THE CO_2 EMISSIONS CHALLENGE:

Some carmakers are running late in the race to 2021

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We believe in making the difference.

Car manufacturers face nothing less than the reinvention of their industry

The need to reduce CO_2 emissions to meet the EU's 2021 target remains one of the biggest issues, alongside E-mobility, connectivity and autonomous driving, facing carmakers in the EU but this is not their only challenge. They are also having to deal with growing political demands for action on diesel and NOx emissions. Then they need to respond to new testing regimes and the announcements by governments of plans to ban internal combustion engines, as early as 2025 in Norway and the Netherlands, and by 2040 in the UK and France. A similar ban is on the agenda in Germany and China, they are still debating the timescales.

There is, however, growing evidence that manufacturers are responding to these developments and making significant changes to their strategies. Volkswagen, facing its own particular difficulties arising out of the diesel emissions scandal, has launched TOGETHER – Strategy 2025, which it bills as the biggest process of change in its history, with a focus on automation, battery development and the production of electric vehicles. It will, however, only have a real impact after 2020. Volvo are going further and saying that they will stop producing vehicles with only internal combustion engines and then just offer vehicles with an 'eMotor' including mild and full hybrids by 2019.

How carmakers stack up

The European automotive industry invests more than €50 billion in R&D annually[1], a large percentage of which goes towards fuel-efficiency technologies, to meet EU emission reduction targets. At the same time, almost all carmakers now have increasingly ambitious plans to increase sales of alternative drivetrains and electric vehicles. This is beginning to have a small impact on sales; by June 2017 there had been almost 100,000 registrations of electric (BEV) or plug-in hybrid (PHEV) vehicles across Europe, compared with 160,000 for the whole of 2016. However, very few are likely to be able to change the make up of their fleets fast enough to meet the immediate challenge of the 2021 EU CO_2 emission reduction targets, and avoid the significant fines for missing them.

This report sets out the findings of PA's annual rankings of the top carmakers in Europe according to their performance against their specific targets (that by 2021, all new car fleet does not emit more than an average of 95 grams of CO_2 per kilometre). The 2017 results show that only four of the eleven are forecast to meet the targets and so the majority of carmakers will face penalties of €95 for every gram of CO_2 above the limit, multiplied by the number of cars they sell in 2020. On current performance, the fines can reach or rise above the €1bn mark for some carmakers.

Figure 1: How carmakers rank on CO_2 emissions – some carmakers are running late for meeting the 2021 targets

		Actual data (g CO_2/km)**				PA forecast (g CO2/km)***		(g CO_2/km)	
Rank*	**Carmaker**	**2011**	**2013**	**2015**	**2016**	**2018**	**2021**	**2021 Target**	**Deviation**
1	Volvo	154.0	130.8	121.9	119.2	110.0	73.1	103.5	-30.4
2	Toyota	126.4	116.8	108.3	105.5	91.7	83.5	94.3	-10.8
3	Renault-Nissan	129.0	119.2	112.1	109.7	106.5	91.4	92.1	-0.7
4	Hyundai-Kia	134.0	129.8	127.3	124.4	115.3	94.9	91.7	3.2
5	PSA (Peugeot Citroen) + Opel	128.5	115.7	104.6	110.3	104.4	95.6	92.6	3.0
6	Ford	132.7	121.8	118.0	120.0	110.8	96.1	93.0	3.1
7	Volkswagen	135.4	128.9	121.5	120.0	115.7	100.3	96.3	4.0
8	FCA (Fiat Chrysler)	118.3	123.8	122.2	120.0	116.6	101.2	91.1	10.1
9	Daimler	153.0	136.6	124.7	124.7	117.2	102.1	100.7	1.4
10	BMW	145.0	134.4	126.4	121.4	119.3	104.7	100.3	4.4
11	JLR (Jaguar Land Rover)	206.0	182.0	165.0	150.0	142.3	130.9	132.0	-1.1

*rank on 2021 forecast **data from ICCT 2016 ***based on actual data until 2016 (ICCT) and PA forecast estimation

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[1] European Automobile Manufacturers Association: www.acea.be/statistics/tag/category/key-figures

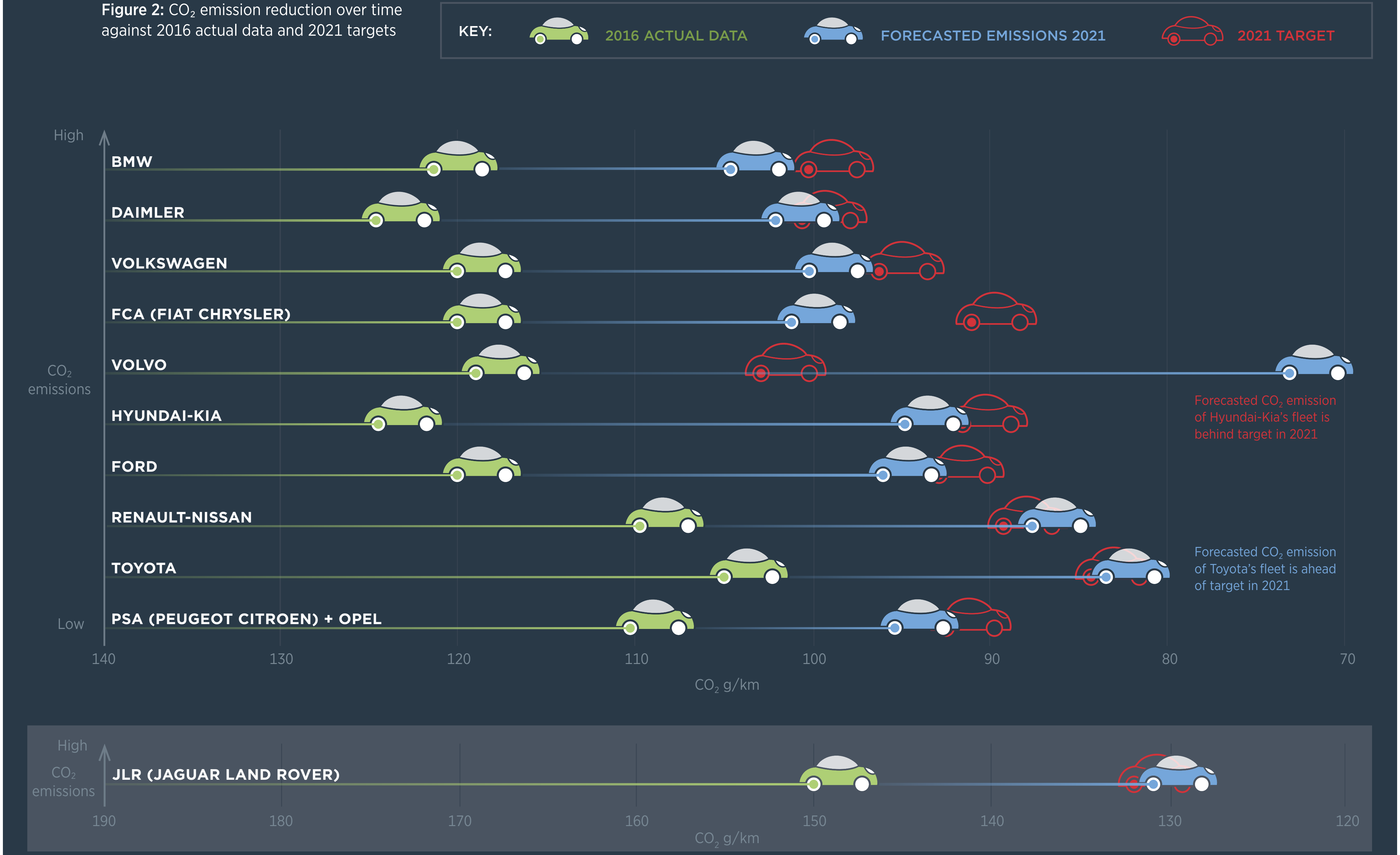
Rankings by manufacturer – change at the top

Our method of benchmarking, which is unavailable anywhere else in the market, examines manufacturers' performance against the overall EU target of 95g CO_2/km as well as the specific targets set for each car maker's business and compares this with their forecasted performance. These specific targets are based on their average vehicle weight, while our performance forecast is based on overall fleet portfolio – taking into account the super credits manufacturers receive for their share of electric vehicles that have emissions below 50g CO_2/km.

The 2016 actual performance show some small variances both from the forecasts we made in 2016 and in the updated forecasts we are now making for 2017. In most cases the differences reflect a degree of over optimism about carmakers' ability to improve their performance.

There has been a dramatic change at the top of the table with **Volvo** jumping to first position from seventh last year. This reflects Volvo's announcement that, from 2019, they will stop selling cars which only have a combustion engine. This is a significant step towards the electrification of their fleet; they plan to introduce at least four plug in hybrids by 2019, and gradually increase the share of pure electric vehicles from 2019 onwards. The fact that Volvo has a history of being a technological pioneer and that it has a new Chinese owner (Geely) focused on electrification and advanced technologies for the Chinese market, means we have assessed that Volvo will meet their emissions target.

Figure 2: CO$_2$ emission reduction over time against 2016 actual data and 2021 targets



Forecasted CO$_2$ emission of Hyundai-Kia's fleet is behind target in 2021

Forecasted CO$_2$ emission of Toyota's fleet is ahead of target in 2021

Toyota remains in second place in the rankings and we expect them to meet their 2021 target easily, with their record on emissions continuing to improve. Their performance reflects the fact that they continue to have the biggest share of the hybrid electric vehicle market (41%, Prius/Prime). However, they still do not have any fully electric vehicles in their portfolio and their attention is now on how to move from hybrids to pure electric or fuel cell vehicles (Lexus LF).

Renault-Nissan remains in third place on the rankings and will meet their 2021 target. Their fleet portfolio of alternative engines (PHEV, BEV already make up more than 2% of their sales portfolio) and low fleet weight are responsible for their successful emissions reduction. They have a particular focus on electrification rather than hybrids, with the Nissan Leaf being the best-selling electric vehicle, and a new version with an improved range is hitting the market 2017. It has proved popular because it can compete on price with vehicles with combustion engines. Renault-Nissan is also doing a lot of work in automated and connected driving and has announced plans to include the necessary technologies and systems in their volume production cars in 2020 at a competitive price.

Hyundai-Kia has moved up from sixth to fourth place in the rankings but is still forecast to miss its CO_2 target by roughly 3g CO_2/km. It has plans in place for a full range of alternative cars (electric, PEV and HEV Ioniq), and within two years, plans a completely new platform for electric cars (Kona) which will lead to the development of a large number of new electric vehicles. How successful these will be in the market, though, remains unclear.

Peugeot-Citroen (PSA), which was last year's top performer, has lost out significantly this year and now is at fifth in the table and forecast to miss its target by 3g CO_2/km. This reflects their announcement that their hybrid diesel programme has been completely stopped and difficulties in integrating GM Europe (Opel and Vauxhall) into their portfolio. From 2019, they plan to develop petrol hybrids and plug-in hybrids (including 3008 PHEV, Ampera-e and Quartz), but it will take time and effort to bring these into the product portfolio, something that is complicated by an ongoing debate about transforming Opel into an e-car brand. Their aim is that from 2023, 85% of PSA's portfolio will be electric driven or hybrids but this will come too late to meet the 2021 target.

Ford, in sixth place (down from fourth last year) will struggle to meet its 2021 target. It currently has almost nothing in terms of electrified vehicles in the portfolio, but plans to make major investment to electrify about 40% of their models by the year 2020, and to focus on CNG vehicles.

Volkswagen has seen a small improvement in its rankings up from ninth to seventh, but is still struggling with the effects of the diesel emissions scandal. It has a reasonable portfolio of PHEVs and plans to launch a major series of new mild hybrid, hybrid and electric models in the coming years (mainly VW, Audi and Porsche), including plans to offer 30 BEVs across their portfolio in 2020. By 2025, Volkswagen also wants 25% of their sales to be electrified cars based on 50 electric

and 30 plug-in hybrid models across their corporate brands. They have also just announced plans to invest €50bn in strategic partnerships for battery production in Europe, China and North America. Their new programme Roadmap E sets out plans to invest another €20bn into electrification of all models across their brands globally by 2030. However, they are unlikely to reduce their average CO_2 emissions quick enough to meet the 2021 target.

Fiat Chrysler (FCA) remains in eighth place, reflecting that they are still dealing with the challenges of merging with Chrysler and selling more big cars and SUVs. The popularity of Jeep with heavy weights and high emission rates and the lack of an alternative drivetrain strategy or options means FCA has increased their average CO_2 emissions three times in the last five years (with only a very small reduction in 2016). As a result, they are likely to miss their targets by the highest margin of all the carmakers. They are still only taking small steps towards electrification, announcing the launch of an electric-driven Maserati in 2019. Beyond this (and some gas-driven models) FCA has no clear strategy for alternative engines.

Daimler remains in ninth place and will miss their target by a small margin of 1.4g CO_2/km because they started later in offering alternative engines. However, their efforts are now moving fast, they have already launched electric (smart) and hybrid cars and are well on the way to the electrification of their fleet (starting with E- and S-class). This is based on a total of 50 new models by 2022, and they are planning to increase their BEV sales to a share of 15% to 25% by the year 2025, adding more than ten purely electric-driven vehicles to their fleet portfolio – these will be launched under the sub brand „EQ“. This EQ vehicles strategy will put even more pressure on BMW brand „i“.

BMW is still at the bottom of the table and though it has chosen to focus on electrification, sales numbers have not been sufficient to significantly decrease the CO_2 fleet emissions. The effect of the BMW i sub brand has also not kicked in yet and new models will have to be electrified in order to change that – they plan for 25 new electric and plug-in hybrid models by 2025, the next i-series has just been introduced as pilot (i-Vision Dynamics). Over the next two years, BMW will develop a broad range of plug-in hybrid cars (X1, X3 and Mini) but it remains to be seen if they sell in sufficient numbers to significantly reduce the CO_2 emissions. As a result, they are forecast to miss their 2021 target by 4g CO_2/km.

Jaguar Land Rover, due to its smaller number of sales, has to meet different regulatory requirements (their target is 132g CO_2/km) but they have made huge progress in the last year in decreasing their fleet emissions by a full 15g CO_2/km. This significant step forward means it is likely that JLR will meet its particular CO_2 targets in 2021. JLR is continuing its focus on this work and announced that by 2020, 50% of the entire fleet will be available as hybrid and by 2025, the entire fleet will be hybridised.

What factors affect the forecasts?

Each manufacturer has specific CO_2 targets based on average fleet weight. The bigger the difference between the carmakers' average fleet weight and the average weight of all car sales, the bigger the effects on the individual g CO_2/km target. To determine the individual values for each carmaker, we assessed the average fleet weight by looking at present and past weight trends, as well as an assessment of each manufacturer's capability to reduce weight in the future. Overall, we expect only small variations in fleet weight during the next few years.

These variations reflect the competing demands manufacturers face. Fleet weight has to go down in order to decrease emissions as lower mass needs lower energy. However, CO_2 emission reduction technologies are often heavier than normal combustion engine technologies (hybrids are heavier than standard combustion engines) which leads to an increase in fleet weights.

Our forecasts also reflect an assessment of the reductions in CO_2 emissions each manufacturer will see from developing different powertrain types, such as internal combustion engines (diesel, petrol, and natural gas), hybrid, plug-in hybrid, electric and other alternatives. We expect these measures to result in annual CO_2 emission reductions per manufacturer – ranging from 0.5% to 2.5%. The next step in our analysis is to assess the respective number of registrations of each type of car to determine the extent of each manufacturers' sales of lower emission vehicles. We then put this data together to develop our forecasts of average CO_2 (g/km) emissions in 2021.

What can carmakers do?

Our analysis shows all carmakers face a number of particular challenges if they are to make progress towards meeting the targets.

The popularity of SUVs

Increasing sales of SUVs are making it harder for a number of manufacturers to reduce emissions. Their market share in Germany is as high as 22.4% of new vehicles sold. At the same time, sales of electric vehicles remain very low, at 1.4% in UK and France and 0.7% in Germany and a full range of models is not expected to be available until 2020. In 2016 roughly 35 electric models were available compared to 400 models with combustion engines in European markets, limiting the choice available to consumers.

Diesel in decline

Another challenge lies in the changing perceptions of diesel. Traditionally, diesel engines represented an essential part of carmakers‘ strategies in Europe to reduce CO$_2$ emissions, given their better CO$_2$ performance than petrol cars due to lower fuel consumption. This strategy is at risk now, given the scrutiny of their higher emissions of nitrogen oxide (NOx). This is clearly deterring customers, with the share of diesel car sales declining from 52% in October 2015 to about 45% in May 2017. This has a particular effect on German premium carmakers with BMW selling 70% of their diesel vehicles in Europe 2015, Audi 68%, Daimler 59% and VW 48%. It is expected that premium carmakers will see at least a further 10% decrease in diesel sales by 2020.

Figure 3: Increasing sales of electric vehicles can play a part in reducing fleet emissions but manufacturers' sales performance is very variable

	2015-2016 registrations EU-28 (%)			CO$_2$ emissions in g/km			2017-2022 new models				Incentives for PHEV
Carmaker	HEV	PHEV	BEV	2016	2021*	Target 2021**	HEV	PHEV	BEV	Other (FCV, CNG, LPG)	Pricing difference PHEV vs. cheapest conventional model***
PSA (Peugeot Citroen)	•	○	•	110.3	95.6	92.6	●	⬤	●	○	●
Toyota	⬤	•	○	105.5	83.5	94.3	⬤	•	•	•	●
Renault-Nissan	○	•	●	109.7	91.4	92.1	◉	◉	⬤	○	●
Ford	•	•	○	120.0	96.1	93.0	•	○	•	○	⬤
Hyundai-Kia	•	○	•	124.4	94.9	91.7	●	●	◉	•	◉
Volvo	○	◉	○	119.2	73.1	103.5	○	◉	•	○	◉
FCA (Fiat Chrysler)	○	○	○	120.0	101.2	91.1	•	•	•	○	⬤
Volkswagen	•	●	•	120.0	100.3	96.3	◉	⬤	⬤	⬤	◉
Daimler	◉	◉	•	124.7	102.1	100.7	○	◉	◉	•	◉
BMW	○	◉	◉	121.4	104.7	100.3	○	●	•	○	•
Jaguar Land Rover	•	○	○	150.0	130.9	132.0	•	•	•	○	◉

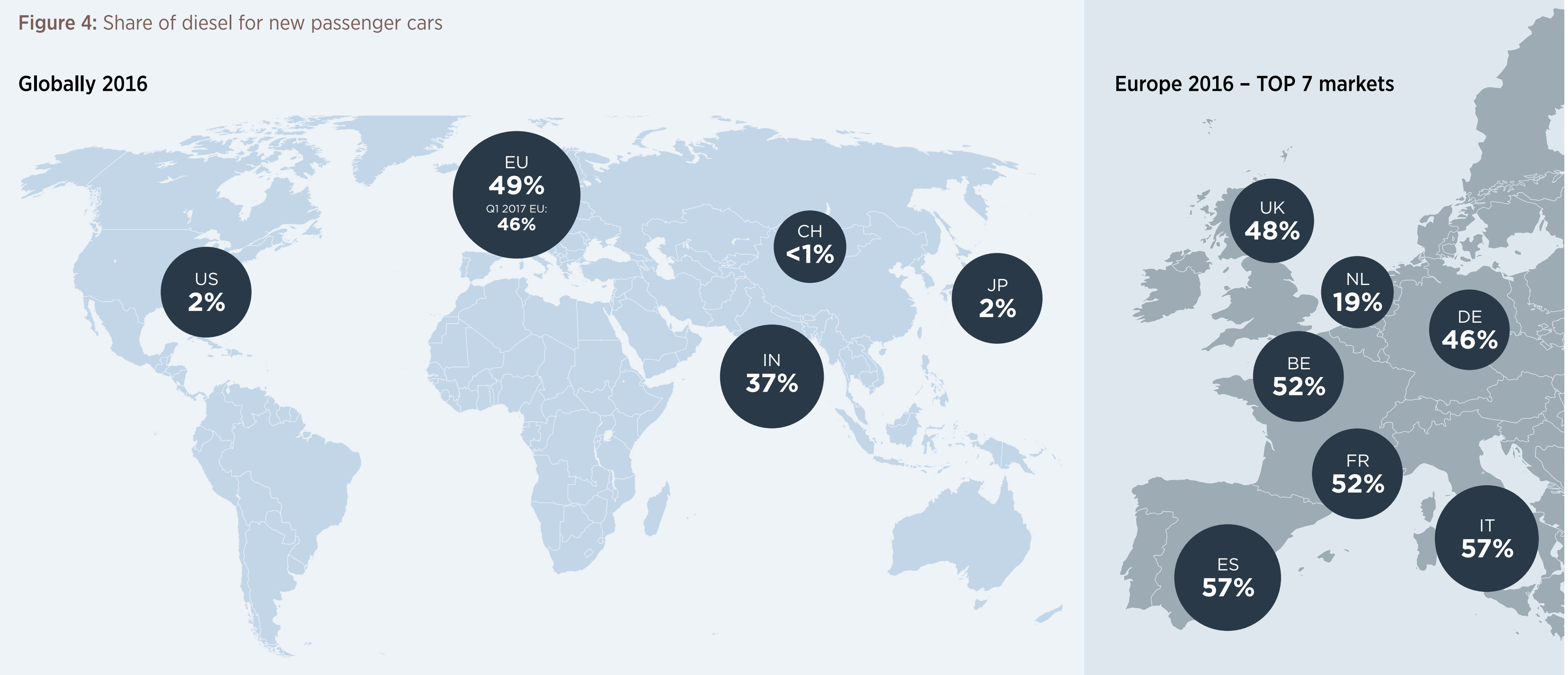
HEV: Hybrid electric vehicle
PHEV: Plug-in hybrid electric vehicle
BEV: Battery-electric vehicle

* PA forecast
** Based on forecasted fleet
*** based on selected mid-size sedans; engine sizes comparable between PHEV and conventional model

○ very low • low ◉ mid ● high ⬤ very high

Source: MarkLines, company websites

Figure 4: Share of diesel for new passenger cars



Developing alternatives

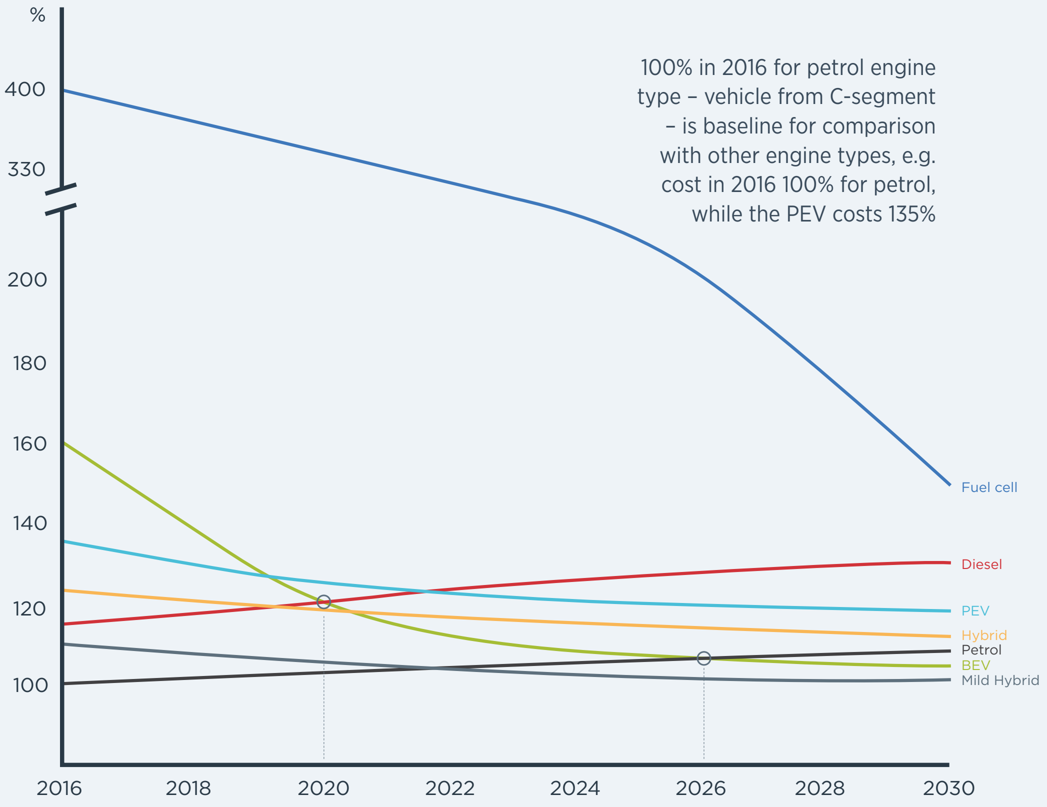
There are a number of actions carmakers can take to address these challenges. The first of these is to support the introduction of mild hybrid vehicles where a traditional internal combustion engine is supported by an electric motor. In the medium to longer term the focus will need to be on developing fully electric vehicles, and a number of manufacturers have already initiated massive investments in new models and announced work to support the development of the infrastructure required.

Over the next five years, every manufacturer plans to launch at least one fully electric vehicle and invest in a range of alternatives. Volkswagen's dramatic change in approach is reflected in their plans for 41 new models (3 hybrids, 22 plug-in hybrids and 8 fully electric vehicle, plus 8 others such as CNG). PSA plan to launch 20 new models (6 hybrids, 8 plug-in hybrids and 6 fully electric vehicle), Renault Nissan 18 new models (5 hybrids, 4 plug-in hybrids and 9 fully electric vehicle) and Toyota will maintain its focus on hybrids, with 11 new models planned.

We are also seeing some carmakers intensify the development of other alternative technologies such as compressed natural gas, LPG and fuel cells.

These developments underline that, while there is a real variation in the particular options favoured by each manufacturer, it is clear that all are focused on developing alternatives to the combustion engine. An interesting option for the future is the development of Synthetic Fuels (OME), but the running costs of these fuels are still not competitive.

Figure 5: Cost curves over time for different engine types



100% in 2016 for petrol engine type – vehicle from C-segment – is baseline for comparison with other engine types, e.g. cost in 2016 100% for petrol, while the PEV costs 135%

Assumptions:

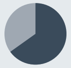
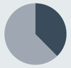
- No change in material and labour cost until 2030
- Price increase for petrol and diesel based on Euro 6 and 7
- Fuel cell
  - Price degression based on volume and technology, tank and cell design (appr. 0.1% in 2020, 1-3% in 2025 and >4-8% in 2030)
  - Range 400-500 km
- BEV
  - Price degression based on volume and technology for battery (appr. 5% in 2020, 15-25% in 2025 and >30% in 2030)
  - Range >400-500 km
- PEV petrol: range appr. 50 km
- Hybrid petrol: range 2-5 km
- Mild hybrid (48V) petrol: no electric driving feasible

Getting the price right

A critical factor in driving up electric vehicle sales will be price and most carmakers are planning for price parity between conventional vehicles (petrol and diesel engines) and electric vehicles from 2020 onwards (diesel by 2020 and petrol by 2027). The cost driver for the manufacture of electric vehicles is the battery (up to 40-50%) but more mature battery technology and higher volumes will drive down costs in the period to 2025. At the same time, the cost of diesel vehicles based on new Euro 6 b, c and d and Euro 7 emission requirements will increase, a further factor in making electric options look more competitive.

There are a growing range of alternative options for engine development ranging from fully electric vehicles to fuel cell electric vehicles, CNG and those using synthetic fuels. It will be important for carmakers to analyse their full well to wheel emissions, running costs and infrastructure required to determine which option to pursue. What is clear is that the falling cost of battery production over the period to 2025 will provide a powerful cost driver for manufacturers to move to electric vehicles. Equally, the significantly lower running costs of electric vehicles (0.08 €/km) compared with conventional petrol engines (0.14€/km) and with hybrid alternatives will make them increasingly attractive to buyers.

Figure 6: With the current electricity mix only BEVs can reduce the overall carbon emissions. Fuel cell has comparable running costs like petrol but much higher investment costs

Engine technology	CO$_2$ emissions	Infrastructure	Running costs		Outlook 2025-2030
	(Well-to-wheel)		*Cost per km	Investment costs	
ICE	Petrol: 164g_{CO2}/Km Diesel: 156g_{CO2}/Km	**~ 14,000** gas stations in Germany	0.14 €/km 0.12 €/km	 	↘ ⊕ Available technology and infrastructure ⊖ High carbon emissions ⊖ Investment cost increase for diesel expected
BEV	~ 75g_{CO2}/Km 100% electricity mix EU ~ 5g_{CO2}/Km 100% renewable	**~ 7,400** public charging stations in Germany	0.08 €/km		↗ ⊕ Charging stations will double until 2020 ⊕ Price decrease for batteries is ahead of forecast ⊖ Still low distance
FCEV	~ 174g_{CO2}/Km 100% electricity mix EU ~ 8g_{CO2}/Km H2 100% renewable	**~ 30** public gas stations in Germany	0.12 €/km		↘ ⊖ Production of H2 is CO$_2$ intensive without green energy ⊖ Charging stations will increase only to ~ 400 in Germany ⊖ Price for H2 cars nearly twice as petrol cars
CNG	~ 124g_{CO2}/Km 100% electricity mix EU ~ 5g_{CO2}/Km 100% Bio CNG	**~ 870** public gas stations in Germany	0.11 €/km		→ ⊕ Small but existing infrastructure ⊖ Relatively small savings on CO$_2$ without bio gas
Synthetic Fuels (OME)	> 200g_{CO2}/Km 100% electricity mix EU ~ 5g_{CO2}/Km 100% renewable	**~ 0** 2 test production facilities are running	~ 0.24 €/km		↘ ⊕ Can be mixed with current diesel and used in adapted diesel engines ⊖ Currently high production / running costs ⊖ Only climate friendly with green energy

Managing uncertainty

One of the challenges facing carmakers is the number of uncertainties about the wider environment and the pace of technological development and how this will affect the emergence and take up of alternatives. We have developed two scenarios, "full power" and "half power" to explore how this environment might change for manufacturers.

In full power the oil price continues to rapidly increase, charging infrastructure is developed rapidly (>100,000 charging stations across Europe) and range is extended (to 600-800km) and charging times reduced (<20mins). This leads to a dramatic increase in the use of alternative powered vehicles, which make up almost three quarters of the fleet by 2030 (with diesel down to 11% and petrol down to 16%). Within that hybrids will make up about 20%, plug in hybrids 15%, and electric vehicles 38%.

In half power, the oil price remains stable, charging infrastructure development is slower (<80,000 charging stations across Europe), electric vehicle range is less than 500km and charging times about an hour. In this scenario alternative vehicles make up more than half of the fleet by 2030 (with diesel down to 16% and petrol down to 25%). Within this, hybrids will make up 17%, plug-in hybrids 13% and electric vehicles 29%.

In both scenarios, electric vehicles will become leading alternative powertrain solution in Europe by 2030, followed by hybrids and with plug-in hybrids taking third place. This underlines that there will be a big shift between conventional and alternative drivetrains between 2020 and 2030, with alternatives increasing from a market share of 10% in 2020 to 60 or 70% in 2030.

Figure 7: Scenarios 2020/2030 – powertrain concepts Europe (market share)

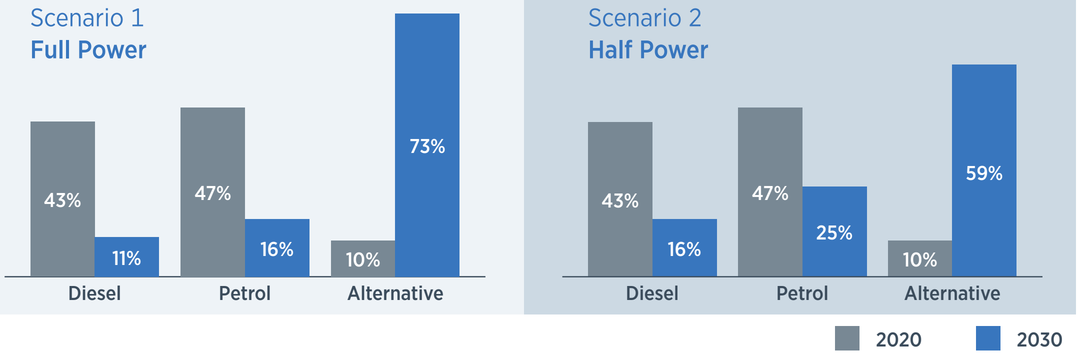
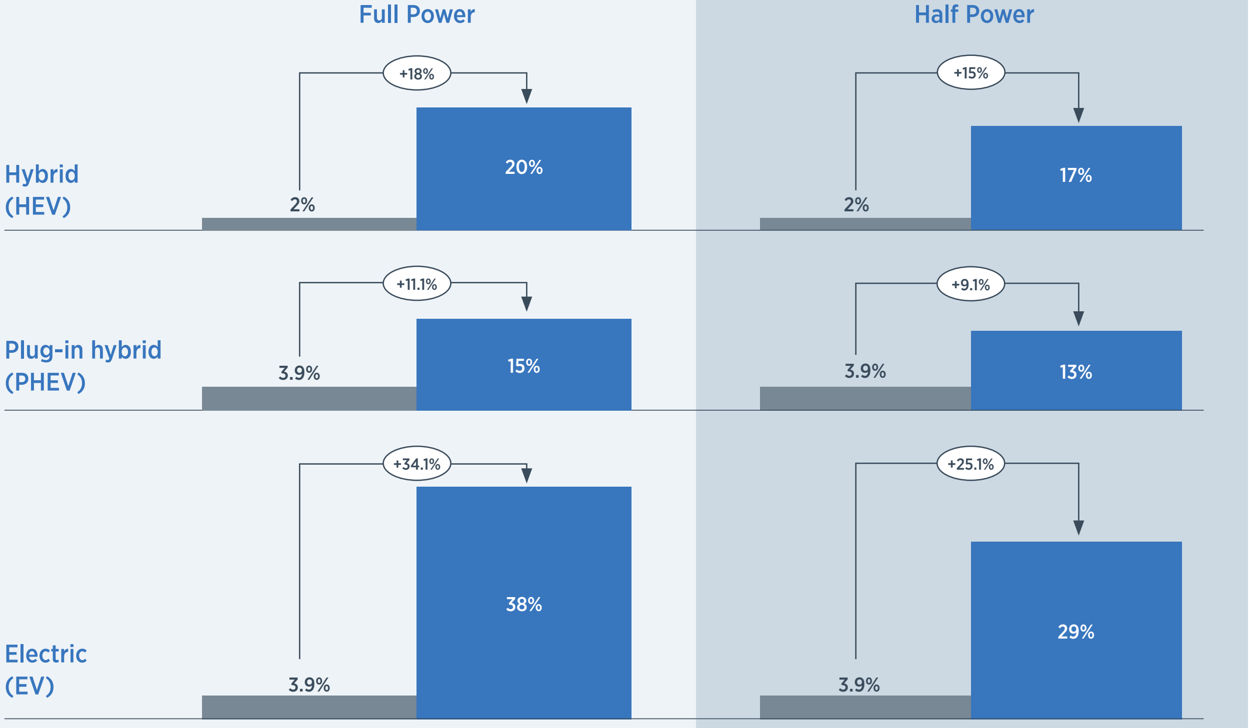


Figure 8: Development of alternative powertrain systems in Europe until 2030



New testing regimes are bringing greater scrutiny and more complexity

Another particular complication facing manufacturers is the impact of the new test cycles. CO_2 emissions performance is currently derived from a test cycle known as the New European Driving Cycle (NEDC), a standardised procedure designed to compare different vehicles under similar conditions. It has now been replaced in the EU by the Worldwide Harmonised Light Vehicles Test Procedure (WLTP) which is designed to provide a more accurate representation of real conditions; longer duration, higher speed and including more acceleration and deceleration.

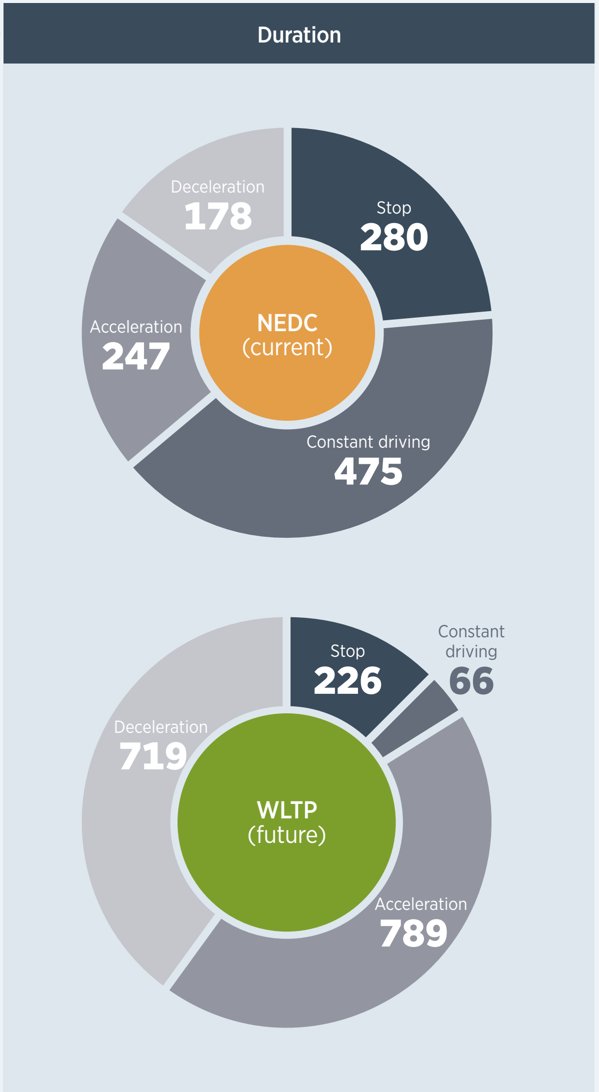
A further element will be the implementation of Real Driving Emissions (RDE) as an additional type approval requirement for the period 2017 to 2020, and which will focus on NOx emissions. The RDE legislation adds road profile, ambient conditions, traffic, as well as driver behaviour, as elements in the new environment for emission testing and certification. However, driving a vehicle on the road under ‘real life’ conditions will never be 100% reproducible and so test comparisons between vehicles will never be entirely accurate. One to one comparison of test results will not be possible; instead it will be necessary to evaluate the test data using statistical methods.

All these changes mean not only will carmakers will have to meet stricter emissions limits but they will be facing much more demanding test procedures. While the WLTP test cycle will not have a direct impact on manufacturers until 2020, consumers will have access to the results from 2017 onwards and so emissions performance is likely to become an even higher profile issue. Carmakers are also considering the impact of WLTP on accessories, as they will have an effect on the test results due to their additional weight. Each combination of accessories in a vehicle will need to be tested individually and, as a result, manufacturers are looking at creating accessory packages which can optimise individual test results.

Carmakers will also need to respond to the fact that real world CO_2 emissions are up to 25% higher than those measured in the NEDC tests. So while there has been steady overall reduction in emissions under the NEDC tests, only about a third of this improvement is attributable to technological advances. The remainder has been the result of optimisation of car operations to meet the requirements of the test. For example, a warm engine will perform better in the NEDC test than a cold one due to lower friction but in many real world journeys, the engine will be starting from cold and in a short journey may not ever reach the optimum warmth.

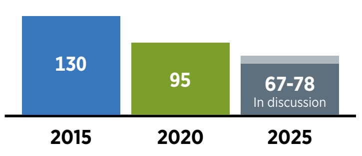
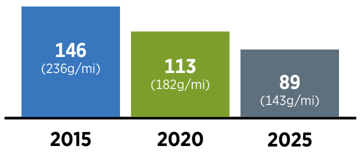
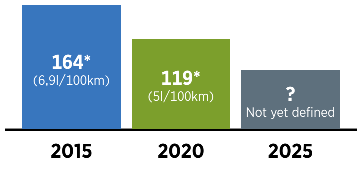
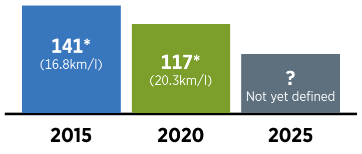
Figure 9: Key differences between the two test cycles discussed in Europe

Criteria	units	**NEDC** (current)	**WLTP** (future)
Duration	s	1180	1800
Distance	km	11.03	23.27
Mean velocity	km/h	33.6	46.5
Maximum velocity	km/h	120.0	131.3
Stop phases		14	9



CO_2 limits worldwide are becoming stricter – while testing procedures are getting longer and closer to reality posing a two-fold challenge for carmakers

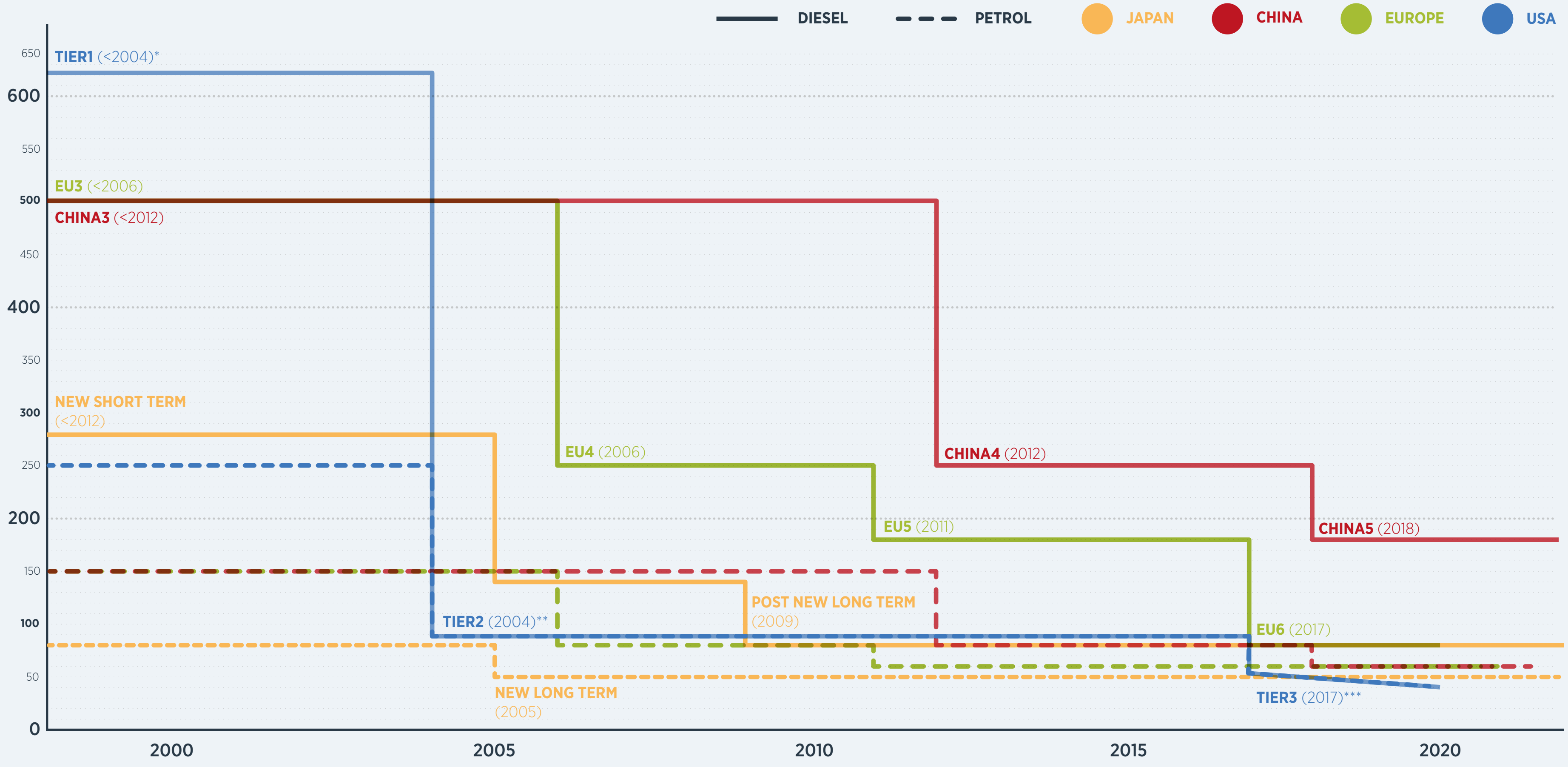
Figure 10: International comparison of test cycles

	Europe	USA	China	Japan
Current emission test	NEDC	FTP 75	NEDC	JC 08
Planned emission test	WLTP / RDE	FTP 75	WLTP / RDE	WLTP
Implementation WLTP	Start in 09/17 Overall SOP 2020	No implementation planned	July 2020 RDE starts in July 2023	Start in 2018 Overall SOP 2022
Other information / support programmes for e-vehicles	**Germany:** 1m e-vehicles until 2020 EU6 limitations in cities **Netherlands:** 2025 no fossil powered cars – PEV hybrids are allowed **Norway:** 2025 only electric vehicles	**$ 22bn** support programme within the next **5 years** **Tax savings** of max **7,500 USD** when **buying an e-vehicle** **Permission** to use **carpool** and **bus lane**	Share of e-vehicles • 2018: 8% • 2019: 10% • 2020: 12% **3.3bn support programme** Increase tax rate for petrol and diesel cars Bejing: 2025 50% e-vehicles	Government takes **50% of the extra cost** of an e-vehicle and pays a **buyer's premium of 6,400 EUR** Japan's car manufacturers are **jointly developing** a **funding programme** for large-scale **pillar-load infrastructure**
Targets reference	CO_2	Fuel economy / CO_2	Fuel economy / CO_2	Fuel economy / CO_2
CO_2 targets [g/km]	 Source: ec.europa.eu	 Source: www.epa.gov	 Source: Energy-Saving and New Energy Vehicle Industrialization Plan	 Source: ICCT

*calc. with http://spritrechner.biz/co2-rechner-fuer-autos.html; 6.9l/100kmx23.7=163.53g CO2/km

USA has the most demanding NOx requirements followed by Japan, the EU and China

Figure 11: Nationwide emissions limits for petrol and diesel LDVs



Source: http://www.transportpolicy.net/standard/
US Source: http://www.transportpolicy.net/standard/us-light-duty-emissions

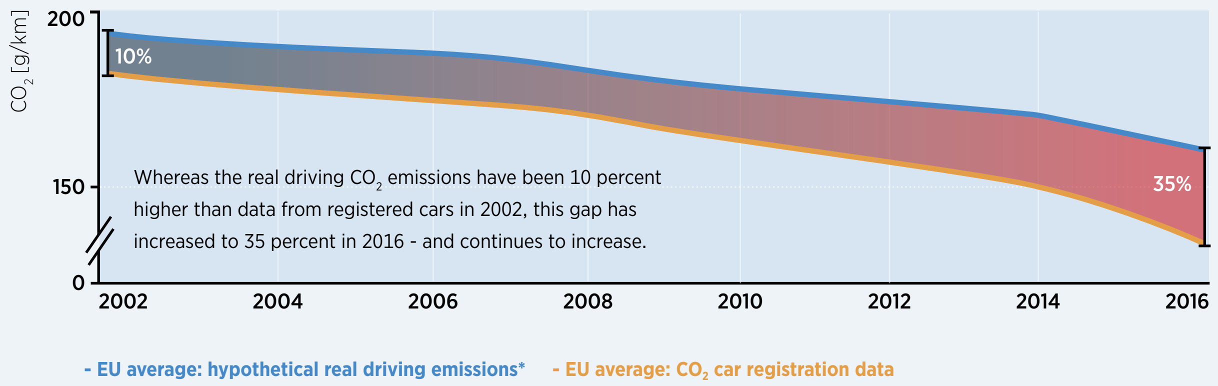
*Tier 1: 50,000 miles
**Tier 2: Emission Standards, FTP 75, g/mi (Permanent bin 8 without phase 1 and supplemental exhaust emission standards)
***Tier 3: Phase-in for LDV and LDT Fleet Average FTP NMOG+NOx Standards [mg/mi]

There will be a number of counterintuitive results from the WLTP tests. Some technologies will perform better such as hybrids, larger engines and those which have sailing (coasting) technology. In contrast, smaller engines will perform less well, as will start stop systems, turbo charging and catalytic convertors, because there will be less stopping compared to the NEDC. Another result of the WLTP test will be that conventional engines will emit slightly less CO2 than under the NEDC test. The lower performance of smaller engine cars is a particular challenge for manufacturers with many small cars in their fleets. While they will still have lower emissions than larger cars, their absolute performance will be worse.

There are also challenges around the differing approaches to CO_2 emission targets and testing regimes across the world. The US have FTP75, Europe use NEDC / WLTP, China NEDC / WLTP and Japan JC08 / WLTP, with Europe now imposing the most challenging targets. In terms of helping carmakers meet these targets, there is no consistency across European governments, while the US and Japan are providing quite a lot of financial support and China is increasing taxes to achieve top down targets for an increase in electric vehicles.

We can see similar variations in the approach to limiting NOx emissions, although all countries have been reducing the limits in recent years. In 2004, the US made a dramatic reduction in its permitted limits, decreasing the limit from above 700mg/100 km to less than 60mg/100km for diesel and petrol vehicles. In contrast, Japan, the EU and China have taken a more gradualist approach, making a series of reductions over the past decade. The EU reduced its NOx limits in 2006 and 2011, with a further reduction this year to 80mg/100km for diesel and 60mg/km for petrol although this is still slightly higher than the US limits. Japan, had always had stringent limits, and reduced these in 2005 and then to 80mg/100km in 2009.

Figure 12: Real driving CO_2 emissions are higher than measured in the NEDC tests — the average difference has more than doubled



Whereas the real driving CO_2 emissions have been 10 percent higher than data from registered cars in 2002, this gap has increased to 35 percent in 2016 - and continues to increase.

* EU average hypothetical real driving emissions based on the deviation level of fuel consumption: data from ICCT and Spritmonitor.de
Source: ICCT, 2017, laboratory road 2016 update and PA research

Figure 13: Technologies are benefitting or suffering from implementation of the WLTP (relative to NEDC)

- ⊕ Hybrid technology: regardless of full, mild or plug-in hybrid
- ⊕ Manual transmissions (allows operation in load optimum)
- ⊕ Large volume engines
- ⊕ Sailing / cruising technology (high sailing share in WLTP)

WINNER

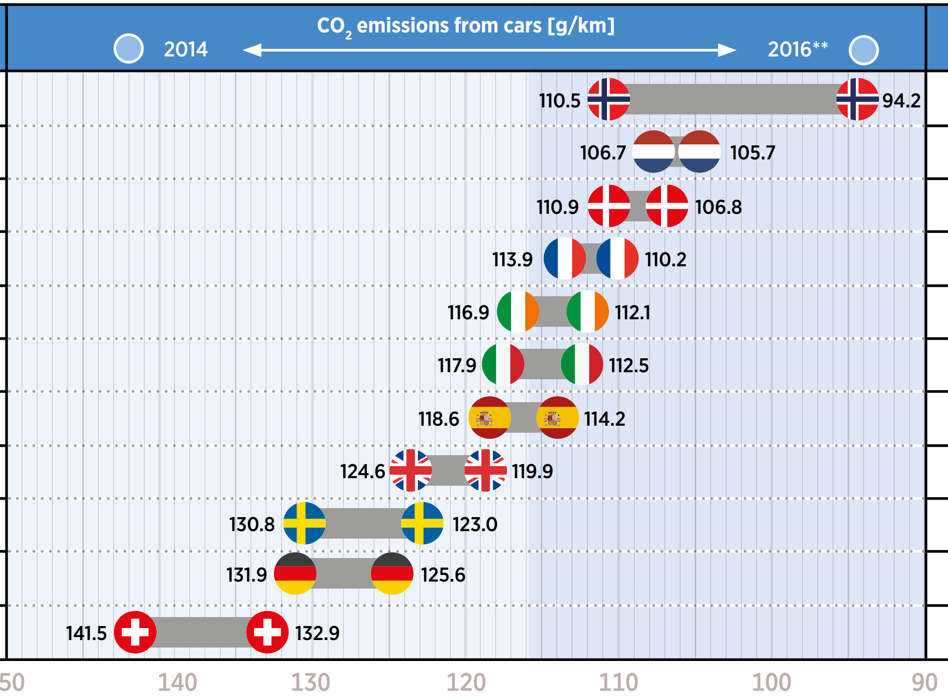
- ⊖ Downsizing (engines with increased efficiency in low load regions are disadvantaged)
- ⊖ Start-stop system (fewer stops in WLTP)
- ⊖ Turbo charging
- ⊖ Catalysator heating measures and extra equipment

LOSER

Carmakers will need to understand this new more complex picture and look at which specific measures can reduce emissions in real driving conditions. These include: electrical systems that can manage brake energy and other factors better; a greater use of hybrids; and technical changes in areas such catalytic convertors, transmission ratios, exhaust gas recirculation rates and valve actuators.

Figure 14: CO_2 emissions from cars in selected countries in the EU

Sources: PA Research, EAFO, EU Pocketbook, Jato, ACEA



Country	CO_2 emissions from cars [g/km] 2014	2016**	Gross domestic product [€] per capita 2016	Share of premium*** cars	Direct PEV* incentive/grant [€]	PEV* % of new cars 2016
Norway	110.5	94.2	98,895	30%	0	29.1%
Netherlands	106.7	105.7	51,297	20%	0	5.9%
Denmark	110.9	106.8	61,571	12%	<2,000	0.8%
France	113.9	110.2	42,175	13%	3,500 - 10,000	1.4%
Ireland	116.9	112.1	53,156	14%	2,500 - 5,000	0.5%
Italy	117.9	112.5	35,137	20%	0	0.2%
Spain	118.6	114.2	30,432	17%	2,700 - 5,500	0.3%
UK	124.6	119.9	44,989	30%	<6,000	1.5%
Sweden	130.8	123.0	58,290	39%	<4,200	3.6%
Germany	131.9	125.6	47,594	31%	3,000 - 4,000	0.8%
Switzerland	141.5	132.9	85,596	31%	0	1.9%

*PEV includes both all-electric cars (BEV) and plug-in hybrids (PHEV)
**Rank based on 2016 values
***Top best selling cars of premium brands (C,D,E segment and SUVs)

Emissions performance varies across countries but Norway leads the way

While the level of emissions varies significantly across carmakers, there are also wide variations in the emissions from individual countries' car fleets. Norway has the lowest level of emissions at 94.2g CO_2/km in 2016 (down from 100.5g CO_2/km in 2015) and the highest use of plug-in hybrids and electric vehicles, which made up 29% of new car sales in 2016, reflecting its policy of banning the internal combustion engine by 2025. The Netherlands has emissions levels of 105.7g CO_2/km and plug-in / electric vehicles make up almost 6% of sales. Denmark comes as third in this CO_2 ranking with 106.8g CO_2/km achieved on a lower level of 0.8% plug-in / electric vehicles. Sweden has a fairly high share of 3.6% plug-in / electric vehicles but a high level of emission of 123g CO_2/km. In contrast, in Germany emissions are at 125.6g CO_2/km and plug-in / electric car sales are only 0.8% of the total and in Switzerland emissions are 132.9g CO_2/km, although plug-in / electric vehicles are more popular with 1.9% of sales.

While the reasons for these results are complex, there does seem to be a link between a country's performance on emissions, levels of electric vehicle use, gross domestic product per capita and the sales of premium vehicles and particular policy measures to encourage the use of electric vehicles.

However, it is clear that policy makers face real challenges in developing actions that will reduce emissions further. Even in Norway where the significant subsidy for electric vehicles has driven sales, there have been concerns about the costs. Germany has set a target of one million electric vehicles by 2020 and is discussing banning combustion engines from 2030 but the subsidy provided to encourage electric vehicles sales is proving controversial and it is unlikely this target will be met.

Meeting the UK's ambitions to ban combustion engines by 2040 will also be a challenge, due to the automotive sector's reliance on conventional engines. Developments of alternatives lag behind other countries and it is not currently well placed to drive this shift to electric options, given it produces 2.5 million combustion engines a year, 15% of European total. It will require clear government support if the industry is to make this transition, as well as an increase in investment in charging infrastructure and action to encourage consumer take up of electric vehicles.

On the brink of a new era

It is clear that car manufacturers still face considerable challenges in meeting the 2021 CO_2 emissions targets. It is also obvious that almost all are now making significant investments in hybrids and electric vehicles to improve their performance. While some of these developments will come too late for the rapidly approaching 2021 deadline, we are seeing an increasingly sharp focus from manufacturers on new models and new approaches. These will be available to customers very soon and could drive a very significant change in the cars we buy.

Methodology

The following assumptions were made to forecast car manufacturers' specific CO_2 targets and emissions: Manufacturer specific CO_2 targets depend on the average fleet weight of each carmaker and their difference from the average weight of all new registered vehicles. We forecasted the average fleet weight of each manufacturer using a PA assessment on present and previous weight trends, as well as their capability to reduce weight in the future. The expected potential of each carmaker to enlarge their product portfolio with smaller and lighter cars is also an important factor.

The specific CO_2 emissions performance reflects a weighted fleet average, taking into account super credits for low emission vehicles (less than 50g CO_2/km). Therefore, we made assumptions for each manufacturer regarding the development of the CO_2 emissions of different powertrain types, such as internal combustion machines, hybrid, plug-in hybrid, electric and others, such as natural gas. Our 2021 forecasts are based on the NEDC test cycle as this will remain in place for manufacturers even though the WLTP tests will be phased in from 2017 for consumer information.

We also calculated the respective number of registrations of each powertrain type for each manufacturer using an extrapolation of current trends and PA market insights into the future focus of individual carmakers.

To find out how our experts can help you meet European carbon emissions reduction targets, please contact us now.

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