Future fuel diversity in heavy duty applications

Introduction

Shifting away from fossil fuels is essential to achieving a zero carbon future and achieving the targets set out in the Paris climate change agreement. As well as reducing global warming, ending the use of fossil fuels will also lower emissions of harmful particulates, improving air quality and people's health.

Across the globe forthcoming legislation will outlaw the sale of fossil fuel-powered internal combustion engine (ICE) cars and vans. These bans will come into force in the United Kingdom in 2030, Germany in 2030 and California in 2035 for example. At the same time heavy duty diesel sectors (such as on-road, off-road and marine) are also seeing greater legislation, backed up by operational regulations in specific areas. Cities are implementing Clean Air Zones and maritime authorities have introduced Emission Control Areas, while major construction projects such as HS2, in the United Kingdom, have set stringent emission targets for the equipment used on them.

All of this means OEMs need to embrace a more diverse range of fuels and/or power systems for their vehicles and equipment. There won't be a single solution, as it will depend on applications and their needs. Battery electric will be the logical choice for passenger cars, but when it comes to heavy duty applications hydrogen, hybrid, biofuels, and clean gas are all options. It is also important to separate the combustion engine as a technology from the fuel it uses – switching ICE to sustainable fuels will ensure we continue to capitalise on more than 100 years of investment and research into the technology.

Based on our experience and understanding, this whitepaper therefore looks at the options for powering heavy duty applications as we move to a zero carbon future.

The challenges of achieving zero carbon mobility

The current frontrunners for decarbonising the overall transport sector are battery electric (BEV) and hydrogen fuel cell (FCEV) technologies. However, these both face performance challenges when it comes to heavy duty applications as in addition to range heavy duty vehicles have specific requirements for refrigeration, power take off and fluid handling.

Battery electric vehicles (BEV):

For a range of reasons, BEV alone is not an option for heavy duty applications. The size and weight of batteries required to power larger vehicles will negatively impact range and capacity, while the amount of time required for charging is too long when fleets need to operate 24/7 to be economically viable.

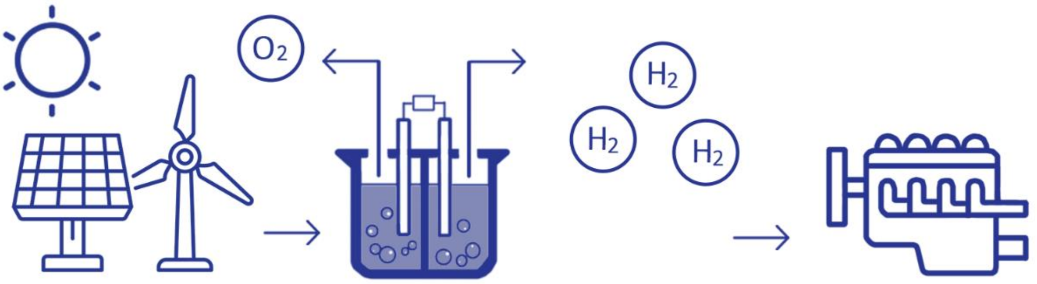
Additionally, generating sufficient green energy for EVs requires major investments across a range of areas, including renewables, grid infrastructure and charging stations. These are likely to add further to costs for heavy duty BEV.

Finally, there are environmental considerations to factor into the use of BEV within heavy duty applications:

- The environmental impact of mining and transporting the rare materials that go into batteries
- Disposal of batteries at end of life, without them adding to landfill
- The energy used to power BEVs, and whether sufficient renewable sources will be available to generate enough green electricity.

Hydrogen fuel cell electric vehicles (FCEV):
Given it does not require multiple, heavy batteries, hydrogen is on paper a stronger fuel source for heavy duty applications. Using hydrogen to create energy produces no emissions, and refuelling is as fast as traditional fossil fuel sources. All of this means it will have much less of an impact on how operators run their fleets, with vehicles kept on-road for similar lengths of time as now, and able to carry the same payloads over the same range.

However, the majority (around 95%) of hydrogen currently produced is not from renewable energy and there are competing demands on the resource from industrial and energy storage applications. This is likely to be a short term challenge as a global green hydrogen economy and corresponding infrastructure develops over the next decade, creating green hydrogen from renewables via electrolysis (see figure below).

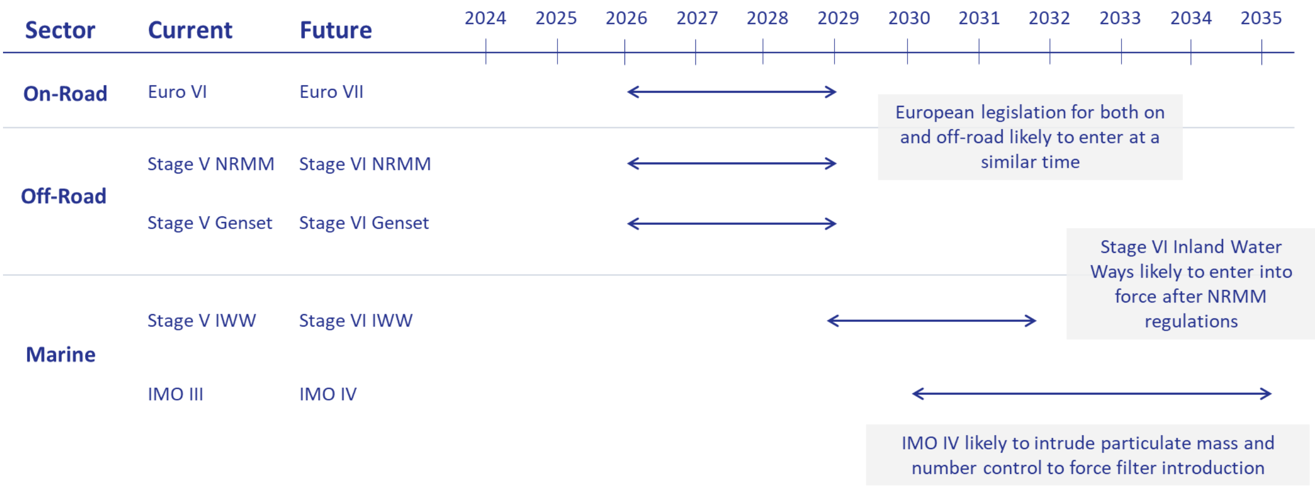


Changing and tightening regulations:

OEMs need to make long-term decisions about power sources and fuels for their future engines. It is highly likely that they will need to adopt a mixed fuels strategy, where vehicles for certain applications will better lend themselves to a particular propulsion technology and fuel type.

While some proposed standards, such as Euro VII for on-road vehicles, are relatively well understood, others, including off-road and marine, are less clear. Given that previous legislation has already delivered major emissions reductions, new standards are likely to require greater efforts, and new techniques (such as hybridisation, as discussed in our previous whitepaper), to achieve them. That means it is vital to start preparing now for future regulations.

EXPECTED LEGISLATION TIMINGS



Building on the ICE

Internal combustion engines themselves are not the cause of pollution – it is the fossil fuels burnt within them. Therefore, replacing petrol and diesel with cleaner alternatives can be a viable option for the heavy duty sector. It enables OEMs to benefit from a known technology that has seen over a century of development, and where the infrastructure and expertise is in place for design, manufacture, usage, and optimised performance.

There are many potential options for re-using the ICE with alternative fuels. Suitability will vary depending on the heavy duty application itself:

Hydrogen/Ammonia ICE

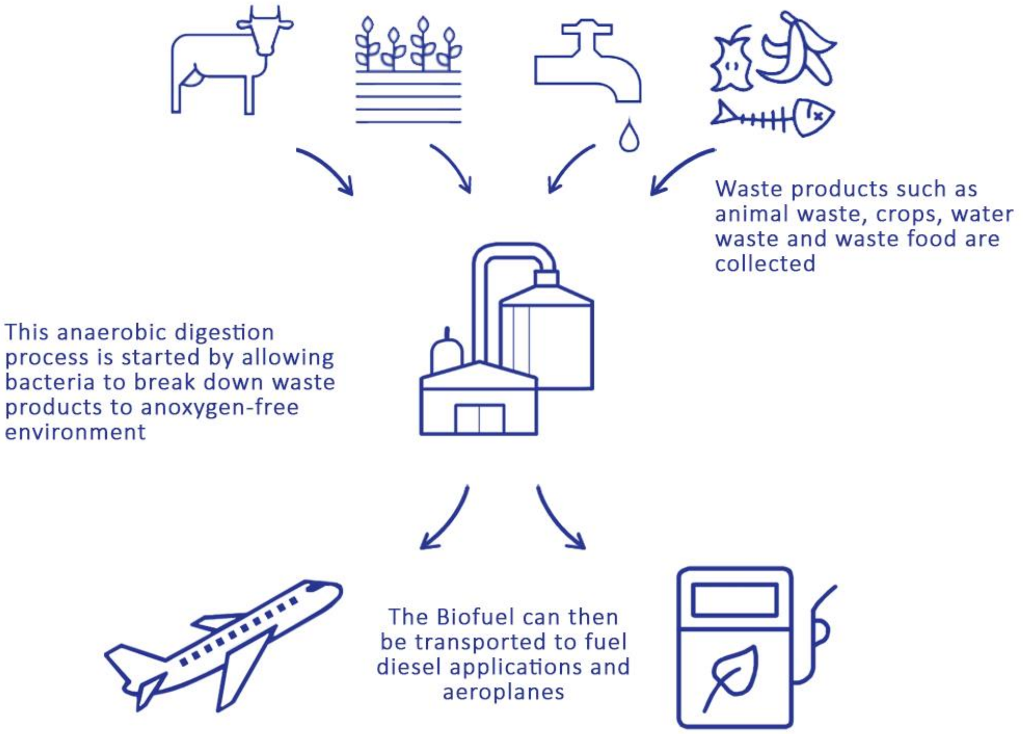
Burning hydrogen or ammonia within the ICE requires minimal changes to existing technology and infrastructure and can even be retrofitted to existing vehicles. This provides a relatively simple path to reducing emissions while retaining ICE in applications such as trucks and marine, with a similar refuelling time and range as current fossil fuel engines. It also delivers a lower environmental cost than mining, manufacturing, and disposing of EV batteries.

However, as discussed above there is a need to create a green hydrogen infrastructure to support a wider rollout of the fuel. Fuelling directly with hydrogen provides a potential zero CO_2 emission solution, but does create some NOx and therefore requires emissions reduction technology to treat the exhaust gas.

While more costly to produce ammonia is easier to store than hydrogen, making it more likely to be used in the marine sector, with future production from hydrogen created via electrolysis. It is likely to initially be deployed in a dual-fuel solution.

Biofuels

Switching to fuels from sustainable sources (such as bioethanol and biodiesel) is another way of re-using existing ICE technology. However, usage is potentially limited by the quantities available, while such fuels still produce (lower) CO_2 emissions. There are also concerns around the source of some biofuels, such as palm oil, the cultivation of which is linked to deforestation and consequent environmental impacts.



Other biofuels are being created from municipal waste, using processes such as the Fischer Tropsch (FT) novel reactor technology jointly developed by Johnson Matthey and BP. Much of this growth in biofuels will meet demand in the aviation industry, which faces potential taxes on the kerosene it currently uses. Annual volumes of biofuel for aviation have increased from under 10 million litres in 2018 to a predicted over 1 billion litres by 2023, and potentially ~8 billion litres by 2030, according to the International Energy Agency (IEA).

Gas

There are already Liquid Natural Gas (LNG) powered ICE vehicles of all sizes in use, from cars to off-road vehicles such as agricultural equipment. However, these currently rely on natural gas derived from fossil fuels. Replacing this source with cleaner alternatives, such as by converting biological waste material (e.g., methane) to fuel delivers lower CO_2 emissions than diesel and recycles potential warming gases. It requires relatively small changes to existing gas-powered ICEs. Catalyst costs are currently high due to the platinum group metal (PGM) loading, and further technology development is required to maintain the viability of natural gas ICE.

A good example of this in the heavy duty sector is the New Holland Low Carbon Tractor project, which aims to develop a commercially viable, sustainable tractor that operates on biomethane, which can be generated from farm and food waste, while complying with the latest European and US emissions standards.

Hybrid

A hybrid approach, for example combining a clean ICE and batteries, helps ensure that engines operate at an optimal temperature for performance, while still reducing emissions. This is particularly useful for applications running at lower operating temperatures or in stop-start use.

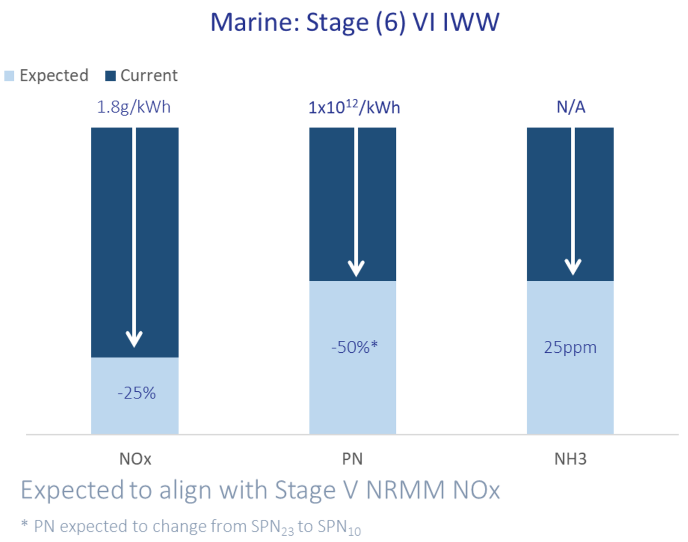
Given that they contain multiple power sources, hybrid solutions are more complex and expensive to package within vehicles, as OEMs essentially need to fit a larger number of components into the existing space. This is a particular issue for smaller applications, such as agriculture, off-road machinery and marine.

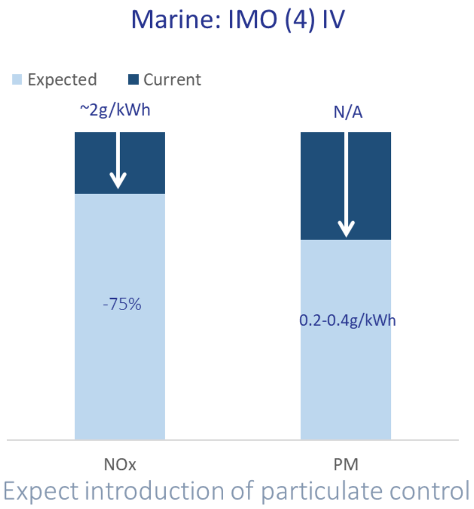
Example ICE applications by sector

The optimum fuel source for particular heavy duty applications is governed by a range of factors. These include range, power requirements, operating temperature, weight, the space within the vehicle/application, and the availability of fuel sources. Based on these the following fuels are best suited to these key applications:

Marine

An initial dual fuel combination of hydrogen or ammonia and diesel is most likely, followed by a switch to solely using hydrogen or ammonia as fuel. Offshore renewables can be used to power hydrogen electrolysis, providing a locally availably fuel source for medium speed applications with 1-10 megawatt engines. This approach will fit with expected legislation, with an update to Marine Stage V expected by 2030 and IMO III being replaced by IMO IV in early 2030s.



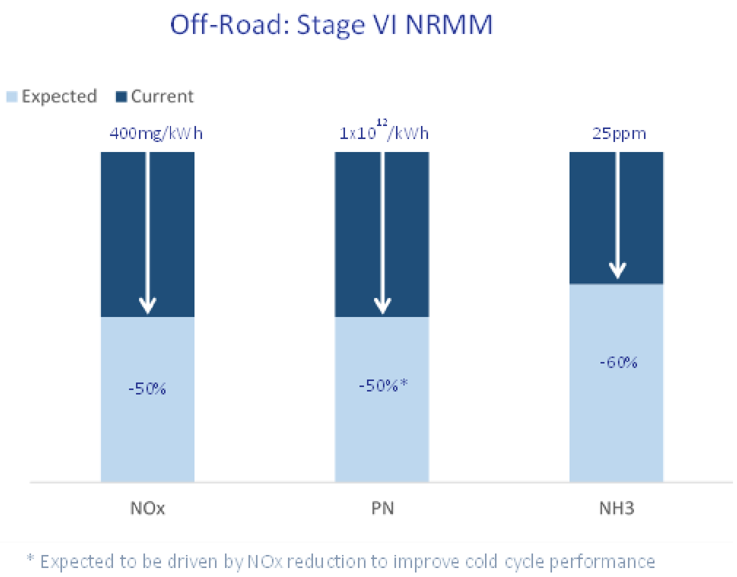


Off-road/Non-road mobile machinery

There are three potential approaches for this sector:

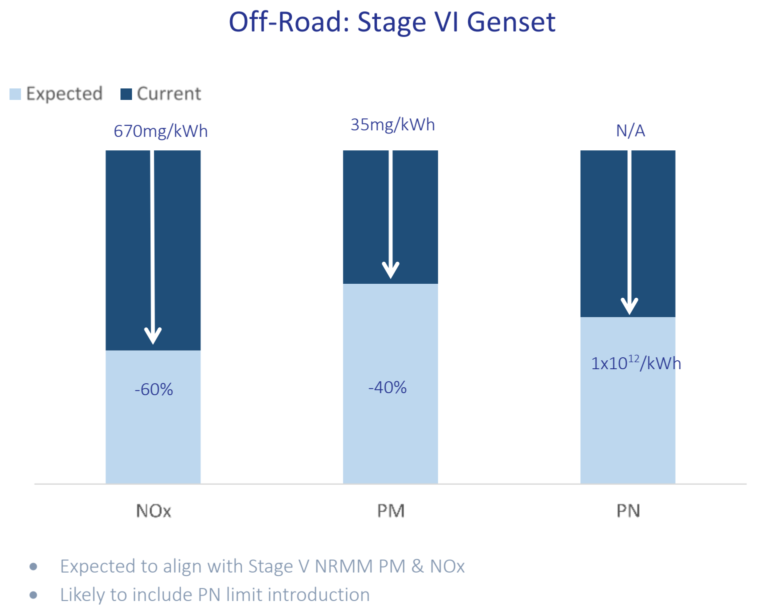
- Improvements to aftertreatment performance coupled with waste heat recovery to maximise overall power system efficiency
- Hybrid, with a downsized engine to make space for batteries
- For agriculture, where biomethane is plentiful, gas power, as seen in the Low Carbon Tractor project.

Emissions control solutions have to meet two particular requirements of off-road – they need to deliver better emissions reduction performance during cold cycle operations, while being able to be deployed on low volume/high cost equipment (such as in construction). Key to success is reducing the development costs and time of exhaust aftertreatment systems (EATS) through a modular approach to bring down the overall system costs.



Gensets

While already a large sector, decarbonising transport is likely to create a major new market for generators – providing electricity to charge BEVs. The most logical approach to meeting this need, without requiring major infrastructure improvements, is to use hydrogen/ammonia to power ICE generators, that in turn will provide BEV charging at point of use. Farms of multiple gensets can also be deployed, generating power as required to deal with demand peaks on the grid.



Looking beyond fossil fuels for the ICE

No single fuel source has the ability to replace fossil fuels across every heavy duty application, meaning there will a variety of approaches adopted:

- Off-road: sustainable biomethane or biodiesel
- On-road: hybrid, hydrogen and biofuels
- Genset/Marine: hydrogen and ammonia linked to renewable power generation

In many ways the landscape now is similar to 100 years ago when a variety of powertrains were developed, from steam and electric vehicles to fossil fuels. Fuel diversity, based on the best fit for individual applications will allow the transport industry to evolve and governments to reach targets for national and global emissions reduction.

Consequently, OEMs need to plan now to be ready for the future and the challenges it will bring. They need to be able to develop solutions cost-effectively at the right scale, ensure they meet emissions standards through effective aftertreatment solutions and improve fuel economy and performance through techniques such as waste heat recovery.

Given the heritage and experience this means that across sectors there is still a central place for ICE, but with different fuel sources in order to bridge the gap to a zero carbon future.

About Eminox

Eminox is your partner for the zero carbon future. We have 25+ years' experience in designing and manufacturing EATS for diesel and gas applications, and a deep understanding of how these can be adapted for future alternative fuel sources, not just diesel, but also CNG and hybrid.

Operating globally and working with a wide range of OEMs, we cover key sectors:

- Non-Road Mobile Machinery (NRMM)
- Marine
- Power generation/Genset
- Agriculture
- Rail (ICE and hybrid/electric)
- On-road (ICE and hybrid/electric)

With our current technology and emissions reduction systems we are successfully bridging the gap to a net zero carbon future, enabling our customers to achieve Euro VI emissions standards, on-road, IMO III in marine and Stage V emissions standards, off-road.

We provide full concept to manufacture capabilities in-house and are continually innovating in areas such waste heat recovery, hybrid diesel/CNG and petrol/electric to enable greater control, efficiency and emissions reduction across operating lifecycles.

Eminox has the technology, experience and expertise to help you achieve current and future emission standards – contact us today to discuss your needs.