The European Association of Internal
Combustion Engine Manufacturers

EUROMOT

FACT SHEET

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New proposed EU Regulation for nonroad mobile machinery engines – COM(2014) 581 final

Frequently Asked Questions

1. General context

Q1: When did exhaust emissions regulation for machinery first take effect, and what happened since?

A1: The EU nonroad emission directive 97/68/EC was first published in 1997 and compliance with this directive first became mandatory for placing diesel engines for nonroad machines on the European Community market on 01 January 1999. Both NOx and PM mass limits of EU Stage IV that applies from 01 January 2014 are now more than 95 percent lower than pre-regulated engine emission levels, which is a massive reduction in just 15 years.

Whilst the existing directive initially only included diesel engines for nonroad equipment used primarily in the agricultural, construction and industrial sectors, it has been expanded in scope over the years. It now additionally includes diesel engines for locomotives, railcars and inland waterway vessels, plus small petrol engines for equipment such as chainsaws and lawn mowers, each with limit values appropriate to the engine size and sector.

Q2 : What power range do nonroad engines span?

A2 : The full range of nonroad machinery uses engines stretching from less than 1 kW with total engine cylinder capacity of a fraction of a litre, through to around 3500 kW with a total engine cylinder capacity in excess of 100 litres. This range of power and cylinder capacity far exceeds the range for all onroad motorcycles, cars, buses and trucks combined. In fact, even the largest heavy-duty onhighway trucks generally use engines of less than 500 kW with a typical capacity not exceeding 16 litres.

Q3 : How common are engines with power greater than 560 kW?

A3 : Despite the very broad range of engines used by nonroad machinery, only a very small proportion of the engines actually have a power greater than 560 kW. Taking all of the nonroad engines used in construction, mining, agriculture and general industry together, it is estimated that greater than 99.9% of these nonroad engines are less than 560 kW. The remaining 0.1% are used predominantly at remote sites in quarry and mining equipment.

The other applications where engines with power greater than 560 kW can be found are primarily in rail locomotives and inland waterway vessels, but in both cases annual production volumes for the EU market will be very low, from single figures to a few tens of units for an engine type. These are the only engines of this size that are already regulated by the existing directive.

Generating sets may also use engines with power greater than 560 kW, but most units of this size will be stationary, in fixed locations, rather than mobile. Stationary engines are not in scope of nonroad legislation but are in scope of proposed Medium Combustion Plant (MCP) Directive - (COM(2013) 919 final.

Q4 : Why does the nonroad sector often follow behind the onroad sector regarding exhaust emissions legislation?

A4: The onroad sector has a much higher in-use vehicle population. It consequently produces a larger share of emissions into the atmosphere and importantly enables the cost of introduction of new technologies to be spread over correspondingly higher production volumes, increasing the cost-effectiveness of regulation. Despite the fact that onhighway regulation often leads, the gap between the sectors is rapidly closing. In fact, the frequency of introduction of new emission stages for nonroad has been faster than for onhighway despite the smaller production volumes and higher product diversity of the nonroad sector. The current nonroad stage IV that commenced in 2014 has emission levels of a similar magnitude to heavy duty onhighway Euro VI that also applies in 2014, except for the absence of the particle number limit, now foreseen for nonroad stage V. Some manufacturers are already producing machines

using the same engine technologies used for Euro VI trucks, where they are of a similar engine power range.

2. European Commission Stage V Proposal

Q5 : What kind of equipment is covered by the proposed stage V regulation? What is not?

A5 : The scope of the proposed stage V regulation is extremely broad. Basically it encompasses almost all mobile engines that are not included in a vehicle regulation elsewhere. It continues to include all the types of equipment that are already in scope of the existing directive 97/68/EC, ranging from petrol-fuelled chainsaws and lawnmowers, through to diesel-fuelled excavators, loaders, forklifts, combine harvesters, transport refrigeration units and mobile generating sets, to rail locomotives and inland waterway vessels. It broadens the range of engine types included for the above equipment by opening the range of power and the range of fuels that are in scope. It adds for the first time engines for all-terrain and side-by-side vehicles (ATVs & SbS) and for snowmobiles.

In fact the EU is the only place in the world where such a diverse range of engine-powered equipment is included in a single regulation. In other regions, such as the US, these applications are spread across a range of different regulations, each of which balances the needs of society with the needs of the specific sector.

Equipment for which the engines would not be subject to this regulation would be any already covered by vehicle emission regulations or equipment used in stationary applications.

Q6 : What impact would the proposed stage V have on manufacturers of construction, agricultural and industrial equipment?

A6 : Stage V would result in the EU having overall the most stringent emission limit values of all the major world economies for general nonroad equipment used in the construction, agricultural and industrial sectors. There are three main aspects to the proposed EU regulation that impact these machine manufacturers, namely expansion of EU regulation to include the smallest (less than 19 kW) and largest (greater than 560 kW) machines for the first time, setting a minimum stringency over the entire power range no less than that which applies in the USA (Tier 4 final), and then overtaking the USA by setting even more stringent requirements for particle mass and particle number over the engine power range 19 – 560 kW. Whilst the proposed regulation (appropriately) does not mandate a specific technology to comply with the proposed particle number limit, as with onroad heavy-duty Euro VI regulation, it is widely anticipated that this will result in the widespread application of diesel

particulate filters (DPFs) on construction equipment across the power range to which it applies.

The technologies chosen by engine and machine manufacturers to achieve Tier 4 final/stage IV vary. Whilst some manufacturers have already chosen to incorporate a DPF, others have chosen an alternative technology path. In consequence, the impact of a particle number limit will vary considerably from one machine manufacturer to another, and in some cases also between product families for a given manufacturer. In those cases where a DPF is already present for stage IV the impact of a particle number limit may be limited to a new type approval for the engine, whilst for other manufacturers the incorporation of a DPF may require a complete re-design of the engine and machine. The distribution of the impact is consequently likely to be highly bi-modal.

Q7 : Are there alternatives to diesel particulate filters (DPFs) to comply with the proposed particle number limits?

A7 : As is already the case for vehicle legislation such as Euro VI for trucks, the legislation sets limit values that the engines must pass but does not mandate the use of a particular technology. Consequently any technology that can pass the limit values could be used. At this point in time it appears that no manufacturer has yet developed an alternative to the so-called wall-flow DPF that is capable of passing the particle number limit.

Q8 : Are DPFs for nonroad mobile machinery the same as those for on-road trucks?

A8 : The basic technology for achieving the filtration inside the DPF is often the same. But overall, the complete DPF will not generally be the same part as used for the trucks.

The filter element must be sized to suit the application then encapsulated into some form of sealed housing that additionally protects the filter from damage due to impact or vibration, whilst being shaped to fit into the available space on the machine. A DPF works by trapping fine particles, which must eventually be removed. The carbon-based material, or ‘soot’, must be frequently burned-off in a process called regeneration, whilst the non-combustible ash must be occasionally cleaned out during service. Consequently the design of any DPF needs to take care of the housing and the regeneration strategy, and ensure there is enough capacity to hold the ash until the machine is serviced. The combination of these factors is usually different for nonroad machines compared to trucks, thus whilst the internal element that performs the filtration may be the same, the overall design may be quite different.

After-treatment systems similar to those for Euro VI, adapted for nonroad, are being used at stage IIIB and IV in power range 56 – 560 kW by some engine manufacturers

for certain engine families. Bespoke multi-can or industrial-derived after-treatment would generally be required for larger engines, quite different from the on-road systems. There are installation and cost challenges to overcome to scale the on-road technology down to the nonroad power range 19 – 56 kW, but compact construction machines with DPF are appearing in some markets.

Q9: Why is the proposed particle number limit for stage V different to the limit for Euro VI trucks?

A9: Even for the exact same DPF, the way in which the engine is operated will change the particle number result that can be achieved. During engine operation a layer of particulate, often called the 'soot cake' builds up on the inner surface of the filter. This soot cake actually improves the filtration efficiency and is necessary to pass the test. The condition of the soot cake during the emission test consequently affects the particle number result.

Onroad and nonroad engines are tested on different cycles that are intended to replicate conditions that the respective onroad or nonroad engine may experience in use. The condition of the soot cake will be influenced by the exhaust gas temperature history, which will be different for each test cycle and may be influenced by the NOx control system warm-up strategy.

This was already recognized for onroad with Euro VI having two different limits for the two different test cycles. For nonroad, the limit selected by European Commission of 1×10^{12} particles/kWh has been used in Switzerland for several years for machinery used on construction sites, and has been shown to require a DPF. However, there is limited data on the achievability of this limit value on the wider range of engine power and test cycles used in the inland waterway sector, especially for engines with power greater than 560 kW.

Q10: What impact would the proposed stage V have on the inland waterway sector?

A10: As currently proposed, stage V would result in the EU having overall the most stringent emission limit values of all the major world economies for marine engines. Over the range 37 – 300 kW the European Commission has chosen limit values that align with the strictest US and IMO limit values. The concern in this sector is that European Commission have gone too far with their proposal for engines with power greater than 300 kW and especially for engines with power greater than 1000 kW.

The EU market for inland waterway engines is currently estimated to be around 150 engines per year across all manufacturers and engine powers. The sector also has particular application constraints, including:

- Completely different cooling system
  - Secondary liquid heat exchange instead of direct radiator cooling
  - Higher intake air temperature = higher NOx compared to similar nonroad/on-road engine
- Restricted surface temperatures (safety & installation constraint)
  - Different design to land-based applications (eg water jacketed exhaust/turbo)
  - Exhaust gas re-circulation not used & lower exhaust temperature for after-treatment
  - Further constrains after-treatment design (regeneration of DPF?)
- Full power required at all times (safety constraint)
  - Engine is needed for braking and steering (what happens if DPF blocks?)
- Ultra-low sulphur diesel (ULSD) not available for International market
  - Technology used must be sulphur-tolerant to enable International market opportunity

Given the high costs involved, it is difficult to see how a valid business case for developing unique products for this niche EU market could be established. Consequently overly ambitious unique EU limits could have a negative impact on the sector.

Q11: What impact would the proposed stage V have on the manufacturers of mobile generating sets?

A11 : As currently proposed, stage V would result in a major jump in technology for the mobile generating set industry. Currently the limit values for the constant speed engines used in generating sets lag behind those for the variable speed engines used in most other machinery, and consequently exhaust after-treatment is not required. The proposed stage V would require after-treatment to be applied in the EU to this sector for the first time. The stringency over the entire power range would be no less than that which applies in the USA (Tier 4 final), but going further than the USA by setting even more stringent requirements for particle mass and particle number over the engine power range 19 – 560 kW.

Q12: By how much will the emission limits reduce in each power range at stage V for general nonroad equipment?

A12: The amount of reduction from the current in-force emission stage to stage V will vary by power range. The largest reductions in the actual mass of emissions from general nonroad machinery will be for those categories where the current EU stage is not yet aligned with the corresponding US emission mass limits, especially for 19 – 37 kW

and greater than 560 kW. In the latter case the emission limits are changing from being completely unregulated to matching the latest US Tier 4 final emission level, which is the most stringent in the world for that power category. On the other hand, although there is a 60 percent reduction in particulate mass emissions across the power ranges 37 –560 kW, the starting point is already very low (0.025 g/kWh), so the absolute incremental reduction in mass is actually very small.

Q13: Why does the proposed regulation differentiate between power ranges? Why do they have different introduction dates?

A14: Unlike onhighway emission regulation where there is a distinction made between the regulation of the smallest and largest vehicles, with separate legislation for motor cycles, light duty and heavy duty vehicles, the proposed nonroad regulation includes in scope engines for a huge range of equipment with engine power from less than 1 kW to around 3500 kW, with total engine cylinder capacity ranging from a fraction of a litre to more than 100 litres. It is necessary to recognise that there is no single technical solution that is optimum or even suitable for this entire range. As a consequence, historically (and globally), the emission limit values, associated test cycles and other technical requirements have been differentiated by application sector and engine power.

During current discussions on the potential adaptation of onhighway heavy-duty Euro VI requirements to the nonroad sector it should not be assumed that all features of the Euro VI regulations are technically or commercially feasible for all engine (and machine) sizes. The availability of certain key technologies (such as particulate filters and NOx after-treatment) is not the only consideration. Substantial development work and resources are required for adaptation of onroad technology to NRMM engines and machines and this adaptation may not be practical or cost effective across all applications and power ranges.

Considerations during the adaptation process include:

- Design changes to withstand the appropriate nonroad conditions, including long-term exposure to more aggressive environments, high shock loading and vibration compared with onhighway applications.
- Physical shape & size reconfiguration in order to fit within dimensional envelope of the variety of nonroad machines and minimise overall size of after-treatment system.
- Wide variety of work/load cycles over which after-treatment systems must work effectively, including rapid transient loading.
- Ensuring appropriate thermal and chemical balances in the exhaust system for effective after-treatment system operation including regeneration of particle filter systems under a wide range of conditions.

- Re-optimisation of entire engine & after-treatment system to ensure acceptable transient response and minimise fuel & reagent consumption.

Consequently, whilst engine & machine manufacturers support the objective of emission reductions, with associated air quality and health benefits, the technical impact and cost-effectiveness of a given emission limit value MUST be individually assessed for different sectors and power classes. It is unacceptable to consider the entire range of engines en bloc. Furthermore, it is impractical for manufacturers to simultaneously re-design all of their engines and machines across all power ranges and it is appropriate to provide some stagger in the introduction dates. In this instance the proposed stagger is minimal, with stage V for most nonroad power ranges applying on 01 Jan 2019, and only a few given extra time until 2020 or 2021.

Q15: Why should big engines with power greater than 560 kW be treated differently? Why should the EU not set ambitious particle number targets for them as well? How large is the market share of these machines/engines?

A15: The machine population data reported in the 2007 JRC review indicated that (for EU 15 in 2005) the engine power range greater than 560 kW encompassed less than 0.3% of all new construction equipment[1]. This equates to less than 0.1% of the combined total of engines for the construction, mining, agricultural and industrial sectors. Up until now the proportion of machines placed on the market in the EU with this size of engine has not warranted emission regulation at all. Whilst the US will have been through several emission steps prior to reaching the most stringent Tier 4 final limit values it is proposed that the EU aligns with these limits in one step. The data collected by Arcadis indicated that aligning with US in this power class gave the highest ratio of environmental gain to compliance cost (almost 12:1).

It is important to understand the use and scale of the machines that would fall into this category. The majority will be used for mass excavation and material handling associated with mineral extraction, such as large quarries and open mines. These sites will typically be remote from areas of population and closed to pedestrian access (for safety reasons), such that the only workers near these machines when in operation will be the machine operators sitting in closed ventilated cabins. Very few machines will be small enough to be transported on the road without being dismantled and most will be assembled on site and remain at a single quarry or mine for their entire working life. These are certainly NOT normally found working in towns & cities.

In some cases, especially at the high end of the power scale, the average number of machines placed on the EU market will be measured in years elapsed per machine sold rather than machines sold per year. Extremely few machines will have EU sales

[1] Reviewing Directive 97/68/EC “Emissions from nonroad mobile machinery”: Final Report of the Impact Assessment Study commissioned by the European Commission to ARCADIS and Transport & Mobility Leuven (ENTR/04/093 Lot 5; SI2.ACPROCE018014400); published on 30 January 2009.

volumes greater than 10 units per year. This would make the recovery of investment in a unique engine/machine for the EU highly doubtful, with the prospect that it becomes more cost-effective to maintain machines with existing (unregulated) engines, compared to replacement with new products. In this case the adoption of overly ambitious limit values could be counter-productive and actually result in higher overall emissions to the atmosphere than would be achieved with less ambitious limits.

Q16: If nonroad engines greater than 560 kW have no particle number limit, will manufacturers not put bigger engines into machines that currently use engines smaller than 560 kW to circumvent the regulation?

A16: Today the general nonroad engines in the 130 – 560 kW power range are already subject to a highly stringent stage IV regulation whereas engines greater than 560 kW are totally unregulated. In addition, a number of manufacturers producing engines in the 130 – 560 kW power range already fit diesel particulate filters. Even with such a huge difference in regulation above and below 560 kW there is no discernable trend to systematically move machines from the lower to the higher power range. This is not particularly surprising when it is realised that more than 80 % of the new machines in the 130 – 560 kW power range are estimated to have have engines < 300 kW and only a very small proportion will have engines close to the 560 kW boundary. The European Commission proposal will actually considerably narrow the difference in emissions between engines above and below 560 kW.

Q17: Why does the limit for hydrocarbon (HC) need to be adjusted for engines operated on natural gas?

A17: Hydrocarbon or 'HC' is basically a measurement of fuel that was not completely burned in the cylinder of the engine and escapes into the exhaust. The EU differs in the way it measures HC compared to regions such as the USA. In the USA the measurement of hydrocarbon excludes methane, because it is considered that it does not directly affect health. In comparison, the measurement of HC required in the current nonroad emission directive, and proposed future nonroad regulation includes methane.

Engines operated on natural gas, such as CNG or LNG, will suffer from having a certain amount of methane 'slip' entering the exhaust. Unless this is converted by a catalyst in the exhaust it will be measured during the emission test. The difficulty is that methane (and ethane) requires a high exhaust temperature in order to be catalyzed successfully (T50 for catalysis of methane & ethane in range 400 – 450 °C). Whilst for spark-ignited engines operated with a stoichiometric ratio of air and fuel, as used in some on-highway applications, the exhaust temperature is hot enough for catalysis, the necessary temperature is not achievable with the type of

lean-burn compression ignition engine foreseen for use in applications such as inland waterways. Consequently the methane slip will increase the overall HC emission. The EU is making a major investment in the natural gas re-fuelling infrastructure for the inland waterways. The adjustment to the HC limit proposed by European Commission enables the introduction of natural gas engines to the sector.

Q18: What does the proposed regulation say about CO_2?

A18: The proposed regulation requires the CO_2 measured during the type approval of the engine to be documented. Whilst this may be relevant for the machine manufacturer, in most cases this is actually misleading for the end-user because the design of the machine in which the engine will be used and the way in which the machine is operated will have the most significant influence on the CO_2 that is emitted. There is a direct correlation between the fuel consumed by a machine and the CO_2 emitted. Manufacturers are continually striving to reduce CO_2 from nonroad machines due to market pressure to reduce fuel consumption.

Q19: Does the proposed regulation limit NO_2?

A19: The proposed regulation applies strict controls on all oxides of Nitrogen (NO_x), which includes NO_2. This is the same approach to controlling NO_2 that is already used in onroad and nonroad sectors worldwide.

Q20 : What happens to machinery already on the market? Does the proposed new regulation affect these machines as well?

A20 : It does not impact these machines directly but may impact the maintenance of such machines. The legislation that is proposed only regulates the first placing on the market of an engine or machine containing an engine. That means machines already placed on the market will not generally be impacted and can still be freely bought and sold.

The exception where the existing machines may be impacted is in case a machine built to an emission level older than stage V needs a new engine at some point in its life. Unlike for cars, trucks and buses in the EU, where manufacturers are permitted to produce new replacement engines where necessary, the proposed new nonroad regulation does not permit this. In fact, even supplying re-manufactured engines re-built from re-furbished parts would be prevented, unless the engine being re-used originated from inside the EU. This limits the options for maintaining the machine when in service.

Q21 : What is the risk that 'old' machines will be used longer?

A21 : That depends whether the proposed legislation strikes the right balance between the stringency of the limit values and the needs of the sector. Is the proposed regulation cost effective for the sector, not just for society as a whole, so that purchasing new machines is an attractive option, or at least a financially viable option, versus maintaining existing machines?

The customer of the machine manufacturer will generally be an organisation that will use the machine to provide a service, such as road maintenance, or will use the machine as part of a production process, such as farming, construction or mineral extraction (mines & quarries). In some cases such as locomotives and inland waterway vessels the machine is used for transport of goods or passengers. The end-consumer will mostly be interested in the cost of the final product or service, (e.g. housing, tax to use/maintain roads, food from the supermarket, etc) but will have very limited interest in the machines used to provide these. Consequently, machine owners will focus strongly on the ability of the machine to perform the required task, the maximum productivity and reliability of the machine, and especially minimum ownership costs (purchase and operating costs).

Whilst there will always be market pressure to reduce fuel consumption (a major element of operating costs) the emission level of the engine is not a key selling feature. It is highly unlikely that customers will be willing to pay a premium for a further lowering of emissions, unless this new machine decreases the overall cost of the service or production process compared to maintaining the existing machine.

In summary, there will be no contribution from a more ambitious stage of nonroad emission regulation if the machines become unattractive for the end-user to purchase, either due to:

- High first cost;
- High cost of ownership; or
- Constrained functionality;

in comparison to maintaining existing machines.

The same considerations exist in respect to attempting to sell such machines into markets where such emission levels are not legislated. Where lower cost higher emission machines remain available in the market, there will be little or no demand for the lower emission variants, even if the correct fuel were available.

Q22 : The previous EU and Japanese nonroad emission stages were largely aligned with those of the US. Now the EU goes forward on its own, will the US & Japan align their limits with those of the EU?

A22 : This would be highly desirable from an engine manufacturer perspective, in order to spread the cost of the latest stages of emission reduction over the largest possible market. It is not yet clear whether this will be achieved, but the European Commission, as the proposer of legislation that disturbs the existing harmonization between these three regions, should, with support of the industry, advocate alignment to the US & Japanese authorities.

Q23 : Aside from the US & Japan what does the legislation look like in other regions outside the EU? What are other countries doing?

A23 : Today most of the world outside of the EU, US & Japan does not have the correct fuel quality to operate, or the infrastructure to maintain, most engines of stage IIIB and later emission level. The number of countries with emission legislation for nonroad equipment is increasing, but generally at a level equivalent to EU stage IIIA or earlier. Consequently, most manufacturers design and build less sophisticated 'export' versions of their engines and machines. This practice is likely to continue until other regions 'catch-up' and is not prevented by the proposed regulation.

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