one of the pollutants of greatest health concern. A recent study [35]

Premature deaths from NO_2 exposure in Europe

Country	Premature deaths (2013)
Austria	910
Belgium	2,320
Bulgaria	570
Croatia	160
Cyprus	< 5
Czech Republic	330
Denmark	60
Estonia	< 5
Finland	< 5
France	8,230
Germany	10,610
Greece	1,490
Hungary	390
Ireland	30
Italy	21,040
Latvia	110
Lithuania	< 5
Luxembourg	80
The Netherlands	< 5
Malta	1,820
Poland	1,610
Portugal	150
Romania	1,900
Slovakia	< 5
Slovenia	150
Spain	4,280
Sweden	< 5
United Kingdom	11,940
EU -28	68,000

Source: European Environment Agency

TRANSPORT & ENVIRONMENT @transenv @transenv transportenvironment.org

Figure 19

[29] World Health Organisation, *Economic cost of the health impact of air pollution in Europe*, 2015 http://www.euro.who.int/__data/assets/pdf_file/0004/276772/Economic-cost-health-impact-air-pollution-en.pdf
[30] Pedersen et al, 2013, Lancet Respiratory Medicine 2013;1:695-704
[31] BMJ, *Association between neighbourhood air pollution concentrations and dispensed medication for psychiatric disorders in a large longitudinal cohort of Swedish children and adolescents*, 2016, http://bmjopen.bmj.com/content/6/6/e010004
[32] BMJ, 2014, *In utero exposure to toxic air pollutants and risk of childhood autism*, 2014, https://www.ncbi.nlm.nih.gov/pubmed/25051312
[33] BMJ, 2009, *Association of traffic-related air pollution with children's neurobehavioral functions in Quanzhou, China*, 2009, https://www.semanticscholar.org/paper/Association-of-Traffic-Related-Air-Pollution-with-Wang-Zhang/b5f282b9d8c26c5aa007d6d1cabc05e0af5c254e
[34] EEA, 2016, *Air quality in Europe – 2016 report*
[35] Nature, *Impacts and mitigation of excess diesel-related NOx emissions in 11 major vehicle markets*, 2017, http://www.nature.com/nature/journal/v545/n7655/full/nature22086.html?foxtrotcallback=true

published in *Nature* estimates that at least 28,500 premature deaths in Europe are caused by secondary small particles from NOx pollution. 11,500 of these deaths are the result of excess NOx emissions beyond what EU standards allow and are attributable to widespread use of defeat devices and test manipulation (discussed later in this chapter).

- NO_x is also a precursor pollutant in the formation of ozone in the atmosphere when it reacts with volatile organic compounds in the presence of sunlight. Transport has been estimated to be responsible for 45% of the emissions leading to ozone formation.[36] Children, the elderly, people with lung diseases such as asthma, and people who work or exercise outside are at risk for adverse effects from ozone. These include reduction in lung function and increased respiratory symptoms as well as respiratory-related emergency department visits, hospital admissions, and possibly premature deaths. Virtually, all EU citizens are exposed to ozone above WHO health guidelines.

3.1.2. Particulate matter

Diesel vehicles are also a significant source of particulate matter – the pollutant of greatest concern to health. The sources and atmospheric chemistry of particulates are far from straightforward, and other sources are also important. Transport emissions do, however, make a larger contribution to individual exposure owing to the proximity of road transport emission sources to other road users and urban populations in general. Traditionally, particulates have been measured in terms of PM_{10} – particles of less than 10 micrometres in diameter –, but it is increasingly clear that the smallest particles are of greatest concern, and these are measured as $PM_{2.5}$ (less than 2.5 micrometres) and are (since 2008) part of the EU ambient air quality regulations.

PM_{10} emissions from diesel cars have been regulated since the start of the 'Euro' emissions standards. Initial limits were not stringent, but they have been tightened successively. A particulate number limit was also added to tackle the ultrafine $PM_{2.5}$ problem from Euro 5, but was until this year only measured in the laboratory. In effect, all modern diesel cars must now be fitted with a particulate trap to meet current standards and, as from September 2017, they will have to pass more stringent on-road tests to prove compliance. This will reduce particle emissions of new gasoline direct injection cars, which have been shown to surpass the Euro 6 limits by an order of magnitude[37].

Small particles penetrate deeply into sensitive parts of the lungs and can cause (or worsen) respiratory diseases, such as emphysema and bronchitis, and can aggravate existing heart diseases, leading to increased hospital admissions, and even premature death. The PM component of air pollution also combines with other toxins in complex ways, leading it to be closely associated with increased incidence of cancer, especially lung cancer. Reflecting this, the International Agency for Research on Cancer (IARC) has long classified diesel exhaust as a 'probable carcinogen'. In 2012, however, in the face of mounting evidence, it reclassified diesel engine exhaust as carcinogenic to humans.

There is little evidence to suggest a safe threshold for particulates, and indeed effects can be detected at little more than background concentrations, especially for $PM_{2.5}$. Particulates remain the main cause of premature deaths from air pollution. The EEA estimates that in 2013, there were just over 430,000 such deaths across the EU, and more in wider Europe.[38]

Currently, 21 Member States are unable to achieve EU ambient daily air pollution limits for PM_{10}. While most monitoring stations comply with the less stringent EU daily limits, between 55% and 74% of EU citizens are

[36] European Environment Agency, *Sector split of emissions of Ozone precursors*, 2014. http://www.eea.europa.eu/data-and-maps/figures/sector-split-of-emissions-of-ozone-precursors-eea-member-countries

[37] Transport & Environment, 2016. *Next round of Real-world Emissions tests: time for Governments to put public health above penny-saving carmakers* https://www.transportenvironment.org/sites/te/files/publications/RDE%203rd%20package%20lobby%20briefing.pdf

[38] EEA, 2016, *Air quality in Europe — 2016 report*

exposed to PM_{10} and $PM_{2.5}$ levels that the WHO considers damaging to health[39]. Road transport accounts for around 15% of the PM emissions in Europe. High diesel emissions are a major reason for the slow improvement in PM levels, especially pre-Euro 5 cars, vans and trucks not fitted with particle filters. More and more evidence[40] suggests that a sizeable proportion of Euro 5 and 6 diesel vehicles still emit excessive PM levels due to faulty filters and illegal tampering.

Despite the widely accepted assumption that the introduction of diesel particulate filters has solved the PM problem of modern diesel vehicles, there has been some concern over the regeneration of such filters. To avoid the filter becoming clogged, it needs to be cleaned up so that it can catch more particles and avoid creating a back pressure in the exhaust. This is achieved through a regeneration of the Diesel Particulate Filter (DPF), oxidising the soot until it turns into CO_2. However, there is some evidence to suggest that not all the soot is burnt, and some instead is broken down into even smaller particles of below 1nm in diameter (nanoparticles). These cannot be easily measured, but pose the most serious danger to health as they can easily penetrate deeply into the lungs and blood stream. Small particles also absorb polycyclic aromatic hydrocarbons (PAHs) that are carcinogenic.

3.1.3. City diesel bans and the "Diesel Summit"

While European governments have been reluctant to penalise diesel carmakers for breaching emissions legislation, the Dieselgate scandal has created a significant shift in attitude towards diesel – particularly in polluted cities that have struggled to curb dangerously high levels of pollution for years, despite different clean air measures. The Dieselgate scandal revealed the biggest source of NOx exceedances in urban areas to be diesel cars, often outside of the direct control of municipalities (vehicle standards are set at EU level while user/fuel taxes are decided by governments). As the only measure at their disposal, cities have announced various restrictions, or even outright circulation bans, in response to illegally polluting diesels. Paris, Madrid, Athens, Stuttgart, Copenhagen and Oslo have all announced bans on dirty diesels by 2025, with many others announcing measures that temporary restrict or make it costly for diesels to enter city centres (e.g. a new toxicity charge in London).

With the threats of city bans, the sales of diesel cars have dropped to below 50% across the EU for the first time in a decade, and are expected to decline further. Notable declines have already been observed in the UK where the proportion of diesel sales in the first half of 2017 was below 40%.[41] In Germany, diesel sales dropped by over 12% in July 2017 alone.[42] While the EU-wide data for 2017 is not yet available, it is expected to follow the downward trend observed across the biggest EU vehicle markets and to be closer to 40%.

Declining diesel sales are causing serious concerns across much of the EU car industry that has invested heavily in diesel technology. In response to that decline, the industry is now fighting back, using a raft of voluntary software fixes to argue diesel can be clean. There is currently a piecemeal approach to the fixes proposed by different car manufacturers, with no harmonised clean-up programme guaranteeing consistent emission reductions and durability for all EU consumers in place. VW Group, Daimler and BMW agreed to fund the emission upgrades in Germany and Austria, but not the rest of the EU. The voluntary programmes of Fiat and Renault are barely known outside Italy and France respectively, and it is unclear whether the offer is EU-wide or national. This greatly undermines the effectiveness and rigour of the industry's attempt to clean up their act.

The long-term effects of the diesel emissions scandal remain to be seen. However, it has caused a wave of consumer lawsuits against the non-compliant vehicles, and it has put into the spotlight the dangerous NOx

---

[39] World Health Organisation, *Review of evidence on health aspects of air pollution – REVIHAAP Project, Technical Report*, 2013. http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap-project-final-technical-report

[40] Helmers, *Does the European diesel car boom mitigate global warming*, 2016. http://green-budget.eu/wp-content/uploads/2016-02-17_Helmers_European-diesel-car-bias-makes-climate-worse1.pdf

[41] SMMT, 2017, *Car registrations*. https://www.smmt.co.uk/vehicle-data/car-registrations/

[42] Reuters, 2017, *German new car sales up 1.5 pct in July -source*. https://www.reuters.com/article/germany-vehicleregistrations/german-new-car-sales-up-1-5-pct-in-july-source-idUSF9N1JO02A

pollution and health damage due to Europe's dash for diesel. The environmental concerns of dieselisation are no longer confined to meetings of environmental groups, and instead they are seen as the main cause for the continuous failure to meet air pollution limits across Europe.

3.2. Land use change through use of biodiesel

Biodiesel, largely made from processed oil-seeds, such as rapeseed and palm oil, is added to diesel as a renewable fuel in Europe. The requirement to use biofuels arises from the EU's Renewable Energy Directive (2009) that establishes binding national targets for the share of renewable fuels that should be used in transport by 2020. Current use of biofuels at EU level is around 5%, most of which is biodiesel (80%). The social and environmental impacts of biofuels from food crops have been widely documented with particular concerns about biodiesel produced from vegetable oils. Additional land demand for biofuels leads to indirect land use change impacts – deforestation, conversion of grasslands and peatland clearance – to make way for food and animal feed production, especially palm oil. The GHG emissions associated with Indirect Land Use Change (ILUC) are significant in the case of biodiesel, as discussed in section 3.4.

Biodiesel is far from the main or only application of palm oil, but the EU biofuels mandate has increased the use of palm biodiesel at EU level. According to the ICCT, "*palm oil imports have risen dramatically in the same period that biodiesel mandates have been introduced and ramped up.*"[43] 2015 data from Oil World show that EU drivers are now the top consumers of palm oil in Europe, with 46% of imported palm oil going to biodiesel.[44] Most EU citizens do not even know that they are consuming palm oil in their cars, due to the general lack of information about the origin and type of fuels at the petrol station. There are a range of environmental, social and ethical concerns about the use and impacts of these activities:[45]

- The production of biofuels can indirectly cause additional deforestation and land conversion. When existing agricultural land is turned over to biofuel production, agriculture has to expand elsewhere to meet the existing (and ever-growing) demand for crops for food and animal feed. This process is known as 'indirect land use change or ILUC. This expansion happens at the expense of forests, grasslands, peatlands, wetlands, and other carbon-rich ecosystems. This can lead to a serious loss of biodiversity – especially in the case of rainforest destruction. It also results in substantial increases in greenhouse gas (GHG) emissions from the soil and vegetation removal, as discussed in Section 3.4.
- Biofuel demands on food and feedstocks, within an already-tightening market, will inevitably drive up prices and put basic commodities beyond the reach of the world's poorest. This, combined with the increasing price volatility that will inevitably accompany it, will exacerbate the problems of hunger and famine worldwide.[46]
- The prospect of a steady market for a new category of oil-based products is stimulating a 'land grab' by major international corporations, depriving local communities in developing countries of possibilities for economic self-sufficiency and locally-driven development. According to a 2016 Oxfam report, a company at the end of the supply chain of European biofuel producers is barring the access by residents to 1,000 hectares of land in Bengkulu – a province on the south-west coast of Sumatra, Indonesia – which the local government had allocated to them. Similar examples of land-grabbing have been reported in other parts of the world, including in South America.[47]

---

[43] ICCT, *Vegetable oil market and the EU biofuels mandate*, 2013. http://www.theicct.org/sites/default/files/publications/ICCT_vegoil_and_EU_biofuel_mandate_20130211.pdf
[44] T&E briefing, 2016: https://www.transportenvironment.org/sites/te/files/publications/2016_11_Briefing_Palm_oil_use_continues_to_grow.pdf
[45] See for example, ActionAid, 2013 *The problem with biofuels*
[46] Transport & Environment, 2017. *Over 100 scientific studies confirm biofuels policies increase food prices - study*. https://www.transportenvironment.org/press/over-100-scientific-studies-confirm-biofuels-policies-increase-food-prices-study
[47] Oxfam, *Burning land, burning the climate*, 2016: https://www.oxfam.org/sites/www.oxfam.org/files/bp-burning-land-climate-eu-bioenergy-261016-en_0.pdf

The above concerns are focused on so-called first-generation biofuels that are derived from food and animal feed crops. This involves biodiesel derived from oil crops, including rapeseed, soy and palm, which are transformed into biodiesel through transesterification (FAME) or as Hydrotreated Vegetable Oils (HVO). Biofuels from food and feed crops account for most of the current biofuel production and consumption at EU level. Due to the environmental and climate concerns around their use, the EU decided in 2015 to limit the contribution of food and feed crops to 7% of energy in transport in the national transport targets of EU Member States.

Advanced or second-generation technologies are also being developed that convert waste or residues – including from forest and agricultural activities – into biofuel. These offer the possibility of utilising biomass that is not directly in competition for land use with food and feed. Alternatives to fossil diesel and biodiesel from food crops include, for example, biodiesel produced from Used Cooking Oil (UCO). However, these options also bring the risk of displacing current existing uses as well as potential negative environmental impacts. This is why an appropriate and robust sustainability framework[48] is needed at EU level, to ensure that only real waste and residues are being used, whilst taking into account their limited availability.

3.3. High demand for diesel in Europe creates a market for (Canadian) tar sands diesel

One of the largest recent oil discoveries has been the 'tar sands' in the Canadian state of Alberta. This is a naturally-occurring form of bitumen, mixed in with sand and other minerals. The bitumen in tar sands does not differ greatly from other oil sources in terms of its chemical composition, but before it can be transported and refined, it has to be separated from the sand. This is done through heating, an extremely energy-intensive process causing substantial CO_2 emissions. Because bitumen is very viscous, it then needs to be upgraded or diluted in order to be used in refineries. The official values allowed in the EU's Fuel Quality Directive indicate a higher permitted default "well-to-wheel" greenhouse emissions of 108.5 g CO_{2eq}/MJ compared to 95 g CO_{2eq}/MJ, the default value for the diesel presently used in EU.[49]

As bitumen cannot be extracted like conventional oil, a further issue is that it is usually recovered through opencast mining, which has a devastating impact on the local ecology, water resources and local communities. Also, it represents a major new source of road fuels, when conventional petroleum reserves are already far too large to be fully exploited if we are to stay within safe levels of carbon emissions.

Tar sands are being exploited in Canada, but the oil is sent to reach refineries in the US, including in the US Gulf Coast, where it is processed in refineries specialised in processing heavy crude oil and in producing diesel fuel.[50] Part of this diesel output is then shipped to Europe. Due to the absence of robust oil reporting requirements, coupled with very little transparency, it is challenging to know exactly the amount of tar sands-derived oil that makes its way in the form of diesel to Europe.

One key question mark regarding the tar sands' threat to Europe is the infrastructure in place to transport the tar sands. In 2015, Barack Obama decided not to approve the pipeline Keystone XL, which would have brought tar sands crude oil from Alberta to the Gulf of Mexico. In March this year, the recently elected US President Donald Trump reversed Obama's decision. However, the project stills faces many hurdles, including several legal challenges by local communities and environmental organisations. Heavy crude oils (or 'crudes'), such as tar sands, are particularly well suited to yield less proportionally gasoline/petrol in refinery outputs, compared to lighter crudes. If the mix of tar sands in Gulf Coast refineries increases, so will the percentage of tar sands included in diesel fuel which is then exported to Europe to feed Europe's demand for diesel. The latest International Energy Agency (IEA) data shows that diesel exports from the US

[48] Transport & Environment, *A new EU sustainable bioenergy policy - position paper*, 2016. https://www.transportenvironment.org/publications/new-eu-sustainable-bioenergy-policy-position-paper
[49] Council Directive 2015/652. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L0652&from=EN
[50] Oil Change International, *Refinery Report*, http://refineryreport.org/

to the EU increased from 21 million barrels in 2006 to 128 million barrels in 2015.[51] Europe's dieselisation is therefore indirectly contributing to an increasing EU demand for crude oil from high-carbon tar sands.

Tar sands companies are also pushing for a pipeline called 'Energy East' to be built between Alberta and the east coast of Canada. If built, this pipeline could also lead to significant exports of tar sands-derived crudes to Europe. A study commissioned by T&E and Friends of the Earth Europe[52] has highlighted that an unexpectedly large share of European refineries has the capability to add tar sand crudes to their inputs. Tar sands crudes have already made their way to Europe, not only from Canada but also from the United States[53]. The US exports can be explained by the recent lifting of the crude oil ban in the US, which now allows Canadian crude oil to be re-exported from the US to Europe. Depending on many different factors, including the pipeline situation in North America, it may well prove increasingly attractive to export tar sands-derived crudes across the Atlantic via oil tankers to be refined in Europe. Overall, the growing EU demand for diesel makes the eventuality of increased the likelihood of higher imports of tar sands diesel and crudes from North America.

3.4. Climate effects

Passenger diesel engines generally achieve better fuel efficiency than petrol engines, and also deliver about 20% more useful power per litre. This is because diesel engines are typically about 27% efficient on average in converting the fuel into mechanical energy compared to around 22% energy conversion for petrol engines. A litre of diesel also contains around 10% more energy by volume than one of petrol (emitting, however, some 15% more CO_2 per litre).

The superior efficiency of the diesel engine arises from the higher temperature of combustion and greater compression and expansion ratio. The engine design also means that diesels are more reliable and have greater longevity. The comparative fuel economy advantage of diesel over petrol increases for larger and heavier vehicles, but the benefits of diesel over advanced, direct injection petrol (gasoline) engines are now being reduced, as these direct injection petrol engines become increasingly "diesel-like" and efficient.

The efficiency of a diesel engine compared to a petrol equivalent on a 'tank-to-wheel' or 'tail pipe' basis does not give a full picture of the climate impacts, for several important reasons, as outlined below. These include higher upstream emissions, higher emissions from biofuel substitutes, the trend for larger more powerful diesel cars and the tendency to drive more when fuel costs are lower. The net impact of these effects is that the claimed climate benefit of diesel cars is not just overstated but probably illusory.

3.4.1. Upstream 'well-to-tank' refinery emissions

Energy is required to convert crude oil into usable fuels such as petrol and diesel, and to deliver them to a refuelling station. As a result, some of the energy from the crude oil is used up (and thus some of the CO_2 is emitted) before it reaches the fuel tank of a vehicle. These 'well-to-tank' emissions (or upstream refinery emissions) of extracting and refining crude typically represent around a fifth of the tailpipe (tank-to-wheel) emissions that occur in the engine when it is burnt. Diesel requires more refinery energy than petrol. The default well-to-wheel GHG emission for diesel, based on extensive studies for the European Commission, is 89.1 g CO_{2eq}/MJ, for petrol 87.5 g CO_{2eq}/MJ, a difference of 1.8 %.[54] This is not a large amount, but it is significant in that it offsets part of diesel's perceived CO_2 benefit.

[51] IEA, 2017, *Petroleum & other liquids: exports by destination*. https://www.eia.gov/dnav/pet/pet_move_expc_a_EPD0_EEX_mbbl_a.htm

[52] MathPro Inc., *Assessment of the European refining sector's capability to process unconventional, heavy crude oils*, 2015. http://www.transportenvironment.org/sites/te/files/FoEE_TE_03_Final_Project_Report_091015.pdf

[53] Fact checking on Keystone XL and exports, Oil Change International, http://priceofoil.org/2014/11/20/fact-checking-keystone-xl-exports/

[54] JRC, 2013, *WELL-TO-TANK Report Version 4.0*. https://iet.jrc.ec.europa.eu/about-jec/sites/about-jec/files/documents/report_2013/wtt_report_v4_july_2013_final.pdf

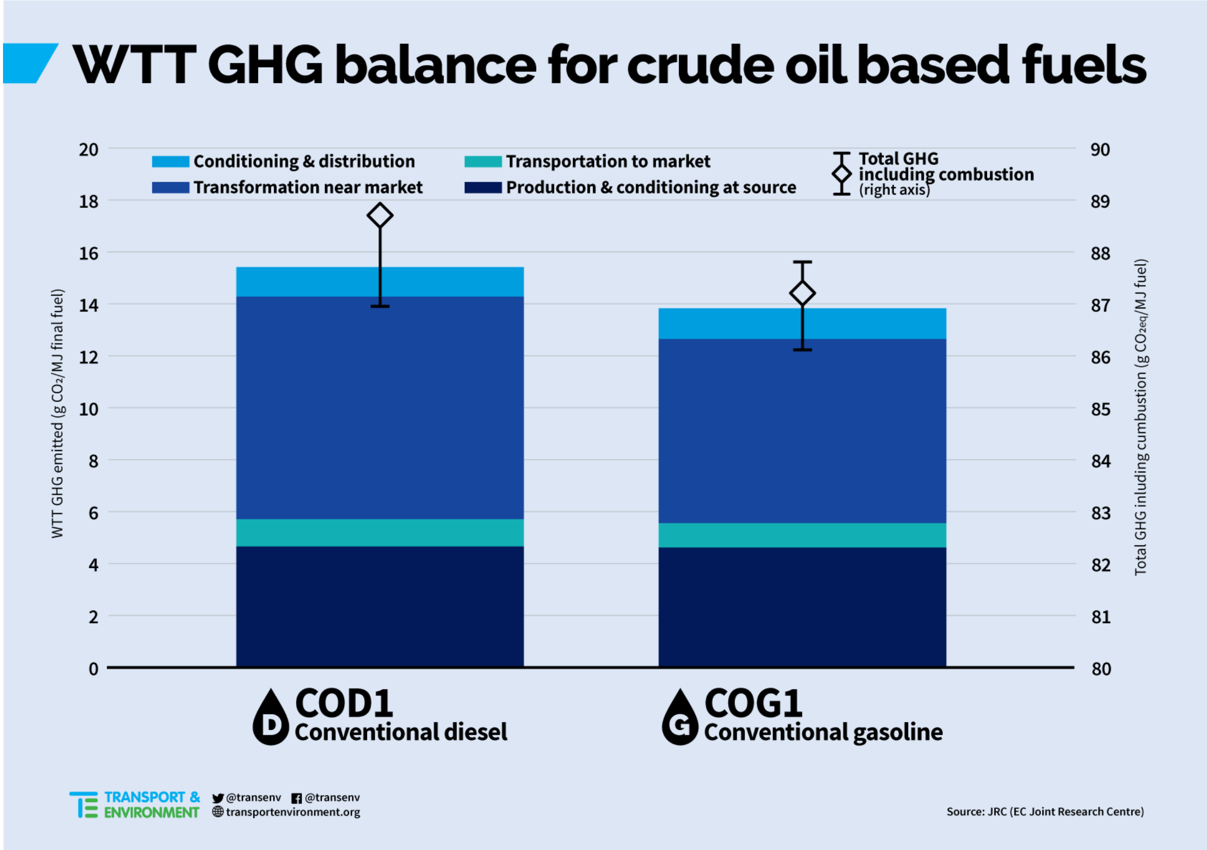


Figure 20

Furthermore, the higher the proportion of diesel that is required from the crude oil being refined, the greater the energy that is required in the refining process. If the diesel (or more accurately, the middle distillates)/petrol 'split'(i.e. ratio) goes up from 1.8 to 3.7, the related reining CO_2 emissions increase by more than 50 %, from around 180 kg CO_2 per tonne of oil to almost 300 kg per ton oil (Figure 21). If refineries continue to produce a high ratio of middle distillates, then there is an additional 10 to 15 gCO_2/km that has to be added to the well-to- tank GHG emissions.[55] This would further shift the balance of CO_2 benefits away from diesel.

[55] See also Schipper L., Fulton L.: Disappointed by diesel? The impact of The Shift Diesels in Europe through 2006. http://metrostudies.berkeley.edu/pubs/reports/004_trb_diesel.pdf

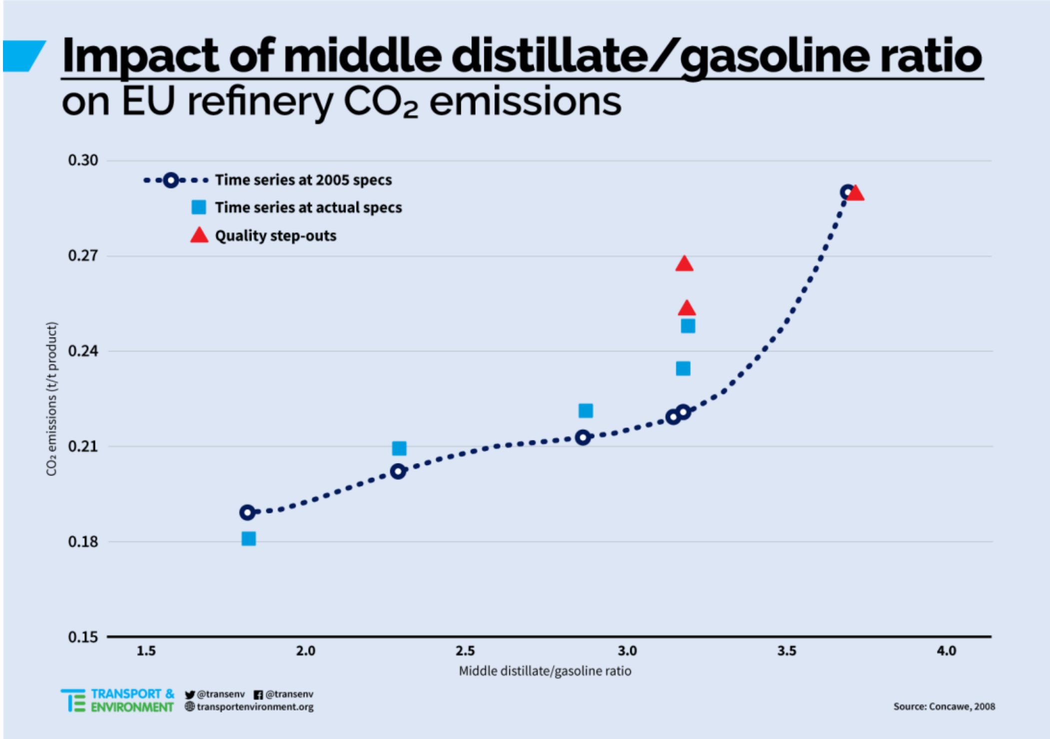


Figure 21

The consumption ratio of middle distillates to petrol in Europe is already above the levels illustrated from the horizontal axis of Figure 21 and this is set to go higher if the current demand continues. Already this is leading to an increasing need to ship road fuels around the world, as described below. There are, however, limits to how far this process will be able to be offset if the previously expected growth of diesel demand continues, and if the refining ratio in Europe increases as illustrated. Dieselisation is therefore leading to increased well-to-tank emissions for both gasoline and diesel production, and a growing imbalance to the detriment of diesel in well-to-tank emissions.

3.4.2. Embedded emissions in vehicle production

Diesel vehicles require 3%-5% more energy to manufacture than equivalent petrol cars.[56] More than 5t CO_2 are emitted when manufacturing a car[57] – which is typically equivalent to the emissions from one to two years of motoring. Diesels have heavier powertrains, requiring more carbon-intensive steels. They are also noisier, resulting in additional noise dampening requirements. For a similar lifetime mileage, a few extra grammes of CO_2 should therefore be added per kilometre to the real-world emissions from a diesel vehicle.

[56] Ricardo, Preparing for a Life Cycle CO2 Measure, 2011. http://www.lowcvp.org.uk/assets/reports/RD11_124801_5%20-%20LowCVP%20-%20Life%20Cycle%20CO2%20Measure%20-%20Final%20Report.pdf
[57] See for example Ricardo, *Preparing for a Life Cycle CO2Measure*, 2011. http://www.lowcvp.org.uk/assets/reports/RD11_124801_5%20-%20LowCVP%20-%20Life%20Cycle%20CO2%20Measure%20-%20Final%20Report.pdf; TUV Nord, *The Golf Environmental Commendation - Background Report*, 2012.

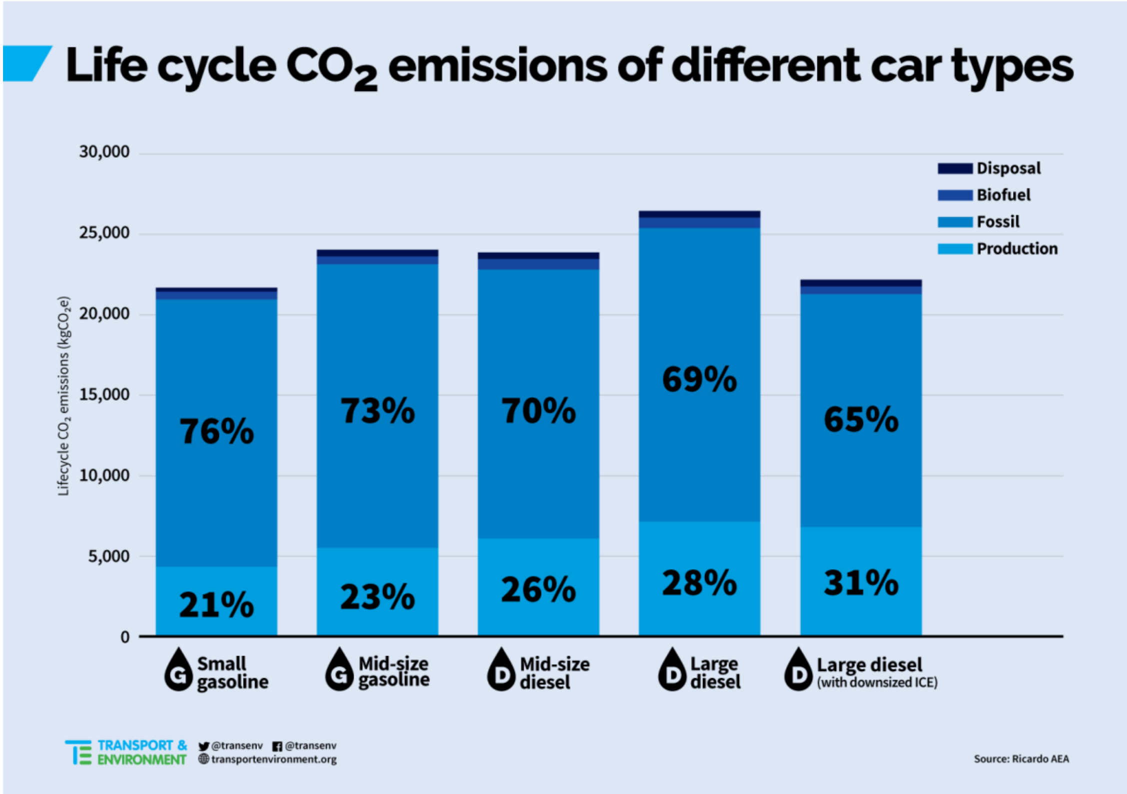


Figure 22

3.4.3. Diesel cars are driven further

As noted in Section 2, diesels are typically driven substantially farther in a year than their petrol equivalents. This is partly because people who choose diesels are mainly those who expect or 'need' to drive long distances, and hence know that the additional purchase cost will be offset by cheaper fuel costs per kilometre. In this analysis, T&E has not assigned the additional kilometres driven to higher diesel emissions, but one can ascertain that part of these kilometres arise as a result of the lower cost of diesel fuel. The so-called 'rebound effect' of driving more as a result of cheaper diesel prices is widely recognised. A comprehensive meta-analysis of studies was produced by the UK Energy Research Centre[58], and this concluded that for private motorists, the rebound effect is between 10% and 30%. For the purposes of this exercise, we therefore assume a 20% mid-point rebound effect from the above, meaning that if fuel is, for example, 10% cheaper, then 8% of this will be taken as cost savings, but the other 2% will be spent on the extra mileage, relative to what would otherwise have been the case.

A typical EU driver could cut fuel costs per km by about 20% by switching from petrol to an equivalent size diesel car through better fuel efficiency, and the average diesel tax bonus across the EU[59]. Applying this 20% price elasticity, it is therefore reasonable to assume that the average motorist in a diesel car will drive an extra 4% than they otherwise would have done if they had had an equivalent petrol car. This is far less than the total gap between the average distance driven in petrol and diesel cars, but realistically reflects the rebound effect that is directly attributable to the diesel bonus and fuel efficiency gains. The higher CO_2 emissions resulting from the rebound effect are presently ignored.

3.4.4. First generation biodiesels are more CO_2-intensive than bioethanols

Biofuels are widely but incorrectly considered to be 'climate-neutral' or 'zero-carbon', since the CO_2 emitted from the combustion is incorrectly assumed to be equivalent to the CO_2 previously taken up by the plant

[58] UKERC, *The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency*, 2007. http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/the-rebound-effect-report.html
[59] Adapted from T&E, 2011, *Fuelling oil demand? What happened to fuel taxation in Europe?*

and stored in the feedstock crop. In practice, emissions also arise from cultivation, transport and production of the biofuel and direct and indirect land use change, which in turn can have major carbon implications for a biofuel's true 'well-to-wheel' (WTW) CO_2 footprint.

Two modelling exercises conducted for the European Commission[60] have looked into the indirect land use change (ILUC) impacts of biofuels at EU level. They have shown that ILUC emissions for biodiesel are significant and often higher than for the crude oil-derived diesel that they are intending to replace.

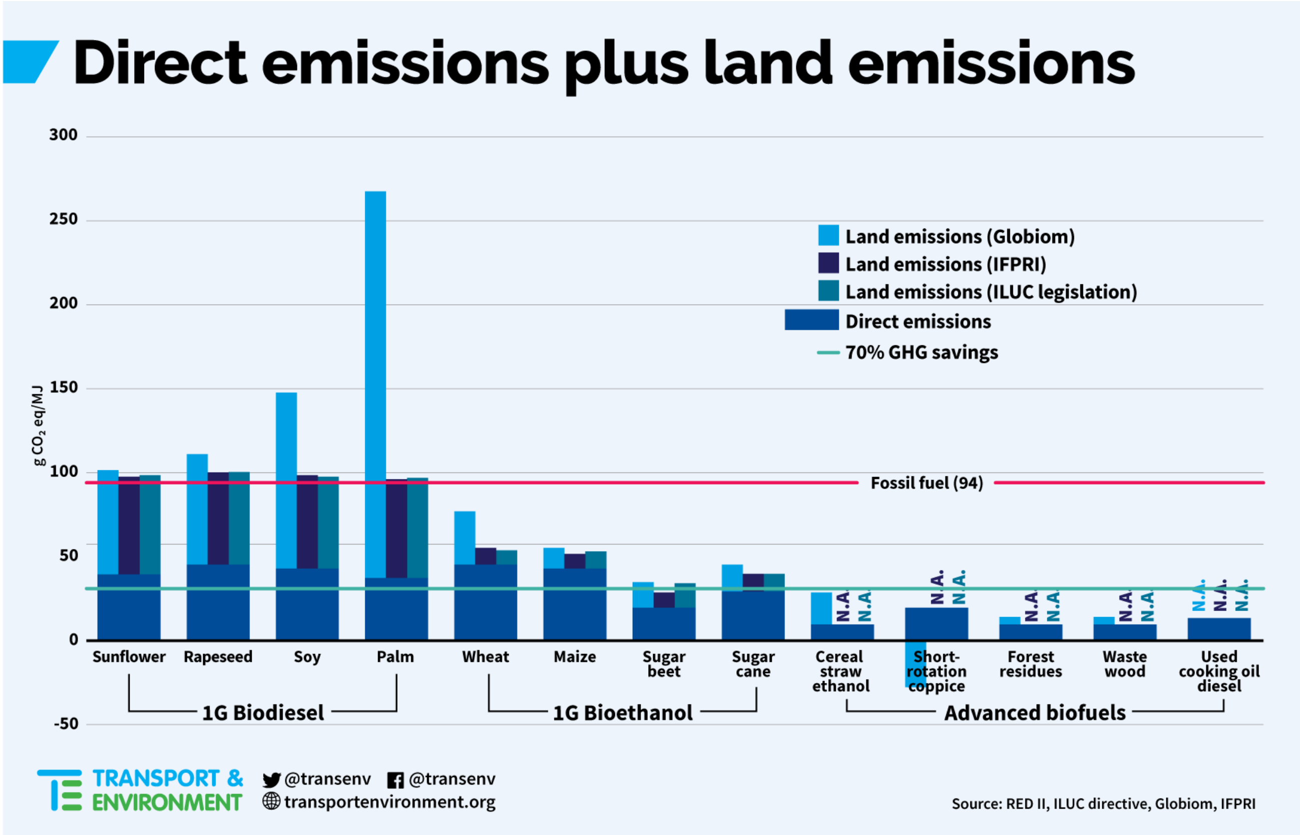


Figure 23

As Figure 23 illustrates, the true well-to-wheel footprint of the range of biofuels typically added to road fuels varies enormously, especially once ILUC factors are added in. The first generation fuels mostly used today all have significant greenhouse gas footprints. On average, biodiesel from vegetable oils is worse for the climate than fossil diesel, when one takes into account both direct emissions from cultivation, transportation and processing, and the GHG emissions from ILUC. According to the most recent modelling study, palm oil biodiesel scores the poorest, with on average three times the GHG emissions of those of the average GHG fossil diesel[61]. Even rapeseed oil, the most common feedstock for biodiesel in Europe, has higher GHG emissions than diesel when ILUC effects are factored in. In contrast, the so-called 'advanced' biofuels do offer very substantial reductions in total net emissions relative to conventional fuels. However, these fuels have been much slower to come to market than was initially hoped and make very little contribution to the current total commercial biofuel production.

[60] Laborde, Assessing the Land Use Change Consequences of European Biofuel Policies, Final Report, 2011. http://www.ifpri.org/publication/assessing-land-use-change-consequences-european-biofuel-policies AND Valin et al, The land use change impact of biofuels consumed in the EU, 2015. https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf

[61] Transport & Environment, 2016, *Globiom: the basis for biofuel policy post-2020*. https://www.transportenvironment.org/publications/globiom-basis-biofuel-policy-post-2020

3.4.5. Lifetime CO2 emissions of a diesel compared to a petrol car

To summarise the evidence assembled above, together with looking at the key lifecycle CO_2 emissions of a vehicle and the fuel it needs over its lifetime, diesel cars will emit a few extra tonnes of CO_2 more than petrol cars, because of pro-diesel refinery settings, the impacts of biodiesel, extra material and energy needed for the manufacture of the diesel car, and the mileage driven (Figure 24). In this comparison, a few assumptions have been made to derive the overall emissions:

- The average petrol lifetime driving distance of 175,000 is taken as the starting point.
- The average diesel car is driven longer as discussed previously; however, only 4% of this is due to the lower fuel price (rebound effect) as shown above. Hence, an additional 7000km are added to the diesel lifetime distance to account for this.
- The latest real-world fuel consumption figures[62] for diesel and petrol are used, 6.3l/100km and 7.1l/100km, respectively.
- To account for biodiesel effects, a conservative estimate of 5% biodiesel content is assumed. The composition of the biodiesel itself uses the average shares of rapeseed oil (48%), palm oil (27%), waste oils (15%), soya oil (5%), tallow & grease (4%), etc.
- Similarly, a 5% bio-blend is assumed in petrol for consistency, using the EU average shares taken from ePure: corn (38%), wheat (37%), sugars (14%), etc.
- The carbon intensity of both biodiesel and ethanol is derived by adding ILUC values (the Globiom EC study) to the direct carbon intensity of different feedstocks.
- Extra manufacturing emissions are taken to be 5% of the average 5 tonnes of CO_2 as shown in 3.4.2 above.
- For diesel and petrol shares of B7 and E95, diesel and petrol specific densities, energy contents and JRC-derived overall well-to-wheel (WTW) carbon intensity factors from section 3.5.1 are used.

[62] Transport & Environment, *Mind the Gap 2016: Fixing Europe's flawed fuel efficiency tests*, 2016. https://www.transportenvironment.org/sites/te/files/publications/T%26E_Mind_the_Gap_2016%20FINAL_0.pdf

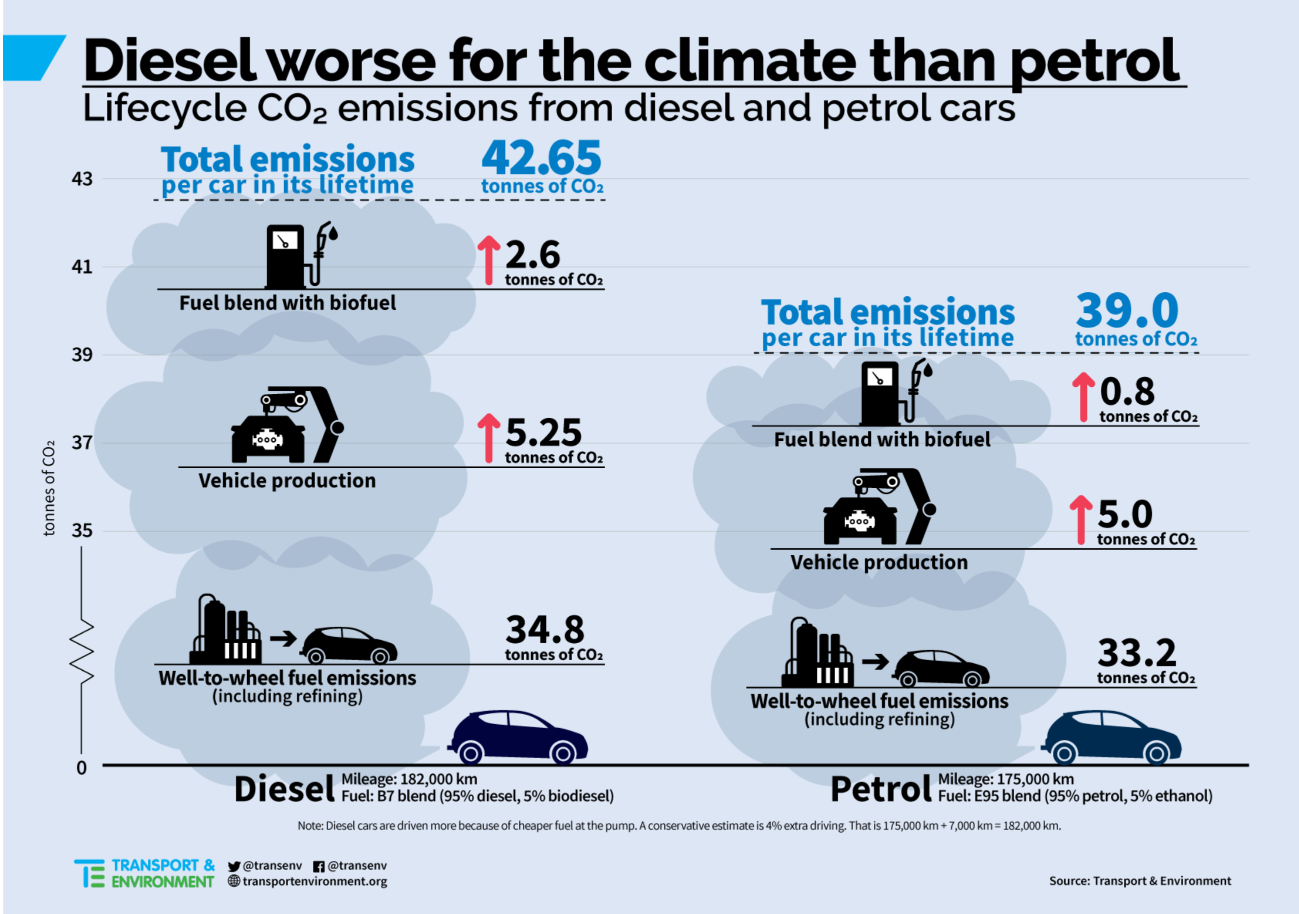


Figure 24

Following the above assumptions, the final calculation from Figure 24 demonstrates that an average diesel car over its lifetime will emit around 3.65 tonnes more CO_2 than a petrol car, eroding its perceived CO_2 benefit, and the associated rationale for continuous political support. Even if the higher emissions of biodiesel substitutes are ignored, the CO_2 emissions of a diesel car are still significantly higher than those of petrol car, mainly due to higher lifetime mileage driven and the more intensive refinery processing. This shows that the net effect of diesel is to worsen GHG emissions rather than reducing the emissions, as a simple tank-to-wheel metric shows. This seriously undermines the case for diesel as a means to lower CO_2 emissions.

3.4.6. Lifecycle comparison with other fuels and powertrains

Going forward, it is could be more appropriate to compare diesel vehicles with alternative low-emission and zero emission powertrains. The most recent and comprehensive lifecycle analysis in this regard has been undertaken by VUB I MOBI, with the key results summarised in Figure 25. The LCA model includes well-to-tank emissions (raw materials, refining, production including components and assembly, and distribution) and tank-to-wheel emissions (use, as well as maintenance and road infrastructure). The analysis demonstrates that the lifetime CO_2 emissions of plug-in hybrids and electric vehicles on different electricity mixes are already substantially lower than comparable diesel vehicles. The benefit will continue to increase in the coming years, as more low-carbon and renewable electricity enters European electricity mixes.

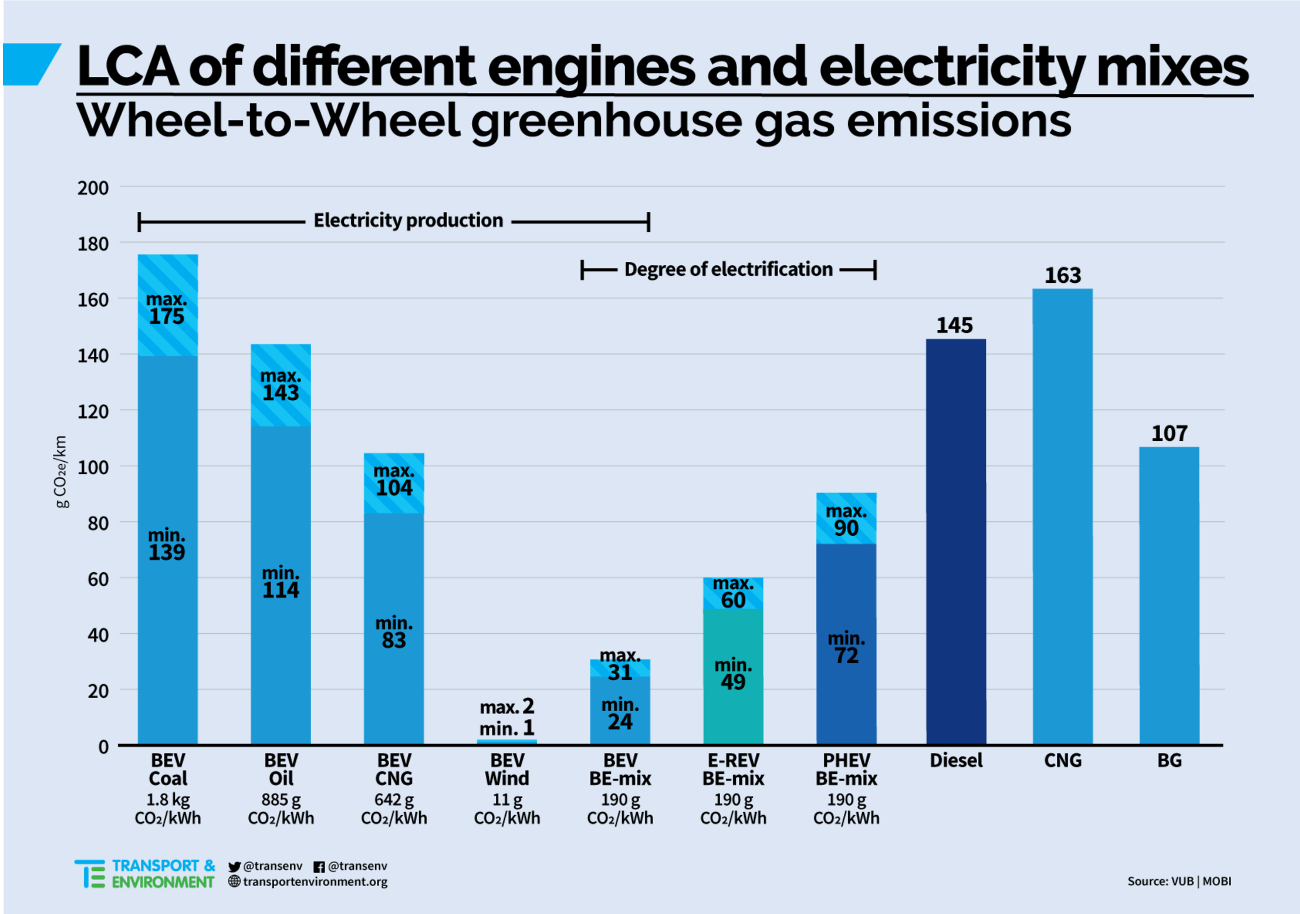


Figure 25

3.4.7. Diesel is not needed to meet EU climate targets

The recent diesel emissions scandal has prompted many to re-think dieselisation as an environmental good. However, there remains pressure from the car industry for a continuation of the generous policies that have driven the shift to diesel, in order to help the industry to meet its car CO_2 targets for passenger cars. Nevertheless, emerging evidence suggests that more diesel is not needed, either to meet either the current 2021 fleet-average target of 95g CO_2 /km, or for future milestones.

Firstly, the average diesel today costs around €2,000–3,000 more than a petrol car, and a comparison of the cost curves of CO_2 emission reduction technologies for diesel and gasoline engines developed by ICCT[63] shows the technology costs and resulting emission gains of a typical C-segment gasoline vehicle in 2025. The solid blue and black lines are the upper and lower range boundaries; this includes hybridisation (but

[63] ICCT, *Summary of mass reduction impacts on EU cost curves*, 2013, http://www.theicct.org/sites/default/files/publications/ICCT_MassReductionImpacts_feb2013.pdf

no electrification until the full internal combustion engines [ICE] reduction potential is achieved. The dotted blue and black lines include the effects of early electrification on costs).

If a manufacturer invested a further €2,000 into increasing the efficiency of gasoline engines for a mid-size

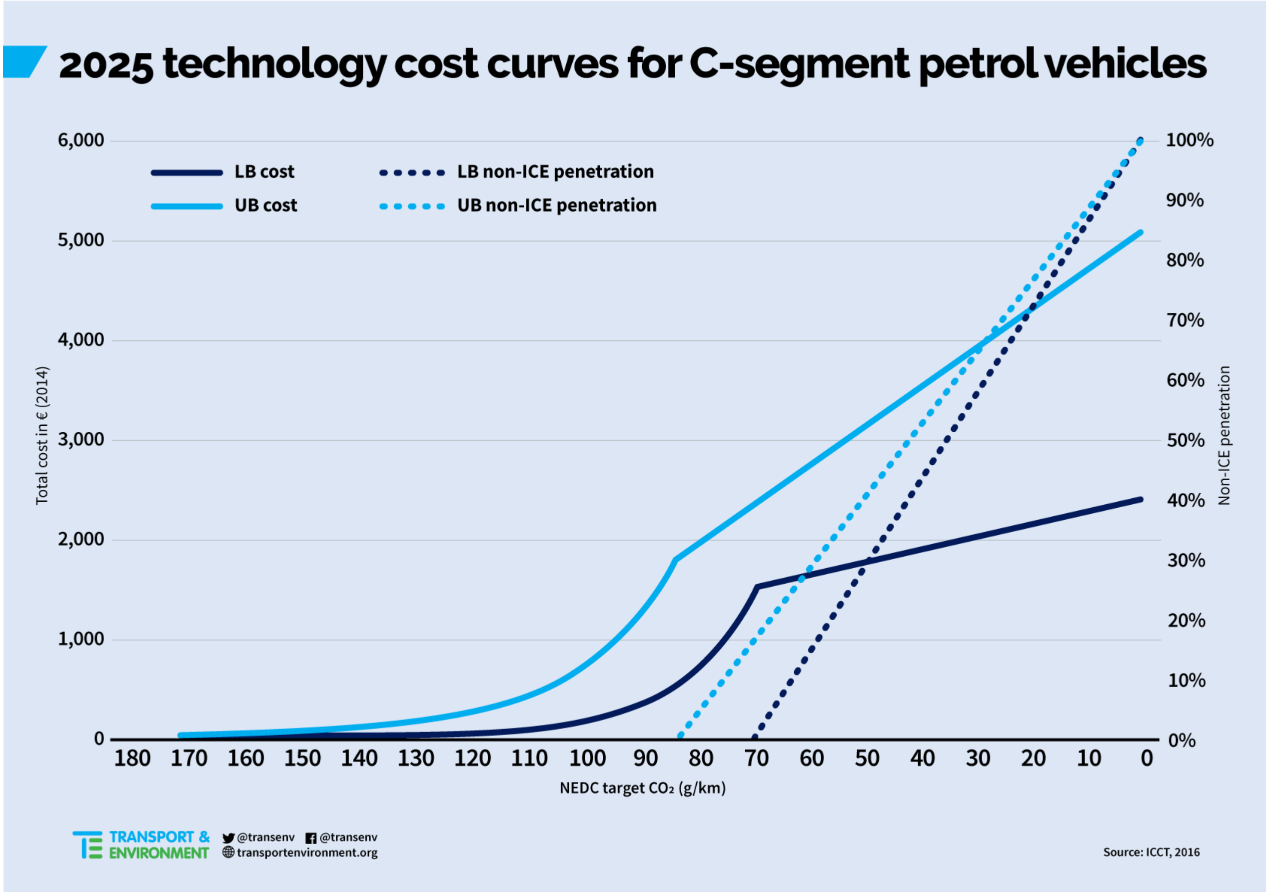


Figure 26

car, its CO_2 emissions would drop to 80g-90g CO_2 per km. This estimation includes the adoption of technologies such as parallel two clutch systems (P2 hybrids) and other hybridisation. The CO_2 emission reduction achieved is significantly below today's average emissions of 119g CO_2 per km for diesel, but this comes at the same cost as today's costly diesel technology. The claims that diesel is more efficient are therefore misleading.

Gasoline vehicles have become much more efficient in recent years, almost closing the gap with equivalent diesel engines. The average CO_2 emissions across all vehicle segments of new petrol cars are 123g/km, against the diesel cars' average of 119g/km[64]. On a one-to-one comparison of similar-powered diesel and petrol engines, the CO_2 difference between the two amounts is a mere 2-3 grammes, whereas the price tag for the diesel car is always a few thousand euros more. Already today, for these same few thousand extra euros, mild- or full-hybrid systems can be fitted to a standard petrol car, making it emit less CO_2/km than a diesel car. For example, the cost of a mild (48V) hybrid system is in the order of €1,000; this will take off around 5g CO_2/km off for a gasoline engine, based on present models on the market. Given that there are extra 'rebound effect' CO_2 emissions related to the typical higher diesel lifetime mileage figures, the tailpipe CO_2 emissions differences are close to negligible. Hence, even if the recent decline in diesel sales was fully replaced by new (but less powerful) petrol vehicles, the overall CO_2 penalty across EU fleets would be minimal.

[64] ICCT, 2017. *SHIFTING GEARS: THE EFFECTS OF A FUTURE DECLINE IN DIESEL MARKET SHARE ON TAILPIPE CO2 AND NOX EMISSIONS IN EUROPE*. http://www.theicct.org/sites/default/files/publications/Shifting-gears-EU-diesel-futures_ICCT-white-paper_06072017_vF.pdf

Secondly, whilst diesel cars might have been the cost-effective way to reduce car CO_2 emissions in the 1990s, in 2017 there are many more cost-effective, better and cleaner solutions. Experience in other global markets such as Japan and the US suggests that light-duty CO_2 targets can be achieved with very low shares of diesel vehicles (e.g. below 5%), via relying instead on alternative powertrains, such as hybrid and electric vehicles. Even in Europe, the country with the lowest CO_2 emissions from vehicles in 2015 – the Netherlands – had diesel sales much below the EU average, at 29%. Instead, the Dutch sales of hybrid cars and plug-in hybrid cars are substantially higher than elsewhere in Europe, amounting to over 15% in 2015. As Figure 27 demonstrates, the average hybrid car emits around 25% less CO_2 per km than its counterpart[65], and in some markets is already cheaper. For example, a quick internet search on the VW website puts the purchase price of the brand new 2017 VW Golf at €30,000, while both Toyota Prius and Hyundai IONIQ SE hybrids come at a cost of €28,000 and €24,000, respectively. A similar trend is seen in the UK, especially when government grants for hybrid cars are taken into account.

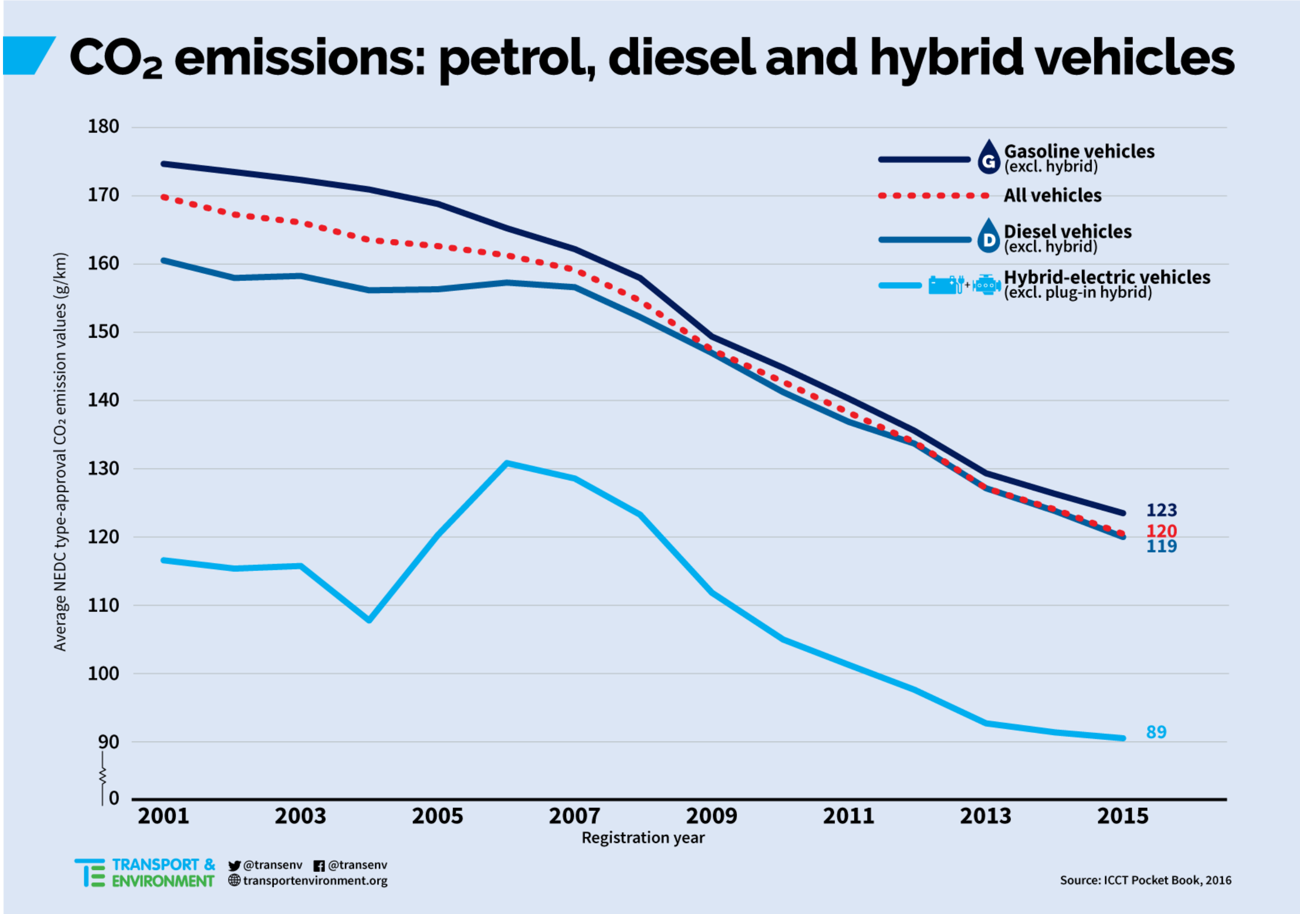


Figure 27

The price advantage of hybrid vehicles will rise further once stricter emission limits for all vehicles come into force in 2019. The need for sophisticated exhaust after-treatment for compliance with the 2019 emission limits will increase the cost of diesels by between several hundreds and a thousand euros, while gasoline hybrid systems will drop in price significantly by 2025. A faster introduction of plug-in hybrids would increase the associated CO_2 benefits even further. In reality, the decreasing diesel sales are likely to be at least in part replaced by hybrid and plug-in hybrid cars rather than petrol cars. This would result in a more ambitious reduction of the fleet average CO_2 emissions across Europe, compared to heavy dieselisation. Switching to fully electric vehicles – expected to reach cost parity with combustion engines by the mid-2020s – with zero tailpipe emissions will accelerate this even further.

[65] Ibid.

3.5. Effects on the balance of trade and energy dependence

Twenty years ago production from the EU's refineries was largely consumed within the European Union. European domestic consumption of petrol and diesel approximately balanced the natural mix of hydrocarbons in crude oil. The rapid dieselisation of the EU car fleet has created a growing imbalance, leading to a diesel shortage and a gasoline excess. In part, refineries have responded by increasing the production of diesel, but at the cost of higher refinery emissions (Section 3.4.1).However, Europe has also had to increase diesel imports, principally from Russia and the US, and this problem is expected to get worse by the end of this decade. At the same time, Europe has had to export surplus petrol to the US, but increasing domestic US oil production and growing use of ethanol blends, coupled with lower demand from more efficient cars, is leading to declines in this export market. In 2015 the net import of diesel was 24.4 million tonnes, corresponding to around 9% of the net diesel consumption. During the same year the net petrol export was 56.4 million tonnes.[66]

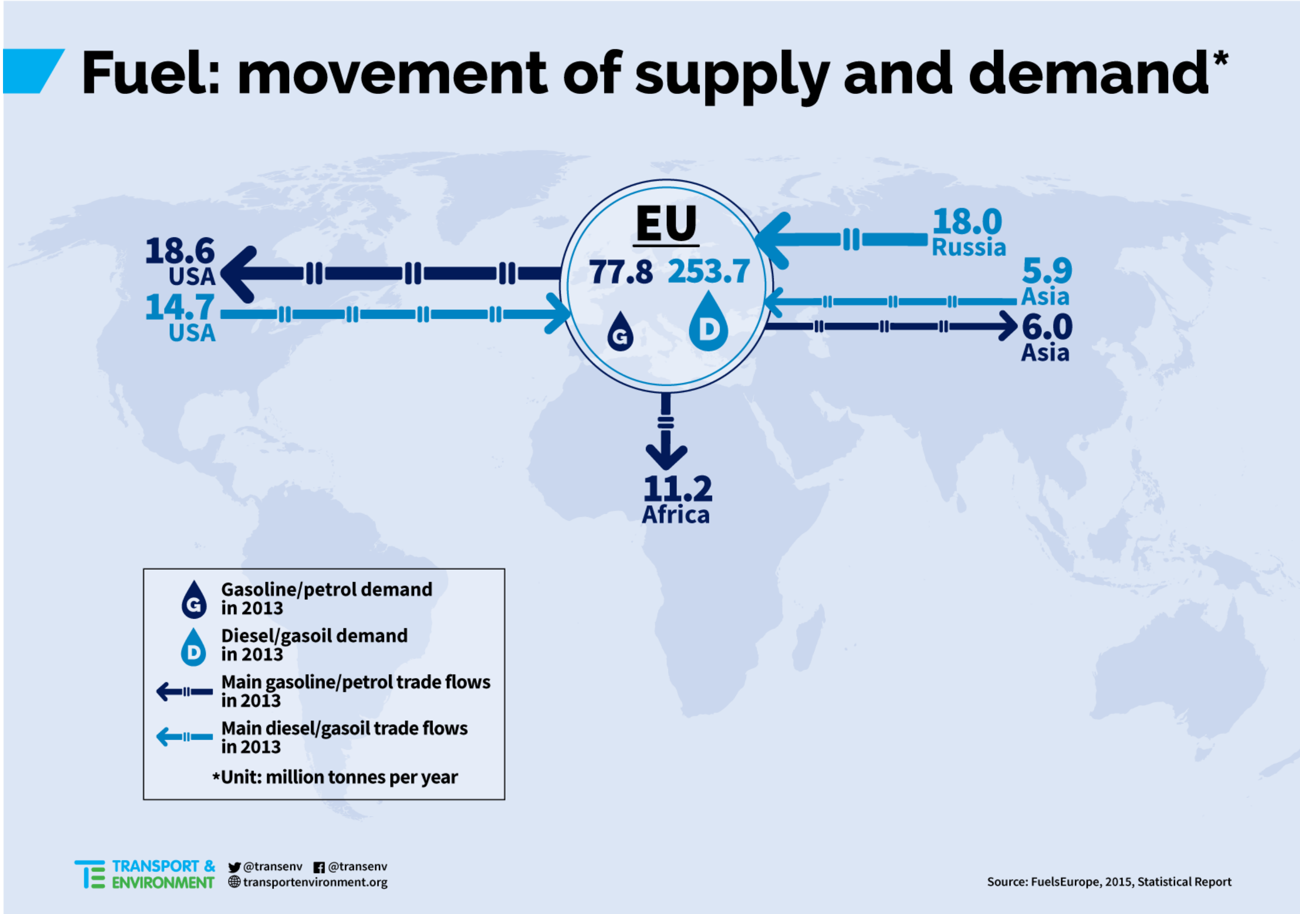


Figure 28

Moving these quantities of refined oil products around the globe is clearly undesirable from an environmental and economic perspective. It also directly contradicts the EU's aspiration to improve its energy security. On the contrary, if the dieselisation trend continues, Europe will become ever more dependent on other countries to balance its road fuel requirements.

[66] Eurostat, 2015 data. http://ec.europa.eu/eurostat/statistics-explained/index.php/Oil_and_petroleum_products_-_a_statistical_overview

3.6. Declining fuel tax revenues

In contrast to the public perception, tax revenues from transport fuels in the EU have been falling since 2000, once they are corrected for inflation. In 2000, these revenues were around €200 billion, but in 2014 they were reduced to €167 billion. These tax revenues are also falling relative to GDP. In 2004, transport fuel tax revenues corresponded to 1.6 % of GDP in the EU27. By 2014, this had fallen to 1.2% of GDP.[67] In absolute terms, fuel tax revenues have remained at around €160 billion since 2002, but they have fallen in real terms by around 20%. The decline in fuel tax revenues preceded the financial crisis, which exacerbated the trend.

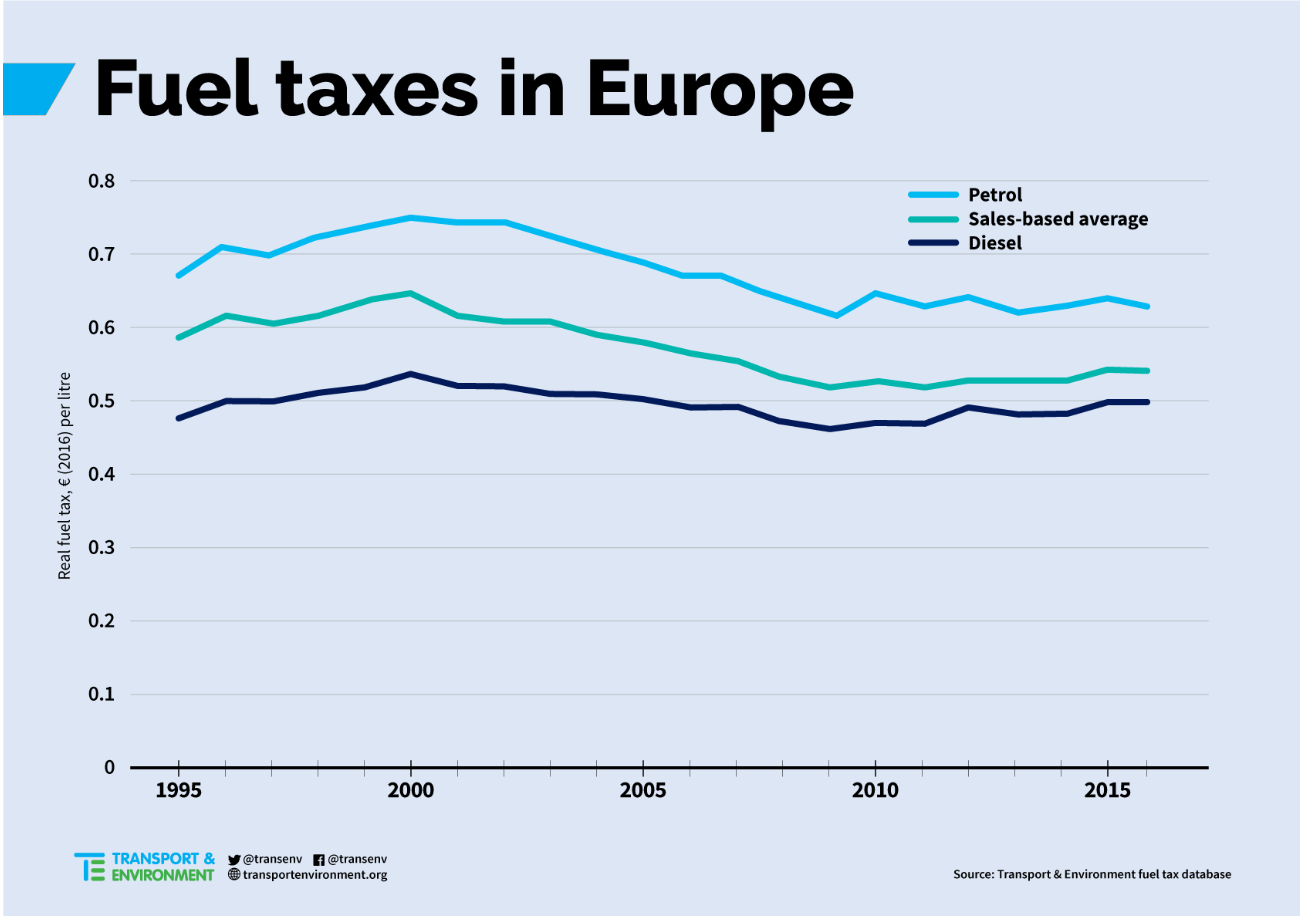


Figure 29

The declining share of tax revenues from fuel duties means that revenues have to be raised from other sources, and/or that public spending has to be reduced.

[67] EU transport in figures. Statistical pocketbook 2013, European Commission.

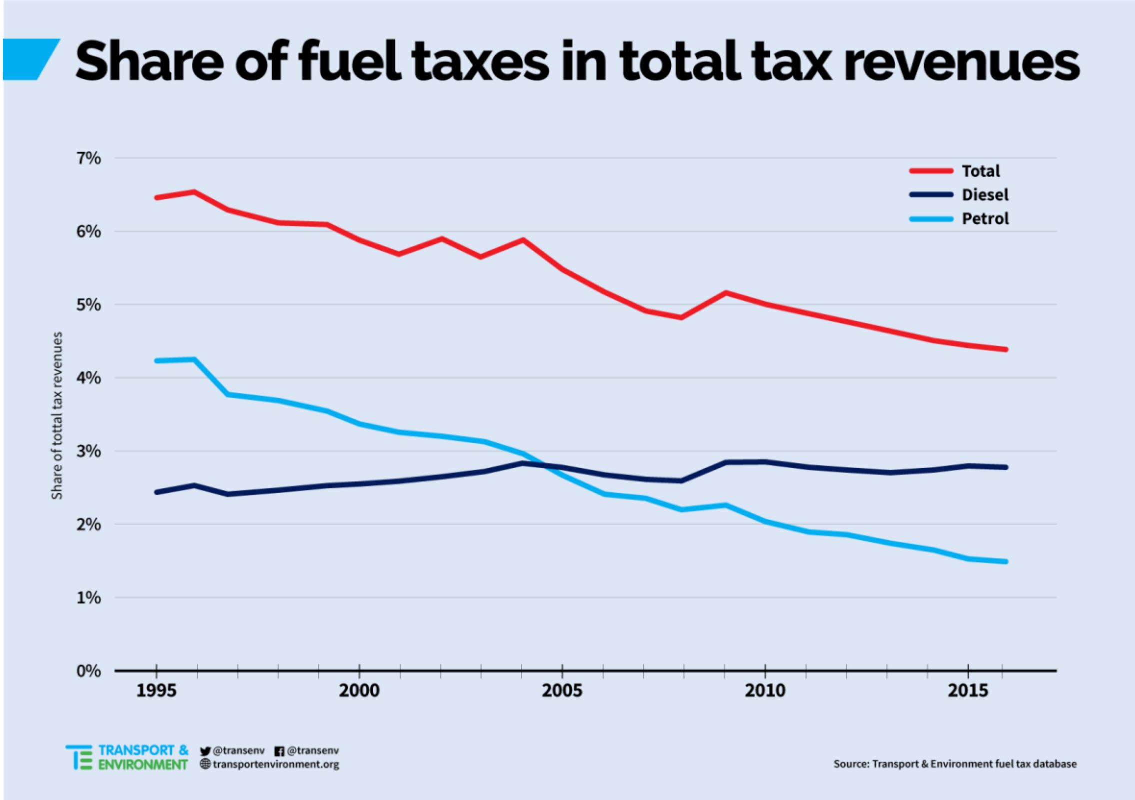


Figure 30

The improving efficiency of cars, which has reduced overall fuel consumption, is an important contributory factor. In addition, the dieselisation of the car fleet has also shifted consumption from highly-taxed petrol to lower-taxed diesel fuel. For example, in 2016,[68] the consumption-weighted average tax on diesel within the EU-15 was around €540/1000 l, and the average petrol tax was circa €750/1000 l. T&E calculations show that if diesel had been taxed in 2016 at the same rate as petrol, the extra revenue for EU Member States in 2016 would have been around €31.8 billion, before taking into account reductions in consumption (i.e. that would occur as a result of a higher fuel price, as some of today's demand is due to rebound effects)[69].

[68] EEA, *Transport fuel prices and taxes*, 2016. https://www.eea.europa.eu/data-and-maps/indicators/fuel-prices-and-taxes/assessment-6
[69] T&E's fuel tax database

4. Global Diesel market outlook

4.1. Worldwide diesel sales of Light-Duty Vehicles (LDVs)

Globally, the automotive market continues to grow strongly, up by 50% since 2000.[70] In 2016, 95 million vehicles were manufactured, of which 72 million were passenger cars and the remainder commercial vehicles, which are predominantly diesels. The available data for light-duty vehicles (which includes predominantly diesel vans) shows that Europe dominates the global diesel light-duty market. Around 11 million diesel cars and vans were sold worldwide in 2015, including around 8.5 million in Western Europe, roughly 1.4 million in India and around 850,000 in South Korea and 660,000 in Turkey. Figure 31 illustrates the scale of the EU's dominance in the diesel car market, as a result of its decade-long regulatory and taxation bias.

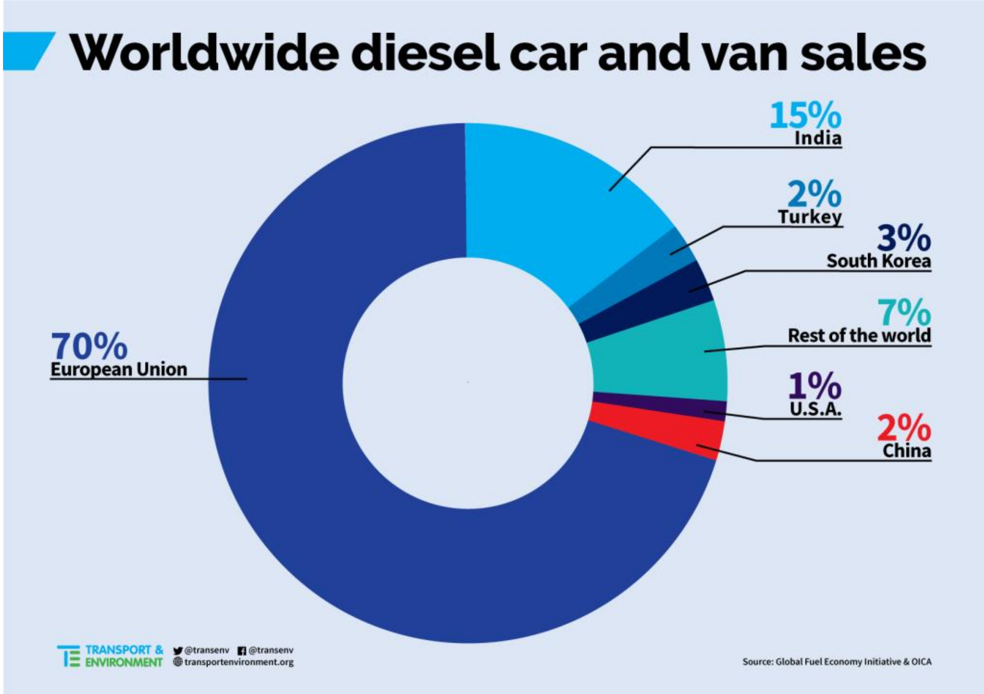


Figure 31

In the other significant global car markets (China, North America, Brazil, Russia and Japan) diesel sales are very low or even absent. In China, the world's biggest motor vehicle market, the share of diesel LDVs is below 2%, while in the US it is below 1%, despite the strong popularity of pick-up trucks.

Europe is a unique case worldwide where diesel engines for light duty vehicles have represented more than 50% of new vehicle sales for the last 10 years. In the rest of the world, just one in 20 new cars is a diesel. Of all major markets, only the EU, and Turkey today have a diesel share of new vehicles above 50%, with South Korea and India at around 45%. Some markets have seen a drastic drop of the diesel share, as in Argentina. Since markets with a low share of diesel are growing faster than the EU market, the global share of diesel cars (including in the EU) has decreased from 20% to 15% of new registrations between 2005 and 2015. Following the global diesel emissions scandal this trend is expected to accelerate; India and South Korea are already updating the laws that favour diesel cars, with the proportion of diesel cars in markets expected to drop significantly as a result.

[70] International Organization of Motor Vehicle Manufacturers' (OICA), *production statistics 2016.* http://www.oica.net/category/production-statistics/

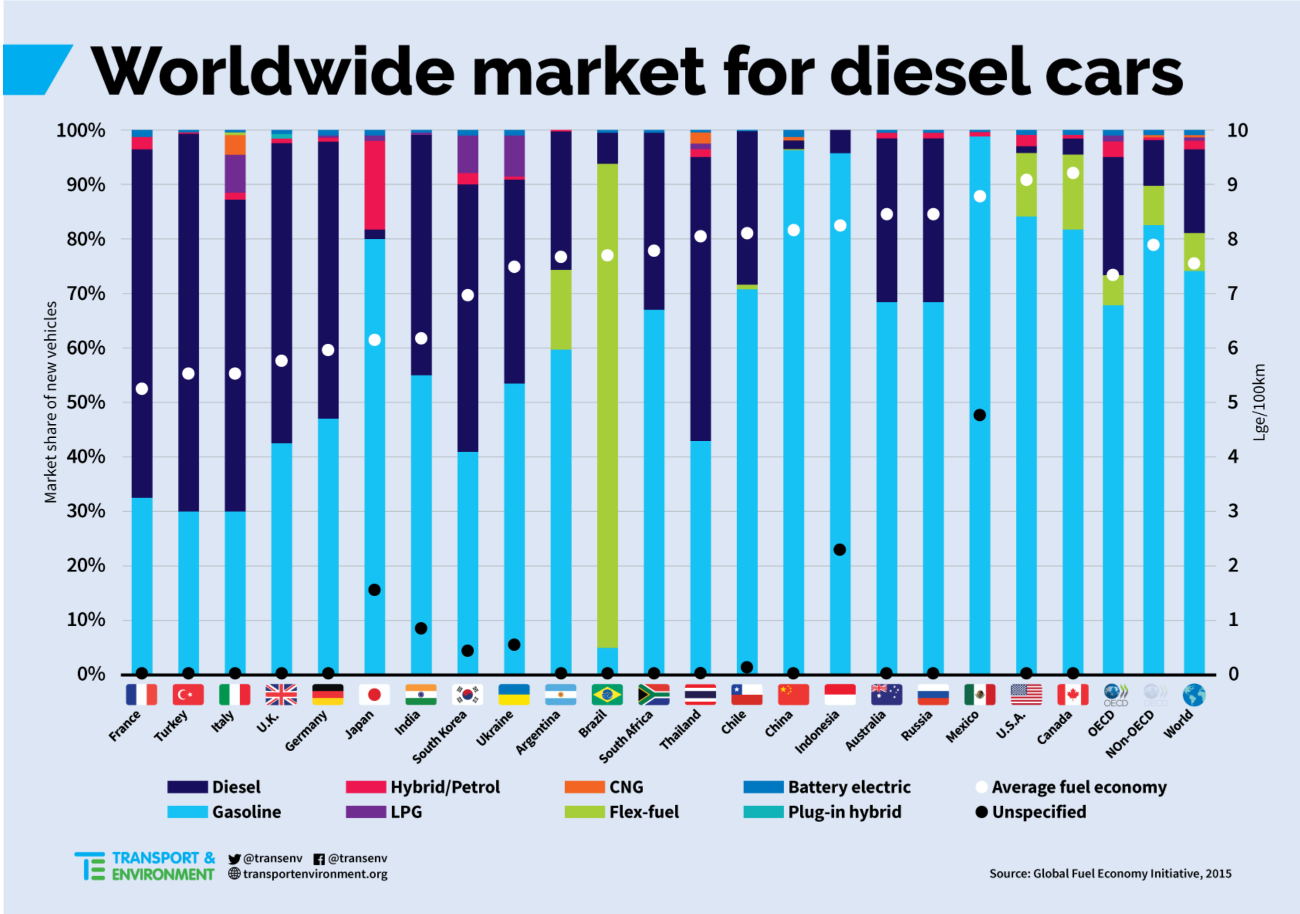


Figure 32

Sales of diesels in Western Europe have grown steadily since 1990, reaching a peak of 55% of new car sales in 2012, but have since fallen back modestly (to 53% in 2014 and 52% in 2015). Trends are consistent across almost all EU Member States. Diesel cars dominate in the larger, heavier car segments and tend to have a much higher power output than their petrol equivalents. Recent years have seen a surge in demand for SUVs across Europe, thereby further boosting the sales of diesels. However, even the European diesel market is expected to see a considerable diesel decline, amidst growing concerns over its toxic exhaust emissions. The speed of the decline remains to be seen, with different scenarios anticipated: e.g. JPMorgan Chase & Co[71] has recently predicted diesel market shares to drop to as low as 30% by 2020, while others remain more cautious, expecting a slow decline towards 2030. Most analysts are predicting the diesel share to fall to 40%-45%, as a result of the more effective RDE test that is expected to require SCR technology to be fitted to most new diesels by 2021. This will virtually eliminate the diesel market in the Supermini Segment (e.g. VW Polo), and lower the diesel share in the Medium segment (e.g. VW Golf). However, the recent scandal and resulting city bans could lead to a much steeper market decline that is beginning to be seen in 2017 in some countries such as the UK, where the diesel tax benefit is less.

4.2. Low- and zero emission alternatives to diesel

Outside Europe, no country has adopted diesels to nearly the same extent, as a pathway towards low CO_2 emissions. Instead, others have pursued progressive electrification of the new car fleet through hybridisation, plug-in capabilities, and full electric powertrains. Although this is a slightly more expensive path in the short term, the progressive electrification of the powertrain, starting with increasing hybridisation (mild, medium and full) through to plug-in hybrid and ultimately battery electric or fuel cell,

[71] Behrmann and Lavell, *Europe's divorce from diesel is about to get messy*, Bloomberg, 2017. https://www.bloomberg.com/news/articles/2017-04-03/europe-s-diesel-decay-set-to-accelerate-in-vw-cheating-fallout

represents a much more logical and ultimately more cost-effective way to make cars substantially cleaner in the medium term (and zero emission in the long run). Pressure to clean up diesel exhaust emissions, and associated stricter regulations, will further erode diesel's cost benefit.

In major OECD markets, the take-up of hybrid cars was gaining momentum until now, especially in Asian countries. Japan is now the clear market leader at 23% of all new sales in 2015. Globally, hybrids have a market share of over 3%, compared to about 1.5% across Europe. Non-OECD markets have as yet a very low rate of introduction of hybrids, partly due to the lack of suitably-trained mechanics, and maintenance capacity.

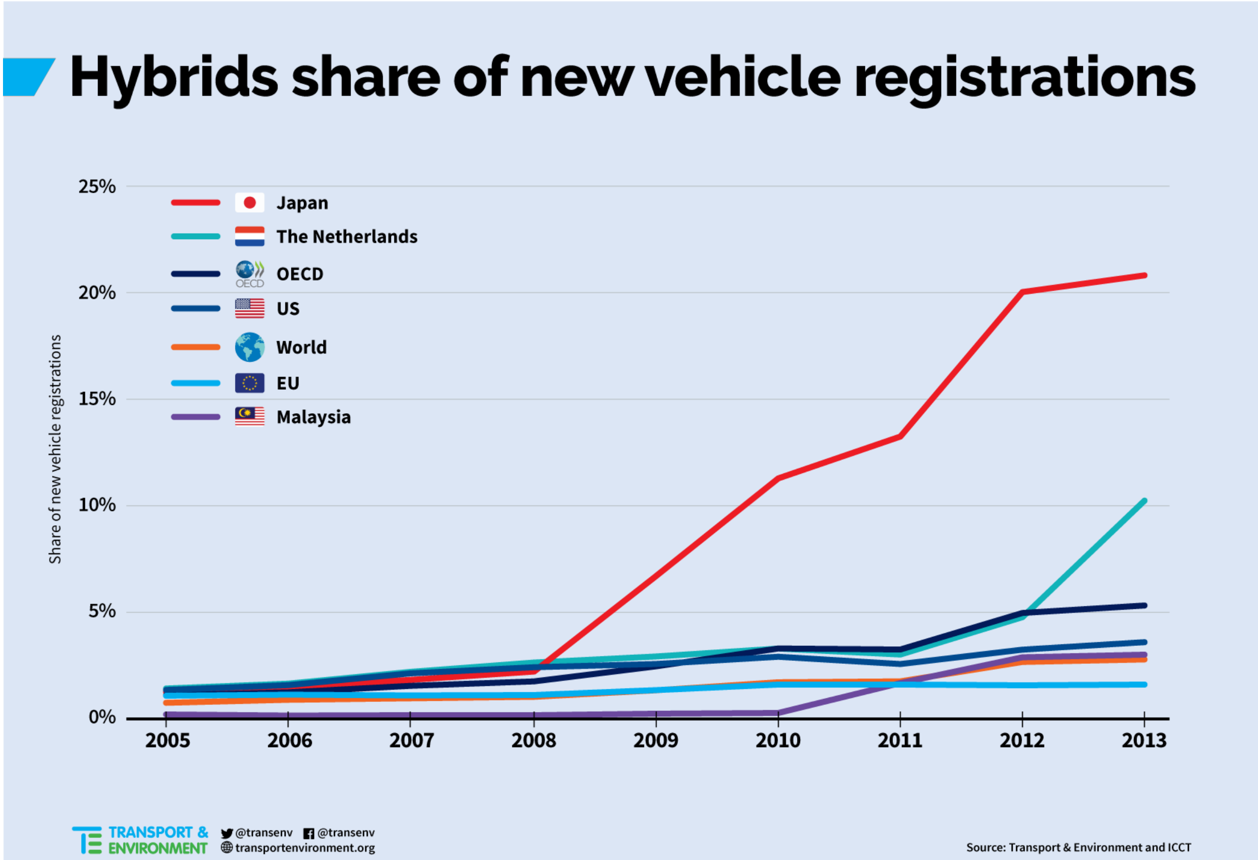


Figure 33

Conventional diesel cars have a price premium over gasoline vehicles of around €2,000; it is therefore more appropriate to compare diesel cars with gasoline hybrid cars. Diesel hybrid vehicles have proven to be too expensive to be popular, and the small number currently on sale may reduce in the future. As shown in the previous section, the cost premium for gasoline hybrids is rapidly closing compared with diesel options. Catalogue prices of hybrids are already today less than their diesel equivalents (e.g. in Germany), and this advantage is sometimes further increased by government subsidies in the form of tax cuts or financial incentives to purchase hybrids, especially plug-in versions. The new RDE emission regulations are expected to further increase the price of diesel cars by an extra few hundred euros. Competition between diesel and gasoline hybrid/plug-in hybrid vehicles is therefore expected to grow strongly in the coming years, as the additional cost and space disadvantages are reduced and more models enter the market. In particular, the quietness and performance of plug-in hybrid vehicles is likely to appeal to an increasing share of premium new car buyers. On top of winning the cost battle, petrol hybrids have also won the battle of fuel economy by comparison to diesel; in Europe, hybrids consume about 25% less fuel than their diesel equivalents according to ICCT.[72] The fuel efficiency advantage will improve significantly as more plug-in versions enter the market, making them a better alternative to diesel cars.

It is electric vehicles (EVs) that have made the real revolution in the global vehicle market, as Figure 34 demonstrates. New registrations of electric cars (both battery electric and plug-in hybrids) increased by 70% between 2014 and 2015.[73] The last two years have seen a major breakthrough in the cost of lithium-ion batteries – the cost per kilowatt-hour has fallen from $1,000 in 2010 to $130-200 in 2016.[74] UBS[75] predicts that electric vehicles will reach parity with petrol cars from the total cost of ownership perspective in 2018 already, much earlier than many expected, with other forecasts suggesting that this will occur by early-to-mid 2020s.[76] Electric engines emit zero tailpipe emissions – toxic pollutants or CO_2 – by nature, and do not require sophisticated emission control technology, or its enforcement. They are thus a much more attractive option in new markets, due to simpler regulation being necessary to police implementation. The regulatory cost of enforcing stricter diesels standards due to in-use surveillance programmes and scrutiny of defeat devices have increased dramatically following the diesel emissions scandal.

Many manufacturers have announced ambitious plans for rolling out of battery electric models, starting with 15%-25% of models by VW, Daimler and BMW in 2025, to 70% of models by Ford, and a complete phase-out of ICES promised by Volvo, for as early as 2019. VW has just announced that they will electrify all of their 300-model range by 2030,[77] with others expected to follow suit, since similarly ambitious plans have already been made by BMW and JLR. Governments are following, too: Norway and the Netherlands plan to ban new diesel and petrol sales by 2025, Austria by 2030 and France and the UK by 2040. The announcements are rather too recent to be able to analyse their long-term effects on the global or European vehicle market, but one thing is certain – the demand for electric cars will surge in the coming years. According to UBS the global sales of EVs will reach 14% already by 2025 already.

---

[72] ICCT, 2017. *SHIFTING GEARS: THE EFFECTS OF A FUTURE DECLINE IN DIESEL MARKET SHARE ON TAILPIPE CO2 AND NOX EMISSIONS IN EUROPE*. http://www.theicct.org/sites/default/files/publications/Shifting-gears-EU-diesel-futures_ICCT-white-paper_06072017_vF.pdf

[73] IEA, 2017. *Global EV Outloook 2016*. https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf

[74] The Economist, *The death of the internal combustion engine*, 2017. https://www.economist.com/news/leaders/21726071-it-had-good-run-end-sight-machine-changed-world-death

[75] The Financial Times, 2017. https://www.ft.com/content/6e475f18-3c85-11e7-ac89-b01cc67cfeec

[76] Stewart and Dodson, Low carbon cars in the 2020s. Consumer impacts and EU policy implications, Final Report, BEUC, 2016. http://www.beuc.eu/publications/beuc-x-2016-121_low_carbon_cars_in_the_2020s-report.pdf

[77] BBC, 2017, Volkswagen plans electric option for all models by 2030. http://www.bbc.com/news/business-41231766

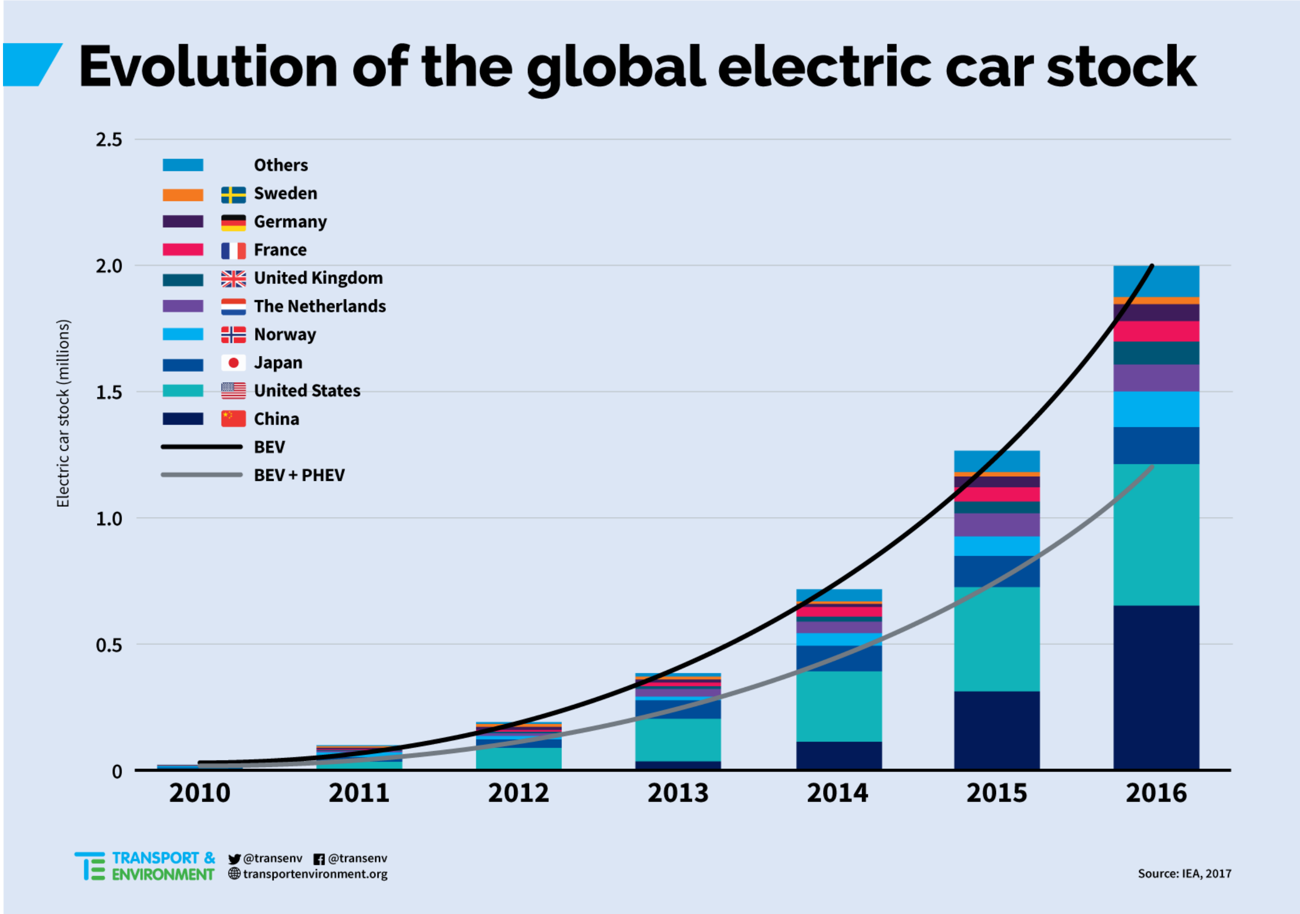


Figure 34

The question now is not if, but how quickly, will Europe phase-out its artificially created diesel market in favour of the innovative zero emission technologies. Asian and American car manufacturers and suppliers have been early-movers at transitioning to alternative technologies, and as a result are now in a much better position than their European counterparts to exploit the new long-term opportunities. Asia, and China in particular, is already leading in global battery supply chains. By contrast, diesels now represent a 'blind alley' which can only take us a small part of the way to the destination of zero-carbon road transport, and at a huge public health cost. Diesel technology can only persist in the medium term with large quantities of cheap, sustainable advanced biofuels. This is an entirely unrealistic prospect and the limited amounts of sustainably produced advanced biofuels will be needed instead to decarbonise aviation, shipping and possibly trucks.

The speed of the transition to electric vehicles and the related supportive industry sectors will determine the long-term competitiveness of the European automotive industry. Analysis by T&E[78] shows the risks associated with failing to develop a sizeable electric vehicle market in Europe. Automotive jobs may decline by as much as 30% by 2030 if the current reliance on diesel continues, due to growing automation in manufacturing and little demand for this engine and vehicle technology elsewhere. However, if there is a large EV market in Europe, the industry will place their vehicle and battery production plant close to the market in Europe, thus leading to an increase in automotive employment compared to today.

[78] Transport & Environment, 2017, *How will electric vehicle transition impact EU jobs?* https://www.transportenvironment.org/publications/how-will-electric-vehicle-transition-impact-eu-jobs

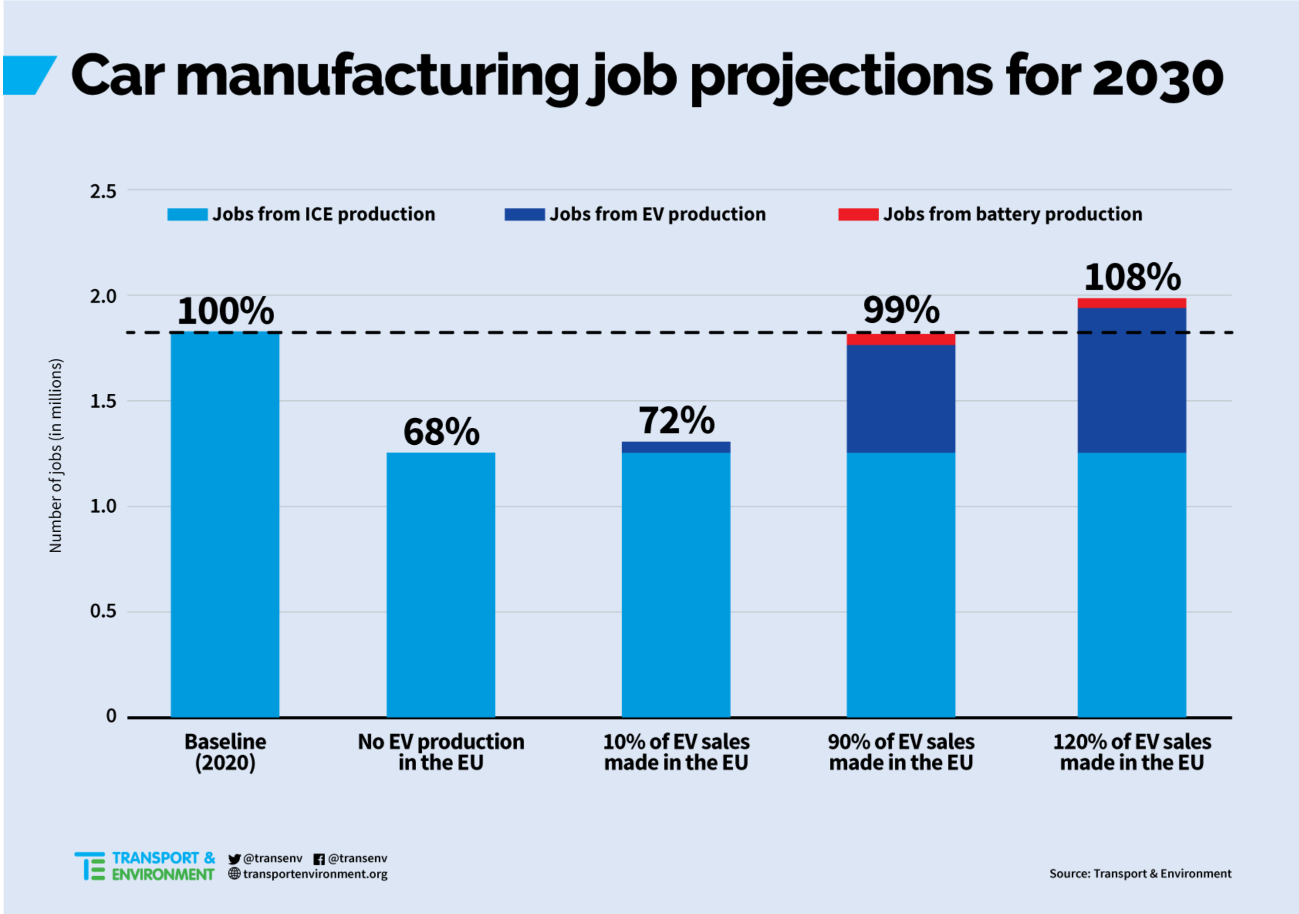

Car manufacturing job projections for 2030
Jobs from ICE production
Jobs from EV production
Jobs from battery production
Number of jobs (in millions)
2.5
2.0
1.5
1.0
0.5
0
100%
68%
72%
99%
108%
Baseline (2020)
No EV production in the EU
10% of EV sales made in the EU
90% of EV sales made in the EU
120% of EV sales made in the EU
TRANSPORT & ENVIRONMENT
@transenv
@transenv
transportenvironment.org
Source: Transport & Environment

Figure 35

5. The road ahead: recommendations for fair clean car policies

5.1. Diesel is not worth Europe's money or effort

This report has shown that the reason behind dieselisation in Europe has not been in answer to consumer demand, but rather due to biased regulations, notably lenient emission standards and distorted taxation. These regulatory and financial measures have skewed the vehicle market in favour of diesel vehicles and raised their share of sales to above 50%, in stark contrast to other global markets where the share of diesel sales is consistently below 5%. The last two years since the diesel emissions scandal have exposed the cost of such dieselisation. Not only has it eroded national tax revenues, but it is the primary reason behind persistent high levels of toxic air pollution across European cities, and resulting death tolls.

There is no doubt that the Dieselgate scandal has trashed the reputation of many German, French, Italian and other carmakers, and the car industry is now experiencing the consequences of destroying consumer trust and becoming a pariah polluter, as the sales of diesels are falling for the first time in a decade. July 2017 saw an unprecedented slump in the sales share of diesel cars in Germany – down to 40.5%, from over 46% in 2016. It is difficult at this stage to predict the long-term effects, but most analysts are forecasting a slow decline in the diesel share of the European vehicle market, to around 40% of car sales by 2020, down from 52% in 2015. This would suggest that the market will decline from sales of around 7 million cars a year in the EU to around 5 million annually. With the global market growing overall, it suggests that the diesel car share will fall to around 5% by 2020. By contrast, electric vehicles will see an exponential upsurge, amounting to 7 million in China alone by 2025 according to Bloomberg.[79] This will hurt European carmakers, which have for too long placed their bets on a technology that few others in the world want to buy.

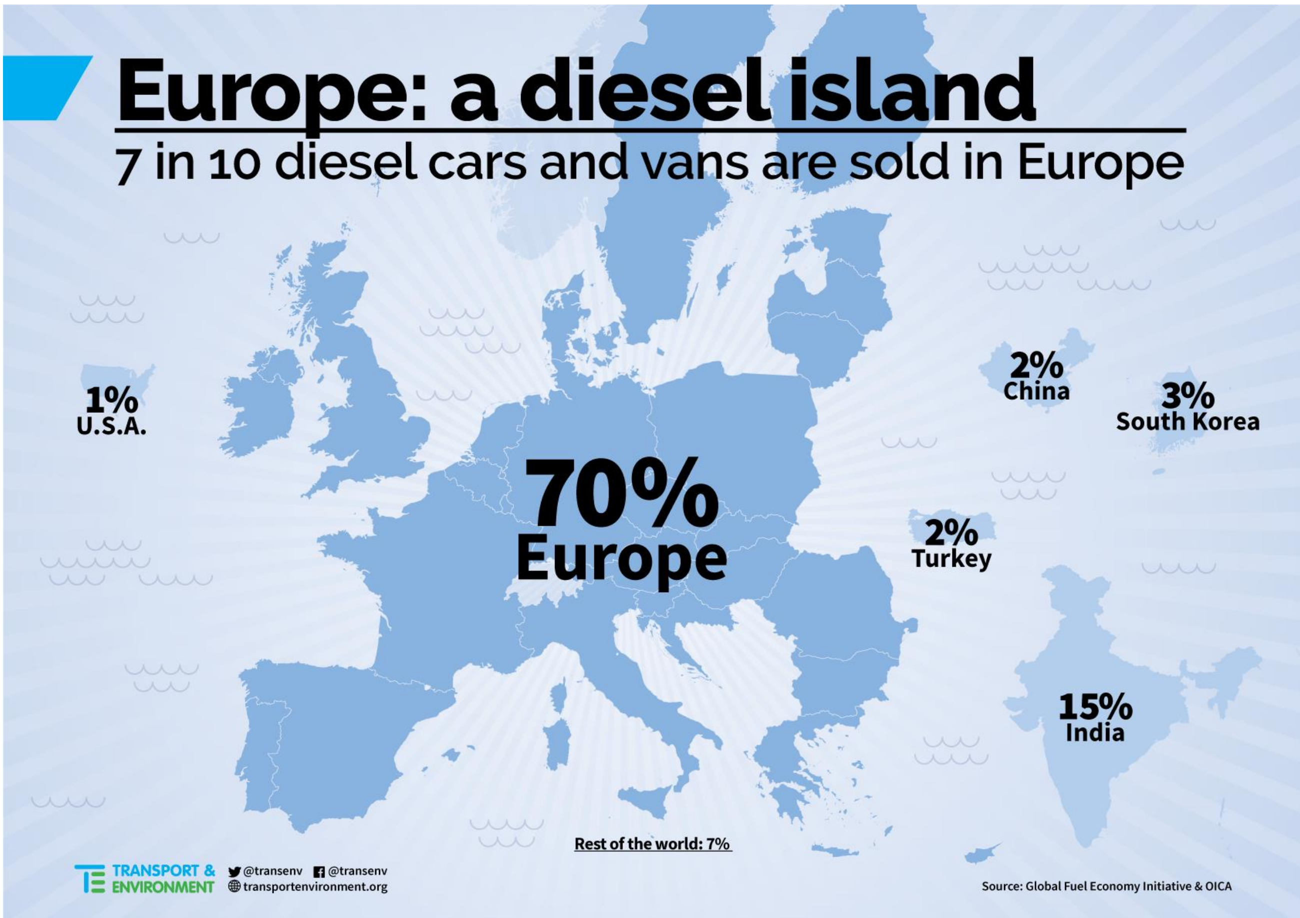


Figure 36

[79] Bloomberg webinar, *The long term outlook for electric vehicle adoption*, 2 August 2017

One of the main drivers behind declining diesel vehicle sales in Europe have been announcements of city diesel bans, as they turn consumers away from diesels for fear of not being able to use their cars in the future. In response, car manufacturers have been fighting back against such policies, criticising such bans as incompatible with the EU internal market rules, or claiming that they are unfair to consumers. The desperate attempt to buy back reputation and trust is particularly seen in the raft of announcements by VW, Daimler, Renault, BMW and others, with regard to emission upgrades and software fixes (the effectiveness of which remains to be verified). Similarly, some governments, notably Germany, have followed suit to help diesel save its battered reputation. The diesel summit organised on 2 August in Berlin was a clear attempt by the German government to bury the diesel scandal debate. In an effort to portray a solution for clean diesel, software upgrades to around 5 million vehicles were announced, promising to reduce NOx emissions. However, the Summit was an abject failure, since instead of closing the issue ahead of the German elections it has ignited a debate on how to resolve the air pollution crisis in our cities, caused by diesel vehicle emissions. Piecemeal software updates for some customers will not achieve much to improve air quality EU-wide. Instead, one robust emissions clean-up programme rolled out across all carmakers for all affected drivers should be the way forward. Similarly, instead of spending billions of euros on making dirty diesels less dirty, car makers should put their money and energy into the truly clean electric solution and in supporting infrastructure, e.g. EV charging points.

Ahead of the proposals on the post-2020 car CO2 standards, the car industry has opened a new front in its battle to improve the battered reputation of diesel-based technology. It argues that diesel is still worth fighting for, since it is the cost-effective solution to reducing Europe's CO_2 emissions. This report has gathered evidence to prove this is wrong; an average diesel car produces 3 tonnes more CO_2 than petrol, because cheaper fuel means it is driven further, it requires more material to produce, it produces higher refinery emissions and also relies on GHG-intensive biodiesel as a fossil diesel fuel substitute.

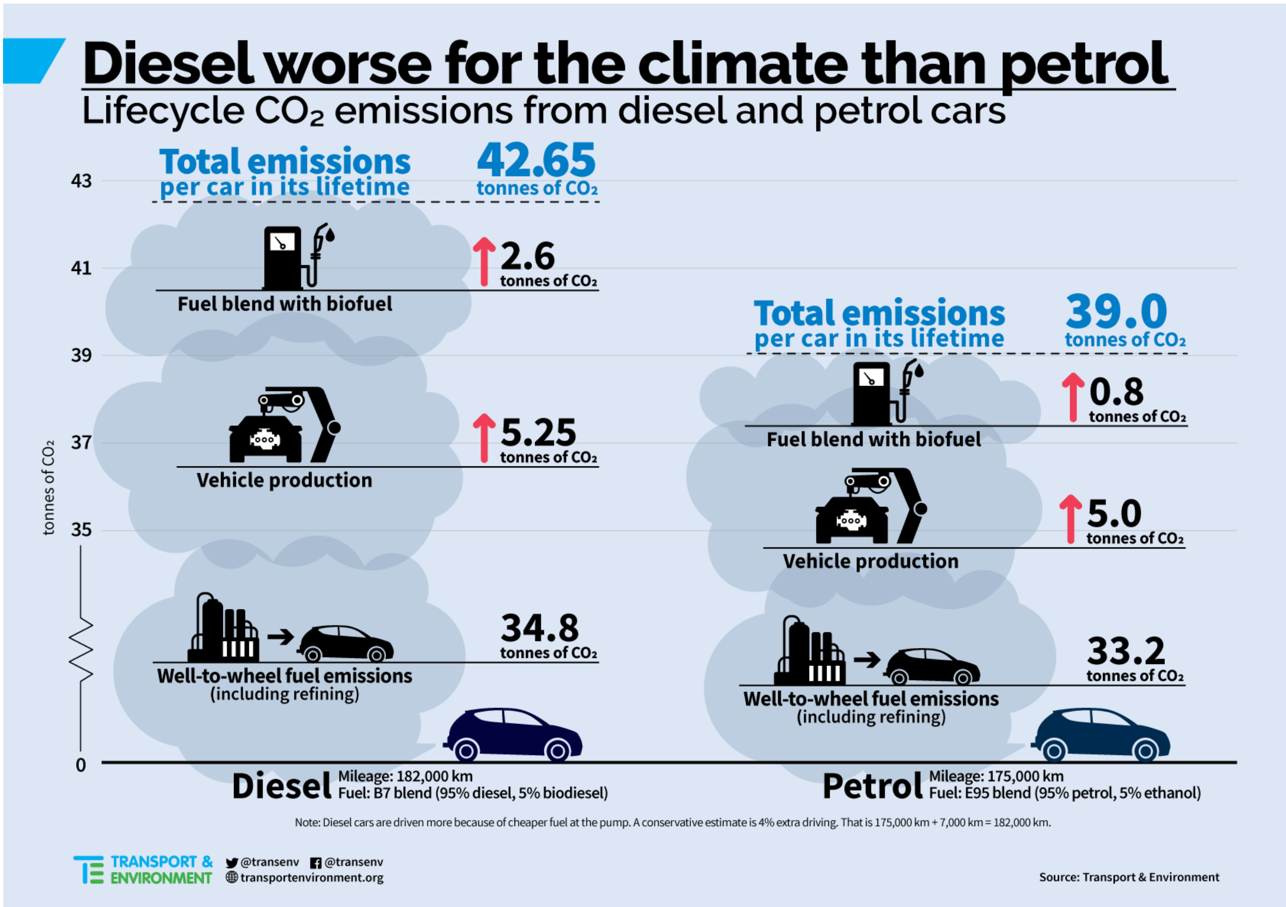


Figure 37

Even on comparative tailpipe emissions, average diesel CO_2 emissions are only a few grammes/km lower than an average petrol car (even prior to accounting for higher lifetime mileage), as much of the efficiency benefit is offset by being used in much larger and more powerful cars. If the cost premium of an average diesel car over its petrol equivalent –, i.e. €2,000 was spent on making gasoline engines cleaner and more efficient – by, for example, fitting mild hybrid technology – they would already today emit less CO_2 per km than diesels. Whilst it is difficult to quantify, clean diesel also comes at a high enforcement cost (e.g. on road checks, market surveillance, screening for defeat devices, etc.) given that complicated engine software codes are used to control emissions.

The car industry does not need diesel to achieve its CO_2 goals, despite its claims to the contrary, as some hybrid vehicles are already cheaper than diesel cars, and electric vehicles will become so in the future. Thus, diesel is no longer the cost-effective solution to cut carbon emissions. Nor is it clean or cheap, coming at an immense air pollution cost, together with a loss of public taxation revenue and competitiveness. In a nutshell, diesel is not worthy of the preferential treatment it presently receives in EU vehicle regulations, or the subsidy that the fuel receives, in excess of €30-billion.

5.2. Ending EU regulatory biases in favour of diesel

5.2.1. Euro Standards

At the EU level, the new real-world driving emissions (RDE) regulations, or Euro 6d, will exert growing pressure on diesel NOx emissions, and should require all diesel cars to be fitted with SCR by 2019/2020. However, the Euro standards remain biased in favour of diesel, allowing it to emit 200% more NOx emissions than equivalent petrol engines even after 2020. The EU should swiftly restore technology neutrality and agree the new Euro 7 emission standards to pave the way for a level playing field among all fuels. Euro 7 standards should ensure that by 2025 diesel cars emit equivalent levels of NOx to state-of-the-art petrol cars on the road; the levels should be set at a level that would enable the WHO air pollution guidelines to be met across cities throughout Europe.

5.2.2. Car CO2 regulations

The EU Cars and Vans CO_2 regulations should also be reformed to ensure a level playing field and to correctly account for CO_2 emissions of diesel vehicles. The standards, set for 2025, should remove the current mass utility parameter, which in effect rewards heavier vehicles including diesel cars: a bonus of 3-4gCO_2/km on average. In addition, a mileage weighting factor should be introduced to accurately account for longer average distances driven by diesel and larger cars and to lower the compliance costs of the regulation. Similar to the new Euro 6d standards, an on-road check using an RDE-type test protocol should be added to the current regulation alongside the new improved WLTP laboratory cycle. This would avoid any growth in the gap between road and laboratory results, and would also encourage carmakers to fit technologies that effectively reduce emissions in real-world driving, instead of investing time into test optimisation. Most importantly, the new Car CO_2 regulation should include a specific zero emission vehicles (ZEV) target, requiring each carmaker to sell at least 15%-20% of zero emission vehicles such as electric and plug-in hybrids in 2025. This would guarantee that enough charging infrastructure and production facilities closer-to-market are rolled out to support the required levels, securing longer term high quality automotive jobs in Europe.

5.2.3. Renewable Energy Directive

The EU biofuels policy currently places the emphasis on quantity targets, without adequately distinguishing between the quality and sustainability of different fuels. This had, and still has, the effect of biasing the EU market towards the use of crop-based biofuels, mainly biodiesel from vegetable oils, which is on average is worse for the climate than conventional fossil fuels. In November 2016, the European Commission released a proposal for a new Renewable Energy Directive for the period 2020 to 2030. The Commission proposal goes in the right direction; it suggests a 3.8% cap on biofuels from food and feed crops in 2030, down from 7% in 2020. The Commission also gives an option to distinguish between biofuels produced from vegetable oils and other biofuels, due to the ILUC impact. However, these measures are not sufficient to ensure that the EU moves its support away from the highest CO_2-emitting biofuels and makes a transition as soon as possible to the most sustainable fuels options in transport. In particular, the EU should move to phase out policy support to biodiesel from vegetable oils as soon as possible, and at the latest by 2025. Biodiesel is increasingly sourced from palm oil and has huge environmental, climate and social impacts, adding notably to the higher CO_2 footprint of diesel fuels. In addition, better sustainability controls and safeguards should be put in place so that future feedstocks of advanced biofuels are truly sustainable and deliver lifecycle CO_2 reductions.

5.2.4. Type Approval

One clear conclusion from the current Dieselgate scandal is that diesel emissions technology has become highly complex and ICT-reliant, which makes it difficult for authorities to regulate and scrutinise for potential circumvention of standards. This is one of the reasons why regions such as China and India are said to be turning away from diesel in favour of simpler electric engines which are clean, without the need for sophisticated exhaust after-treatments. In Europe diesel will remain part of the car fleet in the short- to medium term making strong and independent oversight together with rigorous compliance tests indispensable. Both the EU type approval framework (TAFR) and the periodic technical inspections rules (PTI Directive) have to be swiftly reformed to ensure long-needed transparency, independent testing and rigorous EU controls throughout the lifetime of the vehicle. The current TAFR proposals on the table, as voted by the European Parliament, will help achieve that, but the next few months will face hard negotiations with the EU's Member States, notably Germany and Italy, who are likely to be reluctant to give up national power over carmakers. The European Commission (and potentially a new EU Agency on Vehicle Surveillance) must have a bigger role in vehicle approvals, and on in-use checks and penalties, with more on-road verification testing done by independent third parties, as foreseen by the new RDE regulations.

The most acute short-term problem facing countries across Europe today is what to do with the existing stock of old diesel vehicles, to clean up over 37 million dirty diesels already in use that will continue to be used and pollute the air for years to come. The latest promises from the car industry to fix emissions should be based on transparent on-road measurements and detail of upgrades, to verify that they deliver the promised NOx reductions without affecting vehicles' performance, fuel economy or durability. Such programmes should involve all manufacturers, and should be consistently rolled out EU-wide. Ultimately, due to their voluntary nature regulators should ensure that all concerned vehicles are upgraded, for example through mandatory requirements at annual PTI inspections.

5.2.5. An end of diesel

More broadly, given the inability of diesel vehicle technology to achieve either zero air pollution or CO_2 reductions, and the fact that road transport has to completely decarbonise by 2050, no new internal combustion engines must be sold after 2035 across Europe. The UK, France, Norway, the Netherlands and Austria have all announced plans to phase out sales of cars powered by fossil engines (diesel and petrol) between 2025 and 2040. Plug-in hybrids and electric vehicles will be able to replace diesels even earlier in cities. Given the current rates of cost and technological development, within five years the cost of battery technology is expected to fall to a level whereby the total cost of ownership of battery electric cars will be competitive compared with conventional cars. This will result in increasingly competitive plug-in hybrid and electric models in the small and medium segments, thereby further eroding the diesel advantage. The future is electric, and the faster European car industry acknowledges and makes the required transitions, the better chances it will have to secure automotive jobs and competitiveness.

5.3. National and local policies

5.3.1. Abolishing the diesel tax bonus

Despite the ongoing air pollution crisis in Europe and the Dieselgate scandal, it remains to be seen whether policymakers at a national level will rebalance their taxes and encourage the shift away from diesel. Whilst there has been no effective progress in Germany or Italy, some countries are starting to reform their taxes. In France, the new Macron government promises to align the vehicle excise duty between diesel and petrol by the early 2020s. Similar plans to reduce the diesel bonus have been announced in Belgium and Ireland.

A comprehensive and EU-wide reform of national taxation policies is needed to remove the current diesel bonuses in many countries, and instead promote clean zero emission vehicles. If petrol and diesel fuel were taxed in a fair and neutral way, for instance based on energy content and/or CO_2 emissions, the price relation between the two fuels across the EU would change dramatically. The diesel price per litre would then be realigned from 10%-15% below the petrol price on average to 12%-20% above the petrol price, in itself making diesel cars considerably less attractive than they are at present.

As discussed, the solution has already been proposed in revisions to the Energy Tax Directive (ETD) but remains blocked, because Member States that profit from fuel tourism (e.g. Luxembourg) have always been able to block meaningful progress. Instead, the following approach is now needed:

- The ETD reform is the best tool to ensure that all fuels are taxed correctly, taking full account of their energy and carbon contents. This in itself would align the diesel and petrol fuel taxes across EU Member States.
- In the absence of progress, however, the EU could adopt the Fuel Tax Agreement models used in America. The United States and Canada have the International Fuel Tax Agreement (IFTA), which enables states and provinces to tax diesel on the basis of where the trucks drive, not where they fill up. This eliminates all incentives for states to become 'fuel tax havens' because lowering tax rates decreases would result in decreased, rather than increased, revenues.
- Countries could also consider moving away from such heavy reliance on fuel taxation, and shift instead to charging vehicles based on their use of road infrastructure. The European Commission has earlier this year proposed distance-based road charging for all heavy-duty and light-duty vehicles (the Eurovignette Directive), in line with their use and externalities costs, and the EU Member States must now support and implement such tolls. Such a shift would maintain revenues, but would shift the point of taxation in ways that would reduce or remove harmful tax competition.

5.3.2. Rebalancing vehicle taxation

Most EU countries now have at least some form of vehicle taxation (i.e. registration tax, annual circulation tax or company car taxation) that is fuel-neutral or CO_2-based for conventional engine types. This in itself tends to favour diesels, owing to their generally better fuel economy per km. With the introduction of the new WLTP test cycle, Member States have a unique opportunity to reform their vehicle taxation and introduce fair systems based on real-world CO2 emissions of different vehicles, that should include an air quality increment (e.g. for higher NOx emissions of diesels). Discounts and exemptions from vehicle taxation should only be given to ultra-low or zero emission vehicles.

At a national level, some Member States are already revising vehicle tax policies so that they take account of the higher air pollution emissions from diesel cars. For example, France has introduced a scheme in which scrapping a dirty diesel car and buying an electric car will be supported by a €10,000 incentive. More initiatives of this sort would help greatly in tipping the balance away from diesels and towards more sustainable new powertrains.

5.3.3. Local air quality measures

As enforcement of EU air quality legislation (i.e. infringements) is ramped up, there is growing political pressure on local authorities and mayors to take more action to deal with local pollution problems. Diesel cars are a major focus of such actions, which are likely to include higher charges for access or parking, temporary restrictions and even outright bans in low or zero-emission zones. If this is to be effective it cannot target solely very old diesels, as the emerging evidence suggests that diesel-related NOx has not improved significantly, including up to new Euro 6 vehicles, with some Euro 5 and even Euro 4 vehicles being cleaner on the road than their newer counterparts. Measures will need to be taken against almost all diesel cars, except those fitted with effective and correctly sized and optimised SCR after-treatment systems. Local authorities will thus have to rely on new technologies, such as remote sensing, to build databases of real-world emissions based on individual models, to then identify grossly polluting diesels and design their restrictions and bans accordingly.

As discussed in this report, the car industry is rolling-out software emissions upgrades and fixes on millions of its vehicles as a pushback against city policies and bans. Only a fraction of diesel vehicles on EU roads are included so far, with at best a 25% NOx emission reduction per vehicle, with the probability of achieving significantly less. This will not be sufficient to clean up urban air and bring it in line with the exposure levels that the WHO considers safe for human health. On days when pollution exceeds the EU and WHO concentration levels cities should be allowed to put in place temporary diesel bans and restrictions. In urban areas where EU annual emission limits are continuously exceeded (London, Paris, Brussels, etc.) permanent charges and restriction measures against dirty diesels are needed to bring down the number of air pollution exceedances. Diesel can only be considered clean once it emits no more than an equivalent new petrol vehicle, and even then it cannot be considered as a long-term solution to zero emission, clean air in European cities. Cities therefore should incentivise zero emission modes, solutions and technologies.

5.4. Europe’s next ‘Nokia moment’?

There is presently a vicious circle revolving around diesel cars. New emissions tests and regulations finally require better after-treatment systems, thus entailing higher manufacturing costs. Diesel cars are in the cross-wires of concern about our toxic air and legal pressure to enforce air pollution limits, with diesel bans now proposed in many cities. Increasingly attractive competing technologies are eroding its market share in Europe, notably more efficient gasoline cars and in the future electric cars. Beyond Europe, the hoped-for growth of diesel vehicles in emerging markets has stalled, and thus diesel remains a niche global powertrain for cars. With so many demands on research and development funds, further diesel development is becoming a low priority. All of these factors were inevitably going to dismantle the dominance of diesel in Europe, but the Dieselgate scandal has trashed its reputation as a clean solution; this has probably accelerated rather than initiated its decline.

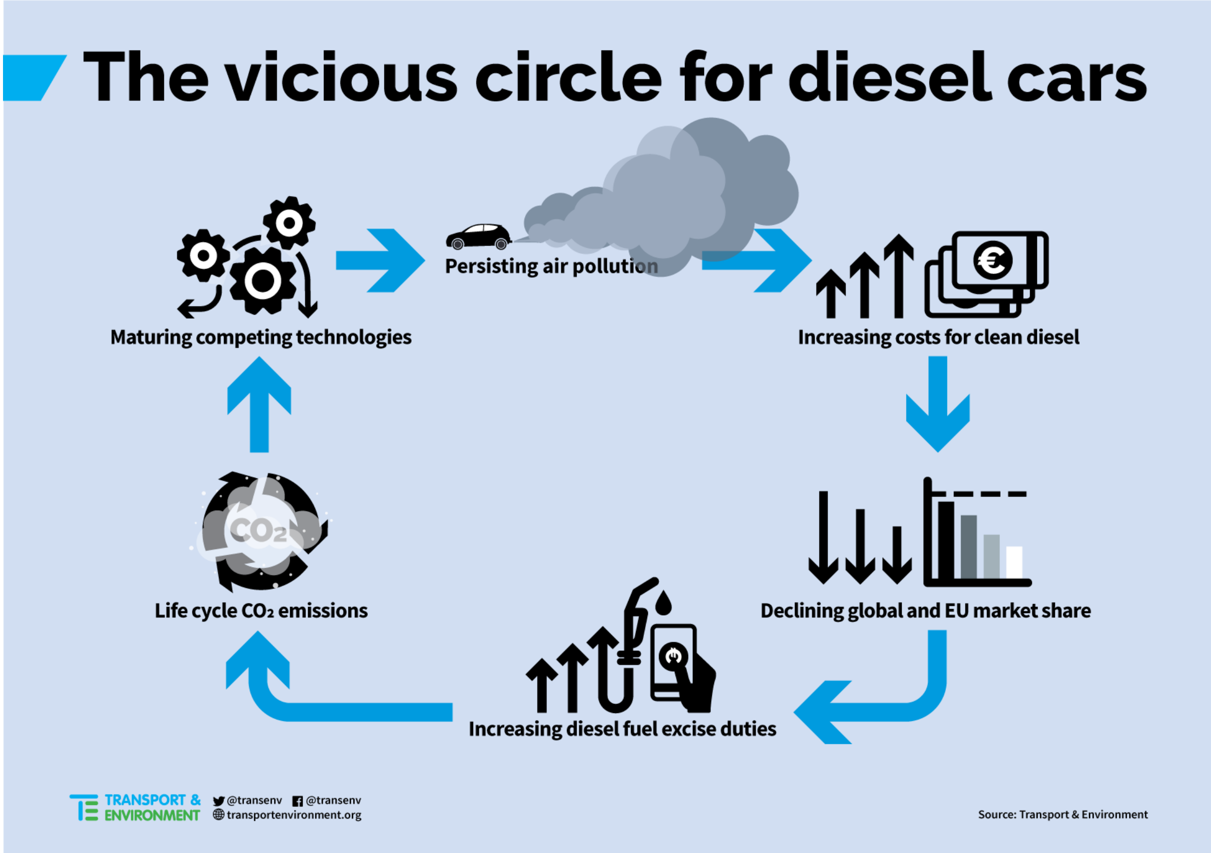


Figure 38

However, most European car manufacturers seem to be in denial about the inevitable trend of a declining diesel share. Like King Canute, they demand that the sea should retreat, and are calling on their friends in Government to ease the pressure on diesel cars by preventing diesel car bans and retaining the tax and regulatory biases that have created the European diesel market. Their mantra of technology-neutrality is suddenly forgotten. Governments would be ill-advised to listen. In the two years since the Dieselgate scandal broke, virtually every company has been shown to have emission systems that turn down, or turn off diesel exhaust after-treatment, and have justified their behaviour on the need to 'protect the engine'. This ludicrous defence is essentially saying that carmakers have designed after-treatment systems that damage the engine so they are not used. As a result, there is now a legacy of over 37 million dirty diesel cars and vans on the road. The car industry must take steps to clean up the air both through upgrades to cars and via contributing to the costs of other pollution abatement measures. They must also swallow the bitter pill that, as a result of their past cheating dirty diesels, in the future this technology will need to be banned when and where needed in order to ensure that the air is fit to breathe.

Instead of trying to preserve diesel technology in Europe, carmakers and Governments must focus on producing clean electric vehicles that are now being recognised as the future – notably in China which is gearing up to supply both its own huge market and export to the rest of the world. If Europe creates a significant home market for electric cars, the cars will be made here along with the battery packs and cells. If the European market remains a niche segment, the likelihood is that the cars will be largely imported from China. Whether or not the European car industry avoids a 'Nokia moment' will depend to a large extent on whether it invests heavily in new solutions, or if it seeks to perpetuate the market for diesel for as long as possible, by retaining tax and regulatory biases. We now need the dash for diesel to be replaced by the dash for electric motors and batteries. From an environmental perspective, there is no justification to continue the preferential treatment that diesel currently enjoys, which has created the bloated European diesel market – now is the time to support and incentivise the shift to clean electric solutions.