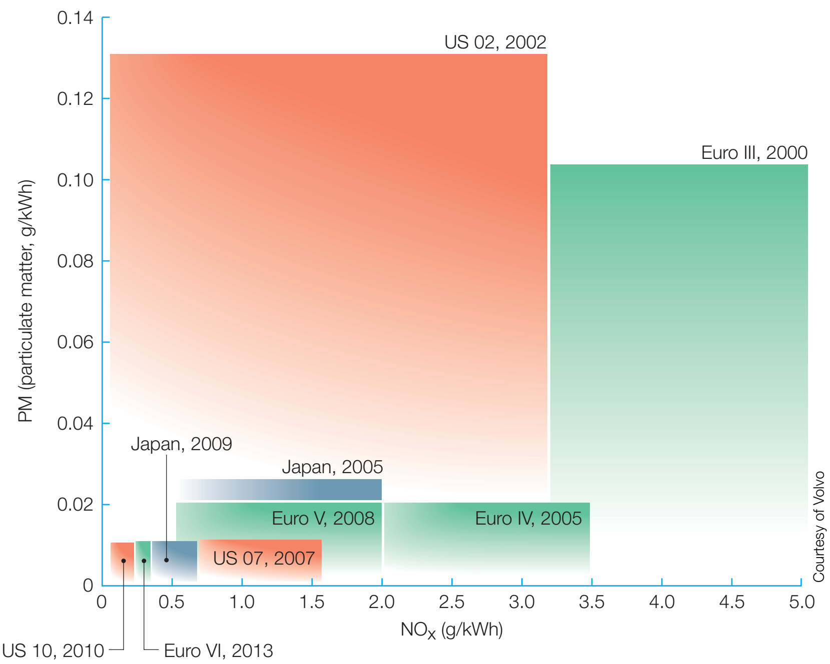
Transportation and fuels: looking ahead at heavy-duty vehicles

To be able to meet future overall efficiency and CO_2 targets, the focus should not be on the engines and the vehicles alone: the entire transportation system must be optimised.

Looking back on developments in heavy-duty vehicle (HDV) technology over the past 20–25 years, one could rightly describe them as a 'total makeover'. The improvements are particularly obvious for exhaust emissions but also for fuel consumption, durability and safety, where progress has been substantial. Improvements in diesel fuel quality have also been an important enabler for making these steps in engine technology possible. The parallel development of engine technology and fuel quality will have to continue into the future, not only in Europe and other developed countries but also, and perhaps even more importantly, in the developing countries around the world.

In everyday language, HDVs are what we usually call trucks and buses. In the EU legal system, they are defined as 'vehicles with a technically permissible maximum laden mass greater than 3,500 kg (N2, N3 for buses; M2, M3 for trucks). Transportation of goods and people is the 'blood circulation system' for economic life in modern society—more than 70% of all goods in Europe are transported by road. Efficient, durable and environmentally adapted trucks and buses are therefore essential, now and well into the future.

Figure 1 Emissions regulations for heavy-duty vehicles



Engine technology and fuel quality developments

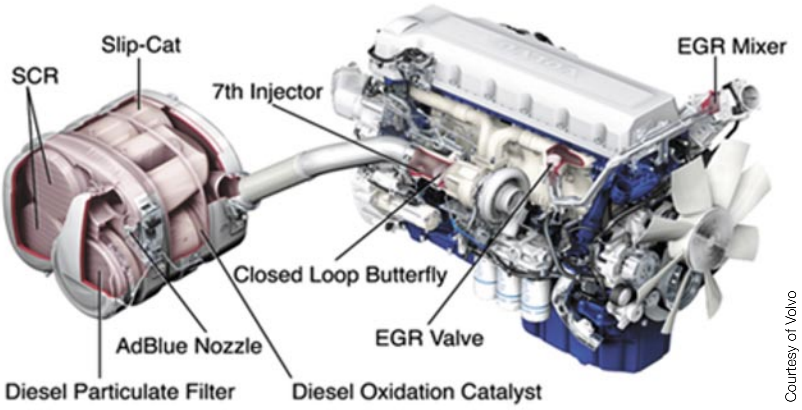
European emissions legislation for HDVs dates back to the mid 1980s (Figure 1). At that time, regulations only limited emissions of smoke and nitrogen oxides (NO_x). In 1992, the legislation on emissions requirements was expanded to include particulate matter (PM), carbon monoxide (CO) and gaseous hydrocarbons (HC). This so-called 'Euro I' regulation was the first step in a sequence of increasingly stringent legislative controls leading to the introduction of 'Euro VI' in 2014. Under Euro VI, all regulated emissions are drastically reduced, by about 95% for PM and by about 90% for NO_x, compared to Euro I some 25 years ago.

In the early years, engine technology improvements were mostly related to increased fuel injection pressure and improved combustion characteristics. The development of technology for electronically controlling fuel injection and combustion events began in the mid-1990s. This introduced new possibilities for affecting emissions formation inside the combustion chamber and for reducing fuel consumption.

The importance of fuel quality, particularly sulphur (S) content, became increasingly pronounced over time. In the late 1980s diesel fuel sulphur was limited to 2000–3000 ppm; this limit moved to 500 ppm for Euro II and 350 ppm for Euro III. When Euro IV was introduced in 2004 a 'step change' in emissions control occurred: exhaust aftertreatment systems (EATS) were also introduced into the various HDV segments (Figure 2). Euro VI, coming in 2014, will require the use of almost all emissions reduction technologies that are technically and economically viable, including exhaust gas recirculation (EGR), diesel particulate filters (DPF) and selective catalytic reduction (SCR).

Europe has been relatively successful over the years in matching fuel quality to changes in legal emissions limits and in-use compliance demands on the engine/vehicle side. The first European diesel fuel standard (EN590) was published by the European Committee for Standardization (CEN) in 1993, about the time that the Euro I HDV regulations came into force. EN590 has been revised periodically to reflect increasing engine requirements. In 1998 the EU Fuel Quality Directive

Figure 2 A typical exhaust aftertreatment system for Euro VI vehicles



(FQD) was put in place to govern environmental parameters (Directive 98/70/EC, amended 2009/30/EC).

The role of fuel quality has grown in importance at each regulatory step. Thanks to good cooperation between the automotive and oil industries through CEN, coherence between vehicle emissions and the necessary improvements in fuel quality has been maintained. This relationship was formalised through the Auto/Oil I and II programmes in the late 1990s, and the conclusions from these important joint industry studies formed the basis for the requirements of the FQD.

About 20 years ago, biodiesel (fatty acid methyl esters or FAME) began to appear as blending components in European diesel fuels. France and Austria introduced national standards or decrees to allow this, and eventually more countries supported the introduction of FAME into their markets. About 10 years ago a European FAME standard (EN14214) was introduced and a limit for FAME was introduced into EN590. Presently this limit is 7% vol. maximum (commonly called B7) and has been specified in the FQD since 2009. The automotive industry expects that, for general market fuels (EN590), this limit will not be changed in the foreseeable future.

As a fuel blending component, FAME has some inherent weaknesses. In particular, the stability and the cold operability characteristics are still of concern, and it is hoped that CEN will continue to work on ensuring the robustness of EN14214 and EN590 in these respects.

Microbial growth is another issue that has been accentuated because of increased FAME use. Because water is more soluble in fuels that contain FAME, microbial growth in fuel tanks can occur leading to problems with fuel filter plugging. Good housekeeping has become even more important than before.

Looking ahead—challenges and solutions

Powertrains and vehicles

For commercial transportation activities in general—and for heavy duty vehicles in particular—fuel efficiency has always been a key criterion. The reason for this is obvious: for a trucking company, the fuel bill is a major cost item, typically 30–35% of the total fleet operational costs, sometimes even more. Thus even a small increase in fuel cost could wipe out a significant part of the yearly profit for a trucking company.

Even before CO_2 emissions became a global concern, customer demands and the competition between vehicle manufacturers have kept fuel consumption at lowest possible levels for each type of application. Therefore, and without any specific regulatory requirements, the HDV industry has been able to significantly lower average fuel consumption over the years. For typical long haul truck applications, the average yearly improvements have historically been in the range of 1% or more. And notably, these improvements have been accomplished at the same time as exhaust emissions have been dramatically reduced.

Mandatory fuel economy requirements for HDVs are in place today in China and Japan. In the USA, the first stage of regulation will come into force in 2014 and the regulatory framework is being finalized in the EU. European legislation will build on a vehicle simulation tool, which will provide flexibility to simulate a large number of vehicle configurations and utilization patterns. The EU Commission, through its Joint Research Centre, is leading the verification of this tool, and the heavy-duty industry (through the European Automobile Manufacturers' Association, ACEA) is heavily involved and supporting this work.

A first step in the EU CO_2 legislation for HDVs will be a fuel economy labelling requirement, possibly coming into force in 2017 or 2018. The timing for the following step, which is likely to include mandatory CO_2 limits, is not yet clear but will probably be well beyond 2020.

Through the EC's 2011 White Paper on Transport, the EU has set some extremely ambitious long-term goals including lowering CO_2 emissions by 60% from the transport sector by 2050. However, commercial transport on highways is foreseen to increase steadily up to 2050, and even today the HDV fleet represents about two-thirds of total diesel fuel consumption in Europe. Consequently, a significant part of transport CO_2 emissions is likely to come from HDVs also in the future.

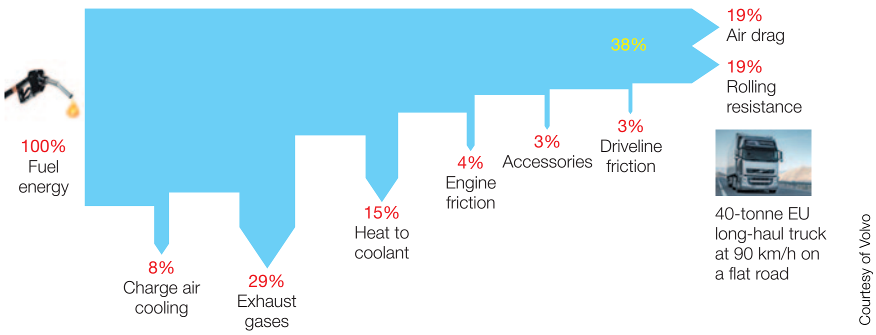
To support the 2050 targets, an estimated 3% per year improvement in fuel economy is likely to be needed from new sales of HDVs. To achieve this, within reasonable cost and complexity, will be a major challenge. Whether this contribution from HDVs will be enough is largely dependent on other factors, for example how transport demand develops over time, the extent to which electrification of the transport system takes off, and the quantity of sustainably-produced biofuels that will be available in the future.

It is important that the vehicle-specific fuel consumption requirements, as well as the long-term EU targets, build on relevant conditions and metrics. The metrics should be based on 'work done' principles, which for trucks means 'per tonne-kilometer' or possibly 'per m^3-kilometer'. In this respect, trucks should definitely not be treated just as 'supersized cars'.

To be able to meet future overall efficiency and CO_2 targets, the focus should not be on engines and vehicles alone: the entire transportation system must be optimised. This involves developments in intelligent logistics (higher average load factors and optimised freight routing), higher allowed cargo weights and improved road infrastructure in general. There will also need to be a contribution from the fuels, particularly biofuels and other renewable types of fuels.

To meet these ambitious regulatory and customer demands, a number of developments are already ongoing or foreseen.

Figure 3 Energy flow 'from fuel to wheels' in a typical HD long haul truck



Developments at the powertrain and vehicle level

The main thrust at the powertrain and vehicle level will be to maximise the efficiency of the combustion process, while minimising energy losses in the powertrain and in the rest of the vehicle setup (Figure 3).

This will require even higher injection pressures (above 2,500 bar) with more sophistication of the fuel injection strategy and phasing. It will also require better and more optimised exhaust catalysts and filter systems, as well as minimising heat losses. Heat recovery systems for exhaust and braking energy will be important elements in the future. To optimise the thermodynamic cycle(s) and move closer to the energetic limits dictated by the 'laws of nature', new combustion systems will be utilised and this may require new fuel properties.

There will be increasing focus on vehicle aerodynamics (including trailers) and 'right sizing' of the engine for the job to be done. Allowing larger and heavier vehicles on highways will also lower the per tonne-kilometer CO_2 footprint of goods transported on European roads. Hybridisation will be a key technology for lowering fuel consumption, especially for duty cycles that require a high degree of 'stop and go'. For city buses and distribution vehicles, the benefits of hybridisation include potential energy savings of up to 35%; such savings can be even greater in some non-road machinery. In the longer term we are likely to see more electrification even in segments that are today completely oriented towards internal combustion engines.

Fuel quality requirements and future fuels

As already noted, it is important that market fuel quality goes hand in hand with the emissions regulatory steps.

This link became mandatory when EATS were introduced by Euro IV. Thanks to the well-established EN590 standard and legal fuel requirements, EU diesel fuel quality is reasonably well under control today. The main quality items that still need to be worked on in CEN are related to:

- Fuel stability (mainly FAME-related): for biodiesel blending components, HVO (hydrotreated vegetable oils) are preferred due to their good combustion and handling properties.
- Cold flow performance and fuel filterability: today's methods and limits are not enough to ensure good cold operability, and efforts are ongoing in CEN to establish better tests.
- Injector deposits: modern common rail systems are more sensitive to internal diesel-injector deposits (often abbreviated to 'IDID').

There are also concerns regarding cross-border traffic travelling outside the EU. East of the EU borders, sulphur-free fuels are not widely available and the situation can be even worse for HDV traffic travelling towards the Middle-East. Only a few tank refills of high sulphur fuel can create significant damage to Euro VI EATS.

As vehicle emissions legislation is introduced and made more stringent around the world, the required fuel quality improvements must take place at the same time. To aid this process, the world automotive industry has issued a fuel quality guidance document, the so-called 'World-wide Fuel Charter' (WWFC). The WWFC can be found on the ACEA web site at www.acea.be.

Figure 4 Volvo DME trucks

Source: Maria Fäldt

Volvo strongly supports the inclusion of adequate market fuel specifications in the global emissions regulations that are being developed by UN ECE WP29 in Geneva. The EU has shown how cooperation between the industries and with the legislator can create a coordinated legal framework for market fuels and engine emissions requirements. The EU example can be favourably used also in other parts of the world.

The coming legal requirements, combined with societal and customer demands, are likely to bring improved and new engine concepts as well as new fuels. For many years to come, however, the mainstream engine technology will be based on diesel or 'diesel like' combustion. This will require:

- more developments in conventional diesel engines: increased importance of fuel cleanliness (FAME related, impurities) and tighter fuel specifications may be needed;
- new combustion concepts: new fuel characteristics may become important, such as volatility, ignition behaviour and oxygen content;
- dual fuel concepts: for example, methane (biogas, LNG/CNG) as the main fuel, with diesel fuel as an ignition enhancer; and
- optimised and sustainable biofuels: well-specified bio-products from non-food sources, methane and oxygenates (for example dimethyl ether, DME).

Increasingly, specially-adapted engines for new fuels and for new energy carriers will enter the market. By adapting the combustion system, the unique characteristics of, for instance 'single molecule' fuels, like alcohols, DME and methane, can be fully utilised.

The well-to-wheels performance (energy efficiency and CO_2), as well as the availability of a large and sustainable raw material base for fuel production, will be key to the success of any biofuel in the future. Volvo considers biomass gasification, with subsequent synthesis to DME, to be a very promising route to lower-CO_2 from transportation in the future. A test fleet of DME vehicles has been running successfully in Sweden over the past few years and DME activities are now being carried out by Volvo in the USA together with industry partners.

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Anders has been working in fuels and lubricants for more than 30 years and joined Volvo Technology in 1989. Before that he worked on FCC catalysts (Katalistiks BV) and additives for fuels and lubricants (Esso Chemical/Paramins). His present role within Volvo Group is as technical and policy advisor for fuels and energy related issues.

Anders is heavily involved in external industry groups, including ACEA WG F&L (Chairman since 2001), EUCAR EG Fuels, CEN TC19 and CEC (Chairman since 2013). He has an MSc degree from Abo Akademi and Licentiate Engineering degree from Chalmers University in Gothenburg Sweden.