

medium-duty trucks stabilised following sharp decreases in previous years. DEUTZ's revenue in the Asia-Pacific region rose by 15.9 per cent thanks to the positive impact of new customer projects.

## RESEARCH AND DEVELOPMENT

### Research and development expenditure (after deducting grants)<sup>1)</sup>

€ million (R&D ratio in %)

2016	50.4	(4.0)	
2015	40.8	(3.3)	
2014	53.1	(3.5)	
2013	52.6	(3.6)	
2012	62.1	(4.8)	

<sup>1)</sup> Spending on research and development after deducting grants received from major customers and development partners.

**R&D spending stepped up as planned** Expenditure on research and development in 2016 amounted to €53.5 million (2015: €49.5 million). After deducting grants received from major customers and development partners, expenditure was €50.4 million (2015: €40.8 million). The R&D ratio (after deducting grants), i.e. the ratio of net development expenditure to consolidated revenue, increased as planned to 4.0 per cent (2015: 3.3 per cent). The rise in R&D expenditure compared to the low level of spending in the prior year was largely attributable to the expansion of our product range and the continuous improvements to current engine series. In the year under review, 18.1 per cent of development expenditure after deducting grants was capitalised (2015: 31.9 per cent).

R&D spending by the DEUTZ Compact Engines segment after deducting grants came to €47.7 million (2015: €38.2 million) and that of the DEUTZ Customised Solutions segment came to €2.7 million (2015: €2.6 million).

**Stage V ready** In previous years, we had completely overhauled our engine portfolio in connection with the introduction of the EU Stage IV/US Tier 4 emissions standards. Our latest 'Stage V ready' TCD engines in the 2.9 to 16.0 litre capacity range are already equipped to meet the next European emissions standard, EU Stage V<sup>1)</sup>, which comes into effect in 2019. The diesel particulate filters needed to ensure compliance are now available as standard or as an option for engines with a capacity up to 7.8 litres. A diesel particulate filter meeting the new emissions standard will be introduced for all the other engines that will not require much additional space for installation. It is not yet known whether a further emissions standard will be introduced in the USA.

**Expansion of the product portfolio** We plan to enhance our product range with further developments. One of these is the D/TD/TCD 2.2, a three-cylinder engine that we are developing on the basis of the existing four-cylinder engine with a 2.9 litre capacity. In addition, we will offer smaller engines not only in a diesel variant but also in a liquefied petroleum gas (LPG) variant. The latter is a particularly interesting option for forklift trucks and other material handling applications. We are also currently developing a completely new 5 litre engine with four cylinders. The TCD 5.0 will supplement the DEUTZ product range in the 100 to 150 kW power range and is, at the same time, the first step in renewing our medium-duty engine series. The design of the engine's underlying technology features minimum pipework, fewer components, strict separation between the hot and cold sides to avoid the need for heat protection measures and a reduction in performance losses from the oil and water circuits. Another feature is its overhead camshaft.

**Preliminary development work at a high level** Exhaustive research and development will continue to form the basis for innovative products and services from DEUTZ in future. We have recently expanded our activity in the field of alternative fuels. As well as looking at natural gas, we are also focusing on hydrogen and fuels that are generated from renewable sources, and we have taken steps to expand our work with universities and other research institutes. A key focus of our preliminary development work is the combination of internal combustion engines and electric motors (hybridisation). We have also continued to concentrate on data transfer and analysis (Industry 4.0) so that we can offer our customers new services in the future.

**Intellectual property rights safeguard our know-how** We protect our know-how from unauthorised outside use by means of patents, patent applications and utility models. In 2016, we submitted 14 new patent applications, eight of which were in Germany. We now hold a total of 147 patents registered in Germany and 178 registered elsewhere.

## PROCUREMENT

Last year was characterised by an overall recovery in the commodities markets. Key purchasing objectives were achieved, such as reducing costs, ensuring continuity of supply, optimising quality and implementing embedded material group strategies.

**Commodity prices rising** While prices had continued to fall in the primary markets in 2015, the trend was reversed in 2016. Overall, all the average prices for the year were slightly higher than the ranges that had been forecast. However, commodity prices have only a limited influence on the price at which DEUTZ procures parts from suppliers because there is a very high element of value added.

<sup>1)</sup> Regulation (EU) 2016/1628 of the European Parliament and of the Council dated 14 September 2016.

**Measures implemented to reduce costs** With regard to the material groups, we primarily focused on exhaust after-treatment, exhaust gas recirculation and filtration last year and were able to reduce costs in the overall system. We see potential for achieving further savings by increasing the proportion of procurement from emerging markets. This applies, above all, to China because of the competitive environment, particularly as quality standards in the supplier industry are continuing to improve there. We have concluded a purchasing agreement with our joint venture DEUTZ (Dalian) Engine Co., Ltd., China, in order to coordinate procurement potential in the Chinese market.

**Supply chain and supplier performance** We have been able to further optimise supplier performance in the supply chain, with the overall trend continuing to improve.

## PRODUCTION

In production and logistics, the areas of focus in 2016 were workplace safety and ergonomics, product and process quality, and efficiency. We also implemented a number of measures as planned as part of efforts to optimise our network of sites.

**The Cologne plants, Germany** Last year, we initiated various steps aimed at improving quality and safeguarding the assembly processes in Cologne-Porz, our largest assembly site for production engines. This included optimising and renewing the cleaning and drying sections of the painting area and the automated adjustment of valve clearance. We also held kaizen workshops to further refine processes and procedures. Numerous tasks were consolidated in connection with vacating the Cologne-Deutz site, such as the management of empties. We also expanded shop floor management.

**Component manufacture** The process of vacating the Cologne-Deutz site began at the start of 2016. In May, the two transfer lines for the processing of crankcase housing for the 2011 and 91x engine series were moved to our plants in Zafra, Spain and Ulm, Germany. The relocation of shaft production from Cologne-Deutz to the newly built shaft centre in Cologne-Porz got under way in April without production being disrupted and was completed in February 2017. A total of 130 pieces of machinery and equipment were removed and then brought back on stream.

**The plants in Ulm and Übersee on Lake Chiemsee, Germany** We continued with our expansion of the Ulm plant in 2016. This site is evolving into the plant for small production runs, focusing on DCS products, project business, exchange engines and models that are soon to be discontinued. The Xchange assembly activities, which had been relocated in 2015, were optimised, costs were lowered and throughput times were shortened. In addition, the necessary preparations for integrating all of the other functions from the Übersee plant were carried

out. The relocation of the remaining functions in connection with the closure of the Übersee site will take place in 2017. In mechanical fabrication, all transfer lines were replaced with production machines; mechanical component production has thus been attuned to the flexibility that is required in small production runs.

**The Zafra plant, Spain** Our plant in Zafra, Spain produces the crankcases for engines of up to 4 litres in addition to the other major engine components already manufactured there, namely cylinder heads, conrods and gearwheels. Relocation of the production of crankcases for the 2011 engine series, which were previously built inhouse in Cologne-Deutz, was completed in 2016. Manufacturing of crankcases for the 2.9 engine series was also ramped up in 2016.

**The Pendergrass plant, USA** In the year under review, we extended our plant in Pendergrass, Georgia/USA, to cover the additional volume resulting from the growth of the exchange engine business. This included expanding capacity for removal and final assembly activities and increasing the number of production employees. There is now capacity for roughly 2,400 engines in one-shift operation.

## QUALITY

**Quality is part of our corporate culture** The DEUTZ name has always been synonymous with high-quality engines. We intend to continue to live up to this reputation.

For this reason, we introduced our zero-error strategy. Our main aim in pursuing this quality assurance programme is to ensure that we always meet our customers' expectations. The idea is to detect errors before they actually occur. And where errors do occur, we have to learn from them quickly in order not to make the same mistakes again.

In 2016, we developed a concept to implement our quality assurance programme and provided multipliers with the necessary training to run workshops. A large number of employees, from both production and administrative areas, took part in these workshops. Managers and employees were given intensive training on topics such as customer satisfaction, quality of work and the constructive handling of errors during two half-day sessions.

In addition, we conducted a study on quality focus in collaboration with the Laboratory for Machine Tools and Production Engineering (WZL). The objective was to assess the quality focus of employees in middle management. The study showed that the quality culture at DEUTZ was very strong on average in terms of external customer focus. In departments with a well-developed culture of quality, there is greater satisfaction among the employees and they value the quality performance of their team more highly.