Eminox

Eminox Stage VI and future fuels white paper:

What is Stage VI and will it have any real benefits?

May 2023

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Contents

Stage VI and future fuels whitepaper: The next stage of emissions legislation, why they may not be all they seem, and why alternative fuels really are the future.

1 - Introduction

In this whitepaper, Dr David Phillips, Engineering Director, Eminox looks at the anticipated Stage VI emission regulations, the potential impact it may bring for emissions reduction, and considers how the world will transition to alternative, low carbon fuels to tackle ever more concerning greenhouse gas emissions.

The Stage VI emissions regulation, like the current Stage V legislation, is expected to focus on reducing emissions harmful to health such as hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM) and oxides of nitrogen (NOx). However, anticipated alignment with the recent Euro 7 directive means Stage VI is unlikely to directly address carbon dioxide (CO_2) emissions.

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2 – Stage VI Emissions Regulations

Over the last few years significant effort and refinement has gone into the development of Euro 7 regulation resulting in well-defined emissions targets and an introduction date of July 2025 for light duty, and July 2027 for heavy duty applications. Now the content of the Euro 7 regulation is established, the definition of Stage VI regulations is expected to be, in comparison, a shorter and less controversial process.

The extent of further emissions reduction in the Euro 7 regulation is expected to carry over into Stage VI, which should drive a similar level of technology development to meet either standard. The introduction date for Stage VI is likely to trail Euro 7 by about two years, leading to a probable introduction timeline of 2029-2030.

A key new feature of Euro 7 is that it will bring light and heavy duty together into a single regulation, the implications are lower here for Stage VI as regulations for non-road mobile machinery (NRMM), generators, rail, and marine inland waterways (IWW) were already combined at Stage V.

Another significant change at Euro 7 is that it is fuel and technology neutral. Its predecessor differentiated emissions targets dependent on combustion mechanism and fuel type. Stage VI is likely to follow suit and will therefore, have default compatibility with alternative low carbon fuels.

The problem is, however, the Euro 7 and Stage VI regulations themselves won't drive the transition to low carbon fuels. The Euro 7 legislation, in this sense, is backed up by prescribed targets for CO2 reduction over the next 15-20 years. As yet, the off-road market does not have equivalent targets to drive down CO2 emissions.

3 – Emissions Reduction Potential

Official estimates of Euro 7 emissions improvement for trucks and buses, over and above the current Euro VI standard, puts NOx reduction at 56% and exhaust particulate at 39%. This does, however, need to be put into context in relation to the engine out emissions, and, by that measure, the potential emissions reduction is more like an extra 2-5 percentage points.

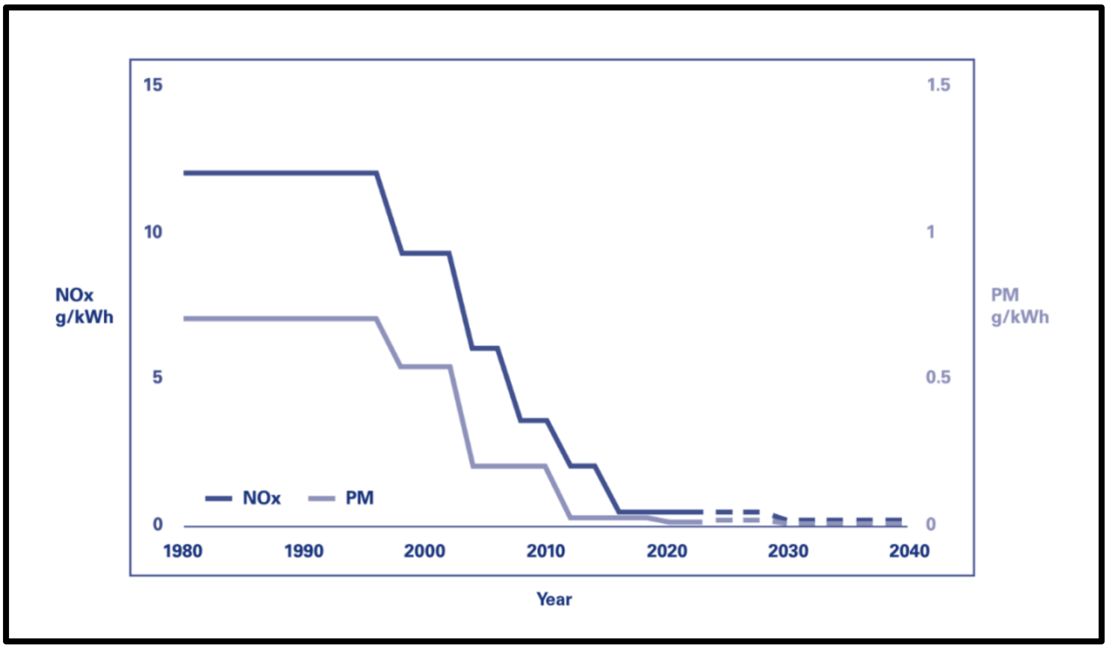

Figure 1. Evolution of emissions regulations

This additional reduction is likely to come at a considerable cost to the consumer. Euro VI emissions systems already combine various catalysts with an active reactant dosing system which is in turn supported by multiple sensors to maintain control of the tailpipe exhaust gas content.

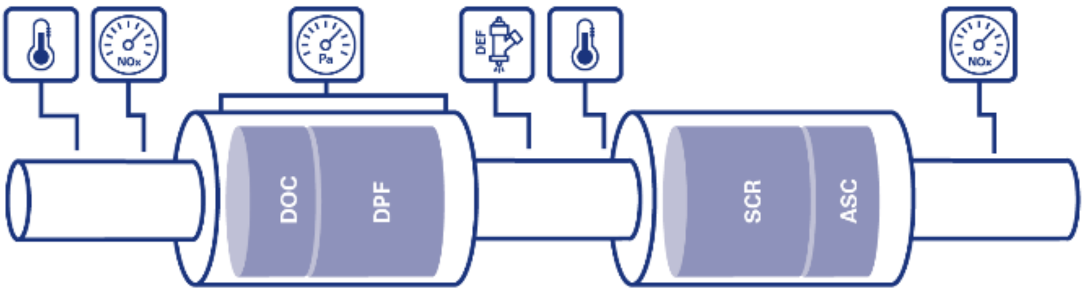

Figure 2. Typical exhaust aftertreatment architecture including sensors

Two key technology additions will likely be required in order to deliver the additional emissions reduction at Stage VI; however, it is yet to be seen if both will be required, or if either one could be used independently to achieve the targets.

The first technology is close-coupled selective catalytic reduction (ccSCR) which requires an additional injector to provide reductant into the system as close to the turbo as possible. This reduces the amount of NOx which passes through the system under cold start conditions when the temperature is too low at the main selective catalytic reduction (SCR) catalyst to support NOx reduction.

The second technology is an electrical heater, which will generate additional heat under cold start conditions to get the system up to catalyst operating temperatures as quickly as possible.

Both technology paths are likely to increase the overall CO2 generated from the power system, and both come with their own technical challenges. Notably, for the end user, both will increase costs.

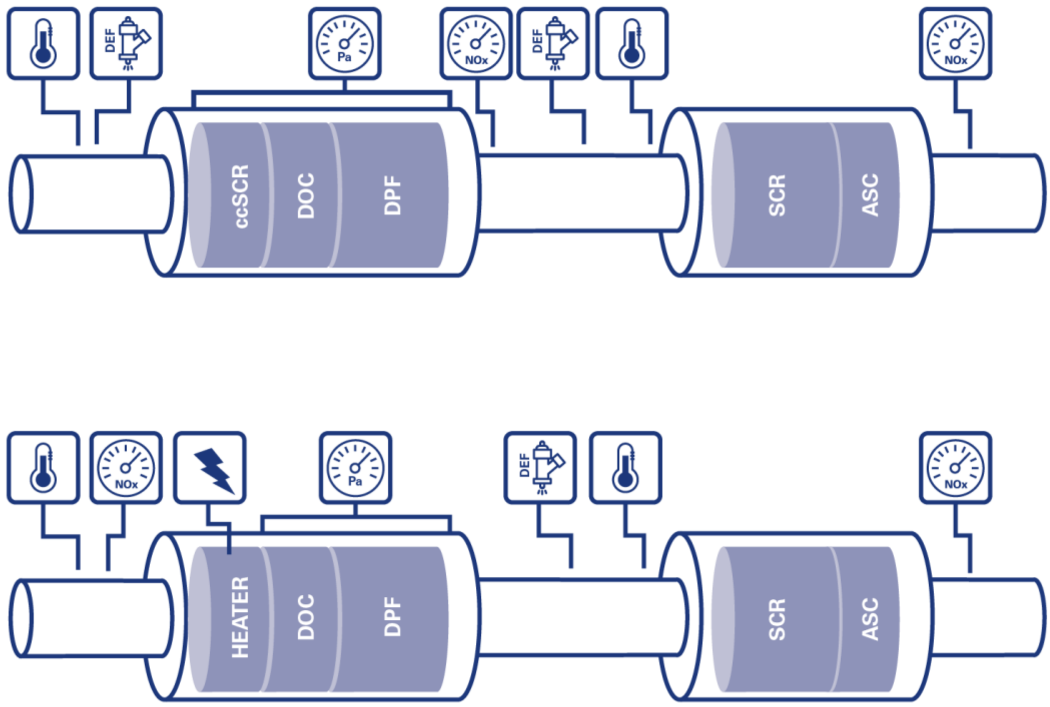

Figure 3. Alternative exhaust aftertreatment architecture including sensors

So how will alternative fuels integrate into future power streams for our vehicles and equipment, and what will that mean for emissions compliance?

4 – Alternative Fuels

Fossil fuels are a finite resource. The world must make the transition to alternative fuels, and because we need to find sustainable sources to ensure long term supply, the fuels of the future will be lower carbon than those derived from fossil sources.

The challenge is identifying fuels which can be readily produced, in sufficient quantity, and that are commercially viable.

There is not a single fuel source that can be readily substituted to replace our reliance on fossil fuels. Therefore, as we head into a period of fuel diversification, we must choose which energy storage vector is appropriate for all the different applications developed over the past 200 years.

The first, and arguably most obvious decision, is to switch passenger car and light commercial vehicles to battery electric. This itself isn't without challenges, such as the impact of lithium sourcing and challenges with recycling, however, as sodium battery technologies become more advanced these issues will reduce.

Moving beyond cars and vans, the picture is less clear and there remains a lot of development work required to establish the best solutions.

What is clear however, is that there is still a place for the internal combustion engine (ICE), albeit powered by alternative fuels. These fuels will include hydrogen, ammonia, methanol, e-diesel, biodiesel, and fugitive methane. Many of these alternative fuels are reliant on one common element, hydrogen. Without an abundance of hydrogen from low carbon sources it is not possible to synthesise low carbon ammonia, methanol, or e-diesel.

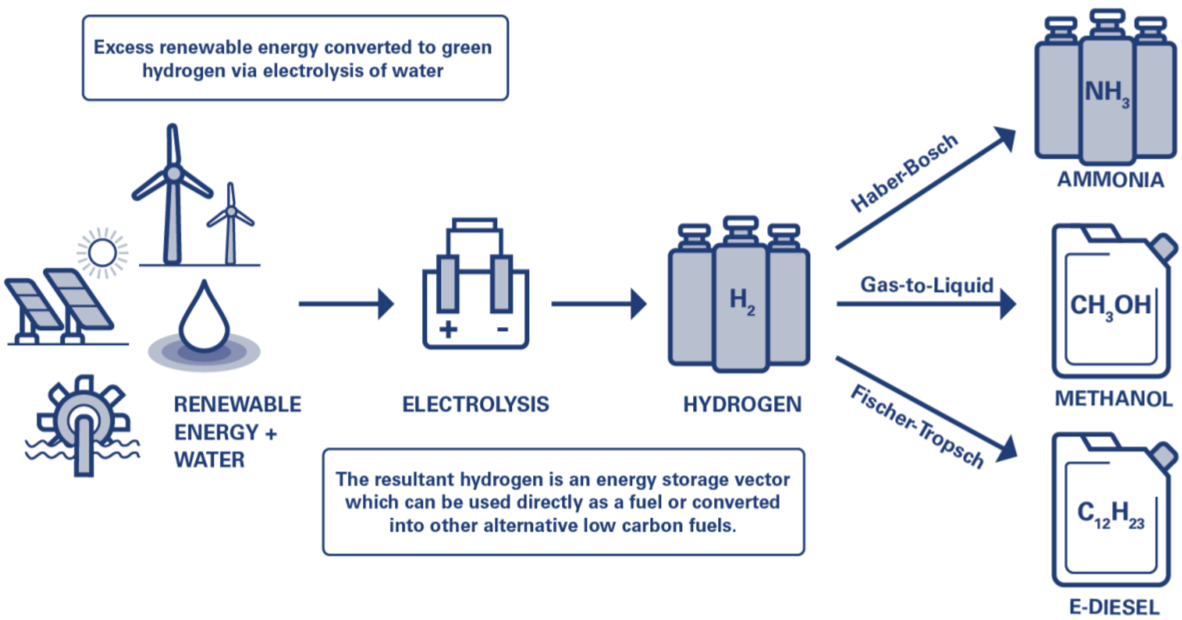

Figure 4. Net zero fuel production

One of the most challenging variables for alternative fuels is the density that is attributed to them.

Pure hydrogen, ideal for stationery power, such as gensets has a high-volume storage requirement (13 x diesel). Further refinement into methanol requires much less storage space (2.5 x diesel) and could be used in marine, mobile power generation such as backup generators on ships and transportation. Similarly, ammonia (7 x diesel) can be used across a variety of applications and can be utilised as a dual fuel. E-diesel, derived from green hydrogen, would offer a direct replacement for fossil fuel diesel (1 x diesel).

It is these challenges, along with how we comply with emissions regulations, now and in the future, which must be overcome quickly to allow us to transition to ICE powered by alternative fuels.

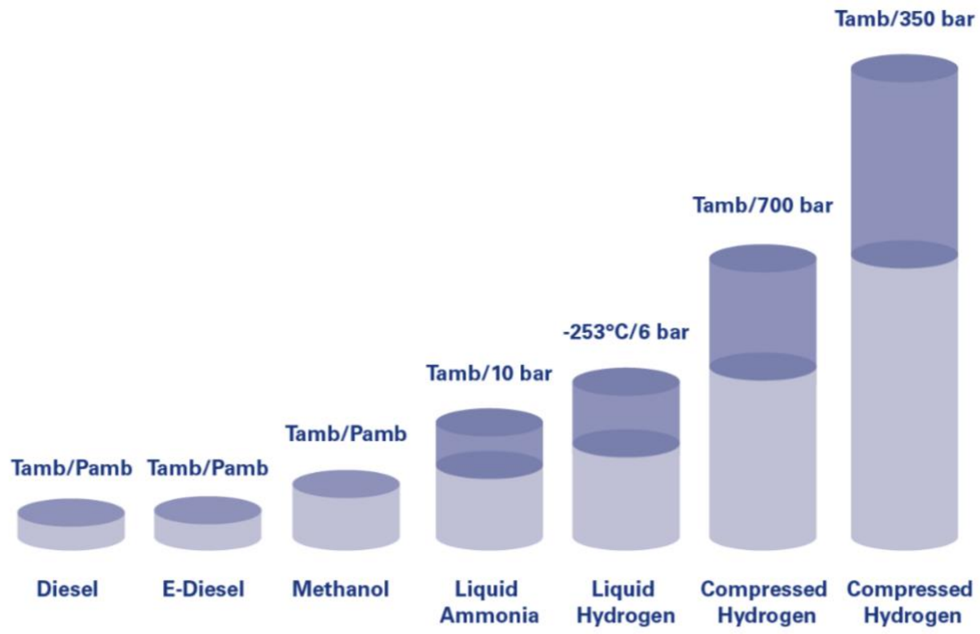

Figure 5. Fuel density comparison

5 – Exhaust Aftertreatment System Technologies

Whilst alternative fuels may solve some of the global challenges being faced, it will not remove the need for emissions technologies and alternative exhaust aftertreatment systems. However, it's important to recognise that the types of exhaust aftertreatment systems will vary for each different fuel type.

Although more challenging to store as a fuel, the exhaust system for hydrogen ICE is relatively simple, consisting of an SCR only. The main challenge for hydrogen ICE will be compacting the exhaust system sufficiently to maximise the available space for onboard fuel storage.

Both methanol and e-diesel will require exhaust treatment systems which are very similar, if not identical, to a current diesel aftertreatment architecture. As carbon-based fuels they will generate HC, CO, NOx, and PM which will require treatment to comply with emissions regulations.

Ammonia requires the most complicated exhaust system, largely owing to the relatively poor combustion properties but also due to the high nitrogen content resulting in significant nitrous oxide (N_2O) generation. The poor combustibility of ammonia necessitates reformation into NH_3 and H_2 on the inlet side of the engine. This process requires heat, which can be harvested from the exhaust system once operating temperature is achieved; up to this point a heater may be required to support the fuel reformation process.

In addition, the exhaust system for ammonia must incorporate an N_2O catalyst. N_2O is a greenhouse gas, 300 times as potent as CO_2, and therefore, emissions as low as 2g/kWhr would negate the benefit achieved by switching from fossil fuel diesel to ammonia. That said, one significant benefit ammonia can offer, is the ability to use the fuel directly as a reductant in the exhaust system, rather than relying on an additional DEF supply.

To that end, considerable work is being done on developing these systems to support the Net Zero drive and switch to alternative fuels, which is far more complex than most would have envisaged.

6 - How Eminox is supporting the transition and next change

Whilst our focus is still very much on continuous improvement of our exhaust aftertreatment system (EATS) technologies to ensure diesel engines in applications from trucks to trains, and ships to power generators comply with the latest emissions regulations, we are also dedicated to exploring power systems of the future and the impact of them on emissions technologies.

Electrification cannot be the answer to replace the internal combustion engine in all market sectors. As stated, although well suited to cars and vans, it is not so practicable for heavy-duty, long-haul vehicles where every operational minute counts.

Similarly, equipping a cargo vessel with battery power is far from a realistic prospect, and mobile power solutions cannot be fully electrified.

Alternative fuels, therefore, will certainly play a crucial and significant role in future mobile and stationary power systems and we are developing systems to facilitate this and pioneer technologies for a greener planet.

7 - Conclusion

Undoubtedly, Stage VI will deliver further improvements to emissions, albeit without compromise and confliction. Quite whether it is the step towards net zero carbon targets required remains to be seen.

Perhaps more consideration needs to be given to a statement in the EU Green Deal which sets a goal for the EU 'to become the first climate-neutral continent by 2050' which will require 'ambitious changes in transport'.

Where those changes are occurring in a cohesive manner is yet to be seen. Currently, it appears that it is private industry in the main which is developing pioneering technologies to explore the full potential of alternative fuels and make those ‘ambitious changes in transport’.

Eminox is prepared for Euro 7 and Stage VI and will continue seamless supply of its EATS to support current requirements across all transport applications, whilst driving forward research and collaborative projects.

Finding the balance of driving forward emissions regulations and not wasting what we have already, must be a primary consideration and this is where developments in emissions reduction technologies can transform industries and achieve the greatest emissions reduction, protect public health, and improve air pollution now, and in the future.

The introduction of Stage VI standards will bring benefits to further reduce emissions; however, substantial gains sit firmly with the development of alternative fuels and systems to support them.

8 – Eminox and its emissions solutions heritage

With decades of experience in designing and manufacturing exhaust aftertreatment systems for heavy duty vehicles and equipment, Eminox is leading the way with its Euro 7 and Stage VI alternative fuel solutions.

It will continue to work closely with governing and legislative bodies to raise awareness, compliance, and standards.

Contact the Eminox team to discover more about emission reduction solutions and how it can help you meet your emission challenges.