Arthur D Little

Viewpoint

The future of diesel engines

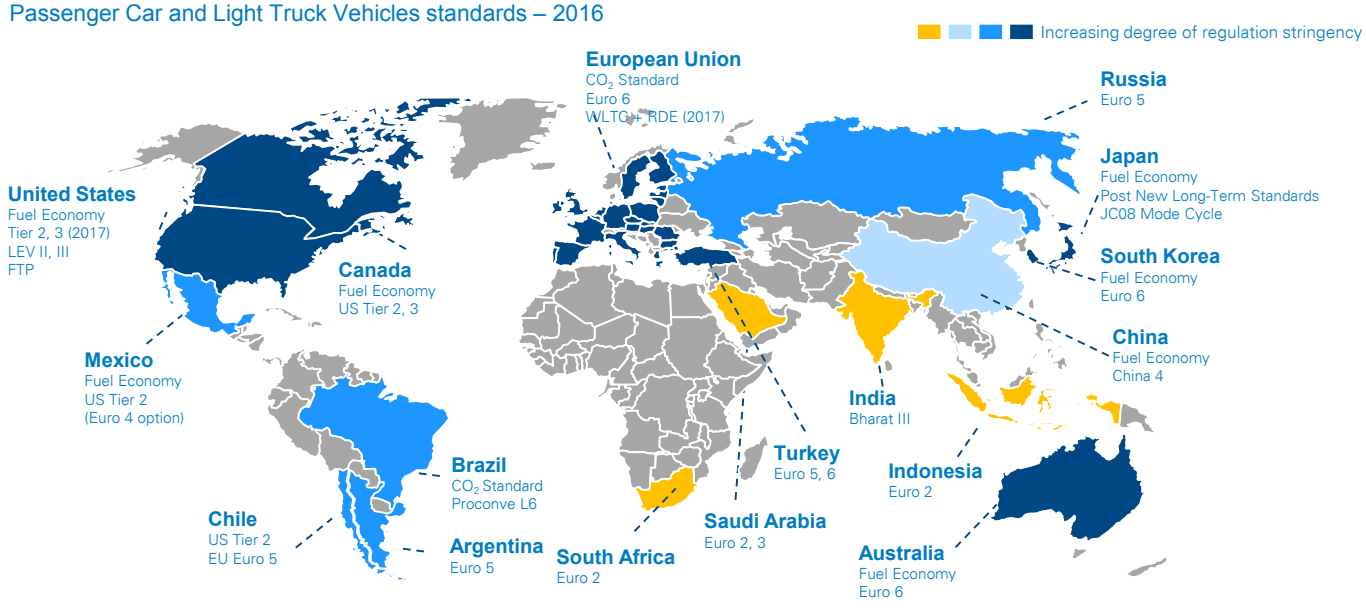
Diesel market share will stay above 50% in medium-upper car segments

Limits on emissions in the automotive sector are expected to become even more stringent in the future, with the US and EU leading the regulation pattern. Diesel accounts for about 50% of yearly car registrations in the EU (though less than 1% in the US) but, unlike with gasoline, exhaust emissions controls (mainly for NOx and PM) are more complex and require implementation of relatively new technologies and higher costs. The most likely scenario is a progressive diesel market-share decrease, though keeping a relevant positioning (above 50%) in medium-upper passenger car segments by 2030.

The "diesel" environmental issue

The transport sector is one of the main sources contributing to emissions of air pollutants, together with the energy, industry, commercial, institutional and household sectors, as well as agriculture and waste. The transport sector has considerably reduced its emissions over the past decade, yet it is still the largest contributor to NOx emissions, accounting for 46% of total EU-28 emissions[1]. Diesel-powered vehicles account for 80% of total NOx transport emissions, ranking as one of the main targets of governmental emissions reduction policies. For NOx emissions from diesel cars, limits were reduced by 68% from Euro 4 to Euro 6; however, recent analyses indicated that "real-world" performance – when driving on road under normal conditions – is much worse than a typical performance measured by "official" laboratory tests using the NEDC driving

Passenger Car and Light Truck Vehicles standards – 2016



Source: Arthur D. Little analysis

1 Air Quality in Europe – EEA 2015

cycle. This is true for a set of pollutants, not only for NOx; nevertheless, the amount of CO_2 (which is linearly correlated with fuel consumption) produced on the road can be 20–30% higher than official measurements indicate, whereas the differences are even higher for NOx emissions, and in particular for diesel vehicles. In the latter case, real-life measurements show that NOx emissions can be, on average, as much as four or five times higher than shown in laboratory measurements.

NOx emissions are then a big issue for diesel engines. And it is mainly a European OEM issue since nearly 50% of yearly new EU car registrations are diesel powered. The situation is different from other major markets. The US, Chinese and Japanese markets are all dominated by gasoline-powered cars, with diesel cars playing almost no role (except in India, where diesel market share is about 50%).

More stringent EU regulations

The EU is actually working not only on tightening emission reduction rules (standard Euro 6 up to Euro 6d), but also on improving testing procedures for pollutant emissions and fuel consumption of light-duty vehicles. Compared to tests under laboratory conditions, light-duty vehicles have significantly higher emissions when actually on the road, and two new testing procedures are currently being developed in order to assess the performance of vehicles under real-life conditions: Real Driving Emissions (RDE) for measuring regulated pollutants, and the Worldwide Harmonized Light-duty Vehicles Testing Procedure (WLTP) for measuring CO_2 emissions.

The European Commission wants to introduce the new mandatory RDE test procedure for type approval of light-duty vehicles by 2017. According to the new procedure, emissions will be measured on the road by a Portable Emission Measurement System (PEMS). This new procedure will imply significant changes for OEMs and higher costs; since exhaust-control systems will have to perform under a broad range of different operating conditions, the logistics of type-approval processes will have to be restructured and new measurement technology will be applied.

Diesel powertrain efficiency costs

Diesel powertrain efficiency improvement will be an important lever for European OEMs that want to fulfill EU emissions targets, either for CO_2 or NOx. In both cases, though, diesel powertrain efficiency improvement could require higher costs for emissions control.

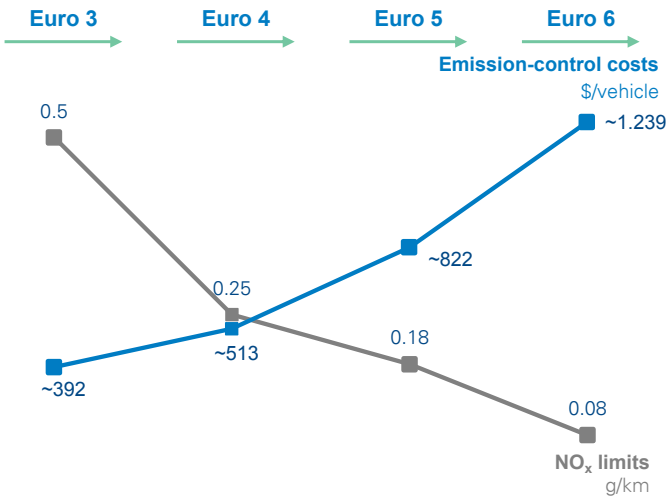
Starting from the actual 2015 target, 35 gCO_2/km reduction is needed to fulfill the 2021 emission target of 95 gCO_2/km.

According to EEA data, relevant contributions will come from ICE powertrain efficiency improvement (mainly from diesel), vehicle weight, aerodynamic drag and rolling resistance progress, alternative propulsion development.

A complete CO_2 reduction strategy should include a "diesel focus" in order to fill in the gap, and investments in R&D will be required.

The analysis of NOx emissions of diesel cars and related emission-control costs is a non-linear proportion: emission-control costs necessary to be compliant with EURO 6 limits are more than three times those required for EURO 3's limits.[2]

NOx limits of diesel cars and related emission control costs



Source: Arthur D. Little analysis on market data; ICCT 2012-215. Emission limits as tested over NEDC cycle. Emission-control costs valued for a European Diesel LDV (diesel engine V<2L)

Diesel engines require higher cost to control and reduce polluting emissions than gasoline engines. For gasoline engines, emission-control technologies (air-fuel control and catalytic after-treatment) have reached a high level of maturity, and the incremental compliance cost is low, even for more stringent standards. On the other hand, emission-control technologies for diesels (involving air management, fuel injection, after-treatment) are more complex and require higher costs.

Diesel engine future scenario

Market trends: Diesel will remain attractive to consumers because TCO will become a strong buying criterion. TCO cost models (including depreciation, fuel costs, insurance, maintenance, fees and taxes, repairs) show that diesel vehicles can have lower TCO than their respective gasoline counterparts in a three- to five-year time frame[3].

2 Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles – ICCT 2012, 2015

Policy and regulations: Analysis has shown that the problem of vehicles generating higher emissions on the road than in laboratory conditions affects mainly diesel vehicles regarding the pollutant substance NOx. On 12 February 2016, the European Council gave its green light for the adoption of the second package of rules to introduce RDE tests, establishing emission limits (80 mg/km) and applying dates in two steps:

- First step will apply from Sep 2017 with 2.1 conformity factor;
- Second step will apply from 2020 with 1.5 conformity factor.

Conformity factor introduces a higher allowance than the established limit, and the aim is to give manufacturers time to gradually adapt to the new RDE rules.

Technology: After-treatment technologies are available to reduce diesel engines' polluting emissions (DOC – diesel oxide catalyst, DPF – diesel particulate filter, SCR- selective catalytic reduction, LNT – lean NOx trap), but they require more investment and eventually higher costs.

Because of increasing costs to be "cleaner", diesel engines are expected to lose market share progressively, especially in lower car segments. That notwithstanding, they will help match the targets of the emissions-limit standards and still play a relevant role in the medium-upper vehicle segments.

Further insight from the industry

Research and development allowed to have even higher-performance engines, though keeping the displacement unchanged, so both premium and mass-market OEMs are reshaping their powertrain portfolios, including a higher proportion of smaller engines. In particular:

- All premium car makers are introducing basic engines of 2000cc, as well as in the medium-upper segments, which reduces the number of cylinders of their entire powertrain line-up (from 8 to 6 or from 6 to 4, with a single cylinder volume of about 500cc) at the same time. The final effect will be engines with higher efficiency and lower fuel consumption;
- Mass-market car makers are focusing on smaller engines (1.6/1.8 liters) and turbochargers that will provide customers with both the requested driving experience and lower fuel consumption due to lower displacement.

Conclusion

In the context of increasingly stringent automotive emissions regulations, "clean" diesel will still play an important role in helping OEMs reach emissions-standards targets in the next five to ten years. Yet clean diesel will require higher costs, and then diesel engines are expected to lose market share progressively, especially in lower car segments, though still playing a relevant role in the medium-upper vehicle segments. Since diesel will mainly remain the EU's "matter" (as well as India's), despite European manufacturers' efforts to push diesel technology in other markets (due to the "diesel scandal" too), OEMs that want to compete in the European market will need to take action on two strategic fronts:

- On the technology side:
  - Develop and implement the required technologies to fill the gap with more stringent standards and RDE test procedures at a reasonable commercial cost for the final client;
  - Accelerate the deployment of alternative powertrain solutions (e.g. electric or hybrid cars).
- On the market side:
  - Shift diesel focus to medium-upper car segments;
  - Convince final clients and policy makers that diesel is not an environmental issue.

Arthur D. Little can leverage its extensive knowledge and experience in the automotive industry and support OEMs in driving this big market, technology and regulatory change:

- Analyzing TCO components and the relative impact on customer choice;
- Identifying the emerging/future market trends in order to be well prepared for the shift of demand;
- Prioritizing technology investment in an uncertain market and regulatory scenario;
- Supporting discussions with regulatory organizations on technical/economical evidence;
- Defining the right communication path for customers.

3 Total Cost of Ownership: A Diesel Versus Gasoline Comparison – University of Michigan (2012-2013)

Arthur D Little

Viewpoint

Contacts

Kurt Baes
Belgium
baes.kurt@adlittle.com

Wolf-Dieter Hoppe
Central Europe
hoppe.wolf-dieter@adlittle.com

Russell Pell
China
pell.russell@adlittle.com

Eric Kirstetter
France
kirstetter.eric@adlittle.com

Fabrizio Arena
Italy
arena.fabrizio@adlittle.com

Hiroto Suzuki
Japan
suzuki.hiroto@adlittle.com

Kevin Lee
Korea
lee.kevin@adlittle.com

Rodolfo Guzman
Latin America
guzman.rodolfo@adlittle.com

Thomas Kuruvilla
Middle-East
kuruvilla.thomas@adlittle.com

Niklas Brundin
Nordic
brundin.niklas@adlittle.com

Jesus Portal
Spain
portal.jesus@adlittle.com

Coskun Baban
Turkey
baban.coskun@adlittle.com

Authors

Fabrizio Arena, Daniele Spera, Wolf-Dieter Hoppe, Hiroto Suzuki, Eric Kirstetter

Arthur D. Little

Arthur D. Little has been at the forefront of innovation since 1886. We are an acknowledged thought leader in linking strategy, innovation and transformation in technology-intensive and converging industries. We navigate our clients through changing business ecosystems to uncover new growth opportunities. We enable our clients to build innovation capabilities and transform their organizations.

Our consultants have strong practical industry experience combined with excellent knowledge of key trends and dynamics. Arthur D. Little is present in the most important business centers around the world. We are proud to serve most of the Fortune 1000 companies, in addition to other leading firms and public sector organizations.

For further information, please visit **www.adlittle.com**

www.adl.com/Diesel