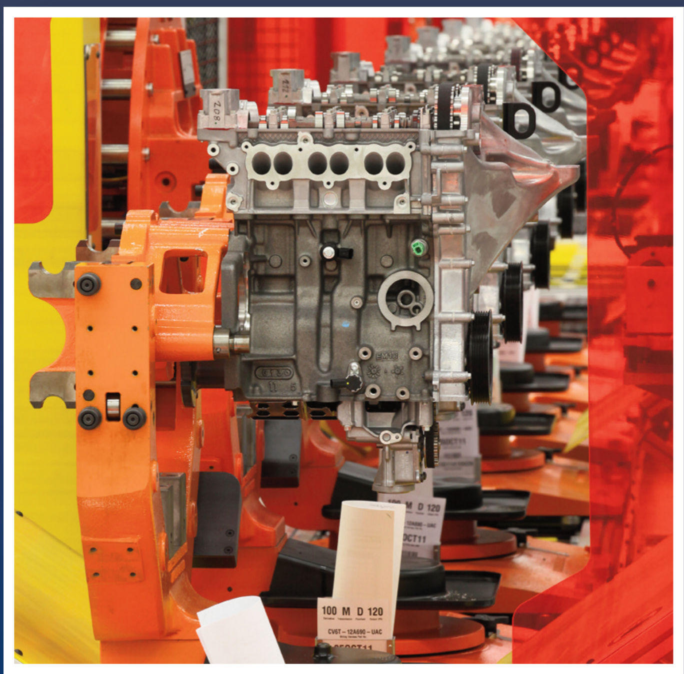
Research Report
ABOUT Automotive

Global Engine Trends & Forecasts to 2020

November 2012

By David Saddington



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Contents

Chapter 1: Introduction

Fuel efficiency was the most influential reason for purchasing a particular vehicle model

According to the Consumer Federation of America, household expenditure on vehicle petrol (gasoline) reached an all time high in 2011, with households spending an average of $2,850 per year. Compared with 2001, the average cost of owning a vehicle in the US has come down by 20%, but in the same time period the cost of gasoline has tripled. The 2012 J.D. Power and Associates US Avoider Study based on data collected from over 24,000 new car owners found that fuel efficiency was 'the most influential reason for purchasing a particular vehicle model.'

A 2012 Consumer Reports survey of 1,700 US households owning at least one car revealed a similar finding; 37% of consumers said their leading consideration when shopping for their next vehicle will be fuel economy, far ahead of quality (17%), safety (16%), value (14%) and performance (6%). The same survey revealed the US motorists are driving less, and contemplating moves to smaller, more fuel-efficient vehicles. In addition, over 81% of respondents said that they would be willing to pay more for a fuel-efficient vehicle if the additional cost could be recovered through lower fuel costs.

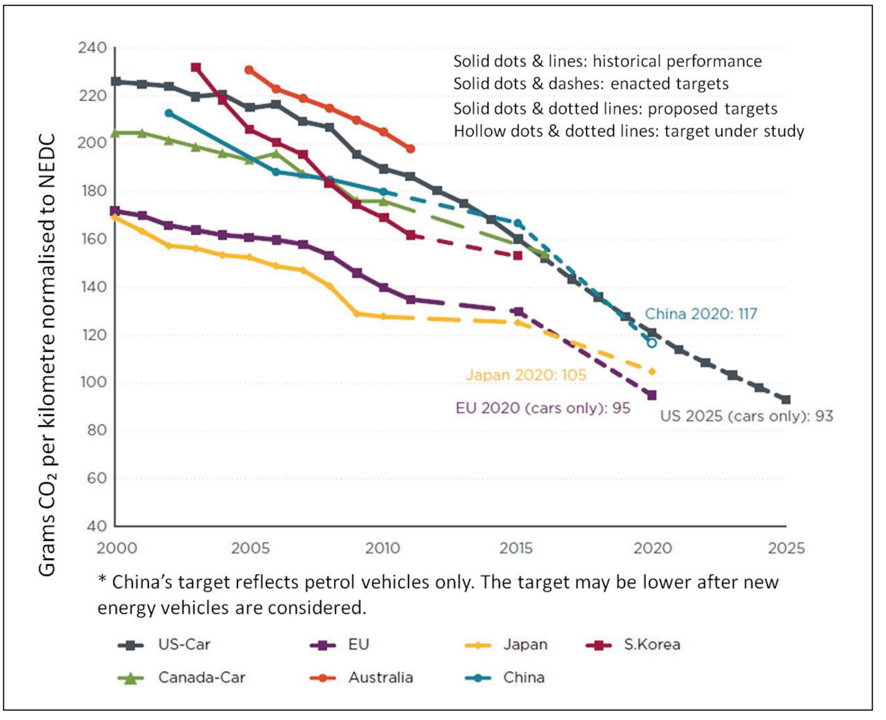
The three main developed-market areas have evolved remarkably different consumer preferences

In Europe fuel efficiency has long been a major influencing factor in consumer car buying preferences due to high levels of fuel taxation. Even in Norway for example, a major exporter of oil, fuel taxes account for over 69% of the price of petrol (total cost equivalent of around $11 per gallon in 2012) and 57% of the price of diesel bought at the pump. Japan has followed similar taxation policies to Europe and exhibits similar consumer preferences towards fuel efficiency as Europe. The falling sales of higher fuel consumption vehicles, and rising sales of their less thirsty counterparts sends a clear message to automakers – fuel efficiency sells.

The three main developed-market areas of North America, Europe, and Japan have evolved remarkably different consumer preferences, complicating the life of the engine designer and product planner. The differences have been shaped at least in part by the fiscal and regulatory policies of governments.

In Europe as mentioned, very high levels of motor fuel taxation has made fuel economy the most prized attribute for the majority of consumers. Consequently the diesel engine now commands the largest share of the European new-car market. The authorities in turn have responded to this preference by writing emissions-control regulations which have made life slightly easier for diesel-engine cars (while in the USA and Japan for example diesel and petrol models are treated more or less on an equal footing). Meanwhile the European manufacturers of diesel-engine cars – including the Japanese importers – have devoted great efforts to overcoming some of the drawbacks once seen as inherent to this type of engine.

Figure 1: Comparison of global CO_2 regulations for passenger vehicles (NEDC gCO_2/km)



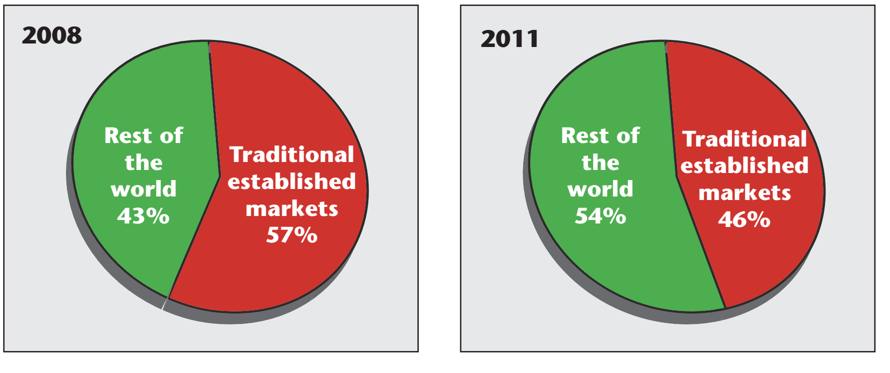
Source: ICCT

2.7: Major vehicle production trends

The numbers reflect a significant shift in vehicle production to the growth markets of China, India, Eastern Europe and other markets

The profile of global vehicle production has changed significantly since the financial crisis began in September 2008. Production in 2009 declined to 58 million vehicles, and although it recovered to 75 million vehicles in 2011, the numbers reflect a significant shift in vehicle production to the growth markets of China, India, Eastern Europe and other markets. Vehicle production in the traditional markets of North America, Western Europe, and Japan, declined by 9% between 2008 and 2011, from 38 million vehicles to 34 million. These markets also declined as a proportion of global vehicle production in this period, from 57% in 2008 to only 46% in 2011. In contrast production in China increased by 50% in 2009, by 32% in 2010, and by 3% in 2011, while India increased production by 17% in 2009, 32% in 2010, and 17% in 2011.

Figure 2: Share of global vehicle production 2008 / 2011



Source: ABOUT Automotive, Industry estimates

In the US and most other markets, the petrol engine is dominant with around 95% market share in the US, 99% in Japan, and 99% in China, and will remain so for the foreseeable future. Apart from the EU, only in developing markets such as India does diesel take significant market share away from the petrol engine. Advances in hybrid, BEV and (in the longer-term perhaps) fuel cell technology will challenge the dominance of the petrol engine, especially as emissions regulations grow ever stricter and plans like the banning of conventionally fuelled vehicles from cities first considered by the EU in its 'Transport 2050' White Paper gain traction in other parts of the world; but not before 2020.

Table 4: Petrol engine production to 2020 (million units)

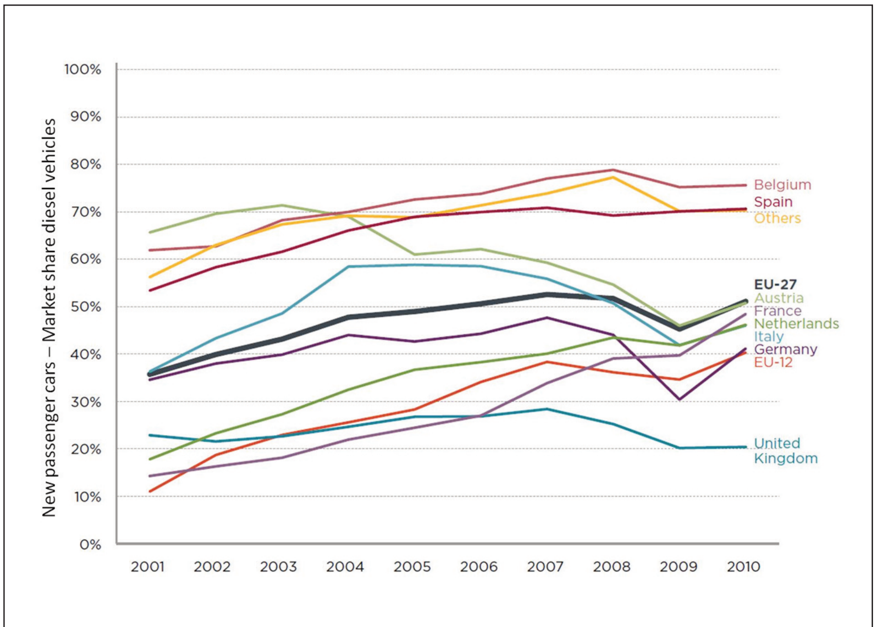
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Europe	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.1	12.2	12.5
North America	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.6	15.0	14.8
Japan	10.8	[illegible]	[illegible]	[illegible]	8.4	[illegible]	7.7	7.2	6.7
China	[illegible]	22.9	[illegible]	[illegible]	23.6	[illegible]	26.9	29.6	29.9
India	2.9	3.0	3.3	3.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Rest of world	23.7	24.2	24.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	83.2	84.4	86.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Source: ABOUT Automotive

2.8.2: Diesel engines

Years of high fuel prices have made fuel economy a key consideration for vehicle buyers in Europe, and market penetration of diesel engines is very high, reaching over 70% in some countries such as Spain and Belgium, and standing around 52% in the EU-27 overall. Even in the UK (the lowest adopting state), diesel still commands over 20% market share.

Figure 3: New passenger cars: EU Diesel market share by member state, 2010



Source: ICCT

Three cylinder engines have become increasingly popular for engines of 1-litre and less capacity

Several engines have also been offered, with three valves per cylinder, generally two inlet and one (larger) exhaust. Ford launched a 999cc three cylinder turbocharged unit in 2012 to great acclaim; Ford's smallest engine yet, the unit has won accolades for its combination of lively performance and fuel efficiency. First seen in the 2012 Focus, the engine generates 123bhp and 170Nm peak torque (200Nm with overboost) coupled with combined fuel economy of 56.5mpg (47mpg US, 5 L/100km) and CO_2 emissions of 114g/km. Three cylinder engines have become increasingly popular for engines of 1-litre and less capacity, often coupled with turbocharging to improve performance relative to naturally-aspirated larger capacity four-cylinder competitors. Manufacturers such as Volkswagen, Toyota, Hyundai/KIA, Mitsubishi and Ford all field three cylinder engines around 1-litre capacity, and Fiat even has a two-cylinder 875cc unit turbocharged unit that launched in 2011.

In all current engines, the valves are opened by cams, sometimes via a cam-following roller mechanism which significantly reduces drive train friction. The valves are closed by coil springs concentric with the valve stem. Care is needed to avoid valve float or bounce due to unsuitable spring rates, and many engines, especially those running at higher speeds, use two springs of different rates for each valve.

3.3.4.2: Variable valve timing and lift

Variable valve timing is in effect an extension of timing choice to suit engine characteristics. In the classic Otto cycle, as illustrated in any simple explanation of how a 4-stroke engine works, the inlet valve opens at the top dead centre (TDC) during the inlet stroke and closes at bottom dead centre (BDC). The exhaust valve then opens at BDC at the start of the exhaust stroke, and closes at TDC. Both valves remain closed during the compression and power strokes. Engine designers realised long ago that the gas flow through an engine is dynamic and has inertia, and that better performance could be achieved by providing valve overlap – periods during which both the inlet and exhaust valves are open.

Ideally the amount of overlap for optimum performance increases with the speed of the engine. Until the 1980s, designers could only make the best compromise choice of timing, but devices (variators) were developed to allow the timing to be altered. The earliest devices were two-position only, and used only to alter the inlet valve timing. In recent years it has become increasingly common to use continuously variable valve timing variators to alter both inlet and exhaust valve timing according to operating conditions, taking control signals from the engine management unit (EMU). While the most common form of variator uses hydraulic pressure to alter the angle of its camshaft relative to the drive sprocket, ingenious solutions have been developed, for example by the British consultants Mechadyne, to vary the timing of valves operated from a single camshaft.

Ingenious solutions have been developed to vary the timing of valves operated from a single camshaft

A further evolution of the principle bring control not only of valve timing but also of valve lift, achieved by a variety of means by different manufacturers. Honda was early in this field with its VTEC system, based on switching between different cam profiles, a principle adopted by other, mainly Japanese, manufacturers, while Honda has evolved VTEC through several stages of development suited to different requirements. BMW meanwhile has developed its Valvetronic system, and applied to engines

Manufacturers are increasingly tending to combine their solutions into a single package

There is a further engineering advantage, from the turbocharger's point of view, that diesel exhaust gases are typically 200°C cooler than those from a petrol engine. This reduces thermal loads on components and has enabled turbochargers with variable-geometry turbine inlets to be used almost routinely on modern diesels, whereas they remain a high-cost rarity in the petrol engine sector.

Compared with most petrol engines, turbodiesels can run higher boost pressures and therefore achieve greater increases in output. The only limits are set by the ability of the engine to withstand the mechanical and thermal loads. Limits are set by the very high combustion pressure acting on the cylinder walls during the power stroke, and by very high rates of heat transfer especially into the piston crown. A conservative approach is often taken to inter-cylinder wall thickness (a turbocharged engine may have a smaller bore than its naturally aspirated equivalent, if one exists), and the technique of oil-spray cooling of the piston crown was first devised for high-output turbodiesel engines.

The challenge is to achieve true auto-ignition distributed throughout the charge without falling victim to detonation

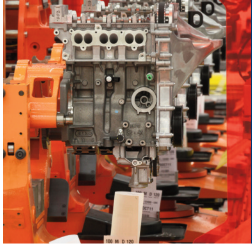
The development of small, low-inertia turbochargers matched to the needs of even the smallest diesel engines (down to the 1.3-litre capacity of the Fiat Multijet 2 diesel, launched in 2009) allied to the prevalence of variable-geometry units, has effectively overcome any impression of turbo lag in a well-engineered turbodiesel. In its simplest form, the variable geometry arrangement simply alters the area of the turbine through which the exhaust gas can flow. A more efficient solution is to equip the turbine inlet with variable-incidence vanes – the angle of incidence being automatically controlled – enabling the gas speed to be maintained even at low rates of mass flow. The latter approach is steadily becoming more common. Another pressure-charging technique which is gaining popularity with diesel engine manufacturers is to use two turbochargers, sometimes of different sizes, in a series/parallel arrangement. Such systems have already been discussed in the petrol engines section, but in the diesel sector the idea is gaining momentum as a way of achieving very high specific outputs (calling for the use of a large turbocharger) while retaining low-end and mid-range response resulting from the use of a smaller unit.

A pioneer in the volume production application of such a system was BMW, which in 2006 launched a 3-litre diesel equipped with such a system (and designated 535d to differentiate it from the single-turbo 530d) delivering 286PS and 580Nm of torque. This contrasted with 272PS and 320Nm of torque delivered by the 530i petrol engine. Since then BMW has applied a similar system to its 4-cylinder turbodiesel engine, PSA has introduced a 2.2-litre unit with 170PS and 370Nm of torque, Toyota has launched a 4.5-litre sequential-turbo diesel for the Land Cruiser and Tundra and Ford has applied the system to light truck turbodiesels.

4.2.3: Alternatives to the turbocharger?

An answer was found in the use of extended authority variable valve timing

While examples exist of petrol engines pressure-charged by mechanical superchargers, the advantages of the turbocharger are such that it rules the light-duty automotive diesel sector absolutely. The only alternative to have been offered in recent years was the Comprex supercharger, which exploited the exhaust pressure-wave effect in a rotating drum to create a complementary wave in the induction system to pressurise the cylinders.



Global Engine Trends & Forecasts to 2020

In this second edition reviewing the key market drivers for petrol, diesel and hybrid engine trends, we extend and update the analysis originally published in 2008, and review the trends in the intervening four years. It provides an authoritative overview of the technology issues (both present and future), and regulatory (emissions) concerns involved with this sector.

Report coverage

Chapter two: The market

This chapter sets out the market drivers and forecasts for global engine trends through 2020. Forecast data is provided by region for petrol, diesel and Hybrid/EV engine production. The chapter discusses global legislation – both current and planned – as well as standards on emissions regulation. This section of the research also highlights consumer trends in engine buying, explaining how the three main developed-market areas have evolved remarkably different consumer preferences.

Chapter three: Current and future SI technologies

Assessing product trends and processes associated with the petrol SI engine. The chapter provides authoritative commentary on engine construction, engine management and emission control as well as exhaust aftertreatment.

Chapter four: Current and future Diesel (CI) technologies

Reviews the compression-ignition (diesel) engine, and analyses the key differences between its petrol engine counterpart. The advantages of the turbodiesel are explained, and the alternatives to the turbocharger are also reviewed. Engine management and emission control, as well as exhaust aftertreatment are also covered.

Chapter five: Hybrid IC powertrain technology

Reviews current hybrid technologies, and looks at whether existing claims made for their efficiency and fuel economy are valid. It also looks at diesel-electric hybrids, and assesses the likelihood of such engines achieving volume production.

Chapter six: Beyond the internal combustion engine

This chapter looks at the principle alternatives, such as fuel cell technology and Battery Electric Vehicles. Will the potential problems associated with the fuel cell hybrid prevent widespread adoption of this technology?

The report provides answers to such vital questions as:

- After losing significant ground to the diesel engine in Europe, will the petrol engine regain market share across the EU-27?
- Will it just be the Japanese vehicle manufacturers that continue to lead the auto industry's move into the hybrid and EV markets in the coming years?
- How viable is the HCCI principle, and will it prove more commercially successful than the fuel cell vehicle?
- What are the main challenges to vehicle engine designers, in terms of emission regulation compliance?
- How do distinctly different consumer preferences in the three main regions complicate both engine design and product planning?
- Will the development of diesel hybrids finally ignite European interest in the hybrid concept?
- Will the fuel cell establish itself as the true power unit of the future, or will it lose its way?

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