

Global light vehicle engine technologies market- forecasts to 2029

April 2015



SAMPLE

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Table of contents

1: Introduction	15
2: PESTER analysis	16
Political	16
Economic	0
Social	0
Technological	0
Environmental	0
Regulatory	0
3: Technology overview.....	18
HCCI/CAI	18
OEMs and HCCI	0
BMW's new family future proofed for HCCI	0
Bosch and DOE project	0
Daimler F700 concept	0
Fiat quiet on HCCI	0
Ford - HCCI imminent?	0
GM and HCCI	0
Honda - moving away from HCCI to HLSI	0
Hyundai - leading the race with Mazda?	0
Mazda - leading the race with Hyundai?	0
Nissan - ready by 2015?	0
VW's two-pronged attack	0
Lean burn	0
Atkinson developments	0
Split cycle engines	0
Stratified charge	0
Variable compression ratio	0
Variable compression ratio engines	0
Audi states intentions	0
Daimler's breakthrough	0
Volkswagen Golf MkVIII to feature VCR?	0
Fuel injection systems	0
Common rail systems	0
Gasoline direct injection systems	0
Diesel	0
Injection rate shaping	0
Variable nozzle	0
Rail pressures	0
Supplier competitive positioning	0
Petrol	0
System types	0

Sector trends	0
Supplier competitive positioning	0
Other developments	0
Controlled solenoid injection system from Continental	0
Delphi's CNG injector	0
Delphi's heated injectors address ethanol engine cold start performance and emissions	0
Fuel injection for use with alternative fuels	0
Liquid-injection propane system	0
Porsche's evolving DI technology	0
Westport Innovations' high pressure direct injection technology	0
Downsizing/downspeeding	0
Downsizing	0
Downspeeding	0
Pendulum dampers	0
Active engine mounts	0
Energy recovery	0
Thermal recovery	0
Kinetic recovery	0
Rankine heat engines	0
Thermoelectric generators	0
KERS	0
Stirling engines	0
Forced induction	0
Turbochargers	0
New entrant	0
Superchargers	0
Turbochargers or superchargers?	0
Technical developments and innovation	0
Bearings	0
Materials - titanium	0
Materials - plastics	0
Electronic controls	0
Manifold-integrated turbochargers	0
Multi-stage and linked dual turbochargers	0
Turbine geometry	0
Twin-scroll turbochargers	0
Electrification	0
Ignition	0
Alternative ignition systems	0
Materials	0
Engine blocks	0
Nemak's dominance	0
Casting technologies	0
CGI set for high volume application in Ford petrol V6	0

Cylinder liners and coatings.....	0
Variable Valve Actuation.....	0
Diesel VVA.....	0
Camless engines.....	0
Cylinder deactivation.....	0
Powersplit hybrids	0
Twin-motor systems.....	0
Single-motor systems	0
Defining trait: electric running	0
CVT perception	0
Cost challenges.....	0
Lithium migration.....	0
Other alternative engines	0
48V mild hybrids.....	0
Introduction	0
What's behind 48V?.....	0
Excuse me, but you look very familiar.....	0
What will 48V bring?.....	0
OEM 48V activity.....	0
Are 48V mild hybrids a Europe only initiative at the moment?.....	0
Supplier 48V activity.....	0
48V market prognosis	0
Alternative fuels	0
Biodiesel	0
Ethanol.....	0
Hydrogen	0
Hydrogen market forecasts.....	0
Global production of hydrogen fuel-cell vehicles (1990-2020 projections)	0
Daimler	0
General Motors	0
Honda	0
Hyundai.....	0
Toyota	0
Natural gas and LPG	0
Future fuels conclusions.....	0
4: OEM overview	19
BMW	19
Steyr, Austria	19
Munich, Germany	19
Hams Hall, UK	19
Landshut, Germany	0
Shenyang, China	0

Link with PSA	0
Daimler.....	0
Asia-Pacific.....	0
Beijing, China.....	0
Europe	0
Affalterbach, Germany.....	0
Berlin, Germany.....	0
Mannheim, Germany.....	0
MDC Power, Kolleda, Germany.....	0
Unterturkheim, Stuttgart	0
North America.....	0
Decherd, Tennessee, USA	0
Fiat-Chrysler	0
Introduction	0
Asia-Pacific.....	0
Ranjagaon, Pune, India	0
Europe	0
Biesko-Biala, Poland.....	0
Pratola Serra, Italy	0
Termoli, Italy	0
NAFTA	0
Dundee, Michigan, USA.....	0
Trenton, Michigan, USA.....	0
Saltillo, Mexico	0
Saltillo South, Mexico.....	0
South America	0
Betim, Brazil	0
Campo Largo.....	0
Ford	0
Asia-Pacific.....	0
Geelong, Australia.....	0
Chonqing, China.....	0
Nanjing, China.....	0
Chennai, India	0
Sanand, India	0
Europe	0
Cologne, Germany	0
Craiova, Romania.....	0
Valencia, Spain.....	0
Kocaeli, Turkey	0
Bridgend, UK.....	0
Dagenham, UK.....	0
Middle East & Africa	0

Struandale, South Africa	0
NAFTA	0
Essex, Canada	0
Windsor, Canada	0
Chihuahua, Mexico	0
Cleveland, Ohio, USA	0
Dearborn, Michigan, USA	0
Lima, Ohio, USA	0
Romeo, Michigan, USA	0
South America	0
Camaçari, Brazil	0
Taubate, Brazil	0
Fuji Heavy Industries	0
GM	0
Asia-Pacific	0
Fishermans Bend, Australia	0
Dongyue, Yantai, China	0
Jinqiao, Shanghai, China	0
Liu Zhou, China	0
Shenyang, China	0
Qingdao, China	0
Talegaon, India	0
Bupyeong, South Korea	0
Changwon, South Korea	0
Gunsan, South Korea	0
Rayong, Thailand	0
Europe	0
Aspern, Austria	0
Kaiserslautern, Germany	0
Szentgotthard, Hungary	0
Tychy, Poland	0
NAFTA	0
Baltimore, USA	0
DMax, Moraine, Ohio, USA	0
Flint, Michigan, USA	0
Romulus, Michigan, USA	0
Spring Hill, Nashville, Tennessee, USA	0
Tonawanda, Buffalo, New York, USA	0
Ramos Arizpe, Mexico	0
Silao, Mexico	0
Toluca, Mexico	0
South America	0
Rosario, Argentina	0

Honda	0
Saitama (Ogawa), Japan	0
Tochigi, Japan	0
Yachiyo (Yokkaichi), Japan	0
Anna, Ohio, US	0
Lincoln, Alabama, US	0
Alliston, Ontario, Canada	0
Swindon, UK	0
Noida, India	0
Tapukara, India	0
Hyundai-Kia	0
Asia-Pacific	0
Asan, South Korea	0
Beijing, China	0
Changwon-Namsan, South Korea	0
Hwasung, South Korea	0
Rizhao, China	0
Seosan, South Korea	0
Sriperumbudur, India	0
Sohari, South Korea	0
Ulsan, South Korea	0
European Union	0
Zilina, Slovakia	0
North America	0
Montgomery, US	0
Jaguar Land Rover	0
Wolverhampton engine plant	0
Changshu, China	0
Links with Ford	0
Mazda	0
Asia-Pacific	0
Nanjing, China	0
Hiroshima, Japan	0
Chonburi Province, Thailand	0
North America	0
Salamanca, Mexico	0
Nissan	0
Asia-Pacific	0
Huadu, China	0
Zhengzhou, China	0
Iwaki, Japan	0
Kohki, Japan	0

Nagoya, Japan.....	0
Yokohama, Japan.....	0
Europe	0
Sunderland, UK	0
NAFTA	0
Aguascalientes, Mexico.....	0
Decherd, Tennessee, USA	0
South America	0
Resende, Brazil	0
PSA Peugeot Citroën.....	0
Asia-Pacific.....	0
Xiangyang, China.....	0
Europe	0
Douvrin, France.....	0
Tremery, France	0
South America	0
Jeppener, Argentina	0
Porto Real, Brazil.....	0
Renault	0
Cleon, France	0
Valladolid, Spain.....	0
Pitesti, Romania	0
Bursa, Turkey	0
Curitiba, Brazil	0
Busan, Korea	0
Toyota	0
Asia Pacific	0
Hekinan/Higashichita, Japan	0
.....	0
.....	0
Kamigo, Japan	0
Kanda, Japan	0
Shimoyama, Japan	0
Tahara, Japan	0
Europe	0
Deeside, UK	0
Jelcz, Poland.....	0
Walbrzych, Poland.....	0
NAFTA	0
Buffalo, West Virginia, US.....	0
Georgetown, Kentucky, US.....	0
Huntsville, Alabama, US.....	0
South America	0

Porto Feliz, Brazil.....	0
Other engine plants.....	0
Volkswagen.....	0
Engine strategy.....	0
Engine production network.....	0
Europe	0
Salzgitter, Germany	0
Chemnitz, Germany	0
Gyor, Hungary.....	0
Polkowice, Poland.....	0
Mlada Boleslav, Czech Republic.....	0
Crewe, UK	0
North America.....	0
Puebla, Mexico	0
Silao, Mexico	0
South America	0
Sao Carlos, Brazil	0
Middle East and Africa	0
Uitenhage, South Africa	0
Asia-Pacific.....	0
FAW VW Changchun, China	0
FAW VW Dalian, China	0
Shanghai-VW, Shanghai, China	0
Shanghai-VW, Loutang, China	0
Chakan, India	0
Volvo.....	0
Skovde, Sweden.....	0
Zhangjiakou, China	0
Links with Ford	0

5: Supplier overview	20
Behr GmbH & Co. KG	20
Overview.....	20
Products.....	20
Organisation	20
Acquisition of Delphi's thermal business.....	20
Background information on Behr GmbH	0
BorgWarner.....	0
Business strategy driven by fuel economy considerations	0
New plant in Hungary	0
Investment accelerates in US production capacity	0
Growth at JLR and Volvo underpins BorgWarner's UK growth	0
Supplier award from Daimler confirms BorgWarner's status.....	0

Chinese market growth increasingly significant.....	0
Business with Hyundai growing	0
Future turbocharger technology developments at BorgWarner	0
Robert Bosch GmbH	0
Diesel systems.....	0
Gasoline systems.....	0
Bosch's common-rail injection system: development milestones	0
Bosch-Mahle	0
Bosch-Mahle entering off-road segment too	0
Continental AG	0
Fuel injection.....	0
Engine cooling	0
Turbochargers	0
Delphi Automotive	0
Fuel injection.....	0
Engine cooling	0
Denso	0
Federal-Mogul	0
Diesel technologies.....	0
Engine parts.....	0
Honeywell International Inc.	0
Honeywell's view of the turbocharger market	0
Increased diesel use in North America boosts Honeywell turbo use	0
Honeywell expecting strong growth in Chinese turbocharger use	0
Honeywell's turbos powering India to improved fuel efficiency	0
Technical focus.....	0
Expansion of production capacity in Europe	0
Honeywell adds new plant in China	0
IHI/IHI Charging Systems International	0
Introduction	0
Long term plans	0
Keihin Corp	0
Mahle	0
Martinrea	0
Mitsubishi Heavy Industries	0
Technology developments.....	0
Manufacturing network developments.....	0
Modine.....	0
Stanadyne	0
Schaeffler Group (INA-Holding)	0

Engine cooling	0
Engine technologies.....	0
Sogefi	0
Valeo.....	0
Engine components	0
Engine cooling	0
Visteon	0
Wabco.....	0
Others.....	0

6: Market forecasts..... **21**

Diesel engines	21
Europe	21
Europe, market penetration rates of diesel powertrains fitted to newly-assembled light vehicles, 2009-2029, (%).....	0
North America.....	0
North America, market penetration rates of diesel powertrains fitted to newly-assembled light vehicles, 2009-2029, (%).....	0
India.....	0
India, market penetration rates of diesel powertrains fitted to newly-assembled light vehicles, 2009-2029, (%)	0
Global forecasts	0
Market fitment/penetration rates of diesel powertrains fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%).....	0
Market volumes of diesel powertrains fitted to newly-assembled passenger cars and light vehicles, 2009-2029, ('000s units)	0
Petrol engines.....	0
Market fitment/penetration rates of petrol powertrains fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%).....	0
Market volumes of petrol powertrains fitted to newly-assembled passenger cars and light vehicles, 2009-2029, ('000s units)	0
Fuel injection systems	0
Market fitment/penetration rates of gasoline port injection systems fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%).....	0
Market fitment/penetration rates of gasoline direct injection systems fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%)	0
Turbochargers.....	0
Market fitment/penetration rates of turbochargers fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%)	0
Market volumes of turbochargers fitted to newly-assembled passenger cars and light vehicles, 2009-2029, ('000s units).....	0

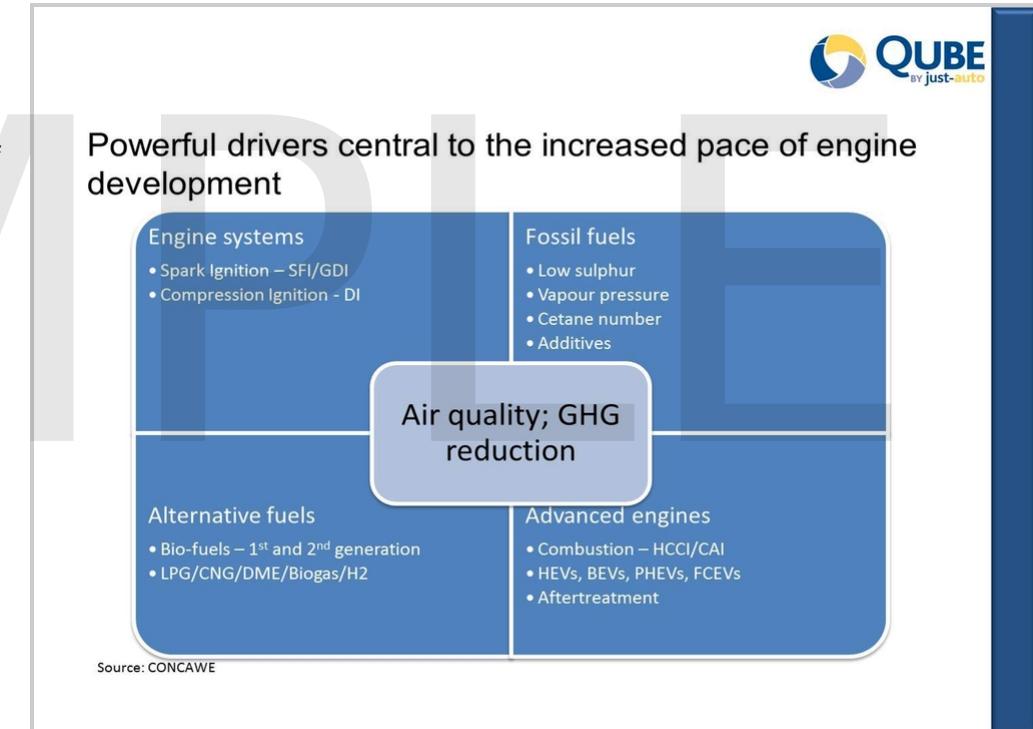
Tables

World manufacturer market shares of diesel injection systems for passenger cars and light vehicles, 2010-2014 (% of volume).....	0
European manufacturer market shares of diesel injection systems for passenger cars and light vehicles, 2010-2014 (% of volume).....	0
North American manufacturer market shares of diesel injection systems for passenger cars and light vehicles, 2010-2013 (% of volume)	0
South American manufacturer market shares of diesel injection systems for passenger cars and light vehicles, 2010-2013 (% of volume)	0
Asian manufacturer market shares of diesel injection systems for passenger cars and light vehicles, 2010-2014 (% of volume)	0
World manufacturer market shares of gasoline injection systems for passenger cars and light vehicles, 2010-2013 (% of volume).....	0
European manufacturer market shares of gasoline injection systems for passenger cars and light vehicles, 2010-2014 (% of volume).....	0
North American manufacturer market shares of gasoline injection systems for passenger cars and light vehicles, 2010-2013 (% of volume)	0
South American manufacturer market shares of gasoline injection systems for passenger cars and light vehicles, 2010-2014 (% of volume).....	0
Asian manufacturer market shares of gasoline injection systems for passenger cars and light vehicles, 2010-2014 (% of volume)	0
Global production of hydrogen fuel-cell vehicles (1990-2020 projections)	0
Bosch's common-rail injection system: development milestones	0
Europe, market penetration rates of diesel powertrains fitted to newly-assembled light vehicles, 2009-2029, (%).....	0
North America, market penetration rates of diesel powertrains fitted to newly-assembled light vehicles, 2009-2029, (%).....	0
India, market penetration rates of diesel powertrains fitted to newly-assembled light vehicles, 2009-2029, (%)	0
Market fitment/penetration rates of diesel powertrains fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%).....	0
Market volumes of diesel powertrains fitted to newly-assembled passenger cars and light vehicles, 2009-2029, ('000s units)	0
Market fitment/penetration rates of petrol powertrains fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%)	0
Market volumes of petrol powertrains fitted to newly-assembled passenger cars and light vehicles, 2009-2029, ('000s units)	0
Market fitment/penetration rates of gasoline port injection systems fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%).....	0
Market fitment/penetration rates of gasoline direct injection systems fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%)	0
Market fitment/penetration rates of turbochargers fitted to newly-assembled passenger cars and light vehicles, 2009-2029, (%)	0
Market volumes of turbochargers fitted to newly-assembled passenger cars and light vehicles, 2009-2029, ('000s units).....	22

Introduction

The automotive sector's requirement to meet future emission and CO2 regulations sees engine technology at the centre of most automakers' R&D efforts at present. While other elements such as the drivetrain, body materials, aerodynamics and tyres can all be further optimised for fuel economy – the engine is by far the biggest contributor to energy losses in a conventional driveline and, therefore, the biggest target for reducing CO2 emissions. Depending on operating load conditions, the engine contributes anywhere between [] and [] % of the energy losses in a vehicle. ZF, the transmission and driveline supplier, estimates that the engine contributes [] % of losses followed by the driveline ([] %), rolling resistance and aerodynamics (each with [] %), weight ([] %) and auxiliary systems ([] %). While work on improving driveline losses, reducing vehicle weight etc. is all ongoing in automakers' R&D departments, engine development remains key to meeting future emission legislation and also for maintaining automakers' brand attributes in terms of performance, driver feedback, comfort and control.

While meeting legislative requirements is a necessity for automakers, the legislation has to be met on a commercially viable basis - i.e. legislation cannot be met at any cost. Currently, it is estimated that the internal combustion engine is the single biggest cost contributor to a vehicle's Bill of Materials, accounting for anything between [] and [] % of material cost depending on the vehicle and engine type. Clearly, adding further cost to this reality is a consideration that has to be undertaken very carefully. Therefore, considered cost-benefit analyses have to be conceived by each automaker for the multiple technological paths that are available for meeting legislative and competitive requirements.



PESTER analysis

Political

- *The two over-riding political or policy drivers, which have determined much of the direction of the automotive industry in recent years, surround the need to reduce fuel consumption and emissions.*

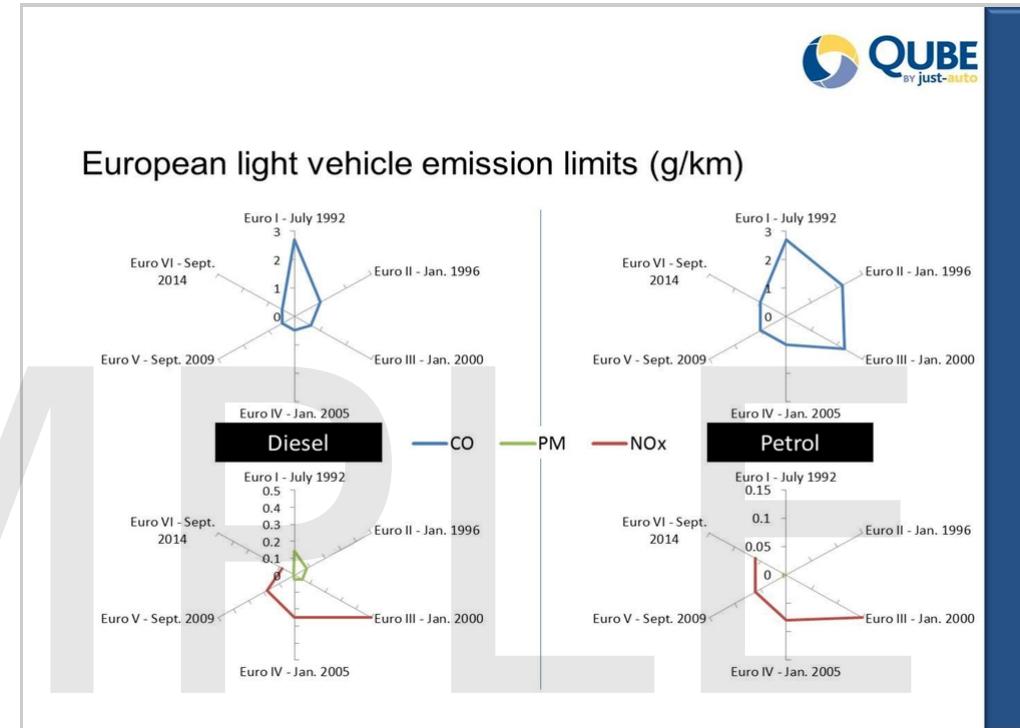
In terms of fuel economy, the political drivers are two-fold, i.e. the need to reduce harmful greenhouse gas emissions, but also energy security. China for example lacks its own major oil supplies so it would not be surprising to see an eventual political driven shift to full electric vehicles in China as the government seeks to reduce its dependence on external supplies of energy.

The more long-standing emission based driver of engine technology development is tailpipe (or criterion) emission regulations which first attracted political action due to their effect on urban air quality and associated health issues (a 2013 MIT study estimated 50,000 deaths a year caused by vehicle emissions alone in the US). Tailpipe emissions were first legislated against on a national basis in 1966 in Japan, but more widely known is the US's 1970 Clean Air Act, which was following California's lead after the state legislated in the 1950s.

A comprehensive reference for worldwide tailpipe emission, GHG emission standards and much more has been compiled by the automotive supplier Delphi and is linked to [here](#) [1], while EU light emission regulations are summarised on the slide.

- *The increasing global focus on fuel economy and CO2 emissions regulations is a key driver of developments in almost all automotive sectors presently and “behind the scenes” it is undoubtedly a key driver of change in engine technology.*

SAM



Technology overview

HCCI/CAI

It could be said that given the operating environment for internal combustion engines that the overriding development goals are to make the diesel engine as clean as the gasoline engine, while making the gasoline engine as efficient as the diesel engine. HCCI (Homogeneous Charge Compression Ignition) or Controlled Auto Ignition (CAI for gasoline engines) engines bridge diesel and gasoline technologies by combining the homogenous mixture injections from gasoline engines and diesel-like compression ignition of lean burn fuel-air mixtures. For HCCI, the fuel-air mixture is auto-ignited by the pressure and temperature of the diesel mixture, while for CAI the gasoline mixture is ignited by residual burned gases.

Using these methods instead of a spark plug means that the fuel-air mixture burns at a lower temperature, and homogeneously, rather than heterogeneously as in a conventional spark-ignition (SI) gasoline engine. Therefore, the exhaust gases from an HCCI/CAI engine contain only trace amounts of harmful compounds such as nitrogen oxide (NOx) and soot (PM) as combustion temperature does not exceed [] degrees Celsius when such emissions can form. As a result, the HCCI/CAI engine offers high thermal efficiency and, when operating at part loads, excellent fuel economy and a reduction in CO₂ emissions.

However, while HCCI or CAI is very appealing due to the inherently lower NOx emissions due to lower combustion temperatures mapping the ignition points of the fuel precisely has been difficult to achieve. Additionally while a high compression ratio would seem the logical path to achieve auto-ignition, research has shown that compression ratios above []:1 cause knocking issues during full-load operation. Therefore, many solutions are now looking at using high-levels of EGR to provide the thermal energy required for auto-ignition and one way of providing this is through valve actuation strategies including early closure of the exhaust valve to cause recompression.

OEM overview

The following section details the engine manufacturing facilities worldwide of the major OEMs, describing the level of integration, production volume and engine types produced.

BMW

BMW has three major engine manufacturing plants in Europe. They are located at Steyr, Austria; Hams Hall, UK and Munich, Germany. Additionally, there is a major new engine plant in Shenyang, China to support its Brilliance JV. Furthermore, BMW has a major castings plant at Landshut, Germany.

Steyr, Austria

- Capacity = █ mn engines per year; petrol and diesel units, 4- and █-cylinder units
- 2013 output = █,█ engines, split █,█ petrol and █,█ diesel
- Produces all diesels for Mini and is BMW's diesel R&D centre; additionally the plant is the source of the █.█L and █.█L diesels supplied to Toyota's Auris and Avensis models.
- Also manufactures crankcases (█.█ mn units in 2013), crankshafts (█.█ mn), cylinder heads (█.█ mn) and con-rods (█.█ mn)

Munich, Germany

- Main petrol engine plant, including high performance M engines
- Machining and assembly of c.█ engines per day, mostly █-cylinder petrol units, but also: V█s for M█ and V█ turbos for M█, X█, X█ and █-series and V█ for BMW █ and Rolls Royce Phantom and Ghost
- In 2013, 4,█ engines were built at Munich, with █,█ being █.█L four cylinder Twin Power units
- In June 2014, the plant produced its one millionth four-cylinder petrol engine just three and a half years after production start

Hams Hall, UK

- New plant, first engine produced January 2001
- Output has risen from █,█ units in 2001 to 2011 peak of approx. 4,█; 2013 output was █,█
- Produces █.

Supplier overview

Behr GmbH & Co. KG

Overview

In late 2013, Mahle became a majority shareholder in the Behr Group, a global manufacturer of vehicle air conditioning and engine cooling for passenger cars and commercial vehicles. This business has since been integrated into the Mahle Group as the Thermal Management business unit.

Products

- Complete HVAC systems, condensers, evaporators, storage evaporators and evaporator coatings, heater cores, blowers, air vents, fragrancing units. Control panels for passenger car and commercial vehicle air conditioning systems. Cooling plates and chillers for lithium-ion battery cooling
- Cooling modules, expansion tanks, high- and low-temperature radiators, exhaust gas coolers, direct and indirect charge air coolers, power steering oil coolers. VISCO® clutches and fans as well as Visco coolant pumps for commercial vehicle applications
- Wax elements, thermostat inserts, integral thermostats, housing thermostats, operating map thermostats, bypass thermostats, transmission oil thermostats, water valves, thermoswitches, coolant regulators, oil temperature regulators and inserts, sleeve valve thermostat inserts (since October 2014)

Organisation

Mahle's Thermal Management business unit employs [REDACTED] people at facilities in [REDACTED] locations.

Acquisition of Delphi's thermal business

In February 2015, Mahle revealed it is to acquire Delphi's thermal business reducing the size of the once huge supplier business, built up under General Motors ownership, still further. Delphi, which was spun off from GM around [REDACTED] years ago, then employed around [REDACTED], [REDACTED] people in the US in [REDACTED] factories. The latest sale will reduce this down to about [REDACTED] in five plants. Its thermal business has approximately [REDACTED], [REDACTED] employees with annual sales last year of US\$ [REDACTED].

Market forecasts

Diesel engines

Europe

We estimate that diesel currently accounts for a little over █% of all passenger car and light truck assembly in Western Europe, up from around █% in 2004.

Diesel's acceptance within Europe - which is in marked contrast to its reception in both North America and Japan - is attributed to a number of different factors, but a key driver has always been assumed to be the differential in excise duty between that levied on diesel and that levied on gasoline. However, the impact of incentivisation at the pump needs to be examined carefully, as the correlation between excise duty and market penetration is by no means a perfect one. Indeed diesel is now more expensive than petrol in many markets, especially the UK.

Diesel's significance in the European market is being progressively reduced by the development of smaller, more fuel-efficient gasoline engines. Turbochargers and other fuel efficiency technologies are seeing increasing application in petrol engines and this, plus the rise of hybrids, is likely to have a negative impact on European diesel sales. Furthermore, a forthcoming tightening of European NOx regulations with Euro █ from September 2014, is set to add considerable cost to the diesel aftertreatment systems. To meet Euro █, and iterations down the line, most automakers will elect to adopt Selective Catalytic Reduction (SCR) DeNOx systems whereby urea is dosed into the SCR catalyst breaking NOx emissions down into nitrogen and water. Automakers are not willing to absorb the additional costs, so it's likely that diesel will increase in price and erode their competitiveness in the market. Ironically, while Euro █ is threatening diesel dominance in Europe it is providing European automakers an easier path to selling diesels in the US market as being fit for sale in Europe will mean little rework for US sale due to emission legislation convergence.

Market volumes of turbochargers fitted to newly-assembled passenger cars and light vehicles, 2009-2029, ('000s units)

Market	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2024	2029
North America	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mercosur	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Western Europe	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Central Europe	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Russia	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Japan	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
China	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
India	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Korea	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Thailand	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Other Asia	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Iran	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
South Africa	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Australia	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total markets	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Source: just-auto, LMC Automotive and industry sources

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