Technical Assessment of Transport Fuel Quality Parameters

Final Report

Study contract no.

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Table of Contents

EXECUTIVE SUMMARY

Context

The Fuel Quality Directive (FQD, 2009/30/EC) has two primary aims: firstly, to ensure a single market for fuels used in the European Union (EU) for both road vehicles and non-road mobile machinery. Secondly, it aims to ensure a high level of environmental and health protection through the use of those fuels. In 2017, as part of the Commission's Regulatory Fitness and Performance (REFIT) programme, the FQD was subject to an ex-post evaluation in order to examine the implementation to date and assess its relevance, effectiveness, efficiency, coherence, and EU value added (European Commission, 2017).

The Evaluation concluded that the FQD is generally fit for purpose. It identified options which would in principle allow for greater harmonisation, including:

- Including higher blends of biofuels into the scope of the FQD;
- Introducing a protection grade for biodiesel;
- Introducing relevant CEN standards into the FQD.

The Evaluation highlighted higher biofuel blends as an area where Member State differences are particularly strong. Different levels of biofuel content in fuels are a legal possibility and this allows for a range of fuels to be classified as being compliant with the FQD. Therefore, the range in permissible bio-content may result in segmentation of the EU market for transport fuels. Currently, the use of higher-strength blends of biofuels is limited to a few Member States and niche applications, limiting the levels of market distortion so far.

Another development has been the recast of the Renewable Energy Directive (RED II, Directive (EU) 2018/2001). This modified the sustainability criteria applicable under the RED, which led to a lack of alignment between the criteria applied under RED II and the FQD.

Aims and Objectives

The aim of this study was to identify options for improving relevant provisions in the FQD, in particular in view of the linkages to RED II. Twelve research themes were identified for technical assessment, under each of which a number of options for potential changes to the standards are identified. Each of these options are assessed in terms of:

- Protection of human health and of the environment from transport related pollution, including greenhouse gas emission;
- Internal market for transport fuels;
- Compatibility between transport fuels and vehicle components;
- Economic implications for different stakeholders, including public administration.

Methodology

A literature review was conducted to cover each of the research themes, drawing on past European Commission studies, relevant reports by associations, companies and NGOs and scientific papers.

A stakeholder survey was sent to 90 identified stakeholder organisations and was open from 4 March until 1 May 2020 (including a one-month extension to allow for disruption due to COVID-19).

Drawing from information gathered in the literature review and the stakeholder consultation, as well as discussions with the project team experts and the Commission, policy options were prepared for each research theme. A stakeholder workshop was held online on the 25 June 2020 where there was opportunity for stakeholders to provide commentary on the identified policy options and the potential impacts of the options.

The possible impacts that may occur due to the changes considered under the policy options were identified from information gathered from the literature review, stakeholder questionnaire and discussions with the project team experts and assessed according to the Better Regulation Guidelines. A combination of quantitative models (PRIMES-TREMOVE, PRIMES-Biomass and GEM-E3) were used to model a 2030 counterfactual scenario and policy option scenarios to inform the assessment of impacts for three of the research themes being assessed.

Results

The findings of this study identify the following considerations for potential amendment to the FQD:

- **Raising of limits on FAME to 10%** could facilitate greater renewable energy uptake and other environmental benefits. While the current limit is found to not prevent the achievement of RED II targets, this change would facilitate increasing take up of FAME in diesel as an available option for meeting the targets.
- **Implementation of a protection grade for B7** could enable the marketing of higher blends of FAME without incurring large costs for vehicle owners. Consideration could be given to including a threshold for size of retailer required to market the protection grade as a means of avoiding excessive cost to smaller or independent fuel retailers from marketing multiple grades.
- **Extending the coverage to higher strength blends of alternative fuels, by updating the reference to petrol and diesel CN codes**, would support consistent quality of these fuels in the single market. There would be benefits in defining specifications for these fuels with regard to certain parameters, most notably vapour pressure in the case of higher ethanol blends, and oxidation stability and water content for higher blends of FAME.
- **Extending the coverage to gaseous fuels** would support consistent quality of these fuels in the single market. The most important parameters for specification are: sulphur content, Wobbe index and methane number to ensure vehicle compatibility and for minimising negative impacts on the environment.
- In the case of **metallic additives**, the majority of stakeholders are in favour of an outright ban due to their impacts on health, the environment, and vehicle engines and emission control systems. Ferrocene is the main metallic additive that industry is currently concerned with. Current provisions have effectively banned the use of MMT as a RON booster in the EU, but a metallic additive ban may provide further benefits with regard to trace amounts in imported fuels. Metallic additive manufacturers argue that the existing risk assessment protocol that has been developed by the European Commission, in response to Article 8a,should be utilised in favour of an outright ban.
- **Article 6** provides an additional option for local authorities to improve local air quality. While it is considered to be a more expensive measure than other local measures, and it has not currently been implemented by other Member States, its value as a potential measure is clear with stakeholders.
- **Alignment of the fuel specifications for NRMM gas-oil with on-road diesel, including FAME content,** would provide more certainty on NRMM fuel quality to

the industry and allow further synergies in engine and aftertreatment technologies with those applied to on-road vehicles. Alignment is expected to have very small direct environmental impacts and minor cost increases, given that a significant proportion of NRMM fuel is already aligned with on-road diesel.

- **Production costs of increasing the minimum RON from 95 to 98 or 102 outweigh the environmental benefits** in terms of carbon and air pollutant emissions reduction. This does not prevent the adoption of alternative policies to promote the uptake of HOP such as a separate petrol specification.
- **Removing vapour pressure derogations for Member States with low summer temperatures** would not be cost-effective; increased production costs are clearly higher than potential benefits associated with NMVOC emissions reduction.
- **Retaining the vapour pressure derogation for ethanol content** would allow for the ongoing demand for this derogation from a few Member States and especially if applications show persisting future difficulties with higher ethanol blends. In any case, the Commission is at liberty to grant or decline future applications if there is any change with the environmental penalty and the economic gain trade-off.
- Regarding **the alignment of FQD specification for petrol and diesel with CEN standards**, the analysis found that since a large majority of Member States have already aligned legislation for fuels sold with the respective standards, alignment in the FQD is expected to have a negligible effect. Such an alignment would only be beneficial if a significant monitoring inconsistency is expected in light of higher biofuel blends, for which no strong evidence was found. Should some parameters be aligned, only oxidation stability and water content could be considered for diesel, and no new parameter would be needed for petrol.

The **outermost region derogation** is not used in any Member States, and its removal would not lead to any negative effects.

1 INTRODUCTION

1.1 This Report

This report, for the project Technical Assessment of Transport Fuel Quality Parameters, presents the methodology, findings and conclusions for twelve research questions relating to potential revisions to the Fuel Quality Directive ("FQD", Directive 98/70/EC).

1.2 Context

The Fuel Quality Directive has two primary aims: firstly, to ensure a single market for fuels used in the EU for both road vehicles and non-road mobile machinery. Secondly, it aims to ensure a high level of environmental and health protection through the use of those fuels.

These aims are set in the context of a multitude of considerations in the sector, for example the need to ensure the technical compatibility of such fuels with internal combustion engines and after-treatments, the burden placed on the refineries and fuel supply sector due to increasingly stringent standards, and the need for increasing health protection. Other, wider factors such as the security of the energy supply and the constraints of resource availability also impact the sector more generally and therefore are taken into account by the Directive.

The regulation of 'sulphur-free' petrol and diesel content of fuels introduced in 2003 (Directive 2003/17/EC) and made mandatory from 2009 has led to substantial reductions in share of emissions of lead and sulphur oxides in transport. This, combined with major advances in engine and exhaust system technology and more stringent environmental legislation means that new vehicles today are substantially less polluting than their predecessors.

Improvements in vehicle fuel efficiency and reductions in emissions of air pollutants from vehicles rely on advanced and increasingly complex powertrain and exhaust systems that are very sensitive to the quality of the fuel used. In this context the FQD, and the standards it sets, are increasingly important in contributing to reducing emissions from vehicles.

Following further revision in Directive 2009/30/EC, the scope of the FQD was extended to include non-road mobile machinery (NRMM), agricultural and forestry tractors and recreational craft when not at sea. Additionally, one of the main requirements from this Directive was a target for the reduction of life cycle greenhouse gas (GHG) emissions from transport fuels by 6% by 2020. The harmonisation of fuel standards and biofuels policy stemming from Directive 2009/28/EC on the promotion of the use of energy from renewable sources (commonly referred to as the Renewable Energy Directive (RED)) and its correlation with the FQD Article 7a, in particular in relation to the GHG emissions of biofuels is clearly important for reducing overall life cycle GHG emissions associated with the combustion of transport fuels. This issue was addressed in Directive 2009/30/EC through regulation of certain fuel parameters and enabled blending of alternative fuels (such as biofuels or synthetic fuels) with conventional fuel blends.

The FQD and RED shared a common methodology for assessing the sustainability for transport biofuels. However, the recast of the RED ("RED II", Directive (EU) 2018/2001) modified the sustainability criteria applicable under the RED. Therefore, there is a lack of alignment between the criteria applied under RED II and the FQD, which, due to the legislative process, could not be closed. The changes of the sustainability criteria in the RED II will become operational as of 30 June 2021.

Additionally, Directive 2015/1513 on the sustainability of biofuels and indirect land use change (ILUC) amends the RED and FQD to prepare the transition towards advanced biofuels and reducing the risk of indirect land use change. This change includes a number of additional reporting obligations for the fuel providers, EU Member States and the European Commission.

In 2017, as part of the Commission's Regulatory Fitness and Performance (REFIT) programme, the Fuel Quality Directive (FQD, 2009/30/EC)) was subject to an ex-post evaluation in order to examine the implementation to date compared to the expectation of the policy at inception. As well as this, its relevance, effectiveness, efficiency, coherence, and EU value added were also examined (European Commission, 2017).

The evaluation concluded that the FQD is generally fit for purpose and should remain in place. A number of options which would in principle allow for greater harmonisation were identified, including:

- Including higher blends of biofuels into the scope of the FQD;
- Introducing a protection grade for biodiesel;
- Introducing relevant CEN standards into the FQD.

Additional recommendations primarily related to the functioning of the internal market for transport fuels considered as options enabling greater market harmonisation.

The FQD evaluation highlighted higher biofuel blends as an area where Member State differences are particularly strong. Different levels of biofuels are a legal possibility and allow for a range of fuels to be classified as being compliant with the FQD. Therefore, the range of permissible bio-content may have led to segmentation of the EU market for transport fuels. Currently, the use of higher-strength blends of biofuels is limited to a few Member States and niche applications, thereby limiting the levels of market distortion.

1.3 Aims and objectives of the study

The aim of the study is to identify options for improving relevant provisions in the FQD, in particular in view of the linkages to RED II. Twelve research themes have been identified for technical assessment, under each of which a number of options for potential changes to the standards are identified. The objective is to define each of these options and to assess the implications of each in terms of:

- Protection of human health and of the environment from transport related pollution, including greenhouse gas emission;
- Internal market for transport fuels;
- Compatibility between transport fuels and vehicle components;
- Economic implications for different stakeholders, including public administration.

1.4 Scope and structure of this report

This report first outlines the methodology undertaken for this project. It then, for each of the research themes, presents:

- An introduction to the research theme
- The policy options identified and assessed
- An analysis of the impacts of the policy options

2 METHODOLOGY

2.1 Literature review

A literature review was conducted to cover each of the research themes, drawing on past European Commission studies, relevant reports by associations, companies and NGOs and scientific papers. The key findings of the literature review are presented throughout this report and have been used to inform the policy options as well as in the assessment of impacts of options.

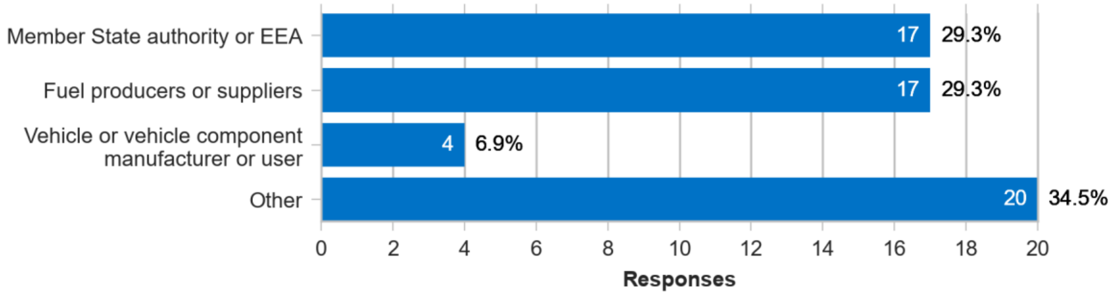
2.2 Stakeholder survey

Relevant stakeholders were identified, in collaboration with the Commission, from EU level sector associations (representing fuel producers and suppliers, vehicle and component manufacturers and users), Member State authorities, standardisation bodies, international agencies and non-governmental organisations (NGOs).

Informed by the Terms of Reference and the literature review, as well as discussions with the project team experts and the Commission, a questionnaire for the stakeholder survey was developed. The survey was launched as an online questionnaire, with invitations sent to the 90 identified stakeholder organisations. The online questionnaire had open access to allow for responses by wider stakeholders, for example from national sector associations, individual companies or other interest groups, where the invitation was passed on to them by the key stakeholders.

The consultation period was from 4 March until 1 May (including a one-month extension to allow for disruption due to COVID-19). A total of 58 responses to the online survey were received, from a cross section of stakeholder groups, as shown in Figure 2-1 based on self-categorisation: as well as NGOs, academics and research groups, the "other" group includes organisations which could be considered to represent vehicle component manufacturers (1) and fuels producers and suppliers (10). The self-categorisation has been retained for the results presented in this report.

Figure 2-1 Responses to the stakeholder questionnaire



Around half (55%) of the responses came from the original stakeholder list, with the remainder coming from wider stakeholders who were forwarded the invitation and a small number who chose to remain anonymous. A small number of stakeholders separately or additionally provided written response via email.

Despite the relatively low number of responses, all of the main interest groups are represented. The only exception was biodiesel producers, and therefore a bilateral telephone interview was held with European Biodiesel Board (EBB), which did not respond to the survey, to ensure the opportunity for representation from the biodiesel sector.

2.3 Identification of policy options

Drawing from information gathered in the literature review and the stakeholder consultation, as well as discussions with the project team experts and the Commission, policy options were prepared for each research theme. In each case the first policy option is a no change counterfactual. Between one and three additional alternative options were defined, depending on the range of possible outcomes that may be envisaged. Where relevant, more than one list of options is defined under a research theme, to represent the range of standards being considered under that theme.

2.4 Definition of key impacts to be assessed, and impact assessment methodology

The possible impacts that may occur due to the changes considered under the policy options were identified from information gathered from the literature review, stakeholder questionnaire and discussions with the project team experts. The Better Regulation guidelines were equally considered in this process, to ensure a wide range of possible impacts were accounted for. Direct technical and administrative impacts were considered, as well as wider environmental and economic impacts. The significance of impacts was assessed qualitatively to screen the priority impacts for which further analysis is proportionate. The method and quantitative or qualitative nature of the assessment has been selected based on expected significance and data availability.

2.5 Stakeholder workshop

A stakeholder workshop was held online on the 25 June as a video conference to allow for maximum participation under the current travel and meeting restrictions in place across Europe as a result of COVID-19. A briefing note was sent to participants on 23 June. This consisted of a brief introduction to the study aims and objectives, the research themes, policy options and identification of impacts intended for assessment.

The workshop consisted of a presentation by Ricardo on each research theme session covering: the context and research question; policy options; impacts for be assessed; and method of assessment of the impacts. There was opportunity for stakeholders to comment at the end of each session as well as a general discussion at the end of the workshop. Stakeholders were invited to send additional comments or information by 6 July 2020.

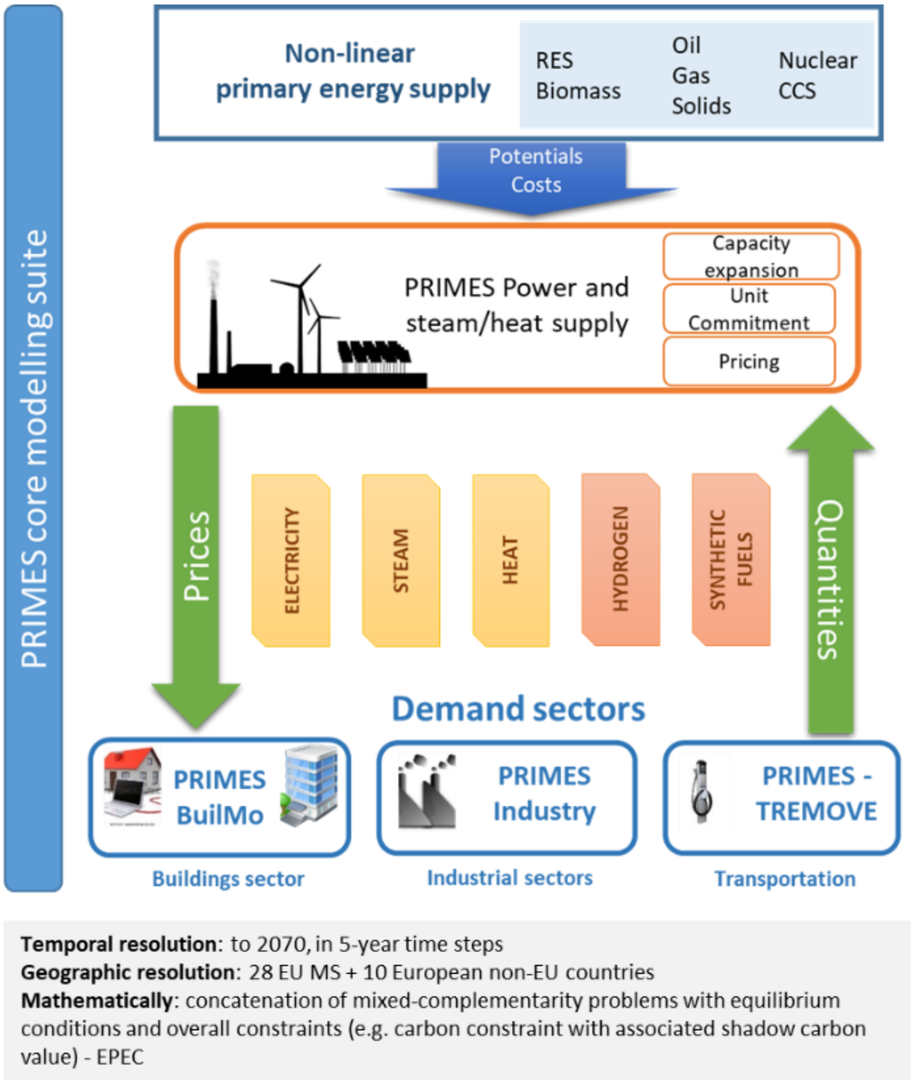
2.6 Quantitative modelling

A Combination of quantitative models (PRIMES-TREMOVE, PRIMES-Biomass and GEM-E3) were used to model a 2030 counterfactual scenario and two policy scenarios to inform the assessment of impacts for three of the research themes being assessed.

PRIMES

PRIMES (Price-Induced Market Equilibrium System) is a large-scale applied energy system model that provides detailed projections of energy demand, supply, prices and investment to the future, covering the entire energy system including emissions. The distinctive feature of PRIMES is the combination of behavioural modelling (following a micro-economic foundation) with engineering aspects, covering all energy sectors and markets. The model has a detailed representation of policy instruments related to energy markets and climate, including market drivers, standards, and targets by sector or overall (over the entire system). It handles multiple policy objectives, such as GHG emission reductions, energy efficiency and renewable energy targets, and also provides a pan-European simulation of internal markets for electricity and gas.

Figure 2-2 Structure of PRIMES Model



PRIMES offers the possibility of handling market distortions, barriers to rational decisions, behaviours, as well as and market coordination issues and includes a complete accounting of costs (CAPEX and OPEX) and investment expenditure on infrastructure needs. PRIMES is designed to analyse complex interactions within the energy system in a multiple agent – multiple markets framework.

Decisions by agents are formulated based on a microeconomic foundation (utility maximization, cost minimization and market equilibrium) embedding engineering constraints, behavioural elements and an explicit representation of technologies and vintages and optionally perfect or imperfect foresight for the modelling of investments in all sectors.

PRIMES is well-placed to simulate medium and long-term transformations of the energy system (rather than short-term ones) and includes non-linear formulation of potentials by type (resources, sites, acceptability etc.) and technology learning.

The PRIMES model is modular and includes all demand and supply sectors of the energy system: the PRIMES-TREMOVE Model is the transport model of PRIMES, whereas the PRIMES-Biomass Supply is the model assessing the supply of bio-energy products.

PRIMES TREMOVE Model

The PRIMES-TREMOVE Transport Model produces projections covering the entire transport sector by 5-year steps up to 2050. The model projects mobility for passengers and freight, allocation of mobility by transport mode, projection of mobility by type of trip, allocation of mobility by mode in transport means, investment and scrapping of transport means, energy consumption and Tank-to-Wheel, as well as Well-To-Wheel emissions of transport means and costs and prices of transport. Choices among alternative options and investment are simulated by agents which are considered to be representative of classes of transport consumers. The choices are based on economics and utility from mobility and also depend on policies, technology availability and infrastructure. The projection includes details for a large number of transport means, technologies and fuels, including conventional and alternative types, and their penetration in various transport market segments. The projection also includes details about greenhouse gas and air pollution emissions, as well as impacts on externalities such as noise and accidents. Operation costs, investment costs, external costs, tax revenues or subsidy costs, congestion indirect costs and others are included in the model reports. Agent choices are derived from structural microeconomic optimisation, in which technology features and transport activity allocation possibilities are embedded.

PRIMES-Biomass Supply

The PRIMES-Biomass supply model computes the optimal use of biomass/waste resources and investment in secondary and final transformation, so as to meet a given demand of final biomass/waste energy products

The PRIMES-Biomass system model is linked with the PRIMES large scale energy model for Europe and its submodules include PRIMES-TREMOVE and can be either solved as a satellite model through a closed-loop process or as a stand-alone model. The biomass model follows the standards of the PRIMES model: it covers all the EU countries and other associated European countries; it performs dynamic projections to the future from 2000 until 2070 in 5-year time period step. It is an economic supply model that computes the optimal use of biomass/waste resources and investment in secondary and final transformation, so as to meet a given demand of final biomass/waste energy products, projected to the future by the rest of the PRIMES model. The biomass supply model determines the consumer prices of the final biomass/waste products used for energy purposes and also the consumption of other energy products in the production, transportation and processing of the biomass/waste products. Prices and energy consumption are conveyed to the rest of the PRIMES model. A closed-loop is therefore established.

GEM-E3

GEM-E3-FIT is an advanced and detailed version of the standard version of GEM-E3, enhanced in the following respects:

- it represents the financial sector explicitly
- it represents policy-induced technical change and innovation-induced growth by two-factor learning curves (learning by doing and learning by research)
- it represents household decisions on education that affects the human capital
- it links the human capital with the creation of knowledge
- it links the human capital with the ability to absorb knowledge spill-overs
- it has an explicit representation of infrastructure

- it provides built-in options for Monte Carlo simulations to perform sensitivity analysis
- it includes a detailed representation of transport (freight and passenger by mode)
- it includes a discrete representation of sectors producing clean energy technologies (wind, PV, CCS, electric vehicles, biofuels, batteries, insulating materials)
- it is calibrated to the most recent version of GTAP 9 and the years 2004, 2007 and 2011
- it has detailed inter-institutional transactions precisely determining the surplus/deficit position of each agent
- it has a high degree of sectoral (economy is disaggregated into 53 productive sectors) and regional resolution (46 countries/regions are represented) it has a new calibration of energy volumes that combine in a consistent way data from energy balances and IO tables
- it has detailed data on energy subsidies globally based on IEA dataset
- it includes learning by doing and learning by research associated with knowledge spill-over matrices based on patent citations data
- accounts for the number of firms by economic activity and calculates the profitability rates of each activity

Figure 2-3: GEM-E3 model schematic

2030 MIX Scenario and Consideration of wider EU Policy

The current analysis is undertaken in the context of the 55% emission reduction target based on the European Commission proposal and as agreed by the European Council in December 2020. The scenario includes the expected effect of the COVID-19 crisis for the short and medium term.

The model includes a large variety of policy measures, which can be mirrored in scenarios. Notably, regulatory measures include the setting of targets and technology standards. EU regulations setting emission performance standards for new passenger cars and new light commercial vehicles respectively as part of the European Union's integrated approach to reduce CO_2 emissions from light-duty vehicles have been explicitly integrated into the model. The current, as well as future, EURO standards on road transport vehicles are explicitly implemented and are important for projecting the future volume of air pollutants in the transport sector and determining the structure of the fleet. The model captures fleet turnover and allows for fuels substitutions. In the context of this project, PRIMES-TREMOVE is used to analyse the impacts of possible changes to the FQD on the EU's vehicle fleet[1], higher blends of specific types of biofuels, including impacts on costs, emissions and fuel compatibility (i.e. the numbers of vehicles that might require protection fuel grades in any given year).

The scenario therefore includes all EU27 level policies as well as national policies: the latter mirror the policies as included in the National Energy and Climate Plans (NECPs) including the blending obligations mandated at national level, the national targets for advanced biofuels (when differing from the RED II obligations) and the expected ways to fulfil these based on the scenarios included in the NECPs. **The inclusion of all Member State provisions already leads to an overachievement of the 14% RES-T target as mandated by the Renewable Energy Directive ("RED II").** The use of biofuels in transport allows achievement of the RES-T obligations and contributes to the reduction of emissions from the transport sector and thus contributes also to other climate targets.

The MIX scenario includes the Re-Fuel initiatives for the aviation and maritime sectors respectively, implying mandates for sustainable aviation and maritime sectors which further increase the share of RES in transport.

The MIX scenario further includes the extension of carbon pricing to the road transportation sector leading to further fuel substitutions in the transport sector. Road transport sees an additional tax due to the EU-ETS that applies to carbon emitting fuels on a TTW basis. Therefore, cleaner vehicle technologies increase their competitive advantage compared to conventional fuel vehicles.

[1] Changes to vehicle scrappage or rate of turnover are not modelled due to low numbers of not compatible vehicles in 2030. These impacts are considered separately in the analysis (Protection grades theme).

3 POTENTIAL BARRIERS FOR REACHING THE TARGETS FOR RENEWABLE ENERGY IN TRANSPORT UNDER RED II

3.1 Introduction

The 2017 FQD Evaluation (European Commission, 2017) identified a perception by some Member States that the FQD limits made it more difficult to meet RED targets. The FQD Evaluation also highlights that there is no evidence the FQD has prevented the RED targets being achieved. However, it notes that alternative measures would be needed, such as the use of advanced biofuels which may be double counted against the target.

In 2018, the European Commission adopted a recast version of the RED, commonly known as RED II, which increased the renewables contribution target to at least 14%, by 2030, as well as adding a sub-target of 3.5% for advanced biofuels. The purpose of this research theme is to establish whether the current FQD limits act as a barrier to the achievement of these RED II targets. It also investigates whether there are inconsistencies between the sustainability architecture of the FQD and RED II (i.e. targets or limits, criteria and the methodologies for assessing GHG intensity).

The FQD sets upper limits for oxygenates in petrol, including 10% v/v ethanol, 3% v/v methanol and 22% v/v ethers of five or more carbon atoms per molecule, as well as limits for alcohols and other oxygenates (as shown in Table 3-1). The overall oxygen content is limited to 3.7% m/m. These limits affect the potential biofuel content, where the bio-based components are alcohols or ethers. For diesel, there is a limit on the content of FAME of 7% v/v, although marketing of a diesel blend with a higher FAME content is permitted providing all other requirements are met. The purpose of these limits is to ensure compatibility of fuels with engine and emission control technologies.

Higher blend fuels than the E5, E10 and B7 grades in current widespread use are being considered for introduction in response to the RED II targets. This is reflected in the additional European Standards that have been established or are under development for a range of blend ratios in petrol and diesel (See Section 4.3.3).

The definitions of petrol and diesel in the FQD refer to CN codes, which state that fuels must contain a minimum of 70% mineral oil (CN codes 2710 11 41, 45, 49, 51 and 59 for petrol, and CN 2710 19 41 for diesel). Therefore, fuel blends with more than 30% biogenic content are not currently within the scope of the FQD[2] and FQD therefore does not prevent reaching the RED II targets via use of higher biofuel content blends. The analysis under this section therefore focuses on blends with less than 30% bio-content, which are covered by the FQD. Analysis of the impacts of extending the scope of the FQD to capture higher strength blends through either removing the link to CN codes in the Directive text, or adding new CN codes, is explored in Section 4.

Drop in fuels comprising of synthetic petrol, synthetic diesel and HVO/HEFA in diesel can be blended in at any percentage. By definition, these are compatible with the FQD standards. The only potential barrier to achieving RED II targets with drop in fuels that FQD may impose would be in relation to differences in the sustainability architecture between the two Directives.

[2] The specific sub-codes cited by the FQD are however now obsolete. More recent developments, and clarification of CN codes and reference to “other similar oils”, makes wider allowance for alternative fuels.

3.2 Policy options

In consideration of the potential development of the EU fuels market by 2030, the following policy options have been determined.

Petrol blends

Maintain current limits on oxygenates shown in shown in Table 3-1.

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Table 3-1: Policy options for revising the FQD limits for oxygenates in petrol

Policy option	% v/v
Methanol	3.0
Ethanol	10.0
Iso-propyl alcohol	12.0
Tert-butyl alcohol	15.0
Iso-butyl alcohol	15.0
Ethers containing five or more carbon atoms per molecule	22.0
Other oxygenates (Other mono-alcohols and ethers with a final boiling point no higher than that stated in EN 228:2012)	15.0

Diesel blends

1. Counterfactual: Maintain current 7% limit on FAME
2. Increase in limit up to 10% for FAME

3.3 Analysis

This section presents an assessment of whether the current FQD limits are a barrier to the achievement of RED II targets, firstly based on information gathered from stakeholders, and then based on a PRIMES-TREMOVE modelled scenario based on the MIX scenario 2030. It also presents information from stakeholders on other potential barriers to the achievement of RED II targets.

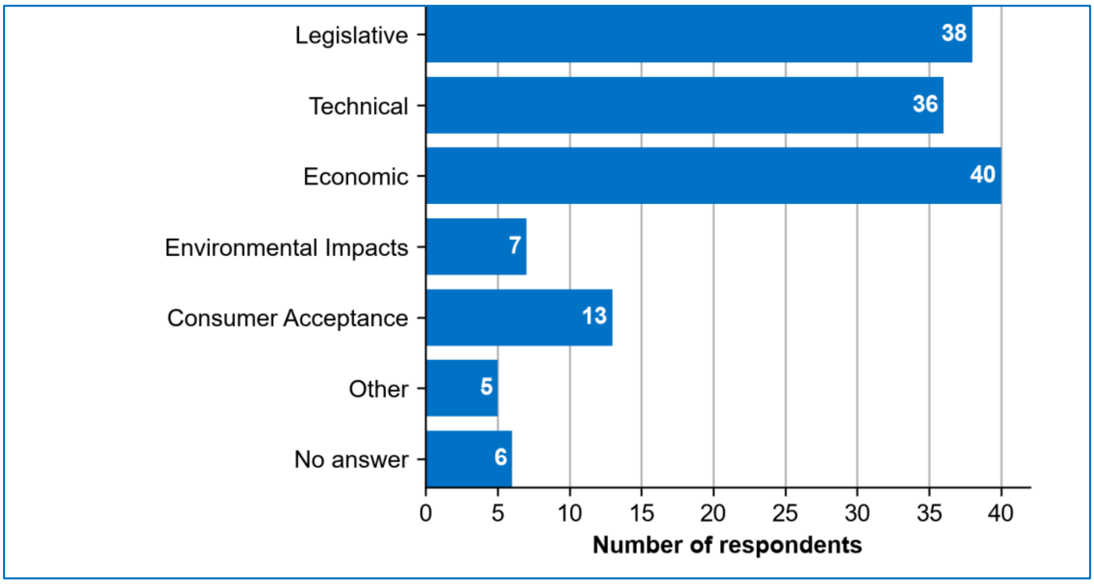
This is complemented by an assessment of the environmental (including renewable energy share), vehicle compatibility and economic impacts of raising the FQD limits on FAME, ethanol and oxygenates, and associated changes to the fuel blends which are used in vehicles in the EU.

Barriers to RED II Targets

The main aim of this research theme is to ascertain whether the current FQD limits on oxygenates and FAME are barriers to the achievement of renewable energy targets under RED II

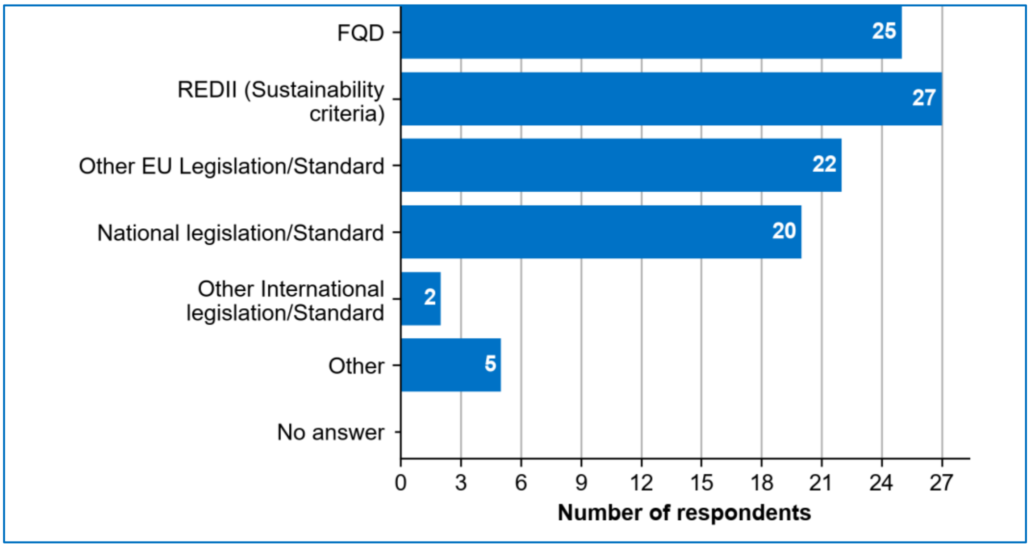
Stakeholders were asked what the main barriers are to prevent or limit the introduction of biofuels and renewable fuels of non-biological origins by 2030, including whether there are legislative barriers associated with the FQD. Stakeholders indicated that legislative, technical and economic considerations are of similarly high level of importance (Figure 3-1).

Figure 3-1 Main barriers to introduction of biofuels an renewable fuels of non-biological origin



The main barrier from the FQD specified by stakeholders is the 7% FAME content limit in diesel fuel, preventing increased FAME uptake and potential GHG savings, with a number indicating that the limit should be increased to 10%, most notably the European Biodiesel Board.

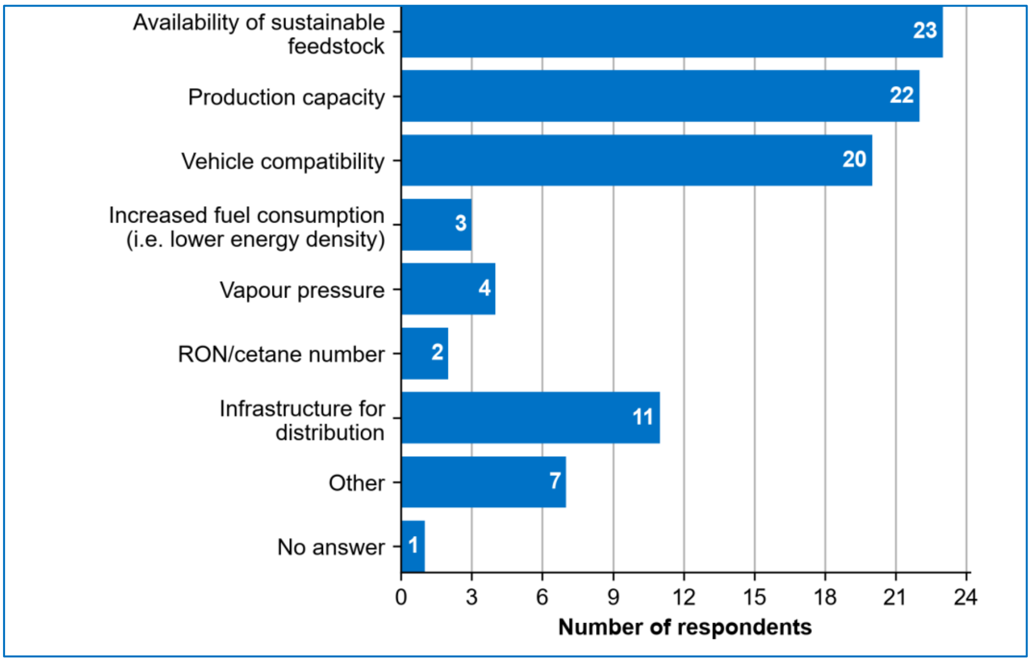
Figure 3-2 Legislative barriers to uptake of biofuels



In relation to technical barriers, stakeholder responses indicated that availability of sustainable feedstock, production capacity and vehicle compatibility in particular are viewed as barriers. A large number of stakeholders also indicated that infrastructure of distribution is a barrier. RON/cetane number, vapour pressure of petrol and increased volumetric fuel consumption received relatively few responses.

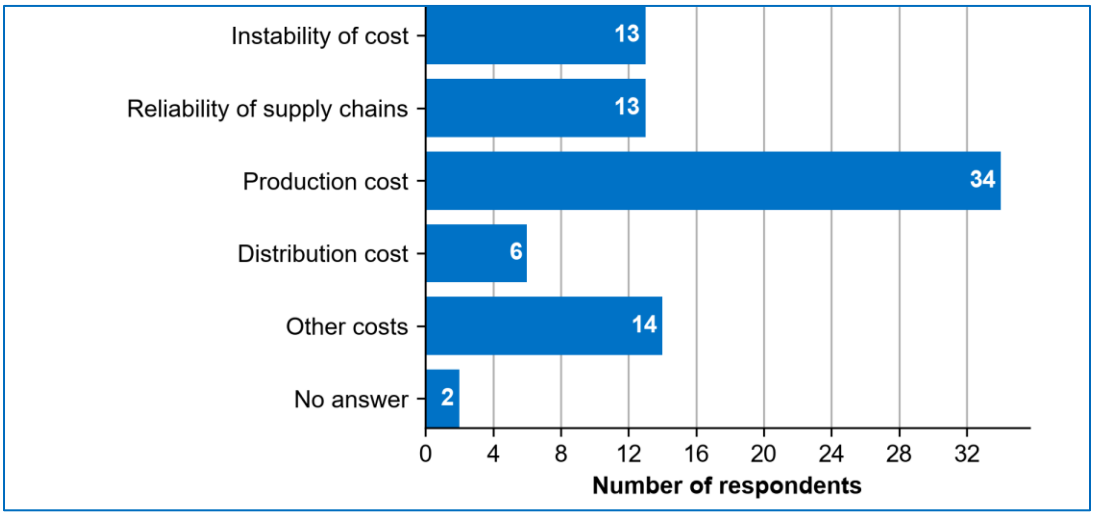
The lack of compatibility of vehicles with higher FAME and ethanol blends, and the lack of information about their compatibility, were raised as key barriers. For B10 fuel, it was mentioned that vehicle manufacturers would need to advise more frequent service intervals to change engine oil, due to possible dilution of engine oil with FAME.

Figure 3-3 Technical barriers to uptake of biofuels



With regard to economic barriers, stakeholders indicated that production cost is the most significant barrier. Biofuels were stated to be in general higher cost to produce than fossil fuel equivalents, although there were split views between stakeholders as to whether this will level out by 2030. In particular, one stakeholder noted that cellulosic biofuels are hindered by production costs compared with first generation biofuels.

Figure 3-4 Economic barriers to uptake of biofuels



Stakeholder responses indicated that the current FQD limits are still perceived to be a key barrier to the uptake of biofuels, along with other key barriers relating to feedstock availability, production capacity, vehicle compatibility and production costs.

The PRIMES-TREMOVE model was run using the MIX55 reference scenario to test whether the barriers to biofuel uptake of the current FQD limits prevent the achievement of REDII renewable energy targets. The MIX scenario achieves an overall RES-T share of 26% in 2030, following the formula as included in the RED II directive with multipliers. The corresponding share of biodiesel (FAME and HVO) and bioethanol is 10% each in energy terms in the overall fuel consumption of transport. Driven by decreasing battery costs and the progressive stringency of the CO_2 standards for cars and vans, electricity penetrates the road transport sector, and electric vehicles contribute significantly to this outcome. Electricity represents 3% of final energy consumption in transport, however with the multiplier for electricity it weighs into the RES-T formula with a factor of 4 for renewable electricity in road transport.

The MIX scenario also includes the fuel mandates in the aviation and maritime sectors which lead to an uptake of renewable fuels in the fuel mix of these sectors in 2030. The respective share of renewable energy in transport excluding the multipliers is calculated to be in the order of 14% in 2030.

This demonstrates that meeting the REDII targets is possible with the current FQD limits, given there are a range of options available. However, 99% of diesel sold in the EU in 2018 is already labelled as B7 (EEA, 2020). This demonstrates the allowance for marketing of a diesel blend with a higher FAME content is not being significantly adopted despite there being potential for increasing FAME content up to 10%. This appears to be due to the stakeholder perception that the 7% FAME limit in FQD is a barrier to further use of FAME in diesel. Increasing the FAME content limits in FQD to 10% would therefore facilitate increased FAME content in diesel as a feasible option to support achieving the RED II targets. Whereas, the majority of petrol sold in the EU in 2018 was marketed as E5 (84%) and only 11% was marketed as E10 (EEA, 2020). This indicates there is still potential for significant increase in take up of bio-ethanol in petrol with the existing FQD 10% ethanol limit, demonstrating that this is not a barrier to achieving the RED II targets.

Alignment of the Sustainability Criteria of FQD and RED II

The FQD states the methodology for the calculation of life-cycle greenhouse gas emissions from biofuels should be identical to that established for the purposes of the calculation of greenhouse gas impacts under RED (Directive 2009/28/EC). However, the modified sustainability criteria in RED II means the methodologies between the two directives are no longer fully aligned. Table 3-2 shows a summary of the main differences identified.

Table 3-2 Differences in the methodological approaches in FQD and RED II.

Difference identified	Brief description
CO_2 equivalence	The global warming potential values used to calculate emissions differ for nitrous oxide.
Default values for cultivation emissions	These do not appear to be equivalent, FQD does not show nitrous oxide emissions but RED does. When calculating CO_2 emissions from RED values these do not align with FQD values for the same fuel biofuel production pathways.

GHG emission calculation formula	RED formula is more detailed, for example in terms of calculating emission savings and dealing with co-generation.
Bonus (years applicable)	Both the FQD and RED refer to a bonus. The time this lasts for after point of conversion varies between the FQD (10 years) and RED (20 years)
Fuel use calculations	RED considers methane and nitrous oxide in the $\mathbf{e_u}$ factor but FQD does not.
Electricity savings from co-generation	RED methodology includes using the Carnot efficiency and explains how to calculate this.
Fossil fuel comparators	These differ between FQD and RED.

Beyond differences in methodology, the FQD only sets limits that impact the biofuel content of fuels indirectly (e.g. upper limits for oxygenates). In contrast, the RED II specifies limits or multipliers for contribution towards the RED II target (14% renewable by 2030) based on the feedstocks used. For example, for fuels derived from cereals, sugars and oil crops their contribution to the target is limited to a maximum of 7% of total share and their contribution to the target is not double counted. For algae, biowaste, straw and animal manure derived fuels their contribution is not capped and their contribution is double counted. Fuels produced from used cooking oil (UCO) and animal fats (categories 1 and 2) have a contribution limited to a maximum of 1.7% of total share, but their contribution is double counted (ICCT, 2019). The contribution of advanced biofuel feedstocks can be double counted and there is no limit on their contribution to the RED II 14% target.

Table 3-3: RED II contribution limits of different fuels (+ different feedstocks) (EEA, 2020)

Fuel type Feedstock	RED II contribution limited?	Contribution double counted
Biodiesel		
Oil crops	7% cap	No
Other (Used cooking oil)	1.7% cap	Yes
Other* (Animal fats)	1.7% cap	Yes
HVO		
Oil crops	7% cap	No
Other (Used cooking oil)	1.7% cap	Yes
Other (Animal fats)	1.7% cap	Yes

Bioethanol		
Cereals and other starch rich crops	7% cap	No
Sugars	7% cap	No

*Other feedstock groups are detailed in the RED II with certain conditions specified.

For food and feed crop feedstock transport fuels, there is a 7% cap in terms of how much they can contribute to the 14% renewable energy target. In this way petrol blends (E10) with ethanol derived from the main three feedstocks identified in 2017 (maize, wheat, sugar beet), would have a contribution limited by this cap. For food and feed crop feedstock transport fuels, RED II also requires that their consumption cannot be more than 1% higher than the recorded percentage share of final consumption in 2020 for each Member State. Therefore, for a Member State that had a 4% share of final energy consumption from transport fuels derived by food or feed crop feedstock in 2020, this could only increase to 5%. There is an exception to this rule, in cases where contribution was below 1% in 2019, the share may be increased to 2%[3].

In the stakeholder questionnaire, one stakeholder commented that a cap on biofuels produced from food and feed crops should also be mandatory in the FQD, and a requirement to reduce the share of crops with high ILUC, to bring in line with RED II. Provision is included in Article 7a of FQD, but is non-mandatory due to the use of "may" instead of "shall" as in RED II.

The Danish Energy Agency commented that RED II limits on crops with high ILUC risk should be incorporated into the FQD as well as the cap on fuels from food and feed crops, however, this will make it difficult to meet the 6% FQD greenhouse gas reduction target due to limiting usage of these biofuels, and may have the knock-on consequence of increasing the cost of other biofuels such as HVO due to higher demand.

Overall, there is opportunity for the sustainable architecture of the FQD and RED II to be further aligned for full coherence and improved clarity.

3.3.1 Vehicle compatibility

The impacts on vehicles of increasing proportions of ethanol and FAME in petrol and diesel are explored in Section 4.3.3 on fuel quality parameters and Section 5 on protection grades. Most post-2003 vehicles are compatible with E10, and approximately 30-50% of vehicles manufactured in 2020 are compatible with 10% FAME fuel.

The raising of FQD limits places an impetus on engine and vehicle manufacturers to develop compatible engines (described further in Section 5). Firstly, in the case of B10, certain manufacturers whose vehicles are not compatible according to ACEA will have greater reason to develop new compatible vehicles, in the case that no B7 protection grade is introduced. However, as described in Section 5, a B7 protection grade would avoid large costs for vehicle owners. The impacts of a protection grade on emissions, as well as the potential costs for vehicle owners, are also estimated in Section 5.

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN

3.4 Conclusions

The PRIMES modelling has established that the current FQD limits do not prevent the achievement of the RED II renewable energy targets. However, there is stakeholder perception that the 7% FAME limit in FQD is a barrier to further use of FAME in diesel. Increasing the FAME content limits in FQD to 10% would therefore facilitate achieving the RED II targets. Whereas, there is still potential for significant increase in take up of bio-ethanol in petrol with the existing FQD 10% ethanol limit, indicating this is not a barrier to achieving the RED II targets.

Benefits arising from increased biofuel usage include reductions in GHG emissions and air pollutant emission reduction benefits. Achieving the full extent of these GHG and air pollutant emission reductions will require vehicle manufacturers to ensure compatibility with 10% FAME in diesel.

4 COVERAGE OF HIGH-STRENGTH BLENDS OF ALTERNATIVE FUELS

4.1 Introduction

High-strength blends of alternative fuels are out of scope of the FQD, since the FQD refers to CN codes for petrol and diesel which define these fuels as containing a minimum of 70% mineral oil[4]. Consequently, there is no EU-level legislation setting requirements for high strength blends on the specifications which have implications for human health and the environment or compatibility with engine and emissions control technologies. Similarly, there is no requirement for monitoring and reporting the quantities of these fuels marketed.

A further consideration is that the mineral fuel component within the high-strength blend is also not captured by the Directive, and so there is the potential that mineral fuels not meeting the FQD specifications could be circulated for the purpose of blending.

At present the volumes sold of higher blends of alternative fuels, i.e. fuels containing less than 70% mineral petrol or diesel is minor contribution to total fuels used. However, there are increasing drivers for the uptake of renewable and alternative fuels.

A group of these alternative fuels are referred to as “drop-in fuels”. These can be blended with mineral based fuels without significantly adversely affecting engine performance. This has the potential to lead to an increase in the quantities of high strength blends being marketed, and subsequently falling outside of the scope of the FQD requirements. High strength blends of other components may have adverse impacts on engines and emissions after-treatment technologies.

Currently, according to the EEA, 5.2% of transport fuel reported was from biological origin in 2018, and no Member States reported the use of renewable fuels of non-biological origin (EEA, 2020). The EU produced 16.2 million tonnes of biofuel (ethanol, FAME and HVO) in 2018. One study projects that the future uptake of renewable fuels could reach up to 54 Mtoe or 16.7% of EU transport needs by 2030 (European Commission, 2017). It is also predicted that synthetic fuels will become utilised in fuel blends in the future, although there is uncertainty to the extent that this will be by 2030.

A variety of different types of alternative fuels blend components are available that have potential to be used in higher blends with petrol and diesel by 2030. The impacts of

[4] The specific sub-codes cited by the FQD are however now obsolete. More recent developments and clarification of CN codes and reference to “other similar oils” makes wider allowance for alternative fuels.

extending the FQD to cover high strength blends varies for these different blend components.

Fuel components predicted to have an uptake by 2030 and the direct associated limit in FQD assessed is summarised in Table 4-1. This task first seeks to investigate these fuel components' effect on the diesel or petrol blend parameters and the respective compatibility with the FQD. Compatibility of these components with other FQD parameters will be considered further in section 4.3.1.

Table 4-1: Overview of potential blend components that could be taken up by the European market by 2030 and current FQD coverage.

Fuel	Blend component	Current FQD coverage
Petrol	Bio-ethanol	10% v/v limit (marketed petrol)
	Bio-methanol	3% v/v limit (marketed petrol)
	Bio-butanol	15% v/v limit (marketed petrol)
	Ethyl tert-butyl ether (ETBE)	22.2% v/v limit (marketed petrol)
	Methyl tert-butyl ether (MTBE)	22.2% v/v limit (marketed petrol)
	Synthetic petrol* (XTL)	No limit.
Diesel	Fatty acid methyl esters (FAME) / Rapeseed Oil Methyl Ethers (RME)	7% v/v limit (marketed diesel). Must meet EN 14214 standard.
	Bio-dimethyl ether (DME)	Not covered.
	Hydrotreated vegetable oil (HVO)	No limit. Must meet EN 15940 standard.
	Synthetic diesel (XTL)	No limit. Must meet EN 15940 standard.

**Synthetical petrol includes predominately fungible bio-gasoline, and potentially also petrol made via non biological routes (e.g. renewable hydrogen, recycled carbon routes).*

There are a number of higher strength blends of alternative fuels which are predicted to be marketed to some extent by 2030. The fuel blend options shown in Table 4-2 have been identified through literature and feedback gathered from stakeholders as having a potential uptake in Europe by 2030. These consist of fuel blends already used in Europe, fuels not yet used in Europe but that have been adopted in other areas of the world, and novel fuels. There are existing standards in place for many of these fuels, as indicated in the Table. These standards may be incorporated in some Member States' national standards but are not mandatory according to FQD. As such, there is scope for the FQD to ensure the compliance with the parameters specified in these standards in order to minimise impacts on the environment and vehicles. It is also the case that some of these fuels lack EU standards such as ED95 and M85, indicating that regulation by the FQD is potentially of more benefit.

The composition of these fuels is considered to inform examination of the need to introduce definition(s) and/or specifications for such fuels within the FQD. It is noted that the actual definition of possible future fuel specifications for these fuels is beyond the scope of this study. The impact of coverage of these fuels under the FQD is investigated in terms of economic and environmental impacts, as well as impacts on vehicle compatibility.

Table 4-2: Overview of high blends of alternative fuels with potential to be taken up in the European market by 2030

Fuel	Fuel blends	Composition	Existing standard
Petrol	E85	85% ethanol + 15% petrol	CEN/TR 15993:2018[5]
	ED95	95% ethanol + 5% ignition improver	Swedish standard SS 155437:2015[6]
	M85	85% methanol + 15% petrol	ASTM D5797[7], National standard in China
Diesel	B100	100% biodiesel (FAME)	EN 14214[8], ASTM D6751[9] German standard DIN V 51606
	HVO/XTL*	100% paraffinic fuel	EN 15940:2016[10]

** As a drop-in fuel, HVO is anticipated to be used in various higher blends of alternative fuels at varying concentrations between 30% and 100%.*

4.2 Policy options

The following options to assess the relevance and impact of extending the scope of the FQD to cover all relevant fuels have been identified.

1. Counterfactual: Maintain the scope based on the current Article 2 definitions of petrol, diesel and gas-oil which refer to CN codes (2710), which define these fuels as being 70% w/w or more obtained from petroleum oils or oils from bituminous minerals.
2. Extend the scope to include all relevant fuels that could be expected to reach the market before 2030 including those containing more than 30% non-petroleum or bituminous based content (i.e. high-strength blends with biofuel, synthetic fuels, renewable fuels of non-biological origin or recycled carbon fuels), **with** reference to specific definitions of fuel specifications (for example, EN standards).
3. Extend the scope to include all relevant fuels that could be expected to reach the market before 2030 including those containing more than 30% non-petroleum or

[5] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:65559&cs=1783AAE5FF3A9DEBBDFBF68F1E8980C12
[6] https://www.sis.se/en/produkter/petroleum-and-related-technologies/fuels/liquid-fuels/ss1554372015/
[7] https://www.astm.org/Standards/D5797.htm
[8] https://www.en-standard.eu/din-en-14214-liquid-petroleum-products-fatty-acid-methyl-esters-fame-for-use-in-diesel-engines-and-heating-applications-requirements-and-test-methods-includes-amendment-2019/
[9] https://standards.globalspec.com/std/14212176/ASTM%20D6751
[10] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:68123&cs=16404BE54904FBDEC7EE531039D8B45CF

bituminous based content (i.e. high-strength blends with biofuel, synthetic fuels, renewable fuels of non-biological origin or recycled carbon fuels), **without** reference to further definitions of fuel specifications.

4.3 Analysis

This section presents the following analysis:

1. An assessment of the potential uptake of fuel components used in higher strength alternative blends of petrol (ethanol, methanol, synthetic petrol and ethers) and diesel (FAME and paraffinic fuels), and the effect of these fuels on transport fuel quality parameters.
2. An assessment of fuel blends currently predicted to be marketed by 2030, their current compatibility with FQD technical specifications and comparison with existing quality standards for those fuels.
3. An assessment of the impacts of regulating fuels not currently covered by the FQD.

4.3.1 Fuel blend components: Likely uptake and compatibility with the FQD

This section presents a summary of fuel blend components utilised in higher blends and assesses how an increase of these components in a fuel blend may impact on parameters specified in the FQD, and if this would affect the fuel's ability to comply with the FQD's limits. Beyond the parameters specified by the FQD, the effect on some relevant parameters that are specified by the respective CEN standards of petrol and diesel have also been investigated.

Currently, according to the EEA monitoring report in 2018, 5.2% of transport fuel reported was from biological origin and no Member States reported the use of renewable fuels of non-biological origin (0%) (EEA, 2020). The EU produced 16.2 million tonnes of biofuel (ethanol, FAME and HVO) in 2018. The consumption of liquid biofuels in the EU's long-term strategy is projected to be between 15.7 to 48.6 Mtoe by 2050 in the baseline and highest scenario (European Commission, 2020).

The projected uptake of renewable fuels in 2030 in terms of absolute quantities and contribution to total EU transport needs in the MIX scenario, is shown in Table 4-3. This indicates that synthetic fuels are also expected to enter the European market in 2030, primarily to supply the aviation sector[11].

Table 4-3: Projections for future renewable fuel uptake and contribution to transport needs in the MIX scenario by 2030.

Biofuel type	Quantity in use by 2030 (Mtoe)	Contribution to total EU transport needs (excl. int maritime) by 2030 (%)
Food-crop based*	~12	~4.3
Advanced (lignocellulosic based)**	~9	~3.1

[11] Aviation fuels are not covered by the FQD. However, the aviation fuels market demand has implications for the road and NRMM fuels market due to availability of supply.

Advanced (HVO-based)***	~3	~1.2
E-fuels**** (a.k.a. synthetic fuels)	~0.8	~0.3

**As defined in the amended RED directive (2009/28/EC)*

*** Annex IX Part A biofuels, as defined in RED II*

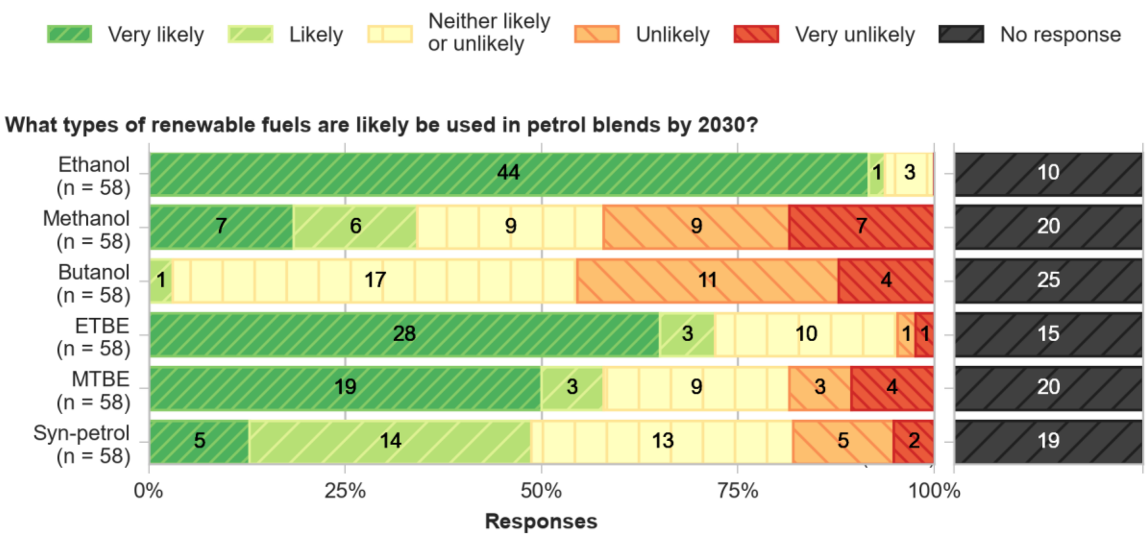
**** Annex IX Part B biofuels, as defined in RED II*

Petrol fuel components

The likelihood of uptake of the fuel blend components shown in Table 4-1 varies. EEA fuel quality data indicates that average ethanol content in petrol sold in the EU in 2018 was 3.7% v/v (EEA, 2020). Methanol made up only 0.1% v/v of petrol components. The data indicates an average 4.1% (m/m) ether component in petrol. Since the EEA data monitors FQD parameters, it does not distinguish which ether is included in blends. A 2017 Concawe report presented data from a fuel survey that indicated the ETBE and ethanol were the most common oxygenates in petrol, followed by MTBE and TAME (Concawe, 2017). There is no evidence of significant syn-petrol or butanol uptake in current blends.

The stakeholder responses to the survey undertaken in this current study, shown in Figure 4-1, give an indication of which components are expected to be used by 2030. Ethanol, ETBE and MTBE are already in use in petrol blends today and are thus expected to continue to be used by 2030. Syn-petrol uptake will be highly dependent on renewable electricity availability and prices. Bio-butanol faces high raw material costs, which is seen as a major obstacle to commercial production (ETIP Bioenergy, n.d.).

Figure 4-1: Overview of stakeholder responses to the question: "What types of renewable fuels are likely to be used in petrol blends by 2030?"



An overview of the effects of increasing the share of different renewable fuel components in petrol blends is presented in Table 4-4. The table indicates that the main parameters to consider in possible new specifications are the limits for oxygen and oxygenate contents, as discussed in section 2.6. The impact of ethanol content on vapour pressure is a key aspect to consider in relation to evaporative emissions. Increasing ETBE and MTBE content decreases the vapour pressure. All potential renewable components are beneficial for RON, as discussed in more detail in section 12.

Table 4-4: Overview of the effects of increasing fuel components in petrol blends on the fuels' parameters and compliance with FQD

Parameter	Specified in FQD	Ethanol	Methanol	ETBE	MTBE
Research Octane Number, RON	✓	↑	↑	↑	↑
Motor Octane Number, MON	✓	↑	↑	↑	↑
Lead Content	✓	-	-	-	-
Density @ 15°C	✗	↑	↑	-	-
Sulphur Content	✓	-	-	-	-
Manganese Content	✓	-	-	-	-
Hydrocarbon Type Content					
- Olefin Content	✓	-	-	-	-
- Aromatics Content	✓	-	-	-	-
- Benzene Content	✓	-	-	-	-
Oxygen Content	✓	↑	↑	↑	↑
Oxygenates Content					
- Methanol	✓	-	↑	-	-
- Ethanol	✓	↑	-	-	-
- Iso-Propyl Alcohol	✓	-	-	-	-
- Iso-Butyl Alcohol	✓	-	-	-	-
- Tert-Butyl Alcohol	✓	-	-	-	-
- Ethers (5 or more C atoms)	✓	-	-	↑	↑
- Other Oxygenates	✓	-	-	-	-
Summer Vapour Pressure	✓	↑/↓	↑/↓	↓	↓
Distillation		↑/↓	↑/↓	↓	↓

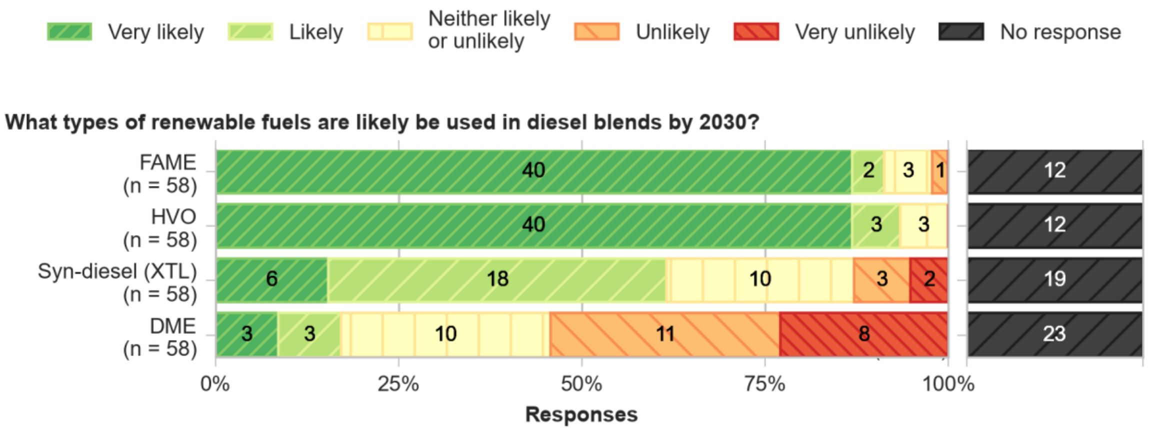
↑ = Parameter increases with increasing share of fuel component
- = Parameter remains similar or is not affected with increasing share of fuel component
↓ = Parameter decreases with increasing share of fuel component
Green = The change is beneficial to compliance with FQD and/or vehicle compatibility
Grey = The change does not affect compliance with FQD and/or vehicle compatibility
Red = The change is detrimental to compliance with FQD and/or vehicle compatibility

Diesel fuel components

An overview of the likely blend components with potential to be used in diesel blends by 2030 was shown in Table 4-1 above. EEA fuel quality data indicates that average FAME content in diesel sold in the EU in 2018 was 5.3% v/v and HVO content was found to average 1.4% v/v (EEA, 2020). European HVO production capacity is predicted to grow in the next 5 years. Many traditional refineries have technology that is suitable for HVO conversion, therefore if the demand for HVO were to increase, a larger supply of HVO could be achieved through refinery conversion. Synthetic diesel costs are currently high and are directly influenced by renewable electricity availability and prices.

The stakeholder responses shown in Figure 4-2 give an indication of which components are expected to be used by 2030. FAME and HVO are already commonly used in diesel blends today and are thus expected to continue to be used by 2030. More than half of respondents find it very likely or likely that syn-diesel may also be used in diesel blends by 2030.

Figure 4-2: Overview of stakeholder responses to the question: "What types of renewable fuels are likely to be used in diesel blends by 2030?"



An overview of the effects of increasing the share of different renewable fuel components in diesel blends is presented in Table 4-5. Some effects are noted in brackets because they depend on the feedstock composition used to produce the fuel component. For example, using a feedstock with a higher degree of saturation will increase the cetane number and stability of the component.

Table 4-5: Overview of the effects of increasing fuel components in diesel blends on the fuels' parameters and compliance with FQD

Parameter	Specified in FQD	FAME	HVO	XTL
Density @15°C	✓	↑	↓	↓
Flash Point	✗	↑	-	-
Cetane Number	✓	↑	↑	↑
Cold Filter Plugging Point	✗	↑	-	-
Viscosity at 40°C	✗	↑	-	-
PAH	✓	(↓)*	-	-
Sulphur Content	✓	-	-	-
Water Content	✗	↑**	-	-
Manganese Content	✓	-	-	-
Distillation				
- 95% v/v Recovered at (360°C)	✓	↑	-	-
Oxidation Stability	✗	(↓)	-	-
Lubricity, (WSD 1,4) at 60 °C	✗	↓	↑	-
Fatty Acid Methyl Ester (FAME)	✓	↑	-	-

↑ = Parameter increases with increasing share of fuel component
- = Parameter remains similar or is not affected with increasing share of fuel component
↓ = Parameter decreases with increasing share of fuel component
Green = The change is beneficial to compliance with FQD and/or vehicle compatibility
Grey = The change does not affect compliance with FQD and/or vehicle compatibility
Red = The change is detrimental to compliance with FQD and/or vehicle compatibility

** FAME may lead to lower PAH due to low content of total aromatics and polyaromatics, but this is not currently clear in the literature.*

***FAME increases the risk of water ingress*

The table indicates that the main parameters to consider in possible new specifications are FAME content and density. However, the setting of minimum density limit has been advised against due to restriction of blending lighter components including synthetic and paraffinic diesel (See Section 11). Further aspects to consider with increasing FAME content are the cold filter plugging point and viscosity, which affect the cold properties and may cause issues for usage in cold weather. Furthermore, esters are high-boiling compounds and therefore have a higher distillation recovery, which may present further issues in cold weather such as engine deposits and emissions of particulate matter.

A key aspect to consider with increasing FAME content is the oxidation stability, which depends on the level of saturation of fuel (IEA-AMF, 2020). Increased content of unsaturated FAME results in a more unstable fuel and potential for formation of peroxides and acids that can damage vehicle parts. Furthermore, FAME has an affinity to water, which may accelerate oxidation. Antioxidants and dehydration of FAME may help to prevent such issues. As such, for FAME blends greater than 10% specifying oxidation stability is relevant to minimise engine damage.

4.3.2 Higher strength blends of alternative fuels: Current usage and likely uptake by 2030

This section presents the fuel blends identified to be most likely to be utilised in 2030[12], and assesses their compatibility with current parameters specified in the FQD.

Ethanol blends

The higher strength blends (>30% non petroleum-based content) of ethanol most likely to be used in 2030 are **E85** (85% ethanol and 15% petrol) and **ED95** (95% ethanol and 5% additives).

- **E85** is already used in a few Member States (notably France, Sweden, Finland and Czechia) but only amounts to 0.2% of petrol fuel sales in the EU (EEA, 2020). There were 4,000 filling stations selling E85 in the EU in 2018. E85 is compatible with flex-fuel vehicles (FFV) and conventional petrol cars with an E85 conversion system. France has the largest E85 compatible vehicle fleet with more than 129,000 cars (39,000 FFVs and 90,000 converted cars).
- **ED95** is an ethanol fuel with additives that is run in modified diesel engines (ePURE, 2020). ED95 is a commercially available product used in buses and trucks, predominantly in Scandinavia, but also in France, Belgium, Poland, Italy and Spain (European Commission, 2017).

Methanol blends

Methanol can be blended with petrol up to 3% in compliance with the FQD and the EN 228 standard. Methanol can also be used as blends such as **M85** (85% methanol and 15% petrol) or in pure form **M100**. Värmlands Metanol stated in the stakeholder workshop that methanol was also tested in old vehicles up to 35% without any significant issues. However, OEMs generally advise against its use and note that it should only be used up to specified limits (e.g. 3% in the EN 228 standard) or in specialised vehicles (WWFC, 2019). M85 and other high concentrations of methanol may be used in special FFVs (IEA-AMF, 2020). M100 is increasingly considered as a viable alternative fuel in the shipping industry,

[12] This section presents analysis of the higher strength blends of alternative fuels that are likely to be marketed in 2030. These represent fuels where differences in technical specifications are most extreme from conventional fuels. Changes to the FQD to accommodate these fuels will also therefore accommodate more intermediate blends with more moderate levels of alternative fuels.

as well as in China, India and Israel. China has been a key driver for growth of methanol production for transport, which was partly driven by lower prices per unit of energy than petrol.

Fuel ethers blends

Alcohols can be converted to ethers, such as ethanol conversion to tert-butyl ether (**ETBE**) or tert-amyl ethyl ether (**TAEE**) and methanol conversion to methyl tert-butyl ether (**MTBE**) or tert-amyl methyl ether (**TAME**) (IEA-AMF, 2020). These ethers can be used as petrol components and have favourable fuel properties, making them preferred over alcohols as petrol components. They have high octane numbers and low vapour pressures, as well as being free of aromatic, olefin and sulphur content. However, there is no evidence of fuel ethers being used in specific high-strengths blends.

Biodiesel blends

The most used higher strength biodiesel blend is pure biodiesel, i.e. **B100** (100% FAME). B100 is mostly used in dedicated fleets and HDVs (European Commission, 2018) but is also available in some public filling stations. The use of B100 in HDVs and non-road vehicles has declined in recent years (AGQM, 2018). The 3IBS project[13] carried out a bus fleet survey covering around 70,000 buses and trolley buses across 24 European countries serving over 100 million inhabitants and found that 9.9% of vehicles were fuelled by biodiesel (3IBS, 2016). The survey also found that 18% of stakeholders wanted to introduce more biodiesel vehicles into their fleets, compared to 43% for hybrids, 28% for batteries, 28% for CNG and 13% for biogas.

Paraffinic fuel blends

Paraffinic fuels include HVO and various X-to-Liquid (XTL) fuels, such as gas-to-liquids (GTL) or biomass-to-liquids (BTL), which are produced using Fischer-Tropsch synthesis. Paraffinic fuels are defined by the voluntary EN 15940 standard. These fuels meet the compositional requirements in the FQD Annex II for diesel and can therefore be used to blend with fossil diesel without any limit or labelling according to the FQD and is compatible with existing engines (Neste, 2016).

- **HVO** currently accounts for an average of 1.4% of diesel blend components (EEA, 2020). Engine and vehicle manufacturers widely support the use of HVO (WWFC, 2019). In contrast to FAME, HVO could feasible be blended with fossil diesel at any content from 0-100%. In the stakeholder questionnaire, ACEA noted that the use of HVO in diesel blends from 31-70% would depend on changes to density limits in the EN 590 standard and that blends with >70% HVO are extremely likely to be used in northern EU in 2030. European HVO production capacity is predicted to grow in the next 5 years (European Commission, 2020). Conversion capacity of traditional refineries is estimated at 12 million tonnes (EAFO, 2020).

1. **Synthetic diesel (XTL)** from both carbon dioxide and biomass is more expensive than diesel, with current costs of e-fuels being up to 4.50 € per litre diesel equivalent (LBST and dena, 2017). The widespread use of these fuels hinges on the increasing availability and falling prices of electricity from renewables. Production increases and favourable electricity prices suggest that the fuel itself (excluding any excise duties) could cost between 1.00 and 1.40 € per litre in the

[13] https://cordis.europa.eu/project/id/314334/reporting

long run (The Royal Society, 2019). Current production scales of power-to-liquid (PtL) fuels are around 0.1-0.2 kt (European Commission, 2020). The EU's long-term strategy estimates e-fuel consumption to be in the range of 0 to 54.3 Mtoe by 2050 for all sectors including transport. PtL fuel consumption in the MIX scenario reaches 31 Mtoe in 2050, with about two-thirds consumed in aviation and international maritime, while the remainder is projected to be consumed primarily in road transport. The costs of PtL are less than 2,000 Euro/tonne in 2050.

Straight vegetable oils (SVO) and fats

Vegetable oil, recycled grease and animal fat are typically converted into fuels that are directly compatible with conventional diesel engines through esterification (biodiesel) or hydrotreatment processes (paraffins). However, these oils and fats can also directly be used in modified or converted diesel engines, used mostly in limited agriculture applications (e.g. fuel lines, injectors and combustion chambers) (IEA-AMF, 2020).

4.3.3 Higher strength blends of alternative fuels: Existing standards and compatibility with the FQD

The existing standards for higher strength blends of alternative fuels are summarised in Table 4-2.

Ethanol blends

CEN/TR 15993:2018 is a voluntary European Standard for the quality and testing requirements for E85 marketed in Europe and provides guidance for producers, blenders, marketers and users of E85. There is currently no CEN defined standard for the quality of ED95 in Europe. However, ED95 standards exist in Sweden (SS 155437:2015) and France (European Commission, 2017). The Subgroup on Advanced Biofuels of the Sustainable Transport Forum recommended in 2017 that a common EU fuel standard for ED95 is created which should include a harmonisation of the additives used in ED95.

The parameter specifications of the FQD and the EN 228 standard, as well as the mentioned standards for E85 and ED95, are shown in Annex A. Table 4-6 summarises the compatibility of E85 and ED95 that meet the relevant standards with the specifications of the FQD and the EN 228 standard.

Table 4-6: Compatibility of E85, ED95 and M85 with FQD and EN 228 parameter specifications

Parameter	Specified in FQD	E85	ED95	M85
Research Octane Number, RON	✓	✓	✓	✓
Motor Octane Number, MON	✓	✓	✓	✓
Lead Content	✓	-	-	-
Density @ 15°C	✗	✗	✗	✗
Sulphur Content	✓	✓	✓	✓
Manganese Content	✓	-	-	-
Oxidation stability	✗	✓	-	-
Hydrocarbon Type Content				
- Olefin Content	✓	✓	✓	✓
- Aromatics Content	✓	✓	✓	✓
- Benzene Content	✓	✓	✓	✓
Oxygen Content	✓	✗	✗	✗
Oxygenates Content				
- Methanol	✓	✓	✓	✗
- Ethanol	✓	✗	✗	✓
- Iso-Propyl Alcohol	✓	✓	✓	✓
- Iso-Butyl Alcohol	✓	✓	✓	✓
- Tert-Butyl Alcohol	✓	✓	✓	✓
- Ethers (5 or more C atoms)	✓	✓	✓	✓
- Other Oxygenates	✓	✓	✓	✓

The main parameters that exceed FQD limits for E85 are the ethanol content and oxygen content (Cincu, 2011). As such, if the FQD is extended to cover higher strength blends of ethanol, derogations will need to be in place for these parameters for these fuels. The existing standard for E85 does not include some of the parameters specified in the FQD (lead, manganese and hydrocarbon contents). The CEN/TR 15993:2018 standard for E85 includes some parameters which are not covered by the FQD (water content, acidity and electrical conductivity. Some of these parameters may be important for environmental and vehicle compatibility related aspects of E85 fuel quality (See Section 4.3.4). The density range specified in the E85 standard is mostly above the EN228 density standard, however this is not regulated by the FQD.

The majority of specifications in the SS 155437:2015 for ED95 are covered by the FQD and with compatible specifications, with the exception of the ethanol and oxygen contents, as is the case for E85. The same FQD parameters that are not covered by the E85 standard are also not covered by the ED95 standard. The density range of ED95 falls outside of the range specified for the EN 228 standard, but this parameter is not included in the FQD.

Vapour pressure is an important parameter with respect to ethanol in blends. This interaction is explored in detail in Section 13. Currently, vapour pressure is not covered in the standards of these higher ethanol blends.

Methanol blends

The compatibility of M85 with FQD parameters is very similar to that of the previous two ethanol-based blends, as shown in Table 4-6. It exceeds the limit for methanol and oxygen content. It also exceeds the limit for density specified in EN 228, but this parameter is not included in the FQD.

Diesel blends

The CEN standard (EN 14214) for FAME gives specifications for all FAME that is either used as B100 biodiesel or for FAME that is used to blend with fossil diesel to any ratio. The FQD specifies that FAME added to diesel must comply with this standard. The European Standard EN 15940:2016 is applicable to HVO and XTL. Following this standard, paraffinic diesel fuels can be used as drop-in fuels. The main difference in specification with the diesel EN590 standard is lower density.

The parameter specifications of the FQD and the EN590 standard, as well as the mentioned standards for FAME, HVO and XTL, are shown in Annex B. Table 4-7 summarises the compatibility of FAME, HVO and XTL with the parameter specification of the FQD and the EN590 standard.

Table 4-7: Compatibility of B100, HVO100 and XTL with FQD and EN 590 parameter specifications

Parameter	Specified in FQD	B100	HVO100	XTL
Density @15°C	✓	✗	✓/✗	✓/✗
Flash Point	✗	✓	✓	✓
Cetane Number	✓	✓	✓	✓
Cold Filter Plugging Point	✗	-	✓	✓
Viscosity at 40°C	✗	✓/✗	✓	✓
PAH	✓	-	✓	✓
Sulphur Content	✓	✓	✓	✓
Water Content	✗	✗	✓	✓
Distillation				
- 95%V/V Recovered at	✓	-	✓	✓
Oxidation Stability	✗	✗	✓	✓
Lubricity, (WSD 1,4) at 60 °C	✗	-	✓	✓
Fatty Acid Methyl Ester (FAME)	✓	✗	✓	✓

In comparison with the FQD, the B100 standard (EN 14214) complies with all but the density and FAME content specifications. The limits for viscosity overlap with those in the FQD. The B100 standard does not specify limits for PAH and distillation recovery. In comparison with EN 590 (B7), EN 14214 allows a higher density, flash point, viscosity and water content, as well as a lower oxidation stability. These parameters are not currently regulated by the FQD, and their potential inclusion is investigated in Section 11.

In comparison with the FQD, the HVO/XTL standard (EN 15940) complies with all parameters. In comparison with EN 590 (B7), EN 15940 is almost identical but has a lower density limit.

Reference to standards in potential amendments to the FQD

This study seeks to assess the need to define fuel specifications for fuels currently not yet addressed under the FQD.

One option for defining fuel specifications is to use external standards to define fuel grades and to define the parameters and specifications that are regulated. The limitation of defining against external standards is that standards may evolve, which can lead to a lack of clarity in coverage of the Directive. This has occurred in the case of the FQD referring to CN codes for petrol and diesel, which having now been superseded gives ambiguity over whether FQD covers fuels of less than 70% mineral content. By contrast, the benefit of reference to standards is it provides immediate clarity in the short term by being specific about the defined fuel grades.

The alternative to this is not referring to standards, i.e. any fuel blend could be covered and need to comply with the FQD specifications. This gives greater flexibility given the uncertainty over the evolution of the fuels market in the future. However, this can lead to less clarity for stakeholders overall as to what fuels are covered by the Directive. In this case, where fuels are to be more broadly captured, consideration could be given to revising the parameters specified in the FQD. Introducing additional parameters or extending the specifications of existing parameters to include both minimum and maximum limits would provide more specific requirements for fuels, including for fuels that are yet to be developed. This indicates a potential shortcoming of this approach, as it is challenging to anticipate all relevant parameters and associated specifications that will be relevant for future fuels. Furthermore, not all parameters covered by EN fuel standards are relevant for the objectives of the FQD in which case it would not be appropriate to include these in the FQD even if these parameters are normally include in EN fuel standards. Analysis of the added value of incorporating additional parameters in to the FQD from current EN standards is presented in section 11.

Table 4-8 below shows the obsolete CN codes referred to by the FQD and new CN codes that may be applicable.

Table 4-8: CN codes referred to in the FQD and new CN codes (European Commission, 2020).

Fuel type	Obsolete CN codes	New CN codes
Petrol	Article 2(1): 2710 00 27, 2710 00 29, 2710 00 32, 2710 00 34 and 2710 00 36	Petroleum oils (light oils) with ≥70% petroleum content, do not contain biodiesel and lead content not exceeding 0.013 g/l: • 2710 12 41 (RON <95) • 2710 12 45 (RON 95-98) • 2710 12 49 (RON ≥98)
Diesel	Article 2(2): 2710 00 66	Petroleum oils (gas oils) with ≥70% petroleum content, containing biodiesel and sulphur content limited to 0.001% by weight[14]: • 2710 20 11 Biodiesel with less than 70% petroleum oil:

[14] The CN codes under this heading are also noted to not contain any waste oils.

		• 3826 00 10 (FAMAE) • 3826 00 90 (Other)
Gasoil	Article 2(3): 2710 19 41 and 2710 19 45	Petroleum oils (gas oils) with ≥70% petroleum content, containing biodiesel and sulphur content limited to 0.001% by weight: • 2710 20 11 Petroleum oils (gas oils) with ≥70% petroleum content and do not contain biodiesel: • 2710 19 43 (sulphur content <0.001%) • 2710 19 46 (sulphur content 0.001%-0.01%)[15]

The introductory notes to Chapter 27 of the Combined Nomenclature explain that the references made to 'petroleum oils and oils obtained from bituminous materials' under heading 2710, do not only cover those oils mentioned, but also 'similar oils, as well as those consisting mainly of mixed unsaturated hydrocarbons, obtained by any process, provided that the weight of the non-aromatic constituents exceeds that of the aromatic constituents' (European Commission, 2020). The explanatory notes published alongside the Combined Nomenclature expand on this and specifically mention that the following mixtures of hydrocarbons are also considered (European Commission, 2019):

- synthetic paraffinic diesel fuels, in particular 'Hydrotreated Vegetable Oils' (HVO) and 'Gas to Liquid Fuels',
- products from renewable sources resulting from the following processes: 'Biomass to Liquid Fuels' or 'Biogas to Liquid Fuels',
- products from the co-processing of renewable feedstock at refineries with petroleum feedstock.

The document further notes that 'Gas to Liquid Fuels', 'Biomass to Liquid Fuels' and 'Biogas to Liquid Fuels' mean the conversion of gas into liquid fuels by the Fischer-Tropsch process or equivalent processes.

These clarifications indicate that the CN codes under heading 2710 also cover fuels with HVO or XtL contents higher than 30%. For diesel fuel, a CN code could be identified for fuels with less than 70% petroleum oil content. However, an equivalent could not be identified for ethanol or ethers.

[15] This CN code is only relevant if sulphur content derogation for gas oil is maintained (see section 7)

4.3.4 High strength alternative fuel blends: Impacts associated with regulation of high strength blends of alternative fuels

The impacts associated with regulation of these options should be considered depending on the policy option chosen. Policy option 2 refers to existing standards, so that fuels that do not currently have a European standard (ED95 and M85) would not be covered by the FQD and would therefore not be impacted. However, policy option 3 would extend the scope to these fuels and set limits for the relevant parameters presented in Table 4-6 and Table 4-7. Therefore, policy option 3 would affect these fuels.

The determination of specifications of identified parameters is not within the scope of this study. As such, impacts of regulation as pertain to specific parameters are assessed qualitatively.

Vehicle compatibility impacts

All identified standards limit the content of sulphur in fuels, as this can be harmful to vehicles and the environment. Sulphur originates from fossil fuel components however and so sulphur content in high strength blends of alternative fuels is likely to be less of an issue than for higher fossil blends if the base fossil components are unchanged.

It is still important to limit sulphur content due to the mineral component that is still present in the majority of higher strength blends of alternative fuels. Currently refineries must desulphurise fuel to meet the FQD limits for the majority of fuel that is marketed in the EU. If high strength blends of alternative fuels start to become more significant, and continue not to be covered by the FQD, then the Sulphur limit in the FQD does not apply to the blended fuel, i.e. including the base fossil fuel. In this case, refineries may stop desulphurising the base fuel, as desulphurisation is a costly process. Refineries do produce heating oil, which has higher S content, and so it may be possible to increase production of higher S diesel for blending. If this was to happen, sulphur content in the fuel blends could become higher than current levels, leading to higher impacts on engines (As well as environmental and health impacts of SOx emissions). Therefore, by regulating higher blends under the FQD, this risk is avoided.

Acidity is a relevant parameter for high strength blends based on alcohols (E85, ED95 and M85) (ASTM, 2016). The respective standards limit acidity to 0.005% (m/m). Strong acidity can lead to rapid corrosion of engine parts, while even weak corrosion may affect long-term durability (IEA-AMF, 2020).

Electrical conductivity is a further parameter that is limited for alcohol-based high strength blends. It reflects the content of metallic ions, such as chloride, sulphate, sodium and iron, in the fuel, which can also have a corroding effect on engine parts (IEA-AMF, 2020).

A further parameter that could be considered is water content. Both ethanol and methanol have an affinity for water, which can lead to increased water content in alcohol-based high strength fuels. Increased water content in the fuel will decrease the solubility of hydrocarbons in blends such as E85 and M85 (ASTM, 2016). This separation can be harmful for vehicles and infrastructure and affects cold starting and drivability (IEA-AMF, 2020). For these reasons, the respective standards limit water content to 0.5% (m/m).

In the case of higher FAME blends, oxidation stability is an important parameter to consider with the potential for formation of peroxides and acids that can damage vehicle parts.

Environmental impacts

The specifications of the Fuel Quality Directive indirectly result in limiting primary air pollutants including particulate matter, nitrogen oxides, sulphur oxides, carbon monoxide and lead. This is also the case for the mineral component within high strength blends of alternative fuels. If these components are imported then there is the potential for regulation to improve their quality with respect to certain environmental parameters, particularly sulphur, and also manganese/MMT (See Section 10). The comparison above of current voluntary standards for the main types of higher strength blends of alternative fuels marketed with current FQD specifications has revealed some potential environmental benefits.

None of the standards identified for the high strength blends have limits for manganese and lead content, which can be harmful to vehicles, health and environment. However, since high strength blends of alternative petrol are already high in octane, MMT and lead usage is unlikely. Options with regard to extending the scope of the FQD to prohibit all metallic additives are outlined in Section 10, which may have implications for higher strength blends for future additives not yet marketed.

Vapour pressure is not currently regulated in high strength blends of alternative fuels. A waiver for vapour pressure specifications in the FQD is potentially allowed for ethanol blends up to 10%, however this is not currently used for the majority of Member States (except for Spain, and Portugal has applied post-2020). Vapour pressure increases when ethanol content increases from 0% ethanol content to low percentages (~5%) but this increase declines after this for higher ethanol content. Based on conclusions outlined in Section 13, it appears likely that Member States would not have issues with ensuring higher strength blends of ethanol comply with current vapour pressure limits in FQD. Due to the fact that vapour pressure is not currently included in voluntary quality standards for these fuels, regulation of these fuels by the FQD will ensure that vapour pressure limits are met for these fuels.

Regulation of these currently unregulated fuels may also help to promote uptake and investment in these fuels by ensuring consistent fuel quality. This uptake of higher strength blends of alternative fuels can lead to increased proportion of renewable energy and drive reductions in greenhouse gas emissions and air pollutant emissions, particularly in captive fleets where such blends are anticipated to be most utilised. The potential for regulation to drive increased uptake of fuels also has significant economic impacts (See below).

Economic impacts

With regulation of high strength blends, fuel suppliers can consolidate production and distribution to sell the same fuel across the single market. This can unlock economies of scale that reduce costs of production. Regulated high strength blends would give potential consumers more certainty over the fuel quality and stimulate uptake. Regulating these fuels has EU added value as MSs will transpose into national legislation improving consistency of higher strength blends across the EU. As an EU Directive, the FQD only sets minimum standards and MSs still have the option to set more stringent limits, so there is still a possibility for some market fragmentation however.

Expanding the scope of the FQD to additional fuel blends will also expand the regulatory burden for fuel suppliers and national authorities. Fuel suppliers that currently produce may have to adjust their production facilities and procedures to comply with an expanded FQD. National authorities would be required to transpose the updates into national legislation and introduce expanded monitoring systems to cover the high strength blends.

Most Member States follow the European Standard EN 14274 in their monitoring approach, which also defines the minimum number of samples taken by each Member State. Monitoring costs are based on sampling numbers **(EEA, 2020)**. As defined in EN 14274, 100 samples must be taken in countries with <15 million tonnes of road fuel sales per year and 200 samples in countries with >15 million tonnes of road fuel sales per year.

The FQD Evaluation gathered information on costs of sampling and analysis (€200 sampling cost and analysis cost of €600 for petrol and €700 for diesel per sample) **(European Commission, 2017)**. In the stakeholder questionnaire undertaken for this study, France estimated an analysis cost of €526 per sample for NRMM gas-oil. To estimate the monitoring costs for higher strength blends, this cost is used due to being more recent and its relevance in considering the extension of monitoring to additional fuels.

Based on the cost data outlined above, the estimated cost of collecting and analysing samples is €2.4 million per blend per Member State. For the five high strength blends discussed in this section as being the most likely fuels to be used in 2030, this results in monitoring costs of €12 million per Member State per year, or €324 million for the EU27. However, these estimates should be considered an upper bound. The number of samples required for high strength blends may be lower than the number for petrol or diesel, due to their lower market share. Furthermore, the estimate does not account for any efficiencies in the monitoring system that may lead to decreasing marginal costs.

4.4 Conclusions

This section has investigated the implications of extending the FQD to cover higher strength blends of alternative fuels.

An assessment of the potential uptake of fuel components used in higher strength alternative blends of petrol (ethanol, methanol, synthetic petrol and ethers) and diesel (FAME and paraffinic fuels), and the effect of these fuels on transport fuel quality parameters was first conducted. The most significant effects identified are the impact of higher ethanol and methanol quantities on octane number, oxygen content, and vapour pressure. The effects of higher FAME are found to mostly impact parameters not specified by FQD but captured by EN590, many of which are investigated in Section 11 of this study (density, flash point, water content).

After this, specific higher strength blends of alternative fuels predicted to be marketed by 2030 were identified (E85, ED95, M85, B100 and 100% HVO) and existing quality standards for those fuels were compared with FQD technical specifications. If the FQD is extended to cover high ethanol blends such as E85, derogations will need to be in place for oxygen content to set a higher oxygen content limit for the high blend grades. For high strength ethanol blends, the existing vapour pressure waiver may need to be amended to include increased levels of ethanol.

An assessment of the impacts of regulating fuels not currently covered by the FQD was then conducted. Current standards for higher strength blends for the most part are aligned with the FQD. Parameters that are relevant due to their impacts on engine components and vehicle compatibility, that are present in the standards but not currently regulated by the FQD, are: acidity, electrical conductivity and water content. Additionally, vapour pressure and distillation are not currently regulated and so there may be benefits in the form of reduced VOC emissions for extending FQD to these fuels.

These standards for the high strength blends are voluntary. Extending the scope of the FQD to include high strength blends would regulate the relevant parameters. As such, any environmental and vehicle compatibility impacts would be provided by any potential improvements in compliance from legal regulation compared with voluntary standards. This could potentially give the market more assurance that the fuel quality is reliable and ensure a unified quality of these fuels across Europe. However, the added value of regulating these fuels via the FQD is unsupported as no evidence was found to indicate the extent to which currently used high strength blends that have a European standard deviate from their respective standards. The potential impact of regulating high strength blends is therefore also not possible to quantify.

ED95 and M85 currently do not have a common European standard. For these fuels, coverage by the FQD would help to facilitate a unified fuel quality across the EU, with associated benefits to the single market. Whilst both ED95 and M85 are identified by a range of sources as having potential for uptake in the EU by 2030, the scale of the market for these fuels has not been identified in the reviewed literature.

The regulation of higher blends of alternative fuels would provide better assurance for vehicle manufacturers and consumers that fuels being used are compatible with their vehicles. It also gives fuel suppliers confidence that they can sell their fuel across the EU. For these reasons it also can potentially help to stimulate the market as the improved regulatory situation gives greater clarity. Regulation however introduces additional regulatory burden for fuel suppliers and national authorities with potentially high monitoring costs.

Policy option	Environmental impacts	Vehicle compatibility impacts	Other economic impacts
Extend scope of the FQD to higher strength blends of alternative fuels with reference to existing EN standards	+ Regulation of **vapour pressure** in higher strength blends potentially leading to (small) benefits (reductions) in **VOC emissions.** Unified fuel quality across the EU for these fuels gives confidence to the market and consumers. This potentially drives **increased uptake of alternative fuels** and associated GHG emission and air pollutant emission reductions. It potentially enables manufacturers to **develop more sophisticated engines and exhaust after treatment systems** with associated air pollutant/GHG emission benefits.	+ Unified fuel quality across the EU ensuring **compatibility for vehicles.** This is particularly the case for ED95 and M85 which do not have a unified European standard. Potential vehicle compatibility benefit from adding parameters in FQD specifications of particular relevance for alternative fuels: Oxidation stability, water content, acidity and conductivity.	**+/-** **Monitoring costs** associated with regulation of higher strength blends estimated at **64 million per additional fuel regulated for the EU27.** Fuel suppliers may face additional costs associated with ensuring compliance with the standards.

Policy option	Environmental impacts	Vehicle compatibility impacts	Other economic impacts
Extend scope of the FQD to higher strength blends of alternative fuels without reference to existing EN standards	This policy option has the same range of potential costs and benefits as those outlined above. The greater flexibility potentially allows for more different grades of fuel to be captured by FQD and marketed. If this flexibility does lead to an increase in the number of fuel grades in market there would be additional monitoring costs and increased supply and distribution costs. However, this outcome is uncertain as other market factors would likely continue to constrain the number of grades in common circulation. Similarly, greater flexibility of introducing emerging fuel grades may potentially lead to increased uptake in biofuels which would result in additional greenhouse gas emission reductions. However, again this outcome is uncertain as the change in the FQD alone would not directly influence this. Additionally, the lack of reference to standards ensures that the Directive remains flexible to any new developments, and avoid distorting potential development of fuel grades either positively through increased confidence and uptake or negatively through increased compliance costs. However, this may provide less clarity to stakeholders.		

5 IS THE REQUIREMENT FOR PROTECTION GRADES STILL APPROPRIATE?

5.1 Introduction

Increasing the biofuel content in fuels above certain levels may affect the functioning of engines and emissions control systems, or increase maintenance requirements, particularly in older vehicles. The FQD therefore required the placing on the market of a protection grade for petrol with a maximum oxygen content of 2.7% and ethanol content of 5% (i.e. E5) until 2013, with allowance for Member States to continue this requirement for a longer period if considered necessary. No similar requirement for a protection grade is made for diesel. While B7 (7% FAME) is currently the most commonly available grade, certain Member States have or are considering the marketing of B+ (higher than 7% v/v blend).

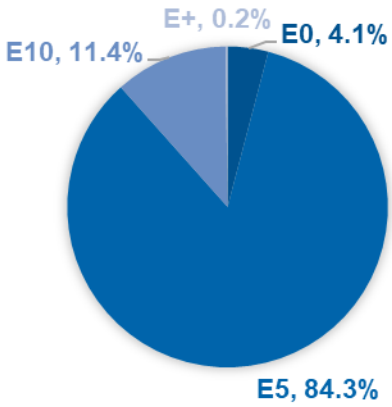
The aim of this task is to investigate what the appropriate requirements for protection grades are for petrol and diesel going forward, considering E10 and B10 blends which may increasingly be taken up by 2030. This includes consideration of the number of vehicles in the EU fleet for which a protection grade may be needed and what the costs would otherwise be for owners of incompatible vehicle owners. A further consideration is the impact on emissions from the change or removal of the protection grade E5 petrol or addition of protection grade for diesel.

The FQD Evaluation identified that there are additional costs to suppliers as a result of multiple grades of fuels being marketed across the EU. The analysis reflects on whether a change to the EU Directive will have EU added value, in terms of the objective for promoting a single market.

Current fuel marketed in the EU

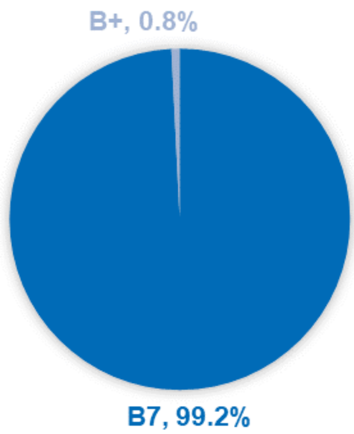
Of the petrol sold in the EU in 2018, 95.9% contained bioethanol (EEA, 2020). The majority of petrol was marketed as E5 (84.3%) and 11.4% was marketed as E10, while the E+ category (petrol blends with more than 10% bioethanol content) accounted for 0.2% of the petrol sales (Figure 5-1).

Figure 5-1: Petrol sold in the EU in 2018 (EEA, 2020).



All diesel sold in the EU in 2018 contained biodiesel, of which 99.2% was labelled B7 and 0.8% was a blend with more than 7% FAME, as shown in Figure 5-2 (EEA, 2020).

Figure 5-2: Diesel sold in the EU in 2018 (EEA, 2020).



Since 2015, diesel sold in France has been B8 or B10. Lithuania's main diesel grade contains 8% biofuel. In the FQD Evaluation the automobile industry and fuel suppliers argued this constitutes fragmentation of the single market. They further requested clear labelling of the B8 blend and the supply of B7 as a protection grade for vehicles that are not compatible. The FQD evaluation staff working document has noted that not offering a B7 protection grade goes against the objective of the FQD to ensure fuel-engine compatibility (European Commission, 2017).

5.2 Policy options[16]

The following policy options have therefore been identified for assessment:

(a) Petrol:

1. Counterfactual: Leave FQD provisions on E5 unchanged (i.e. no mandatory protection grade for E5).
2. Reintroduce a mandatory protection grade for E5.

(b) Diesel:

1. Counterfactual: Maintain no requirement for a protection grade.
2. Introduce a B7 protection grade.

5.3 Analysis

5.3.1 Economic impacts

Vehicle Compatibility Impacts

<u>Vehicle compatibility with fuel grades</u>

A 2017 report for the European Commission noted that most post-2003 vehicles are E10 tolerant (European Commission, 2017). ACEA publishes a regularly updated comprehensive list[17] of vehicles compatible with E10 fuel. An overview of the findings on compatibility is presented in Table 5-1.

Table 5-1: Vehicle compatibility with different petrol blends based on literature

Blend	Vehicle compatibility
E5	Compatible with all petrol vehicles.
E10	Compatible with the majority of post-2003 petrol vehicles (Vehicle age of 27 years in 2030) (European Commission, 2017).

The most widely sold blend of diesel is B7, which is compatible with all diesel vehicles. The vehicle producers association ACEA published a list[18] of passenger cars compatible with the B10 diesel fuel in 2018 (ACEA, 2018). The list indicates that not all vehicles were marked as being compatible with B10. All Citroën and Peugeot vehicles introduced after 2000 and Renault vehicles with type-approval Euro 5 or higher are compatible. For other car manufacturers, ACEA's list indicates that only certain vehicles are compatible.

A more recent list of B10 compatible vehicles prepared by biofuel producer associations AGQM and MVaK was published in 2020 (MVaK, 2020). The list highlights that many

[16] Policy options have been adjusted following further research and discussion after the workshop held in June 2020.

[17] https://www.acea.be/uploads/publications/ACEA_E10_compatibility.pdf

[18] https://www.acea.be/uploads/publications/ACEA_B10_compatibility.pdf

vehicles are marked as compatible to run on B10 is outside of Europe. Next to those approved in the ACEA list, the AGQM and MVaK list also notes that all BMW, Dacia and Opel vehicles with type-approval Euro 5 or higher are compatible with B10.

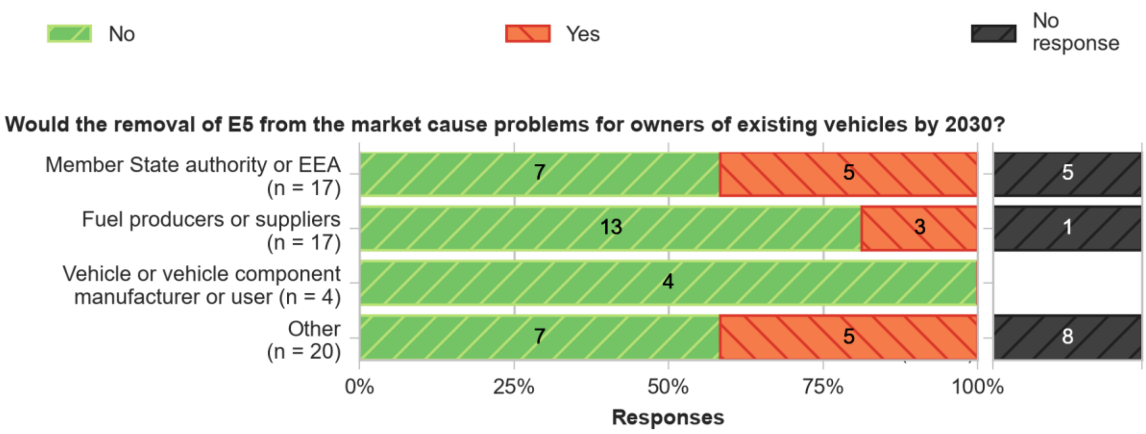
The vehicle manufacturers noted above (ACEA and MVaK lists) comprise 33.7% of the diesel vehicle market in 2019, meaning that the proportion of compatible vehicles should exceed this, as the ACEA list indicates some models from other manufacturers are compatible (ICCT, 2020). An overview of the findings on compatibility for biodiesel blends is presented in Table 5-2.

Table 5-2: Vehicle compatibility with different diesel blends based on literature

Blend	Vehicle compatibility
B7	Compatible with all diesel vehicles.
B10	Compatible with more than 33.7% of diesel vehicles, dependent on model and manufacturer (ACEA, 2018) (MVaK, 2020).

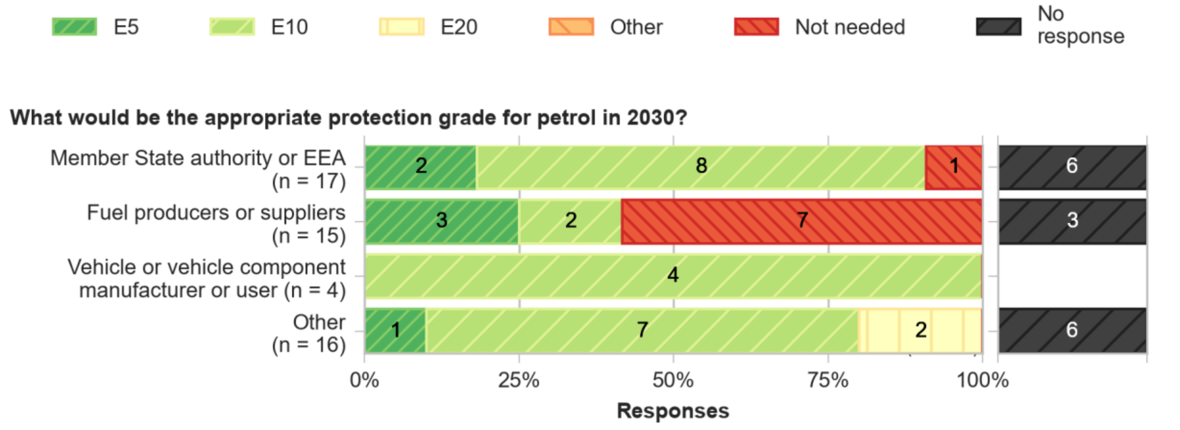
The majority of stakeholders indicated that no problems would be caused by the removal of the E5 protection grade, particularly in the case of vehicle manufacturers and fuel producers/suppliers (Figure 5-3).

Figure 5-3: Stakeholder responses to the question: "would the removal of E5 from the market cause problems for owners of existing vehicles by 2030?"



Stakeholders were also asked what they believe to be the appropriate protection grade for petrol by 2030, if any. As shown in Figure 5-4, the responses indicate that the majority believe E10 would be an appropriate protection grade in 2030. One stakeholder group which has a differing view to this are fuel producers or suppliers, for which the majority believe that no protection grade is needed in 2030.

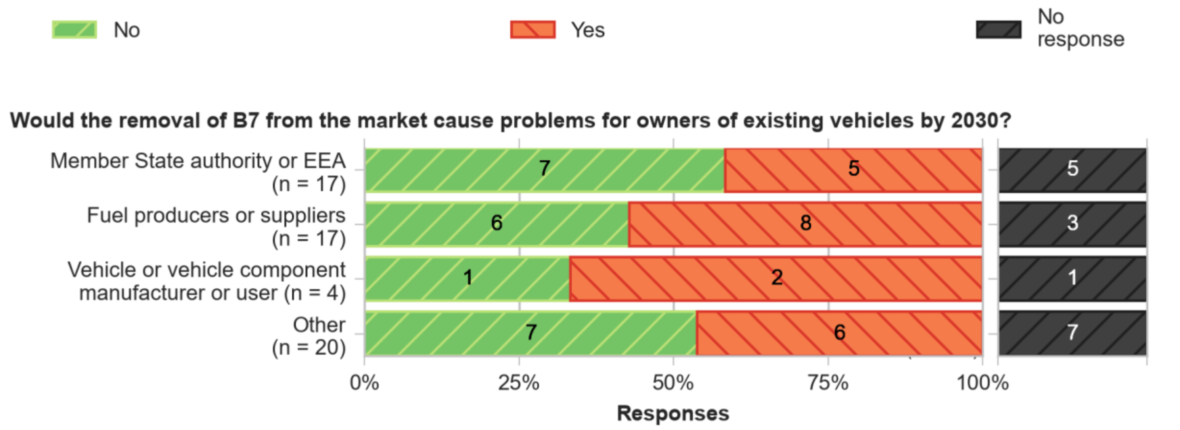
Figure 5-4: Stakeholder responses to the question: "what would be the appropriate protection grade in 2030?"



There is less consensus on the compatibility of diesel vehicles with blends of biodiesel that exceed 7% FAME. Based on the references noted above, at least 33.7% of new vehicles are compatible with B10, although this figure is likely higher as not every vehicle marked as B10 compatible could be identified. One vehicle manufacturer organisation noted in the stakeholder questionnaire response that all their vehicles sold after 2000 are compatible, and another organisation indicated that all vehicles with Euro 5 type-approval or higher are compatible. Based on this information, it is assumed that potentially 50% of new vehicles in 2020/2021 may have compatibility issues with B10 fuel.

The expectation by stakeholders of consequences of a removal of B7 from the market is split, as shown in Figure 5-5. The responses indicate that half of the stakeholders responding to the survey believed that no problems would be caused by such a removal, while the other half believed problems would be caused.

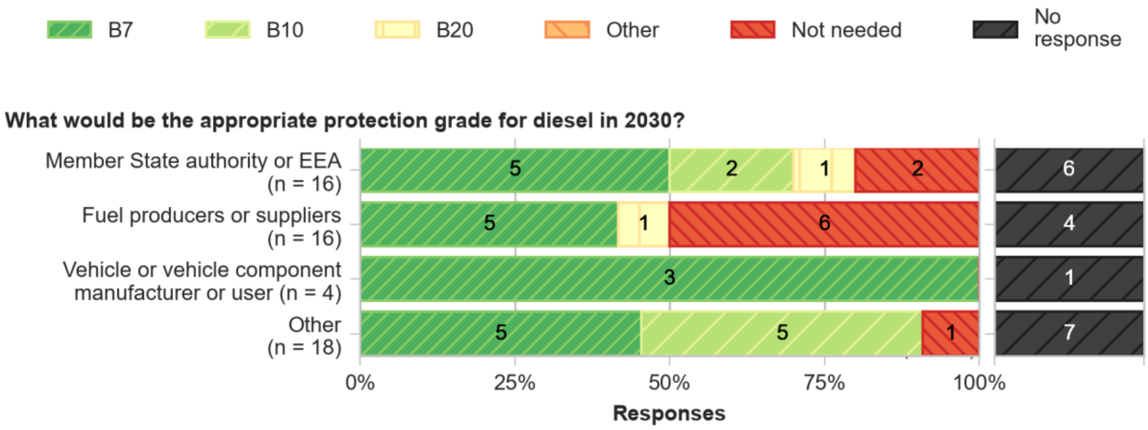
Figure 5-5: Stakeholder responses to the question: "would the removal of B7 from the market cause problems for owners of existing vehicles by 2030?"



When asked what an appropriate protection grade for diesel in 2030 would be, the responses indicate that half of stakeholders believe a B7 protection grade should be introduced, as shown in Figure 5-6. A quarter of respondents, mostly from the fuel producers and suppliers group, believe that no protection grade for diesel is required. Some respondents (19%) indicated that B10 would be the appropriate protection grade.

All vehicle manufacturers responding to the question indicated that a B7 protection grade is appropriate.

Figure 5-6: Stakeholder responses to the question: "what would be the appropriate protection grade in 2030?"



The focus of this study is impacts in the year 2030. The PRIMES-TREMOVE model projects the European 2030 vehicle fleet composition with respect to vehicle ages. The PRIMES vehicle fleet projection does not disaggregate by age the very small proportion of vehicles over 19 years old. Therefore, no estimate is available for the number of vehicles that require an E5 protection grade that will remain in the fleet in 2030, i.e. vehicles aged 27 years or older in 2030. Small numbers of vehicles of this age will still be in circulation, particularly in the case of classic car enthusiasts. For vintage cars such as these, compatible petrol supply may be considered via special interest groups rather than in the general market.

In the case of diesel vehicles, compatibility is less certain. From the available information described above, we have assumed that approximately 50% of vehicles registered in 2015-2020 are compatible with B10. A protection grade for diesel would only be required should adoption of 10% FAME become more widespread. We have assumed that in response to such an increase in B10, all manufacturers would adapt their new vehicles to be compatible, resulting in all vehicles registered between 2025 and 2030 being compatible.

Table 5-3 European Fleet of diesel cars and LDVS in 2030 by age according to PRIMES-TREMOVE model and fuel compatibility (000's of Vehicles)

Vehicle age in 2030	2030 Number of vehicles (000s)		Proportion of vehicles not compatible with B10
	Cars	LDVs	
0-4 years	18721	4581	0% assumed* not to be compatible
4-9 years	23305	4713	Approximately 10% of vehicles assumed* not to be compatible
9-14 years	22989	6395	Approximately 50% of vehicles estimated not to be compatible, based on information from literature and stakeholders
14-19 years	9695	3020	Approximately 70% of vehicles estimated not to be compatible, based on information from literature and stakeholders

*estimated, based on the assumption that new vehicles will be adapted to be compatible with B10 in response to increased marketing of B10.

These assumptions lead in a calculation that 28% of the combined car and LDV fleet is not compatible with B10 in 2030.

Cost of Vehicle Upgrades or Retrofits

There would be economic impacts for some vehicle owners if there is no protection grade for diesel (for FAME content) if the common market fuel grade becomes B10. Owners of non-compatible vehicles will need to replace their vehicle with a newer, compatible model.

Costs are calculated on the basis of owners replacing their diesel vehicle earlier than the end of life, leading to lost residual value of the vehicle and an effective cost associated with incurring the replacement costs earlier than they otherwise would. This effective cost is due to the difference in present value of the cost, calculated using a social rate-of-time preference 4% annual discount rate.

Table 5-4 Cost of Vehicle Upgrades in Absence of Protection Grade (Diesel vehicles not compatible with B10) 2015 Price Year

Vehicle type	Lost residual value of vehicles	Effective cost due to earlier vehicle purchase)	Total cost
Cars (Diesel)	€62.1bn	€110bn	€172.4bn
LDVS (Diesel)	€22.7bn	€43.4bn	€66.1bn
Total (Diesel)			€238.5bn

Costs are significant in the case of diesel vehicles due to the larger number of vehicles potentially not compatible with B10. Some Member States have much older vehicle fleets than others: Lithuania (average vehicle age of 16.9 years), Estonia (16.7 years), Romania (16.3 years) Greece (15.7 years), and so changes to protection grades would disproportionately impact some Member States (ePure, 2020).

In the case of petrol vehicles and bio-ethanol, retrofits are an alternative to vehicle replacement. Retrofits involve new fuel system gaskets and in few cases new high pressure injection pumps. The gaskets (€20-30) and associated labour costs (€100-200) put the cost of a retrofit at around €200 (European Commission, 2017). A UK DfT report estimated a retrofit may range from simple fuel hose and seal changes costing about €225 including labour costs to a full fuel system upgrade costing around €550 (UK DfT, 2020).

Costs for Fuel Suppliers

The introduction of a protection grade for diesel could lead to some filling stations marketing an increased number of fuel grades and which may require making associated investments in storage and refuelling infrastructure. An estimate for the investment cost of around €100,000 for a filling station to market an additional grade of E85 in 2015 is made in (European Commission, 2020). Europe's Independent Fuel Suppliers (UPEI) provided a higher cost in the stakeholder survey, indicating that the introduction of additional marketed grades could cost between €200,000 and €2,000,000 per filling station. Beyond investment in additional tanks, pumps, hoses, store management systems and electronic pricing information at the retail location, new grades would also affect the cost of storage & handling (S&H). A lot of factors, such as the volume of each grade, if it is a blended or straight product or if it can be blended in a truck (on-board blending) will affect the costs. Furthermore, truck usage would also become less optimised if additional blends were required, which could lead to additional distribution costs.

Depending on market uptake of higher biodiesel content in diesel, the share of filling stations required to make such an investment may differ. Here we consider three scenarios: a) 10% of filling stations, b) 50% of filling stations and c) 100% of filling stations. Based on the cost data gathered from the literature and stakeholder survey, a cost estimate of €200,000 is used per filling station for marketing an additional grade of fuel. There were 75,396 active filling stations in the EU in 2018 (FuelsEurope, 2019). We assume the same number of active filling stations in 2030. As shown in Table 5-5, the estimated cost to fuel suppliers is between €1.5 Billion and €15 Billion.

Table 5-5: Estimated cost of supplying additional grades for scenarios of different % of petrol stations marketing additional protection grade 2015 Price Year

Scenario	Number of filling stations	Estimated cost (million €)
Scenario a) - 10%	7,540	1,508
Scenario b) – 50%	37,698	7,540
Scenario c) - 100%	75,396	15,079

In different Member States, ownership structures of filling stations varies, with some being dominated by a small number of larger companies (Germany, Greece, Italy), while in others ownership is largely by smaller independent retailers (Poland) (European Commission, 2017). Smaller, independent retailers are likely to have less available funds for investing in additional infrastructure and would be disproportionately affected by the need to market an additional grade of fuel. As an alternative response, these retailers may choose to market only the protection grade, leading to reduced biofuel uptake (See Environmental Impacts).

Impacts on the Single Market

Protection grades can negatively impact the EU single market. If the protection grade is optional, then some Member States will choose to adopt it and some will not. This fragmentation can affect owners of vehicles requiring the protection grade, in the event of driving across borders of different Member States. In countries where it is adopted, the protection grade may become the dominant or only fuel that is sold, as is currently the case for E5 in many Member States.

5.3.2 Environmental Impacts

Greenhouse Gas and Air Pollutant Emissions

The costs of marketing multiple grades of fuel means that some filling stations, particularly smaller stations or those independently owned, may need to market only the protection grade, therefore reducing biofuel uptake and greenhouse gas emission savings.

In the case of ethanol and an E5 protection grade, the number of vehicles for which this fuel is necessary has been estimated to be very low in 2030 and demand for E5 negligible. The removal of the E5 protection grade may therefore help to facilitate greater uptake of E10. As such, this would have benefits in terms of greenhouse gas emissions reductions and in contributing to renewable energy targets.

The introduction of a 7% FAME in diesel protection grade would reduce the greenhouse gas reduction and renewable energy uptake benefits that would be realised in a situation with increased uptake of B10.

The impacts are therefore calculated in the context of reducing the potential benefits. This impact depends on the extent to which protection grade fuel is marketed. Impacts are estimated for two scenarios: firstly, where the protection grade is only used by vehicles that require it; and secondly where the protection grade is utilised by a larger proportion of the fleet. For the latter, the protection grade take up is assumed to be 70% as per current E5 protection grade usage.

In the case of diesel and B7 protection grade, it is estimated that approximately 28% of the car and LDV fleet is not compatible by 2030. Table 5-6 shows the estimated emissions impacts of protection grades in the form of reduced benefits of the PRIMES-TREMOVE modelling scenario.

Table 5-6 Emissions Impact of B7 Protection Grade

Percentage of fleet using Protection Grade	NO_X emissions impact relative to PRIMES-TREMOVE Scenario	SO_2 emissions impact relative to PRIMES-TREMOVE Scenario	CO_2 emissions impact relative to PRIMES-TREMOVE Scenario
28%	4.3 kt	16.4t	9,602 kt
70%	10.8 kt	41.1t	24,006 kt

Note: This table reflects the impacts relative to the PRIMES modelling scenario, where in the absence of the protection grade there is total fleet uptake of a diesel blend with 10% FAME and 10% HVO. As such, these impacts are an upper estimate of the emissions impacts of the protection grades given the ambitious nature of the PRIMES modelling scenario.

5.4 Conclusions

The introduction of an EU-wide B7 protection grade for 7% FAME in diesel would support availability of compatible fuel for the potentially 28% of diesel vehicles not compatible with B10 expected to be in the fleet by 2030. It is considered necessary by vehicle manufacturers and half of fuel supplier stakeholders that engaged in the consultation for this study. However, the extent to which the non compatibility exists is disputed by some stakeholders. Without the protection grade, owners of incompatible vehicles would incur costs of early vehicle replacement, with relatively higher incidence in Member States with older average fleet age, which are also among the Member States with lower than average GDP per capita.

The disadvantage of introduction of a B7 protection grade is that it may lessen the increase in uptake of biofuels and consequently lead to lower than otherwise environmental benefits. There could also potentially be additional costs for fuel suppliers resulting from marketing of multiple diesel grades, depending on whether the protection grade must be available in all filling stations or only a smaller proportion, for example those above a certain size.

In the case of ethanol in petrol, a protection grade is less clearly required. The majority of stakeholders that engaged in this study indicate there would be no impact caused by a lack of E5 grade. Only vehicles aged 27 years or greater in 2030 require an E5 protection grade. Given the very small numbers of such vehicles, and that most will be vintage vehicles owned by enthusiasts, these vehicles could be serviced by specialist fuel suppliers. Alternatively, it may be possible for these vehicles to be retrofitted to be E10 compatible at a low cost per vehicle, in the range of €200 to €550. Not having a E5 protection grade will facilitate increased uptake of E10 and the associated environmental benefits, as well as avoiding additional costs for fuel suppliers of marketing multiple petrol grades.

Table 5-7 Impacts of Protection Grade Policy Scenarios

Policy option	Environmental impacts	Economic impacts
No protection grade for diesel	++ Potential for full realisation of uptake of B10, with associated environmental benefits including **greenhouse gas and air pollutant emission reductions**	**Costs to vehicle owners** from premature replacement of cars and LDVs not compatible with B10; estimated at **-€ 339bn** by 2030
B7 (7% FAME) protection grade	Lesser increase in B10 uptake due to marketing of protection grade leading to reduced environmental benefits **Up to 70% reduction in emission benefits**	**Costs to fuel suppliers** from marketing additional grade of fuel estimated in the region of **-€1.5bn to -15bn** investment cost by 2030

Policy option	Environmental impacts	Economic impacts
No protection grade for petrol (Counterfactual)*	++ Potential for full realisation of uptake of E10, with associated environmental benefits including **greenhouse gas and air pollutant emission reductions**	E5 protection grade is not widely needed for vehicle compatibility. In 2030, only 27+ year old vehicles require this grade and given the small number of such vehicles these could be supplied via specialist fuel suppliers. Alternatively, these vehicles may be retrofitted at a low cost per vehicle (circa. €375) to be E10 compatible.
E5 protection grade reintroduced	-- Lesser increase in uptake of E10 and associated reduction in environmental benefits.	Requiring a E5 protection grade would bring **costs to fuel suppliers** from marketing additional grade of fuel.

*Note: The impacts assessed for this policy option assume that the E5 protection grade, no longer required to be marketed by the FQD, will cease to be marketed. However, it is possible that some MS will continue to choose to market E5 as they have currently done, despite it not being a requirement.

6 SHOULD THE SCOPE OF THE FQD BE EXTENDED TO COVER GASEOUS FUELS (LPG, CNG, LNG)?

6.1 *Background*

The FQD currently only covers liquid fuels, in the form of on-road petrol and diesel and off-road gasoil. The FQD evaluation showed that a number of Member States requested for gaseous fuels to be covered by the FQD to give the fuels more support in their uptake (European Commission, 2017). Increased use of gaseous fuels is being considered for on-road and off-road applications as a means of reducing GHGs and certain air pollutants (e.g. PM). This includes fossil derived gaseous fuels, such as Liquefied Petroleum Gases (LPG), Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG), as well as bio-methane and hydrogen. In light of this, it is important to understand what aspects of fuel quality may need to be considered for gaseous fuels, especially in terms of the protection of the environment and the need to ensure vehicle compatibility.

The quality of methane-based fuels can vary based on regional differences in natural gas sources, such as sulphur content. In the case of gas derived from biomass fermentation (biogas), impurities in feedstocks such as silica compounds are important to consider in gas quality (WWFC, 2019).

The purpose of this task is to assess which parameters of fuel quality are relevant for the protection of the environment and ensuring compatibility with vehicles and could be included in legally binding fuel specifications. The actual definition of possible future specifications is beyond the scope of this study.

6.2 Policy options

1. Counterfactual: Maintain current scope which does not include gaseous fuels specifications or fuel quality monitoring.
2. Include gaseous fuels with fuel quality monitoring and incorporating specification for parameters specified by CEN standard EN16723-2 for natural gas and biomethane in transport
3. Include gaseous fuels with fuel quality monitoring and incorporating specification for parameters specified by CEN standard EN589 for LPG
4. Include gaseous fuels with fuel quality monitoring and incorporating specification for parameters Total Sulphur, Methane Number and Wobbe Index range.

Note: Policy Options have been updated following the stakeholder workshop conducted in June 2020 for this project, following comments and further information that has arisen.

Standard EN16723-2 for natural gas and biomethane in transport aims to ensure safety and compatibility of vehicles as well as enabling cross-border trade. However, some important parameters identified by stakeholders are absent from the standard, namely total sulphur, Wobbe index and methane number. As such, a separate policy option containing these parameters is examined. LPG has its own standard EN589 and relevant parameters which are also considered in a separate policy option.

6.3 Analysis

This section first presents the types of gaseous fuels utilised in transport, and available data on their current usage and projected uptake by 2030. Following this, existing standards for these gaseous fuels are presented, and the technical parameters in these standards assessed for their impacts on the environment and vehicle compatibility, in order to assess their relevance for inclusion in the FQD.

6.3.1 Gaseous fuels in transport: Current usage and likely uptake by 2030

Natural gas (LNG, CNG): Overall, natural gas vehicles accounted for 0.5% of the total European passenger car fleet in 2020, consisting mostly of CNG vehicles (EAFO, 2020). As of 2020 there were 1.2 million natural gas-fuelled cars registered in Europe. The 45,488 new registrations of CNG cars in 2020 accounted for a market share of 0.6% in 2020. These vehicles are supported by a European network of 3,630 Compressed Natural Gas (CNG) and 311 Liquefied Natural Gas (LNG) fuelling stations. This includes vehicles fuelled by CNG, LNG and their bio equivalents. The European Agency of Energy Regulator's forecasting model predicts that gas usage in the transport sector is expected to grow in the next decade, with Compressed Natural Gas (CNG) in road transport potentially increasing to 23.9 billion m^3 and Liquefied Natural Gas (LNG) to 34.5 billion m^3 (7.5% and 20% of final energy consumption) (European Commission, 2015).

Bio-methane: Currently, biomethane is not widely used in transport in the EU, with the exception of Italy where there is a support scheme and high availability of feedstock (Eyl-Mazzega, 2019). A 2019 study focusing on 15 Italian municipalities found the potential biomethane production varies from 80.4 million m^3 /year to 102.8 million m^3 /year, with an overall net present value ranging from € 135 to 187 million (Cuchiella, 2019). Although biomethane is not yet widely used in transport, Europe is the world's leading producer of biomethane and production is increasing. In 2011 there were 187 biogas plants in Europe upgrading their production to biomethane. This number has grown rapidly and reaching 497 in the first quarter of 2017. The countries which saw the most biomethane plant construction in 2016 were Germany, Sweden and France (Gas Infrastructure Europe, 2017). There may therefore be a further growth of activity in terms of using biomethane as a transport fuel by other European countries that are large producers of biomethane and have similar transport systems. One European Commission study has indicated that after 2020, biogas and biomethane could count towards the 32% target of renewable energy share of the EU energy consumption, and towards a sub-target of minimum 14% of the energy consumed in the transport sector by 2030 towards the REDII (European Commission, 2019). One of the main current barriers to biomethane uptake is cost, with country specific studies finding that biomethane needs financial support to be competitive with natural gas (European Commission, 2020).

LPG: In 2020, 3.2% of passenger cars in the EU28 ran on LPG, up from 3.07% in 2012 (EAFO, 2020). This accounts for 7.7 million passenger cars. New registrations in 2019 were 180,057, accounting for a 1.5% market share. A total of 32,019 refilling stations in Europe supplied LPG in 2020. Using a scenario based on current policies, LPG consumption is projected to continue to grow in all regions including Europe (WLPGA, 2019). Consumption is expected to reach a peak of a little over 31 Mt in 2030, but it then goes into gradual decline, dipping to just under 30 Mt in 2040 (WLPGA, 2019). One estimate projects bio-LPG to reach around 2 Mt by 2030, however this is heavily dependent on HVO production levels, since the production processes are interlinked (European Commission, 2020).

Hydrogen: As of 2020, around 1,500 hydrogen cars had been deployed in Europe (EAFO, 2020). New registrations reached 479 in 2019, of which 357 were in Germany (201) and the Netherlands (156) (EAFO, 2020). The total number of H_2 filling stations in Europe reached 125 in 2020, although the majority (84) are in Germany. In Europe, hydrogen fuel cells are also powering fleets of public buses (European Commission Horizon 2020, 2016). Although the market penetration remains low, use of hydrogen as an alternative fuel in the transport sector is growing rapidly, as is the investment in infrastructure. Although there remain pre-commercial barriers to ensuring widespread deployment, the Hydrogen Council projects the number of hydrogen powered commercial vehicles to rise to approximately 45,000 by 2030 (The Royal Society, 2019) (SPGlobal, n.d.). The European Hydrogen Strategy aims to build up hydrogen production capacity (i.e. building electrolysers) with at least 6 GW of renewable hydrogen electrolysers by 2024 and 40 GW by 2030.

6.3.2 Existing standards for gaseous fuels

Currently there is a lack of EU-wide gas quality regulation and monitoring for road transport. Standards EN16726:2015 introduced a standard for natural gas quality with the aim of minimising negative effects and maximising safety while as far as possible enabling the free flow of gas within the internal market. The CEN Technical Committee introduced further standards for biomethane for injection in the natural gas network (EN16723-1)[19] and for natural gas and biomethane for use in transport (EN16723-2)[20] in 2016 and 2017, respectively (CEN, 2018).

In the definition of EN16726, it was noted that a common Wobbe Index could not be defined due to differences between Member State specifications and the lack of

[19] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:59781&cs=193AB741DC4F3AE4584E03DE130F55D78

[20] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:41008&cs=1D7CD581175157FBF537040E3716A707E

understanding on the impacts on integrity, efficiency and safety of broadening Wobbe Index. The EN16723-2 standard does not currently specify an upper limit for sulphur because of a difference between the needs for automotive applications (10 mg/kg) and what the gas industry can provide (30 mg/kg) (BIOSURF, 2017). As such, sulphur is of particular importance in consideration of parameters to be added to future automotive fuel specifications.

In 2019, the Worldwide Fuel Charter for Methane-Based Transportation Fuels was published, with fuel categories based on fuel quality and emission performance. Category 5 is the highest quality fuel.

A summary of the different standards and the technical specifications for biogas and biomethane is shown in Table 6-1. While EN16723-2 is the standard for natural gas and biomethane in transport, there are some parameters included in standards EN16723-1 and EN16726 which may be important for consideration of inclusion in the FQD.

Table 6-1: Specifications natural gas and biomethane parameters of different EN and literature standards.

Parameter	Unit	EN16723-1	EN16723-2	EN16726	WWFC Cat. 5
Methane Number	-			Min. 65	Min. 75
Relative density	-			0.555 - 0.7	
Total sulphur	(mg/kg)			Max. 30	Max. 10
Mercaptan sulfur	(mg/m^3)			Max. 6	
H_2S + COS	(mg/kg)		Max. 5	Max. 5	Max. 5
Hydrogen	(mol%)		Max. 2		Max. 2
Carbon monoxide	(mol%)	Max. 0.1			Max. 0.1
CO_2	(mol%)			2.5 – 4	Max. 4.5
Oxygen	(mol%)		Max. 1	Max.1	Max. 1
Liquid Hydrocarbon	(dew point degrees C)		Max. -2 C	Max. -2 C	Max. 2 C
Water	(dew point degrees C)		Climate dependent	Max. -8 C	Max. 5 C
Silicon	(mg/m3)	Max. 0.1	Max. 0.1		Max. 0.1
NH_3	(mg/m3)	Max. 10			
Particulate	-				Not detected
Lubricating oil	(mg/m3)				Max. 15
Wobbe Index (WI)	(MJ/m3)				Min. 46

For LPG, CEN Standard EN589:2018 introduced quality specifications for automotive use, with 2018 being the most recent version of the standard, which includes a sulphur limit value of 30mg/kg.

Table 6-2 Specifications for EN589 LPG Standard

Parameter	Unit	EN589:2018
Methane Number	-	Min 89
Total sulphur	(mg/kg)	Max. 30
Butadiene	(mol%)	Max. 0.1
Total dienes content	(mol%)	Max. 0.5
Evaporation residue	(mg/kg)	Max. 60

CEN members are bound to enshrine these standards as national standards, i.e. as non-mandatory standards (SIS, 2017). The EMPIR initiative, co-funded by the EU's Horizon 2020 research and innovation programme, is currently undertaking a project to increase awareness of the EN16723-1 and EN16723-2 standards within the biogas and biomethane industries and to support their uptake, as well as to evaluate the EU industry capability for measuring and monitoring total silicon and sulphur in line with the standards (EMPIR, 2019). It is unclear at present the extent to which gaseous fuel are compliant with the specifications set out in the CEN standards and as such there is benefit from the inclusion of gaseous fuels within scope of the FQD and the setting of specifications most relevant to the environment and vehicle compatibility.

There is limited information currently available on the current compliance with standards EN16723-1 and EN16723-2 in the EU. CEER (2016) gathered information on national limit values for gaseous fuels for some parameters in 17 Member States.

Table 6-3 Information on current Member State limit values for gas quality parameters (CEER 2016)

Technical Parameter	Compliance with CEN Standard in Member States
Hydrocarbon Dew Point	Of the 9 MS reporting their limit values for hydrocarbon dew point, 6 were compliant with the CEN standard of -2° C. Those not compliant were Spain (5° C), Poland (0° C) and Italy (0° C).
Total Sulphur	Of the 13 MS reporting their limit values for total sulphur, only 5 were compliant the the EN16726 standard[21] of 30 mg/m^3 with some Member States having limits significantly higher, most notably France (150 mg/m^3), Italy (150 mg/m^3) and Hungary (100 mg/m^3).

[21] There is no sulphur limit in the EN16723-2 transport gaseous fuels standard.

Technical Parameter	Compliance with CEN Standard in Member States
H_2S	Of the 13 MS reporting their limit values for H_2S, only 3 were compliant with the CEN standard limit of 5 mg/m^3, with some being considerably higher: Spain (15 mg/m^3), Hungary (20 mg/m^3).
Mercaptan Sulphur	Of the 12 MS reporting their limit values for mercaptan sulphur, 4 were compliant with the CEN standard limit of 6 mg/m^3), with some being considerably higher at 15.5 mg/m^3 (Italy), 16 mg/m^3 (Latvia, Lithuania, Poland), 17 mg/m^3 (Spain), or not setting a limit (Portugal, Hungary).

The indication of a current lack of consistent gas quality standards across the EU and lack of compliance with CEN standards in the legislation of some MS indicates that the FQD can bring notable benefits in the setting of standards for gas quality parameters. Section 6.3.3 outlines the parameters relevant to quality of gaseous fuels and assesses their potential impacts on environmental protection and vehicle compatibility.

6.3.3 Fuel quality parameters and impacts on environment and vehicle compatibility

Fuel quality parameters identified as being relevant from the viewpoints of the protection of the environmental or for ensuring compatibility with vehicles, that could be included in legally binding fuel specifications for gaseous fuels are summarised in Table 6-4. This includes parameters from standards EN16723-2, EN16723-1 and EN16726, and also some additional parameters identified not captured in the standards. The impacts of these parameters are then assessed with regard to environmental protection and vehicle compatibility below. This is done firstly for parameters in standard EN16723-2 for transport fuels, after which relevant parameters for EN16723-1, EN16726 and other parameters are assessed.

Table 6-4 Summary of gaseous fuel quality parameters identified and their relevance from the viewpoints of the protection of the environment and ensuring vehicle compatibility

Parameter	Parameter relevance	
	Environmental Protection/Safety	Vehicle Compatibility
Carbon monoxide (CO)	Moderate	Moderate
Silicon	N/A	High
Ammonia (CH_4)	Low	Low
Hydrogen sulfide (H2S) & Carbonyl sulfide (COS)	Low	High
Hydrogen (H)	N/A (Positive Impact)	Moderate
Oxygen (O_2)	N/A	Moderate
Liquid Hydrocarbon	Low	Moderate
Water	N/A	Moderate

Parameter	Parameter relevance	
	Environmental Protection/Safety	Vehicle Compatibility
Methane Number (MN)	High	High
Relative density	Low	Low
Total sulphur (TS)	High	High
Mercaptan sulphur	Moderate	Moderate
Carbon dioxide(CO_2)	Moderate	Moderate
Butadiene	Moderate	Moderate
Total dienes content	Moderate	Moderate
Evaporation residue	N/A	Moderate
Particulate Matter (PM)	Low	Moderate
Lubricating oil	N/A	Moderate
Wobbe Index	High	High

High = parameter is very relevant for this aspect, Moderate = parameter is relevant to this aspect. Low = Parameter has negligible relevance to this aspect/ is not related.

Parameters specified in EN16723-2 for natural gas and biomethane in transport

Hydrogen sulfide and Carbonyl sulfide

It is appropriate to separately specify the level of Hydrogen sulfide (H_2S) and Carbonyl sulfide (COS), a precursor to H_2S. H_2S is corrosive to internal vehicle/engine parts and fuel storage systems. It is present naturally in raw gas, including biogas. Combustion also leads to the formation of SOx air pollutant emissions.

Environmental protection issues	Low
Vehicle compatibility issues	High

Hydrogen

Hydrogen is sometimes added to gaseous fuels (such as natural gas) to reduce combustion related NO_X and/or greenhouse gas emissions. However, hydrogen can cause embrittlement of the high-tension steel used in CNG vehicle fuel tanks. High hydrogen content in methane-based fuel results in the need for special vehicle/engine calibration to accommodate hydrogen's different burning velocity. In this way, hydrogen content impacts vehicle compatibility and hydrogen-methane mixtures must be managed separately from other methane-based transport fuels.

EUROMOT has stated that hydrogen content in gas blends should not exceed 2% to ensure reliable operations of engines (EUROMOT, 2017).

Environmental protection issues	N/A (Positive impact)
Vehicle compatibility issues	Moderate

Oxygen

The oxygen concentration is important due to flammability. In methane-based fuel, the oxygen concentration must be limited to ensure safe storage and fuelling, and to prevent explosion in high pressure CNG tanks (Worldwide Fuel Charter, 2019).

Environmental protection issues	N/A
Vehicle compatibility issues	Moderate

Liquid Hydrocarbon (hydrocarbon dew point)

Hydrocarbon dew point (HCDP) refers to the temperature at a given pressure at which hydrocarbon components will start to condense out of the gaseous phase. A higher HCDP normally indicates a higher proportion of heavy hydrocarbon components, and lower quality gas. The presence of liquid hydrocarbon in the fuel may cause difficulty in controlling the amount of fuel injected into the engine. Also, if a liquid pool of higher hydrocarbons (with very low methane number) suddenly reaches the engine, severe knocking might result that can seriously damage the engine (Worldwide Fuel Charter, 2019).

Environmental protection issues	N/A
Vehicle compatibility issues	Moderate

Water

For vehicles intended to use hydrocarbons in a gaseous state, the presence of water is not desirable (Worldwide Fuel Charter, 2019). The water dew point can be used to monitor the minimisation of water in the fuel. Excess water can cause engine compatibility issues. For example, fuel line plugging, due to the presence of the water itself and the formation of ice particles or frost formation within the fuel system. Condensed moisture can also cause corrosion in the fuel line and cylinder.

Environmental protection issues	N/A
Vehicle compatibility issues	Moderate

Parameters specified in EN16723-1 for natural gas and biomethane in transport and injection in natural gas networks

Carbon monoxide

Carbon monoxide (CO) in fuel reduces engine power output resulting in lower efficiency and higher relative CO_2 emissions, and so achieving the lowest concentration possible is desirable. Additionally, CO can penetrate rubber components leading to swelling, cracking or blistering damage.

Environmental protection issues	Moderate
Vehicle compatibility issues	Moderate

Silicon

Some raw biogas contains significant amounts of siloxanes which if present during combustion, can form silica that deposits onto many internal vehicle parts including cylinder walls, lambda oxygen sensors and valves. This can cause exhaust gas misalignment, blockage of pistons and cylinder heads and abrasion (Worldwide Fuel Charter, 2019). Silica also deposits on sensor elements, harming oxygen sensors of engines.

A standardised test for measuring silicon at the concentrations specified in EN16723-2 is not yet available.

Environmental protection issues	N/A
Vehicle compatibility issues	High

Ammonia

Ammonia exhibits a high resistance to auto-ignition and very slow kinetics, leading to compatibility issues (Pochet, 2020). Ammonia generates harmful nitrogen oxides (NO_X) during combustion, and is itself a pollutant in the event of passing through the engine without combusting. Ammonia contamination is however not of major concern in gaseous fuels.

Environmental protection issues	Low
Vehicle compatibility issues	Low

Parameters specified in EN16726 for gas infrastructure

Methane Number[22]

The methane number (MN) of a gas is a measure of the resistance of natural gas to engine knock (uneven detonation) when it is burned as a motor fuel in an engine. Methane has a high knock resistance and is given an index value of 100, and methane number is as such largely determined by the proportion of methane by volume in a gaseous fuel mix (ISO, 2014). Hydrogen has a low knock resistance with an index value of 0.

The importance of methane number on engine functioning varies with different types of engines. Knocking can cause serious damage to engines. Higher MN ensures good combustion and lower CO_2 emissions. Most engines have the best fuel efficiency for a MN higher than 80 (EUROMOT, 2017). Engines can also be tuned to run on a lower MN, but this has negative impacts on the fuel efficiency and the response speed to required changes in power output. Due to the importance of methane number to engine compatibility, and the variation in methane number between different types of gases, regulation and monitoring of methane number will help to ensure compatibility, particularly in natural gas and other gas blends.

Environmental protection issues	High
Vehicle compatibility issues	High

Relative density

Relative density refers to the density of gas in relation to the density of air. Density determines the space that is required to store the fuel in the vehicle and affects the range a vehicle can travel with a given amount of fuel, dependent on pressure.

Environmental protection issues	Low
Vehicle compatibility issues	N/A

Total sulphur/Mercaptan Sulphur

Amounts of sulphur in gas mixes varies regionally with natural gas sources. Total Sulphur (TS) stands for the sum parameter of all organic and inorganic sulphur compounds. It comes from natural gas supplies, gas derived from other sources and sulphur-containing odourants. In diesel and petrol fuels, sulphur levels have been reduced to 10 mg/kg.

Lower Total Sulphur produces lower SO_2 emissions when fuels are combusted. SO_2 in exhaust emissions can poison the catalysts in selective catalytic reduction (SCR) exhaust treatment fitted to vehicles to reduce NO_X emissions, reducing their efficiency. Sulphur can also contribute to emissions of fine particulate matter.

As well as leading to increased air pollutant emissions, total sulphur also lead to various engine compatibility problems, such as increased corrosion rates. Sulphur reacts with water at temperatures greater than 80°C and can cause localised corrosion of mild steel. In this way corrosion in engines can be caused by sulphuric acid formed by the combination

[22] *Relevant for LNG, CNG, bio-methane; not relevant for LPG, DME, hydrogen.*

of sulphur present in the fuel with water that enters or is generated in the engine (SAE International, n.d.).

Gas odorants often contain sulphur in the form of Mercaptan sulphur. Methyl mercaptan is the only mercaptan sulphur in natural gas and is used as an odorant in the natural gas industry.

Environmental protection issues	High
Vehicle compatibility issues	High

Carbon dioxide

Carbon dioxide (CO_2) in fuel gas can penetrate rubber engine components, leading to damage. CO_2 also reduces the engine's power output as it as inert gas, leading to lower engine efficiency and as such higher CO_2 emissions. If present at high levels, CO_2 can condense at elevated pressures and low temperatures. When the condensate revaporises at reduced tank pressures, the gas mixture may then have a different composition. This can cause a reduced ability to control the air-fuel ratio and vehicle/engine exhaust emissions (Worldwide Fuel Charter, 2019).

Environmental protection issues	Moderate
Vehicle compatibility issues	Moderate

Parameters specified in EN589:2018

Butadiene/ Total dienes

Excessive diene content can affect engine performance due to increasing the likelihood of residue problems in regulators and vaporisers. Dienes can also reduce the octane rating of LPG causing vehicle compatibility issues (ELGAS, 2019).

Under EU Classification, Labelling and Packaging (CLP) Regulations and EN589:2018 LPG, fuel that contains over 0.1% 1,3-butadiene must be labelled as having the potential to cause cancer and mutations (Public Health England, 2016).

Environmental protection issues	Moderate
Vehicle compatibility issues	Moderate

Total dienes content

Dienes, including butadiene, are hydrocarbon gases containing two carbon double bonds. As described above, excessive diene content can increase the likelihood of residue problems in regulators and vaporisers and can reduce the octane rating of LPG causing vehicle compatibility issues (ELGAS, 2019). Furthermore, dienes such as butadiene are carcinogenic and can have negative environmental impacts. EN589:2018 specifies a limit of a maximum of 0.5 (mol%) total dienes content.

Environmental protection issues	High
Vehicle compatibility issues	High

Evaporation residue

LPG can be contaminated with oily residues during its production or transport. Transport contamination can be a result of shared pipelines, valves and trucks used for the distribution of other products (Da Vinci Laboratory Solutions, 2018). Production sources such as the desulphurization process may contribute sulphur absorbent oil to the LPG stream. Control over residue content is essential in end-use applications of LPG. Residues can affect engine compatibility by leading to deposits that will accumulate and corrode or plug the LPG engine fuel filter, the low pressure regulators, the fuel mixer or the control solenoids (Da Vinci Laboratory Solutions, 2018).

Environmental protection issues	N/A
Vehicle compatibility issues	Moderate

Other parameters identified

Particulate Matter

Whilst the particulate matter is not specified by European standards, the Worldwide Fuels Charter (WWFC) states particulate matter can cause undesirable blockage of vehicle fuel systems. To clean gaseous fuel such as CNG, a dedicated filter should be placed as close as possible to the filling nozzle (Worldwide Fuel Charter, 2019). Fine particulate matter is an important air quality pollutant and small contribution may be made to PM that passes into exhaust emissions.

Environmental protection issues	Low
Vehicle compatibility issues	Moderate

Lubricating oil

Lubricant oil used in gas compression equipment can cause contamination by leading to injector fouling and the disabling of vehicle pressure regulators (Worldwide Fuel Charter, 2019). Some oil types also can damage certain types of rubber materials. Lubricant oil for compressors should be carefully selected (Worldwide Fuel Charter, 2019). WWFC recommends a maximum of 15 mg/m3 of lubricating oil.

Environmental protection issues	N/A
Vehicle compatibility issues	Moderate

Wobbe Index

Wobbe index (Gross Wobbe Index) is a metric of energy density of methane based fuels. Gross WI and Methane Number have a linear inverse relationship so that the minimum MN also acts as an upper limit for the WI. In this way, different gases have different WI and the introduction of hydrogen, biomethane and other gases into the gas supply has an impact on the range of WI. Specifying a WI range is relevant to engine compatibility as this minimises fluctuations in energy content of the fuel gas supply, and allows for optimising engine tuning for efficient performance. Large variations in WI negatively affect engine durability, performance and greenhouse gas emissions (Liu, 2019) (BP, 2011).

Wobbe Index is regulated by every national authority in the EU, however the current ranges vary across Europe (

Table 6-5). The publishing of CEN standard EN16726 did not include a Wobbe Index range because an agreement on a suitable range could not be agreed among Member States. The setting of a WI range at entry and exit points to the EU gas system is now under consideration by CEN due in 2021, following a voluntary adoption announced by the EC in 2016 (CEN, 2019). This consideration includes the different classification of entry and exit points where WI range would be limited, including the option for exit points to have a wider range (Ofgem, 2019).

Defining a Wobbe Index range can be problematic for certain countries that are currently at the upper and lower end of the range which may therefore have to invest to process the gas to meet a specified range (CEER, 2016). A further complication is the conflict between ensuring performance and compatibility, and the diversification of gas supplies and associated decarbonisation benefits. Biomethane and hydrogen are at the lower end of the ranges, while LNG imports are typically at the higher end (ENTSO-G, 2016) (IGEM, 2017). A stricter range would require investments in facilities to correct the Wobbe Index, thereby leading to increasing costs for end users (GIE, 2011).

Table 6-5 Wobbe Index Ranges in EU Member States (CEER 2016)

Country	Minimum	Maximum
Belgium	12.2	13
Croatia	12.7	15.8
Czech Republic	12.7	14.5
Estonia	12.7	14.7
France	13.4	15.7
Hungary	12.7	15.2
Ireland	13.1	14.3
Italy	13.1	14.5
Latvia	13.1	14.4
Lithuania	14.0	15.5
The Netherlands	13.9	15.5
Poland	12.5	15.8
Portugal	13.4	16.0
Slovenia	13.8	15.7
Spain	13.4	16.0

The Worldwide Fuels Charter (WWFC) for methane-based transport fuels published in 2019 recommends the WI should vary less than +/- 3 MJ/m^3 to ensure engine performance and minimise emissions. EUROMOT expresses the view that a maximum WI should be set at 53 MJ/m^3, which should ensure a Methane Number (MN) higher than 70. In addition to this, WI should not vary more than 3 MJ/m^3. Despite this, discussions around the setting of an EU-wide WI range, what this range should be and how it should be implemented are still being investigated.

Environmental protection issues	High
Vehicle compatibility issues	High

Uptake of gaseous fuels and contribution to renewable energy targets

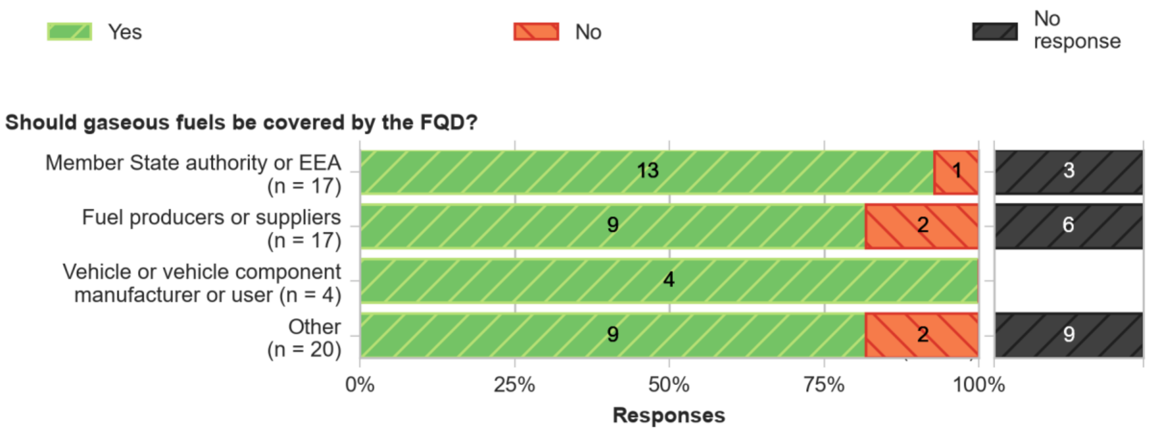
Between 2021 and 2030, biogas and biomethane count towards the 14% of renewable energy share of EU energy consumption in the transport sector target of the Renewable Energy Directive (2018/2001, RED II). Biomethane can also contribute to the 3.5% target for advanced biofuels if certain feedstocks are used such as manure/sewage sludge, bio-waste and agricultural residues.

Stakeholders have indicated that such regulation can be highly beneficial particularly in the case of Wobbe index and methane number, and LPG quality (See Section 6.3.4). The regulation of gas quality by the FQD may promote and facilitate the increasing uptake of gaseous fuels in transport in the EU, and as such help promote the achievement of renewable energy targets.

6.3.4 Stakeholder feedback

In the stakeholder questionnaire, the overall view of stakeholders echoes those of Member States in the FQD evaluation, with stakeholders broadly in in favour of extending the scope of the FQD to gaseous fuel (Figure 6-1)

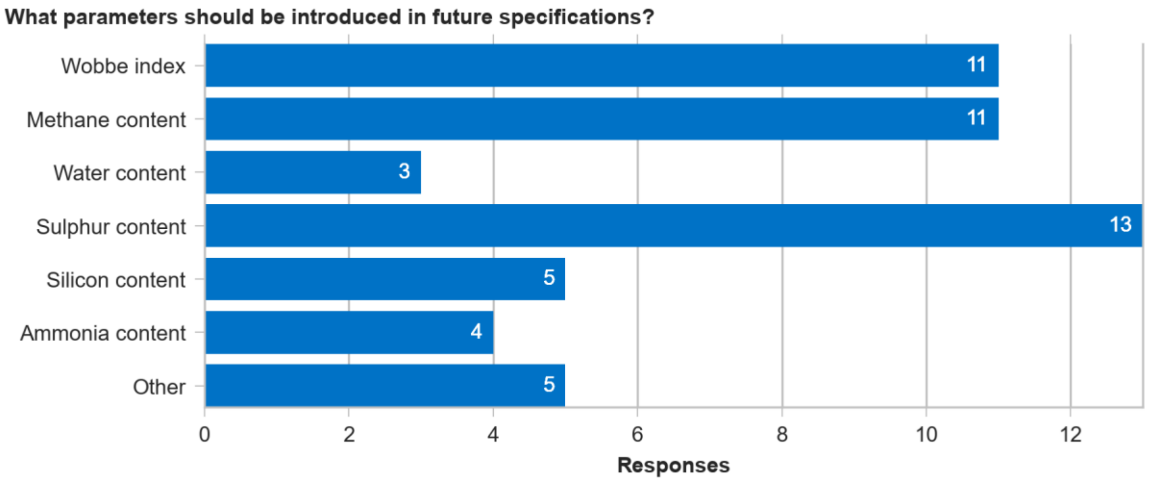
Figure 6-1: Summary of relevant responses to the stakeholder consultation on whether the FQD be extended to cover gaseous fuels.



Stakeholders were also asked what parameters should be introduced in the FQD with respect to gaseous fuels. Sulphur content, Wobbe index and methane number received the highest level of support from stakeholders, as shown in Figure 6-2. Other parameters received more limited positive responses, with water content receiving the least responses.

Other potential parameters suggested by stakeholders included octane number and propane/butane ratio, and also for hydrogen to be defined as a separate fuel (CLEPA). ACEA also stated the importance of introducing specifications for combustion hydrogen and fuel cell hydrogen in EU law, especially given hydrogen is likely to have a key role to play in future EU policy. LPG was also mentioned as a key fuel where introducing regulation of parameters will be beneficial (ACEA).

Figure 6-2 Stakeholder responses to question: Which technical parameters should be regulated for gaseous fuels



6.3.5 *Economic implications of extending the scope of the FQD to gaseous fuels*

Monitoring Costs

Under Article 8 of the FQD, Member States are required to monitoring compliance with the requirements of Articles 3 and 4 for petrol and diesel fuels. If the scope of the Directive is extended to gaseous fuels, equivalent provisions would need to be introduced for gaseous fuels in order to ensure internal coherence of the Directive and to achieve the intended outcome associated with the specifications put in place.

There is not a current complete picture of the extent of gas quality monitoring in different Member States. Information on the monitoring of a range of gas quality parameters in 17 MS was gathered by CEER in 2016 ***(CEER, 2016)***. It found that the range of parameters monitored varied by country, with Lithuania, Hungary and France monitoring the most parameters (19, 20 and 21 parameters respectively), and the Netherlands, the UK and Belgium monitoring the least (8, 9, 9). The parameters monitored varied, although some parameters were more commonly monitored, most notably Wobbe Index (16 MS), hydrocarbon dew point (15 MS), carbon dioxide (15 MS) and methane number (14 MS). Total sulphur (13 MS), relative density (13 MS), oxygen content (13 MS), mercaptan sulphur (12 MS) and H2S (12 MS) were also monitored by the majority of MS responding to the CEER questionnaire.

This indicates that there is variation in the gas quality monitoring between Member States, and that the incorporation of monitoring requirements in the FQD for gaseous fuels may represent an additional cost for some Member States. This however may not be the case for some of the most important parameters that appear to be already monitored in the majority of Member States (WI, methane number, and total sulphur). In the case of silicon, a crucial parameter identified for environmental and vehicle impacts of biomethane, existing monitoring is uncertain. The ongoing EMPIR study seeks to evaluate the EU’s measurement capability for total silicon and capacity for assessment in accordance with CEN standards ***(EMPIR, 2019)***. It is important to note that information available on gas quality monitoring represents capacity for gaseous fuels overall and not specifically for transport fuels.

In the FQD evaluation, there was a wide range in the estimated monitoring costs for liquid fuels, at 173k-650k euro/year per Member State. The market for gaseous fuels in transport is currently small, but is projected to increase. The projected consumption of CNG and LNG according to the PRIMES MIX scenario is about 11 Mtoe in 2030, or about 4% of final energy consumption in transport. It can be assumed that the monitoring costs associated with gaseous fuels will be proportionate to the market share of gaseous fuels in transport and so will be lower than the costs estimated for liquid fuels.

Compliance costs for Gas Processing

Gas quality standards currently vary across the EU. As such, incorporation of mandatory specifications for technical parameters may lead to additional costs for fuel suppliers to supply fuel meeting this standard. This may require investment in, for example:

- Acid gas removal based on liquid absorption technology, for the removal of sulphur and sulphur compounds
- Investments to comply with WI range in specific countries. It has previously been estimated that the cost of achieving compliance with a unified gas standard are between 4€bn for a wide WI range to €9.6bn with a narrow WI range (Entire gas industry i.e. not only transport fuels), with costs concentrated in a small number of Member States (European Commission, 2012).

6.4 Conclusions

This Section first outlines the parameters identified with the highest relevance for inclusion in the FQD on the basis of environmental protection and ensuring vehicle compatibility. Following this, the impacts of the policy options are summarised.

Environmental Impacts

The following presents the gaseous fuel parameters which have been identified to have a moderate or high impact on the environment and as such with relevance to be included in the FQD. Table 6-6 summarises these parameters and indicates what the impacts of regulation would be.

Table 6-6 Parameters identified with moderate or high impact on environment and human health for gaseous fuels

Importance	Parameter	Impact
High	Total Sulphur	**Air Pollutant Emissions** Sulphur content reduces the efficiency of exhaust aftertreatment systems and sensors. It also contributes to the emissions of fine particulate matter and oxides of sulphur.
Moderate	Mercaptan Sulphur	**SO_2 Emissions** Mercaptans produce toxic air pollutants on combustion including hydrogen sulphide and oxides of sulphur.

Importance	Parameter	Impact
Moderate	Butadiene	**Toxic substance** Butadiene is carcinogenic to humans and animals and fuel must be labelled as a carcinogen >0.1%
Moderate	Total Dienes	**Toxic substance** Dienes are carcinogenic to humans and animals.
Moderate	Carbon Dioxide	**Fuel efficiency and CO_2 emissions** Carbon dioxide is an inert gas and reduces engine efficiency.
Moderate	Carbon Monoxide	**Fuel efficiency and CO_2 emissions** Carbon monoxide is an inert gas and reduces engine efficiency.
High	Methane Number	**Fuel efficiency and CO_2 emissions** Higher MN ensures good combustion and lower CO_2 emissions.
High	Wobbe Index	**Fuel efficiency and CO_2 emissions** Wobbe Index is an important parameter for engine performance and associated CO_2 emissions.

The parameters identified as being the most relevant for inclusion in the FQD with respect to environmental impacts of gaseous fuels are sulphur, most notably in the form of **Total Sulphur** but also extending to **mercaptan sulphur**. Regulation of these parameters will mitigate the impacts associated with sulphur in fuels, namely the reduction of efficiency of exhaust aftertreatment systems, and the generation of air pollutant emissions. This is echoed by stakeholder feedback from the questionnaire, with total sulphur being the parameter most frequently suggested for inclusion in the FQD. There is currently no sulphur limit in the EN 16723-2 standard for natural gas and there appears to be a large range in the nationally mandated limit values set in different Member States (CEER, 2016). As such, there is the potential for significant environmental benefits from adding sulphur to future automotive fuel specifications.

Wobbe Index and **Methane Number** are also of particular importance according to information from stakeholders and the literature. However, work is ongoing by CEN in the establishment of an EU-wide WI, to determine what the range could be and how it should be implemented. As such, the completion of this work will be necessary before these parameters could be considered for inclusion in the FQD.

Parameters also considered to be important from an environmental perspective are total dienes and butadiene due to their toxicity if released in to the environment, and carbon dioxide and carbon monoxide for their impact on fuel efficiency and greenhouse gas emissions.

Benefits to engine emissions performance and fuel efficiency resulting from the regulation of these parameters will lead to a reduction in greenhouse gas emissions contributing to the achievement of EU climate change objectives.

Reductions in emissions of oxides of sulphur will lead to reductions in negative impacts on soil and water quality, eutrophication, and contribution to particulate aerosols (EEA, 2010).

Vehicle Compatibility Impacts

The following presents the gaseous fuel parameters which have been identified to have a moderate or high impact on vehicle compatibility and as such with relevance to be included in the FQD.

Table 6-7 Parameters identified with moderate or high impact on vehicle compatibility for gaseous fuels

Importance	Parameter	Impact
High	Silicon	**Engine health** Deposits of silica from combustion can cause engine damage.
High	Hydrogen sulfide (H2S) & Carbonyl sulfide (COS)	**Engine health** H2S is corrosive to engine components and fuel systems.
Moderate	Hydrogen (H)	**Engine compatibility/ Engine health** Hydrogen can cause damage to steel in CNG fuel tanks and levels must be limited due to having a different burning velocity in methane-based fuel mixes
Moderate	Liquid Hydrocarbon/Hydrocarbon dew point (HDCP)	**Engine health** A high proportion of hydrocarbons (Indicated by HCDP) can affect fuel injection and lead to engine damage.
Moderate	Water	**Engine health** Water content in fuel causes engine damage such as fuel line plugging, and corrosion in the fuel line and cylinder.
High	Methane Number (MN)	**Safety/Engine Compatibility** Knocking events can cause damage to engines.
High	Total sulphur (TS)	**Engine health** Higher sulphur content leads to increased corrosion rates in engines.
Moderate	Carbon dioxide(CO_2)	**Engine health** Presence of CO_2 in fuel can penetrate rubber engine components leading to damage
Moderate	Oxygen (O_2)	**Safety** Oxygen content must be limited in fuel mixes to prevent explosions.
Moderate	Butadiene	**Engine health** Increasing diene content increases the likelihood of residues affecting regulators and vaporisers **Engine compatibility** Diene content can reduce octane rating with associated impacts on compatibility.

Importance	Parameter	Impact
Moderate	Total dienes content	**Engine health** Increasing diene content increases the likelihood of residues affecting regulators and vaporisers **Engine compatibility** Diene content can reduce octane rating with associated impacts on compatibility.
Moderate	Evaporation residue	**Engine health** Residues can lead to deposits that accumulate and corrode engine fuel filters, low pressure regulators, fuel mixers, or solenoids
Moderate	Lubricating oil	**Engine health** Lubricant oil can cause contamination of engine components and so amounts should be limited to prevent this.
High	Wobbe Index	**Safety/Engine health** Large variations in WI negatively affect engine durability, and knocking events can cause engine damage.
Moderate	Particulate Matter (PM)	**Engine health** PM can cause blockages in fuel systems and should be completely filtered from fuels
Moderate	Carbon Monoxide	**Engine health and performance** CO can penetrate rubber components leading to engine damage.

The most relevant parameters identified for vehicle compatibility in gaseous fuels include **Silicon** due to its potential to cause engine damage, and **Total Sulphur** and **H2S/COS** due to their contribution to engine corrosion. **Wobbe Index** and **Methane Number** are also of considerable importance due to their impacts on engine durability and relation to knocking events which can cause engine damage.

Regulation of parameters with benefits to engine health will result in reductions in vehicle maintenance costs for vehicle owners.

Policy Options impacts

Table 6-8 presents the impacts associated with the policy options identified and finalised around the stakeholder workshop. It presents a qualitative scale indicating the magnitude and direction of impacts resulting from each policy option with respect to the environment, vehicle compatibility, and other economic impacts.

Incorporation of parameters from existing standards is assumed to have an impact for parameters which are important for the environment and vehicle compatibility. This is due to the fact that standards EN16723-2 for natural gas and biomethane and EN589 for LPG do not yet appear to be incorporated into national legislations of Member States. This is evidenced by the ongoing study by EMPIR into the promotion of these standards and understanding Member State testing capacity for key parameters of silicon and sulphur, as well as the large variation in Member State limits for gas quality parameters presented in CEER (2016).

The policy option for specification of total sulphur, methane number and Wobbe index range, along with EN589 parameters for LPG, captures the most critical parameters from the perspective of the protection of the environment and ensuring vehicle compatibility. Specification of gas quality in this way may help to facilitate increasing uptake of gaseous fuels in vehicles, including biomethane, with associated benefits to wider climate change targets including renewable energy targets under RED II.

Table 6-8 Summary of Impacts of Policy Options for Extending Scope of the FQD to Gaseous Fuels

Policy	Environmental Impact	Vehicle Compatibility Impact	Economic Impacts
Include Parameters from EN16723-2	**o** Does not capture the majority of technical parameters identified as being most important for environmental impacts	**+** Captures a number of key parameters for vehicle compatibility including H2S/COS and hydrogen, with associated impacts on engine health. A number of key parameters not included in the standard, notably silicon, sulphur, wobbe index and methane number.	**--** Increased monitoring and compliance costs
Include Parameters from EN589	**+** Captures key parameters for LPG including dienes as well as setting limits for sulphur and methane number, with associated impacts on sulphur emissions, and fuel efficiency and CO_2 emissions.	**+** Captures key parameters for LPG including dienes as well as setting limits for sulphur and methane number, with associated impacts on engine health and safety.	**-** Increased monitoring and compliance costs
Include Total Sulphur, Methane Number and Wobbe Index Range	**+** The setting of WI range and a limit on Methane Number ensures engine performance and associated reductions in greenhouse gas emissions. However, the practical implementation of an EU-wide WI range is still being investigated.	**+** The setting of WI range and a limit on Methane Number ensures engine durability and safety. However, the practical implementation of an EU-wide WI range is still being investigated.	**-** Increased monitoring and compliance costs, particularly in certain Member States who may have to invest to meet a specified WI range.

7 SHOULD FUEL SPECIFICATIONS FOR GAS-OIL USED IN NON-ROAD MOBILE MACHINERY (NRMM) BE INTRODUCED, AND SHOULD THEY BE ALIGNED TO THOSE FOR DIESEL?

7.1 Background

Non-road mobile machinery (NRMM) covers a variety of different machines including agricultural tractors, construction machines, generator sets, rail and inland water engines. The main fuel used in NRMM is gas-oil, which accounted for 9.7% of transport fuel sales in the EU in 2018 (EEA, 2020). A very small proportion of NRMM use other fuels such as gaseous fuels (LPG, DME) and bio/renewable fuels. As an example, alkylate petrol is a synthetic fuel used in handheld NRMM such as chainsaws, with a limited production volume in Europe of around 140 million litres, as reported by Aspen, a Swedish biofuel supplier. In addition, as pointed out by UFOP during the workshop for this study, the use of rapeseed oil is being considered for agriculture applications. While this section essentially concerns gas-oil in NRMM, the treatment of other NRMM fuels is also considered in the policy options.

A 2019 European Commission report estimated the size of the NRMM fleet (excluding railways and inland waterways) at around 9.6 million, with 49% agricultural machinery, 36% construction machinery and 15% generator sets (European Commission, 2019). The report also estimated annual sales at around 0.7 million and noted average machinery lifetimes of 10 to 16 years.

There have been significant reductions in other, previously higher contributing, sources of air pollutant emissions in recent years and as such NRMM is becoming an increasingly significant contributor to certain air pollutant emissions. Depending on the Member State, region or city, the contribution of NRMM to overall NO_X and PM emissions can vary significantly (European Commission, 2019). The contribution of NRMM to total NO_X emissions in the EU28 in 2018 was 7.9%, while the contributions to PM_{10}, $PM_{2.5}$, CO and NMVOC emissions were 1.9%, 2.4%, 3.3% and 1.3%, respectively (EMEP, 2020). Considered as a percentage of transport pollutant emissions only, the contributions by NRMM were 16.9% for NO_X, 15.5% for PM_{10}, 18.4% for $PM_{2.5}$, 14.3% for CO and 10.7% for NMVOC.

Policy background

The fuel specifications for diesel (Annex II) do not apply to gas-oil used in non-road mobile machinery (NRMM). Currently, the only specifications for NRMM gas-oil under the FQD are a limit on sulphur content and a limit on manganese content. FQD Article 4 sets a 20 mg/kg limit on sulphur content to accommodate for minor contamination in the gas-oil supply chain[23], which is higher than the 10 mg/kg limit for on-road diesel. FQD Article 8a limits the methylcyclopentadienyl manganese tricarbonyl (MMT) content in fuels to 2 mg/l. Therefore, the specifications defined for on-road diesel in FQD Annex II for cetane number, density at 15°C, distillation recovery, polycyclic aromatic hydrocarbons (PAH) and FAME content do not apply for NRMM gas-oil.

The 2012 study investigating the possibility of applying the FQD requirements for on-road diesel to NRMM gas-oil found that Member States (DE, ES, FI, IT, FR, MT, PL, PT, SE) accounting for at least 50% of NRMM gas-oils consumed in the EU already require FQD Annex II or similar standards for NRMM (European Commission, 2012). EUROMOT noted in an interview for this study that apart from in the individual Member States mentioned

[23] The Directive sets a 10mg/kg sulphur limit by default but allows for 20mg/kg at the point of final distribution to end users for NRMM applications

above, there is no specification for non-road gas-oil quality, other than that of the FQD. A further point made in the interview is that where taxation policy does not differentiate between NRMM gas-oil and on-road diesel, the fuel quality specifications in legislation are likely to be the same. UPEI's view expressed during an interview for this study was that the actual level of alignment between diesel and NRMM gas-oil is much higher than 50%, but could not provide any hard data or further evidence on the extent to which this is reflected in the legislation. The higher level of alignment in practice compared to 2012 may be related to the fact that the sulphur limits at the refinery point have been aligned for many years (since 2008) and supply chains may be already consolidated in many market segments. UPEI added that manufacturers of large NRMM such as tractors and forestry machines demand to use EN590 diesel because of the guaranteed cetane number. EUROMOT noted in the stakeholder workshop that since NRMM technology and emissions requirements are almost equivalent to those for road technologies, they should also legally have the same fuel requirements.

The individual parameters of diesel and gas-oil were also considered in the 2012 study, which found that some parameters were likely to already be aligned (European Commission, 2012). The 95% v/v distillation recovery at max 360.0°C and maximum PAH content of 8.0% m/m were already expected to be aligned for NRMM gas-oil. The report notes that it could not identify if NRMM gas-oil outside of the Member States mentioned above was aligned with the maximum density of 845 kg/m^3 parameter, but indicates that it expects there to be a high degree of alignment in the majority of Member States.

On the cetane number parameter, the 2012 study indicates that in Member States in which the marketed fuels were not aligned, the cetane number in gas-oil can be found to be around 45 or even as low as 40, compared to the on-road diesel specification of 51 (European Commission, 2012). As part of an interview for this study, EUROMOT commented that NRMM vehicle and component manufacturers and final users have little control over the fuel quality and the cetane number in particular. The quality of fuel used may also vary with application of the machinery, for example the fuel used in small agricultural settings may sometimes be heating oil. This lack of control over the fuel quality can cause uncertainty for manufacturers and final users. From their side, UPEI stated that the use of fuel with cetane number lower than that of the FQD on-road diesel specification may be essentially related to the use of heating oil in NRMM.

As described in detail in section 8, the sulphur content at the point of use was found to be around 20 mg/kg on average and higher than 20 mg/kg in some supply chains (EUROMOT, 2017), indicating some sulphur contamination along the fuel distribution.

Regarding the regulation of NRMM fuels other than gas-oil, a Swedish biofuel supplier stated that currently alkylate is regulated in technical standards of some countries (e.g. Sweden, Switzerland, Germany) but there is no EU standard yet. Since existing standards in several Member States do not allow blending ethanol or other oxygenates to alkylate to reduce its GHG emissions, alkylate petrol does not fulfil the 6% GHG emission intensity requirement as set out in the FQD Article 7a. Some Member States may interpret that the FQD also applies to other NRMM fuels, which creates an incompatibility for alkylate petrol.

Relevant parameters

The **cetane number** measures the ignition behaviour of diesel and gas-oil. A higher level of cetane enables faster ignition, improved control of ignition delay, improved combustion stability and lower engine noise (WWFC, 2019). A further benefit is an improved cold start performance, as cold starting engines running on diesel fuel with minimum 51 cetane number is easier, produces less white smoke and decreases crank time compared to NRMM gas-oil with a cetane number of 45. A reduced crank time leads to improved combustion stability, as well as lower noise, vibration and harshness (NVH) (WWFC, 2019). The 2012 NRMM study indicated that an that increase in the cetane number can lead to decreased

NO_X emissions from HDVs, increased PM in LDVs but no effect on PM for HDVs, and decreased HC and CO emission from both LDVs and HDVs (European Commission, 2012). The PM effect may be related to the higher combustion temperature achieved with increased cetane number, which also leads to more cracking reactions and increased PM formation for some engines. In an interview EUROMOT also noted that an engine misfiring due to low cetane number may emit more HC and CO.

A recent study by Concawe (Concawe, 2019), however, concludes that the effects of higher cetane number (from 46 to 54) on the fuel consumption and air pollutant emissions were highly vehicle and test dependent. The same behaviour can be expected for NRMM, which would depend on the type of engine and its use. The 2012 study (European Commission, 2012) also suggests that engines designed to meet more stringent emissions standards are more sensitive to cetane number. This was confirmed by EUROMOT during the workshop for this study. Therefore, ensuring an alignment between the NRMM gas-oil cetane number and that of on-road diesel would allow implementation of improved emission control technologies. A further consequence of aligning cetane number specifications is the potential increase in refining costs due to higher energy use and increased use of cetane enhancers.

Higher **density** fuels may result in higher NO_X and PM emissions (European Commission, 2012). Therefore, a maximum density is specified for diesel in the FQD. The effect on HC and CO, however, is more uncertain; higher density tends to increase CO and HC emissions in LDVs but reduce them in HDVs. Adopting this requirement for NRMM gas-oil would potentially require increased imports or investment in refinery processing equipment to comply with the requirement. However, the extent of such changes is uncertain because the degree to which NRMM gas-oils sold in the EU already align with the FQD limit is unclear.

FAME content in on-road diesel is limited to 7% (v/v) by the FQD, although FQD Article 4 allows Member States to market diesel with more than 7% FAME. For the Member States that do not already align specifications for NRMM gas-oil with on-road diesel, there is no limit on FAME. The 2012 study (European Commission, 2012) noted that an alignment of specifications could lead to consolidation of supply chains, and therefore an increase in FAME content for NRMM applications. There are concerns about potential detrimental impacts on engine reliability due to increased levels of FAME (European Commission, 2012). The concern about degradation due to FAME content is also reflected in the stakeholder questionnaire results from this study, which shows that 44% of respondents believed that alignment of NRMM gas-oil standards with on-road diesel standards would increase concerns over FAME. Other insights from the questionnaire include that 41% of respondents believe that an alignment would have a significant positive impact on the ability to achieve lower emissions. Other aspects, such as fuel efficiency and vehicle compatibility were not expected to be significantly impacted by an alignment.

Several stakeholders contributing to the questionnaire and workshop, including EUROMOT, noted that the concerns about FAME content, specifically the poor oxidation stability and the propensity to support microbial growth, should essentially apply to applications in which NRMM are left unused for long periods with fuel in the tank. Another concern is related to the higher capacity of FAME to absorb moisture and cause corrosion or performance issues, which may be particularly relevant for inland waterways. EUROMOT noted in the interview that FAME content is often seen as the cause of engine issues, but that it is difficult to establish a causal relationship, since there are many other factors that play a role. In addition, EUROMOT argued in the stakeholder workshop and in the interview that a limit would give end-users better protection, even if FAME content may rise.

Although **sulphur** is already limited in NRMM gas-oil to 10 mg/kg at the refinery point and at 20 mg/kg at the point of final distribution to end users, there is still concern about its adverse impacts. Fuel sulphur can be converted into sulphuric acid which will have corrosion effects on metal components. Hence, increased sulphur content leads to increased corrosion and wear of engine systems, leading to reduced engine life (WWFC, 2019). Furthermore, it can also have adverse effects on the engine aftertreatment systems.

Beyond an increase in SO_2 due to increased sulphur content, the exhaust of SO_3 and SO_4 may also increase. SO_4 coalesces with water molecules to form aerosols or forms heavier particulates with nearby carbon atoms, thus significantly affecting PM emissions. Without diesel oxidation catalyst (DOC) systems, the conversion rate from sulphur to sulphate is very low, typically around 1%, so the historical sulphate contribution to engine-out PM has been negligible. When diesel oxidation catalyst (DOC) systems are in use, however, the conversion rate of SO_2 to SO_4 increases from 1% to 100%. Most modern vehicles systems include oxidation catalysts, meaning that they will impact the PM emitted in proportion fuel's sulphur content. A reduction in sulphur from 500 ppm to 30 ppm would result in PM emission reductions of 7% from light-duty vehicles and 4-9% from heavy-duty trucks (WWFC, 2019).

Increases in SO_4 will also lead to poisoning of the diesel oxidation catalyst (DOC) and thereby reduce the DOC's capacity to control CO and HC emissions (WWFC, 2019). Furthermore, the DOC also functions as a heat generator for diesel particulate filters (DPF) and selective catalytic reduction (SCR) devices. If the DOC is poisoned by sulphate, it cannot fulfil this function and will impact the DPF's and SCR's ability to reduce PM and NO_X, respectively.

Beyond the indirect impacts of sulphur on the DPF and SCR devices through a poisoned DOC, sulphur content in fuels will also have a direct impact on technologies such as Lean NO_X traps (LNT), SCR devices, DPFs and other technologies (WWFC, 2019).

Air pollution emission standards

The EU norm for permittable levels of CO, NO_X, HC and particle emissions by NRMM are set differently depending on the type of engine and power level of machinery (Provice, 2017). Regulation (EU) 2016/1628 began to phase in Stage V standards for NRMM from January 2018 to January 2020 for approval of new NRMM engine types and will require all new engines entering the EU market to comply with Stage V standards by January 2021 (European Commission, 2016). The current NRMM regulation lags behind on-road diesel engines although the gap in the standards has been reduced with recent non-road Stages (IEA-AMF, 2018). The most recent standards, as shown in Table 7-1, show that the Stage V standard for non-road engines is similar to the standard for heavy duty vehicles (Regulation (EC) No 595/2009), although lower than for light duty vehicles (Regulation (EC) No 715/2007).

Table 7-1 Most recent emission standards for light duty vehicle (LDV) engines (Regulation (EC) No 715/2007), heavy-duty vehicle (HDV) engines (Regulation (EC) No 595/2009) and non-road engines (NRE) (Regulation (EU) 2016/1628)

Standard	NO_X limit (g/kWh)	PM limit (g/kWh)	CO limit (g/kWh)	HC limit (g/kWh)
Euro VI (LDVs)	0.08	0.0045	0.5	0.10
Euro VI (HDVs)	0.40 (WHSC[24]) 0.46 (WHTC[25])	0.01	1.5 (WHSC) 4.0 (WHTC)	0.13 (WHSC) 0.16 (WHTC)
NRE Stage V (56 – 130 kW)	0.40	0.015	5.0	0.19

The increasingly stringent regulation on emission has led to increased use of aftertreatment control technologies in non-road vehicles, such as diesel particulate filters (DPF) to control PM emissions and selective catalytic reduction (SCR) to control NO_X - emissions (IEA-AMF, 2018). Fuel quality is important for the performance and durability of aftertreatment technologies, which is why alignment of fuel standards may facilitate alignment of vehicle technologies, with benefits for reducing emissions and cost for vehicle development. EUROMOT states that the prerequisite for the correct performance of NRMM aftertreatment systems is the availability of ultra-clean market fuels (EUROMOT, 2020). It further argues that the latest emissions regulations for NRMM (Stage V) requires the same advanced technology levels as for on-road vehicles, therefore also requiring the same fuel quality standards. EUROMOT expanded on this in an interview and underlined that the lack of certainty over fuel quality results in difficulties for manufacturers to meet Stage V standards with an optimal setting.

The testing of an NRMM engine type or engine family to determine whether it meets the air pollution emission standards should use a reference fuel specified in Regulation 2017/654. According to this, in the absence of either a CEN standard for non-road gas-oil or a table of fuel properties for non-road gas-oil in the FQD, the diesel (non-road gas-oil) reference fuel in Annex IX of Regulation 2017/654 shall represent market non-road gas-oils with a sulphur content not greater than 10 mg/kg, cetane number not less than 45 FAME content not greater than 7,0 % v/v. EUROMOT suggested in an interview for this study that diesel with a cetane number of 45 is generally used to test air quality standards for NRMM, as it represents the worst case within the fuel range in terms of emissions performance.

The alignment of the on-road and NRMM diesel specifications in the FQD may change the situation as the reference diesel to be used for the test would have to be in line with the on-road diesel FQD specifications. This mainly concerns the minimum cetane number of the reference diesel, which would increase from 45 to 51. This means in practice that manufacturers would optimise the design of the NRMM engine and aftertreatment systems to meet Stage V standards for a cetane number of 51, instead of 45. Since the emissions performance of new engines would be still determined by the standard limits, an alignment with on-road and NRMM diesel specifications would mainly allow for an optimised design of new engines with equivalent emission levels. Potential changes in pollutant emissions, however, may be expected for existing engines designed for a lower cetane number.

[24] WHSC: World Harmonised Stationary Cycle

[25] WHTC: World Harmonised Transient Cycle

7.2 Policy options

The literature review and consultation have highlighted that the lack of specifications for NRMM gas-oil leads to a lack of consistency and certainty for NRMM applications. This manifests itself in an end-user uncertainty about fuel quality and potential damage to vehicles, as well as in an uncertainty for NRMM manufacturers about engine and aftertreatment design. An alignment or partial alignment of NRMM gas-oil quality standards with on-road diesel standards may alleviate these concerns. Furthermore, it may allow engine manufacturers to develop more efficient engines and aftertreatment, thus addressing the concerns about air pollutant emissions from NRMM. Therefore, following policy options have been identified for assessment, based on the literature review and consultation:

(a) Gas-oil

1. Counterfactual: No change specifications for NRMM gas-oil.
2. Align the fuel specifications for NRMM gas-oil with on-road diesel for cetane number, density and sulphur limit.
3. Align fuel specifications for NRMM gas-oil for all parameters except for FAME.
4. Fully align fuel specifications for NRMM gas-oil with on-road diesel (including FAME).

The identified policy options consider full alignment (Option 4) and partial alignment (Options 2 and 3). The options for partial alignment are considered to reflect that some parameters might face barriers or result in potential issues or unintended effects.

The varying treatment of alignment for FAME is based on the uncertainty about the effects of FAME on NRMM engines. If increased FAME content is considered harmful to NRMM engines and an increase in FAME content is expected as a result of an alignment, then options 2 or 3 avoid this potential issue. Conversely, a full alignment would result in more overall consistency of NRMM gas-oil quality between Member States. This would reduce any concerns about varying levels of quality and the associated impacts on engine manufacturers or end-users.

(b) Other fuels

1. Counterfactual: Maintain current scope which does not include separate specifications for other fuels used in NRMM.
2. Clarify the scope of the FQD regarding other NRMM fuels.

This policy option concerns the possibility of clarifying the role of other fuels such as alkylate petrol and rapeseed oil in the FQD specification for NRMM. This is meant to avoid potential misinterpretations of the scope of the FQD leading to incompatibilities with current national standards for these fuels and, in particular, to comply with the 6% GHG emission intensity requirement as set out in the FQD Article 7a. This is considered to be essentially a technical issue to be resolved through the adoption of appropriate CEN standards. In fact, a Swedish biofuel supplier reports that CEN is considering a standard for alkylate petrol. While the standardisation is being considered at European level, it seems reasonable to clarify the scope and exempt these other NRMM fuels from the FQD, where there is a clear incompatibility with national standards.

The analysis of impacts below focuses only on gas-oil (a) options.

7.3 Analysis

As mentioned above, at least 50% of EU NRMM gas-oil is already aligned with diesel FQD specifications in legislation. Further, parameters such as distillation recovery, PAH content and density are already expected to be aligned in practice in the EU. Therefore, the impacts of aligning NRMM gas-oil with on-road diesel can only be a consequence of changes to the parameters which are not yet fully aligned in the Member States. This mainly concerns the cetane number, the FAME content and the sulphur content.

Environmental impacts

The environmental impacts resulting from a full or partial alignment of NRMM gas-oil standards with on-road diesel standards can be grouped into two categories. The first is the direct impact of the improved fuel quality on the existing NRMM fleet, and the subsequent changes in pollutant emissions. The second is the impact of increased deployment of more efficient engine and emissions control technologies, unlocked by more reliable fuel quality.

Cetane number: Introducing a minimum of 51.0 for the cetane number, as defined in FQD Annex II for diesel can have environmental impacts resulting from the reduction in pollutant emissions and improved fuel efficiency. As discussed in section 7.2, an increased cetane number results in less pollutant emissions (except for PM, which could increase for some engines) and slightly decreased fuel consumption. These effects would mostly apply to existing engines that have been certified with a lower cetane number. As an alignment would also increase the minimum cetane number (from 45 to 51) of reference diesel used for emission standards testing, new engines are expected to be optimised to meet emission standards with a cetane number of 51.

EUROMOT noted in an interview for this study that there is a trade-off between NO_X and fuel economy in engine design. Therefore, if the minimum cetane number is set to 51, new engines may be designed to optimise fuel economy, while existing engines will see improvements in emissions and durability, but not in fuel economy.

The 2012 NRMM study estimated that for Member States in which NRMM gas-oil specifications are not currently aligned with on-road diesel, a 2% decrease in NO_X emissions could be the result, assuming an increase of the cetane number from 45.0 to 51.0 (European Commission, 2012). The study also notes that an increase in cetane number from 50 to 58 would lead to a 6% reduction in HC emissions under operating duty cycles, but PM emissions could increase by 5% for LDVs. Small NRMM engines would have a similar performance as LDVs and, hence, observe an increase in PM levels with an increased cetane number. Although the difference in cetane number from 50 to 58 is not fully relevant for our assessment, given the lack of other information, it is used to provide some quantified indication of the possible scale of change that may be seen for the 45 to 51 change.

As above mentioned, at least 50% of the EU NRMM gas-oil is already aligned with diesel FQD specifications in legislation. Assuming the worst possible case that 50% of the remaining NRMM gas-oil used by the existing fleet have a 45 cetane number and that increasing cetane number from 45 to 51 results in 2% reduction of NO_X, there would be at most an overall 0.08% reduction to EU emissions, considering that the contribution of NRMM to total NO_X emissions in the EU28 in 2018 was 7.9%. However, under the same assumptions, the increase in PM could represent at most 0.05% of total PM emissions in the EU, considering that the contribution of NRMM to total PM emissions in the EU28 in 2018 was 1.9%.

However, as pointed out by some stakeholders, the actual level of alignment is considered to be much higher in practice, which means that the direct environmental impacts on air pollutants for the existing fleet associated with setting a minimum of 51 for the cetane number (options 2, 3 and 4) may be more limited.

Indirect impacts related to the optimisation of new engines resulting from a higher certainty on cetane number levels may also be relevant but not quantifiable. As commented by EUROMOT, designing and testing engines for a higher cetane number would allow for improved fuel economy in new engine designs. This optimisation of the fuel efficiency would have to trade-off the effects on NO_X emissions, which will need to fall within the limits of the air pollution standards, so the percentage improvement on fuel economy and associated GHG emission savings would depend on the final engine configuration. In any case, a better fuel quality allows for better refinement and optimisation of that balance.

FAME: An increase in FAME content for NRMM applications could be expected, especially those that currently rely on FAME-free gas-oil, typically inland waterways. At the same time, reduced quantities of FAME could be expected for fuels used in NRMM where current FAME content is above 7.0% v/v. However, the 7% limit is not expected to affect current uses of 100% FAME fuels (e.g. some agriculture applications) where these are graded accordingly, as noted by EUROMOT during an interview for this study. Anyhow, the net effect on GHG emissions cannot be quantified as the potential changes in the demand for FAME are highly uncertain. In addition, the 2012 study indicates that any reductions in GHG emissions derived from the use of biofuel rather than fossil fuel may be partially counterbalanced by the potential reduction in fuel economy (European Commission, 2012).

IEA-AMF suggests that FAME generally has a positive effect on engine pollutant emissions, depending on engine technologies and fuel properties (IEA-AMF, 2020). IEA-AMF presents a 2002 EPA study on the effect of FAME content on heavy-duty vehicle emissions, which may be equivalent to large engines used in NRMM. The study showed that a 20% FAME blend compared to a 0% FAME diesel blend would increase NO_X emission by 2.0%, but reduce PM, HC and CO emissions by 10.1%, 21.1% and 11.0%, respectively. The effectiveness of FAME to reduce pollutant emissions is attributed to its oxygen content, which allows better oxidation of PM, HC and CO, but is also likely to contribute to the increase in NO_X.

Again, the net effect on air pollution of aligning fuel used by NRMM with FAME limits (option 4) would depend on the current level of alignment and the extent to which supply chains for diesel and NRMM gas-oil would further consolidate.

Sulphur content: The application of a sulphur limit of 10 mg/kg at the point of use (instead of the current 20 mg/kg limit) may have effects on air pollution emissions depending on the sophistication of the emission control systems in place in the NRMM. With limited emission control systems, any decrease in the sulphur content at the point of use would mostly lead to decreases in SO_2 and other sulphur oxide (SO_X) emissions. A decrease in SO_4 would also lead to a reduction of PM emissions.

Assuming the worst possible case that the sulphur content of the remaining 50% of the NRMM gas-oil is 20 mg/kg and that decreasing the sulphur content from 20 kg/mg to 10 mg/kg results in a 0.15% reduction of PM levels[26], there would be at most an overall 0.001% reduction to EU emissions, considering that the contribution of NRMM to total PM_{10} emissions in the EU28 in 2018 was 1.9%.

While the direct effect on PM emissions is found to be relatively small, the indirect impacts on the performance and durability of after-treatment technologies, including DOC, LNT, SCR and DPF, may be more important, as these clearly benefit from lower sulphur fuels. These would indirectly affect the levels of PM, NO_X, HC and CO. As an indication, increasing sulphur content from 3 to 16 ppm can reduce the NO_X conversion efficiency by 30 to 40%.

[26] This has been extrapolated from the reported reduction of 8% of PM levels when sulphur content drops from 500 ppm to 30 ppm (WWFC, 2019) and assumes a linear relationship

Similar effects are expected for the SCR devices. Similarly, DPFs tested with 3 ppm and 30 ppm sulphur fuel saw the PM reduction efficiency drop from 95% to around 73% (WWFC, 2019). The overall indirect effects on air pollution through affecting the performance of after-treatment systems would depend on the extent to which after-treatment systems are used and combined in the NRMM fleet.

Stakeholders responses to the survey tend to align with these arguments. Most stakeholders expect no or negligible impacts on fuel consumption as a result of an alignment of NRMM gas-oil standards with on-road diesel standards

Figure 7-1). Only 4 out of the 20 who responded expect a significant impact. When asked about the potential effects on the ability to achieve lower vehicle emissions (Figure 7-2) the proportion of those who expected a significant impact is slightly higher (9 out of 23 who responded). Regarding the contribution to RED II and FQD GHG reduction targets through increased bio content (

Figure **7-3**), only a minority of stakeholders expected a significant impact (6 out of 21 who responded).

Figure 7-1: Questionnaire responses to the question: 'What would be the implications of aligning NRMM gas-oil standards with on-road diesel: Ability to improve fuel consumption efficiency'

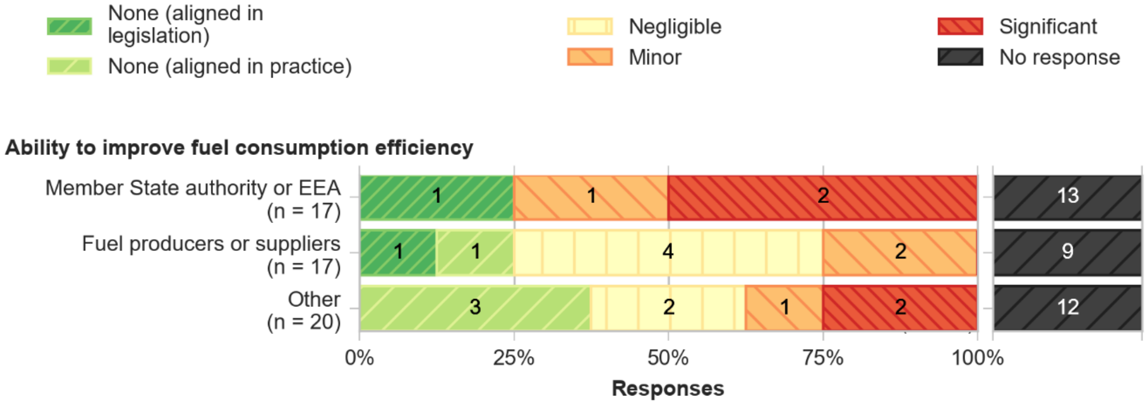


Figure 7-2: Questionnaire responses to the question: 'What would be the implications of aligning NRMM gas-oil standards with on-road diesel: Ability to achieve lower vehicle emissions'

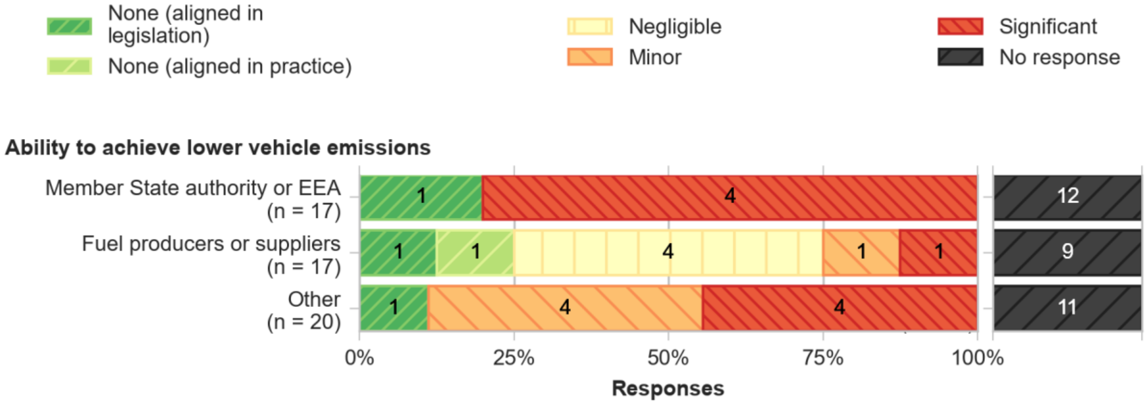


Figure 7-3: Questionnaire responses to the question: 'What would be the implications of aligning NRMM gas-oil standards with on-road diesel: Contribution to RED II and FQD GHG reduction targets through increased bio content'

Vehicle compatibility

The major concern in terms of vehicle compatibility is the potential increase in FAME content resulting from the alignment with on-road diesel specifications. In addition, lower sulphur content may also lead to benefits in terms of durability.

FAME: Most NRMM manufacturers already provide machines designed to be able to run on gas-oil with up to 7% FAME, as there is a high level of alignment between on-road and off-road engine technologies. In addition, as part of an interview for this study, EUROMOT noted that, despite the concerns on FAME content, it is difficult to establish a causal relationship between higher FAME content and specific engine issues, as many other factors play a role. EUROMOT further stated that, from their perspective, the priority should be to reduce uncertainty on the FAME content to optimise engine design and performance and the alignment with the on-road diesel cap would contribute to this. A cost to consider is that some machines do rely on FAME-free fuel, e.g. for inland waterways purposes, and may face increased costs if the availability of FAME-free fuel is reduced.

Stakeholders who responded to the survey seemed to be more concerned with degradation or contamination issues related to increased FAME content (Figure 7-4) than potential impacts on vehicle compatibility (Figure 7-5).

Figure 7-4: Questionnaire responses to the question: 'What would be the implications of aligning NRMM gas-oil standards with on-road diesel: Concerns over degradation/contamination as a consequence of FAME content'

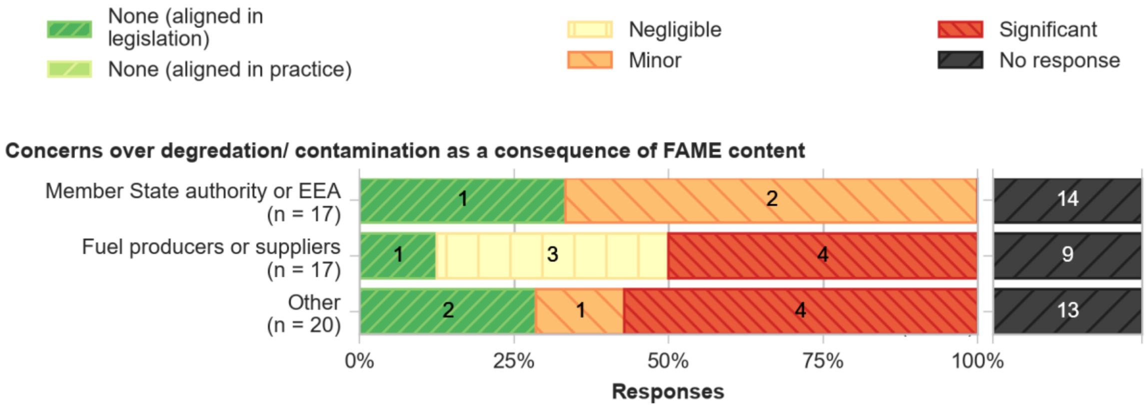
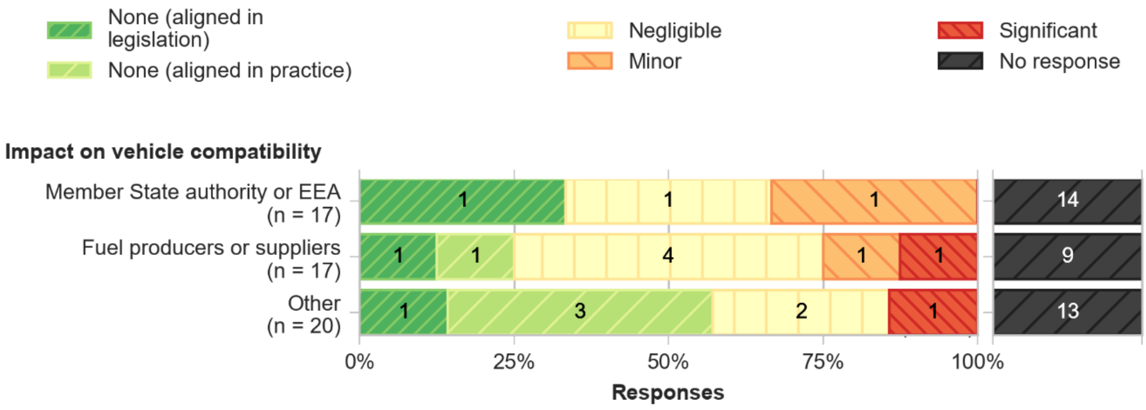


Figure 7-5: Questionnaire responses to the question: 'What would be the implications of aligning NRMM gas-oil standards with on-road diesel: Impact on vehicle compatibility'



Sulphur content: A limitation of sulphur content to 10 mg/kg at the point of use may increase the durability of engines by limiting the generation of sulphur acid, which is highly corrosive. WWFC reports that an increase in sulphur content from 10 ppm to 1460 ppm would double or triple the wear amount (WWFC, 2019). Following this, the reduction in wear amount would be at most 1.4% when sulphur content is reduced from 20 ppm to 10 ppm.

Economic impacts

The economic impacts resulting from a full or partial alignment of NRMM gas-oil standards with on-road diesel standards come in different forms. There may be direct economic impacts from the increased production costs associated with aligning the standards. However, the alignment may lead to consolidation of supply chains for both fuels and engines, which could unlock economies of scale. This would further be amplified by the strengthened single market resulting from the alignment[27].

For an increase in **cetane number** from 45 to 51, the 2012 study estimated a cost of around 0.002 EUR/litre or 2.35 EUR/tonne (European Commission, 2012). A contribution from a cetane improver producer to the stakeholder workshop for the current study indicated a cost of 0.5 EUR/tonne when applying average treatment rates of 500 ppm to reach a cetane number of 51. These additional production cost may increase gas-oil prices by 0.07%-0.33%, considering an average price of diesel in the EU in 2019 (pre-covid) of 605 euros per thousand litres. This price increase falls within the range of normal price volatility and, hence, would be hardly noticed by fuel users.

A recent study (Concawe, 2019) finds that the effect of a higher cetane number on the fuel economy of existing passenger vehicles is either very small or not statistically significant, and highly dependent on the type of vehicle and test calibration. A similar behaviour may be expected for NRMM. EUROMOT also noted in an interview that engine designs are currently set to achieve a certain level of reliability for lower cetane numbers. If similar levels of reliability are to be achieved with engines designed for higher cetane numbers, improved fuel economies are to be expected in new engines.

The economic impacts of increased **FAME** content would be related to impacts on fuel efficiency. Increasing FAME from 0% to 5% (or up to the 7% limit) has little effect on fuel

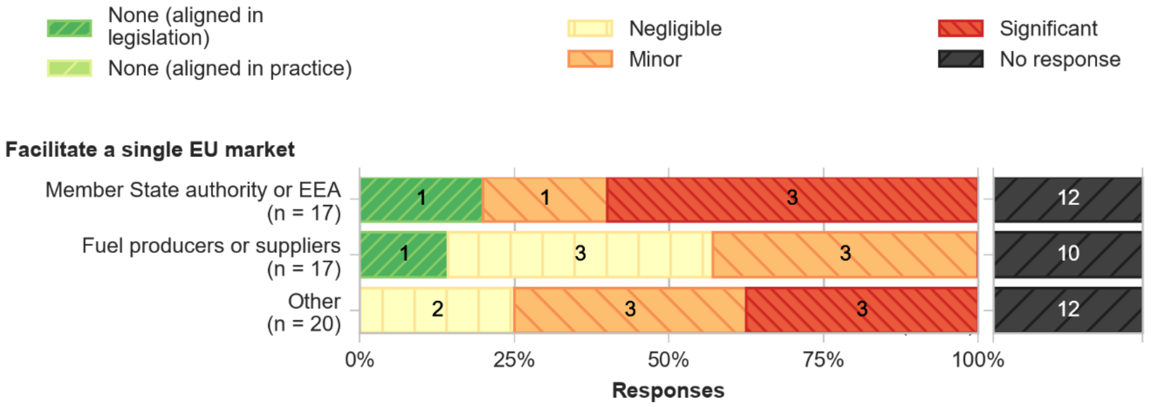
[27] The partial or full alignment of NRMM gas-oil with diesel specifications in the FQD may also be related to administrative costs for industry stakeholders and public authorities related to increased testing, monitoring and reporting. However, these are considered in section 8

efficiency (IEA-AMF, 2020). On the other hand, the 2012 study also suggests that the reduction in fuel efficiency may be offset by an increase in fuel efficiency due to engine tuning. Hence, the net effect is expected to be small.

The full or almost full alignment with on-road diesel would mean that the **sulphur limit** at the point of use should decrease from 20 mg/kg to 10 mg/kg. However, this would not affect costs for refineries as the limit is already 10 mg/kg at the refinery. There might be some costs due to needing to avoid contamination in the distribution, but if there is alignment with road diesel it can share the same distribution so this issue would be minimised compared to a situation where the distribution is shared with heating oil or maritime fuel.

Aligning the standards for NRMM gas-oil with on-road diesel would ensure more consistent fuel quality across the EU. Alongside the benefits discussed above, this would also strengthen the single market, since manufacturers would no longer have to consider varying fuel quality. Specifically, an alignment of the limits for sulphur would allow NRMM engine manufacturers to consider more sophisticated emissions control systems in their design, aligning with modern on-road diesel engines. The 2012 study notes that CONCAWE suggests the alignment of standards would reduce supply and distribution costs, and have no major impact on refineries, because on-road diesel is already supplied according to the specifications and constitutes the majority of fuels (European Commission, 2012). Therefore, supplying off-road diesel to these same specifications is unlikely result in significant additional expenditures. However, most of the stakeholders who responded to the survey (14 out of 20) stated that they do not expect these policy options to have a significant impact in terms of facilitating a single EU market (Figure 7-6).

Figure 7-6: Questionnaire responses to the question: 'What would be the implications of aligning NRMM gas-oil standards with on-road diesel: Facilitate a single EU market'



In the stakeholder questionnaire, CECE (organisation representing the interests of national construction equipment manufacturer associations in Europe) stated that manufacturers are currently facing the issue of variations in NRMM fuels across different region, as there is currently a lack of a harmonised standard. CECE further noted that, considering that the same fundamental technologies are used for on-road engines, harmonising the fuel standards for both off-road and on-road in the FQD will help to align markets.

7.4 Conclusions

Table 7-2 summarises the impacts of the alignment of NRMM and on-road diesel specifications. Since parameters other than cetane number, sulphur content and FAME are found to be mostly aligned already, options 2 and 3 would lead to similar impacts and are grouped together.

The alignment of the minimum cetane number between on-road and off-road diesel may lead to a marginal reduction in air pollutant emissions from existing NRMM engines, while new engines are expected to improve their fuel economy if these are certified with a minimum cetane number of 51. The expected additional production costs linked to cetane enhancers are found to represent a very small proportion of the fuel price.

The alignment of the sulphur content between on-road and off-road diesel would lead to marginal direct effects on PM levels but could lead to indirect benefits by improving the performance and durability of after-treatment systems used in recent NRMM engines. Additional costs are expected associated with the need to reduce sulphur contamination along the supply chain.

The application of the on-road diesel FAME cap for NRMM may provide more certainty and benefit the design of NRMM engines but could lead to adaptation costs for applications relying on FAME-free fuels. Impacts on GHG and air pollution emissions are not expected to be significant.

Overall, the alignment of NRMM diesel with on-road diesel would have very small direct economic impacts and minor cost increases, given that a significant proportion of NRMM diesel is already in line with on-road diesel specifications. However, the full alignment may give more certainty to the industry and allow further synergies in engine and aftertreatment technologies with those applied to on-road vehicles.

Potential incompatibility issues for other NRMM fuels are found to be essentially a technical issue to be resolved through the adoption of appropriate CEN standards. However, the FQD could be slightly revised to clarify whether other NRMM fuels fall within its scope. This clarification could somewhat reduce the administrative burden for suppliers of other fuels for NRMM.

Table 7-2: Summary of impacts from the alignment of NRMM and on-road diesel specifications in the FQD

Policy	Environmental Impact	Vehicle compatibility	Economic Impact
Gas-oil (a) – Options 2 and 3: Align the fuel specifications for NRMM gas-oil with on-road diesel for cetane number, density and sulphur limit (and potentially other parameters but not FAME content)	**+** Limited direct effect on air pollution emissions. Upper bound reduction over EU levels: 0.08% for NO_X and 0.05% for PM Improved performance of after-treatment systems associated with lower sulphur content. Potential indirect effect on fuel efficiency and lower GHG emissions as a result of higher cetane number.	**O** No significant impacts	**-/+** Limited cost of cetane enhancers Increase in gas-oil price by 0.07%-0.33%. Additional costs to avoid sulphur contamination. Benefits in economies of scale for producers/suppliers.
Gas-oil (a) – Option 4: Fully align fuel specifications for NRMM gas-oil with on-road diesel (including FAME)	**+** Impacts above AND The net effects of FAME content on air pollution and GHG emissions are expected to be small	**-/+** Impacts above AND No evidence on compatibility issues with existing engines caused by FAME, while decreasing the level of uncertainty on FAME content may lead to benefits in engine design. Only applications relying on FAME-free fuels would need adaptations if there is a consolidation in the supply chain	**-/+** Impacts above AND No significant FAME-specific impacts
Other fuels (b): Clarify the scope of the FQD regarding other NRMM fuels	**O** No significant impacts	**O** No significant impacts	**+** Potential reduction in administrative costs

8 SHOULD THE MONITORING OF FUEL QUALITY BE EXTENDED TO GAS-OIL USED IN NRMM?

8.1 Background

Policy background

The FQD does not currently oblige fuel suppliers or Member States to monitor and report NRMM gas-oil, as is the case for petrol and diesel. Introducing this would facilitate the Commission's role in monitoring correct implementation of the Directive by Member States, to ensure proper functioning of the internal market.

It has previously been considered that NRMM emissions were less likely to affect air quality in densely populated areas, and so standards and monitoring were deemed less important than for road vehicles. However, emissions from NRMM are becoming increasingly significant as emissions from other sources are reducing and the potential for alignment of standards on monitoring warrants reconsideration.

As discussed in section 7.1, the only two requirements for NRMM gas-oil are a 10 mg/kg sulphur limit (or 20 mg/kg at the point of final distribution) and a 2 mg/l manganese limit. EUROMOT raised concerns about the exceedance of sulphur limits of NRMM gas-due to lack of monitoring (EUROMOT, 2017). The distribution system of heating or marine gas-oil could overlap with non-road gas-oil. The sulphur content limit of 20 mg/kg is permitted at the point of final distribution to end users for off-road gas-oil in order to accommodate minor contamination in the supply chain, as an optional derogation permissible to Member States. Given that heating and marine gas-oil may have a sulphur content of 1000 mg/kg or more, any substitution with these fuels could cause significant exceedance of the NRMM gas-oil sulphur limit. The risk primarily stems from the possibility that fuel suppliers may store NRMM gas-oil in tankers that have previously been used for gas-oils with higher sulphur content. This is why the fuel supplier industry requested a differentiation between sulphur content requirements between off-road gas-oil and on-road diesel.

Samples collected by EUROMOT have shown that only 48% of NRMM gas-oil sold in France complied with the limit from 2013 to 2017 (EUROMOT, 2017). However, the average sulphur content in gas-oil samples tested in the EU, excluding the samples taken in France, averaged around 20 mg/kg +/- 10 mg/kg in 2017. EUROMOT went on to state that a stricter monitoring aspect is required for NRMM gas-oil as it is challenging to ensure that the NRMM gas-oil sold to end users is not contaminated with gas-oil from other supply chains. EUROMOT further noted in an interview that the upstream part of the supply chain is monitored in the same way as for on-road diesel, but that the final point of distribution is not monitored, which is where non-compliance issues where identified.

8.2 Policy options

Some of the policy options discussed in section 7.2 imply more regulated parameters for off-road gas-oil. If monitoring requirements were introduced, these could mirror the requirements set out following an alignment or partial alignment of off-road gas-oil with on-road diesel. Alternatively, monitoring requirements could be introduced to target specific parameters, which are of most concern. The following policy options have been identified for assessment, based on the literature review and consultation:

1. Counterfactual: No requirement for monitoring of gas-oil used in NRMM.
2. Introduce requirement for monitoring and reporting of sulphur and metallic additives content in gas-oil.
3. Introduce requirement for monitoring and reporting of gas-oil aligned with on-road diesel specifications.

Policy option 2 addresses the concerns on adequate quality control procedures for NRMM gas-oil are required at the final point of distribution by requiring monitoring of sulphur content for off-road gas-oil. It also includes the monitoring of metallic fuel additives (MFAs), which would currently only concern a limit on manganese, as discussed in section 10, but could include further MFAs if more limits were introduced. Policy option 3 would go beyond only monitoring sulphur and metal additive contents, and align the monitoring and reporting requirements for off-road gas-oil with those for on-road diesel. This option is consistent with a full alignment of on-road and NRMM diesel parameters described in section 7.

8.3 Analysis

Environmental impact

As discussed above, there is evidence to suggest that not all fuel sold complies with the limit on sulphur content in NRMM gas-oil (EUROMOT, 2017). A monitoring requirement for sulphur content would provide greater certainty for manufacturers and end-users that the limits are not broken. The Worldwide Fuel Charter underlines that sulphur in concentrations higher than what is compatible with engines can lead to various adverse effects (WWFC, 2019). Sulphur can reduce engine life by increasing corrosion and wear. Furthermore, sulphur has a significant impact on fine PM emissions, as it causes formation of sulphates. Moreover, sulphur poisoning reduces the effectiveness of exhaust after-treatment systems, rendering them increasingly ineffective at reducing NO_X and PM emissions. Since the supply chains of different gas-oils may overlap to some extent, there is an increased risk of sulphur entering NRMM gas-oil at heightened levels. Since heating and marine gas-oil may contain up to 1,000 mg/kg, a contamination of as little as 10 litres of heating and marine gas-oil in 1,000 litres NRMM gas-oil could increase the sulphur content by 10 mg/kg and thereby push the sulphur content over the limit.

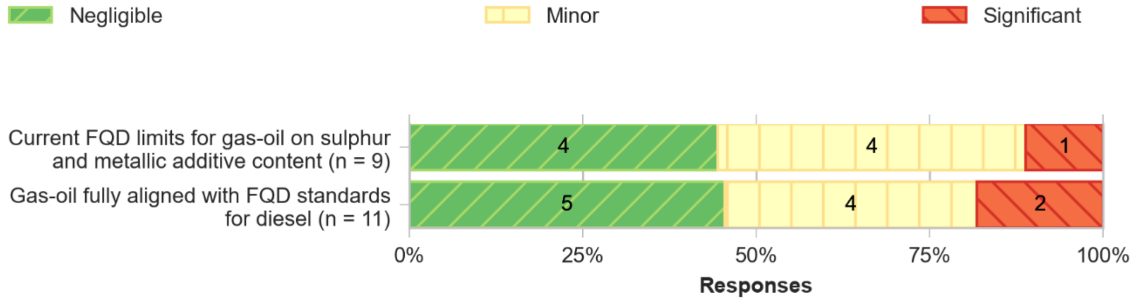
The environmental impacts of a lower sulphur content are discussed in detail in section 7, while those relative to metallic fuel additives (MFAs) are included in section 10. Any environmental impacts resulting from monitoring of MFA content in NRMM gas-oil depend on if MFA levels would change as a result of monitoring. As mentioned above, only manganese is currently limited by the FQD to limit the content of Methylcyclopentadienyl manganese tricarbonyl (MMT). In contrast to the sulphur limits, no evidence was found that the limits for metal content were broken. Therefore, any monitoring activity would be less likely to impact the actual levels of MFAs in fuels and thereby not have environmental impact.

Economic impact

The FQD Evaluation identified costs of the current road fuel monitoring and reporting obligations for Member States and found significant variability. Fuel distribution and marketing for NRMM gas-oil is likely to have even greater variation between different Member States due to the variation in applications of NRMM in different countries, reflecting differences in levels of industrialisation, construction, agriculture and other activities in which NRMM are used.

In the questionnaire, stakeholders were asked what the impacts on cost would be for two scenarios for introducing monitoring: current FQD limits for gas-oil on sulphur and metallic additives (policy option 2) or gas-oil fully aligned with FQD standards for diesel (policy option 3). Stakeholder responses were almost identical for the level of impact of both options, as shown in Figure 8-1. For both cases, the majority of stakeholders indicated that impacts would be negligible or minor, however a minority of stakeholders did indicate that there would be significant impacts.

Figure 8-1: Questionnaire responses to the question: 'what would be the impact on cost or hours if monitoring of fuel quality is required for gas-oil?'



The estimates for incurred costs for overall fuel sampling and monitoring for road fuels identified in the FQD Evaluation ranged from €173,000 to €650,000 annually per Member State. However, these estimates should be considered indicative since they were based on inputs from only 6 Member States. France further detailed taking a fuel sample costs €200, while laboratory analysis costs were around €600 for petrol and €700 for diesel.

In the stakeholder questionnaire conducted as part of the current study, France provided an estimate for the expected costs in the two scenarios outlined above. In the scenario of monitoring and reporting requirements for current sulphur and MFA content, France estimated a cost of €14,400 per year, estimating that 200 samples would be tested at an average cost of €44 per sample for MMT monitoring and €28 per sample for sulphur monitoring. In the scenario of monitoring and reporting requirements that are fully aligned with on-road diesel, a cost of €105,200 was estimated, at €526 per sample for 200 samples. These estimates likely only represent analysis costs as the respondent noted that the estimates did not include any costs for working hours or reporting and administration costs. This is in line with the estimates reported in the Evaluation.

Based on the estimates given above, an upper bound of €1.0 million additional monitoring costs were estimated for policy option 2, requiring monitoring of metallic additive and sulphur content. For policy option 3, an upper bound of €2.7 million of additional monitoring costs was estimated. The estimates assume that no off-road gas-oil is currently monitored and that the number of samples taken by each Member State in a given year are similar to the number of samples taken for diesel monitoring.

However, the above estimate does not account for possible ICT solutions being in place that simplify the monitoring and reporting process for fuel supplier and MS authorities. If these are already in place for road fuels, adding non-road fuels to the system would likely only represent an incremental change in costs, as no new software would need to be developed. This would therefore lower the additional monitoring costs for NRMM gas-oil.

Beyond the cost associated with monitoring NRMM gas-oil, reporting of the fuel quality will also lead to greater assurance to operators of consistent fuel quality. Furthermore, monitoring the quality may also lead to higher quality fuels, which would lower maintenance costs. Similarly, monitoring can give manufacturers greater confidence in fuel quality and therefore allow them to optimise engine and component design.

8.4 Conclusions

Table 8-1 summarises the impacts of the alignment of NRMM monitoring requirements with on-road diesel monitoring requirements. Overall, the most significant environmental impact of monitoring NRMM gas-oil would likely come from greater insurance that NRMM gas-oil are sulphur free (<10 mg/l). This would benefit the design of NRMM engines as more sophisticated exhaust treatment systems could be put in place. Furthermore, it could also result in higher certainty on the fuel quality, since there is evidence that current limits are not complied with.

The monitoring of NRMM gas-oil would result in increased monitoring costs. These can reach up to €1.0 million for monitoring of sulphur and metallic additive content and up to €2.7 million for monitoring of all parameters. However, these estimates do not account for potential efficiencies in the monitoring process as NRMM gas-oil monitoring and parameters may align with the requirements for diesel.

Table 8-1: Summary of impacts from the alignment of NRMM and on-road diesel monitoring and reporting requirements in the FQD

Policy	Environmental Impact	Vehicle compatibility Impact	Economic Impact
Option 2 - Monitor sulphur and metallic additive content	+ *Monitoring may reduce harmful sulphur content.*	+ *Greater certainty of compliance enables improved engine designs.*	- *Upper bound: €1.0 million additional monitoring costs.*
Option 3 - Monitoring aligned with diesel requirements	+ *Monitoring may reduce harmful sulphur content. Other parameters may be affected.*	+ *Greater certainty of compliance enables improved engine designs.*	- *Upper bound: €2.7 million additional monitoring costs.*

9 SHOULD FQD ARTICLE 6 ON THE MARKETING OF FUELS WITH MORE STRINGENT ENVIRONMENTAL SPECIFICATIONS BE MAINTAINED?

9.1 Background

Article 6 of the FQD provides flexibility to Member States to allow for the marketing of fuels with more stringent standards to be targeted at use within specific agglomeration or ecologically or environmental sensitive areas. The FQD Evaluation identified that this provision has not been implemented by any Member State. However, since the evaluation, Member States have been required to develop National Air Pollution Control Plans (NAPCPs) and National Energy and Climate Plans (NECPs) and so more attention is being given to options for reducing vehicle emissions, particularly in areas with air quality concerns.

Given other more cost-effective and easier to implement policy options (e.g. Low Emission Zones) are available for local pollution abatement, Article 6 is seen as a last resort option, however there is support that it should be retained for this purpose (European Commission, 2017).

9.2 Policy options

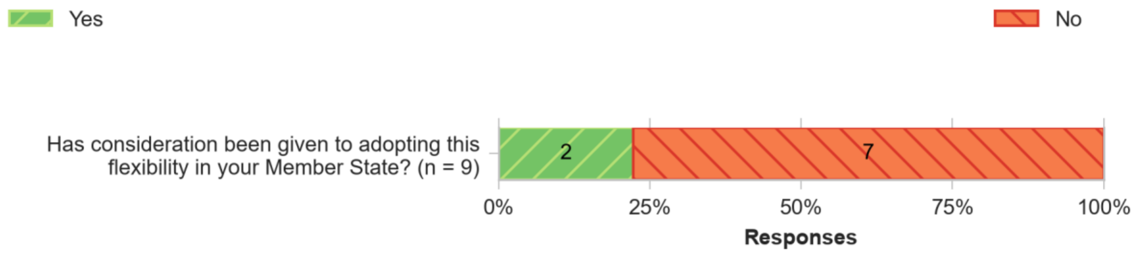
The following policy options have been identified:

1. Maintain the flexibility permitted by Article 6.
2. Discontinue the option for flexibility under Article 6.

9.3 Analysis

In the stakeholder engagement undertaken for this study, Member States were asked if adopting the flexibility allowed under FQD Article 6 had been considered. The responses, as illustrated in Figure 9-1, show that most Member States that responded had not considered adopting the flexibility, while two Member States, namely Sweden and France, had considered adopting it.

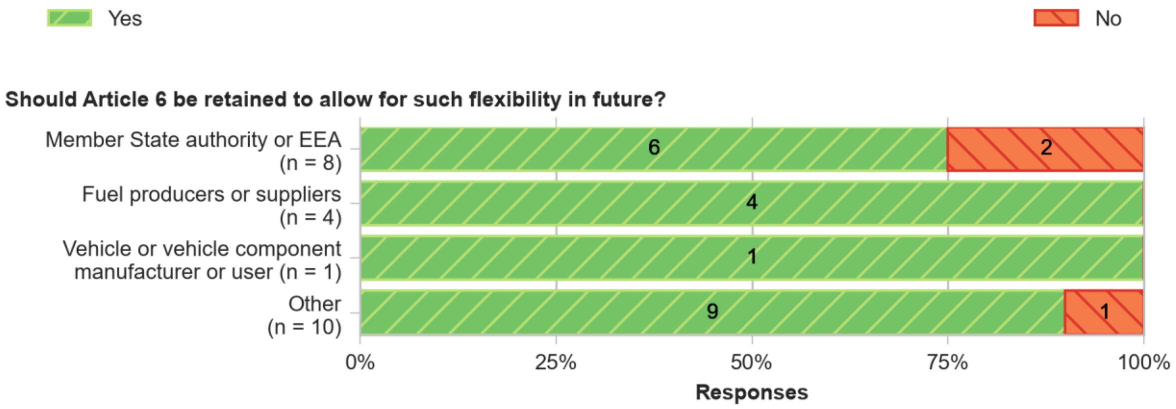
Figure 9-1: Member State responses to the question if consideration had been given to adopting the flexibility allowed under Article 6 in their Member State.



France noted that it was still under consideration. France’s consideration of the flexibility was focussed on cities potentially banning diesel vehicles in some areas and only allowing B100 or biomass-to-liquid (BtL) fuelled heavy duty vehicles. In Sweden, Article 6 has not been implemented, but fuels are classified based on environmental standards, with most diesel being sold in the country being environmental class 1 (EC1), which is more stringent than FQD specifications.

Stakeholders were asked if they believe that FQD Article 6 should be retained to allow the flexibility for use in the future. The responses shown in Figure 9-2 indicate that the majority (87%) of respondents indicated preference for the flexibility to be retained, stating that this should be maintained as an option for the future.

Figure 9-2: Questionnaire responses to the question if the flexibility allowed under Article 6 should be maintained in the future.



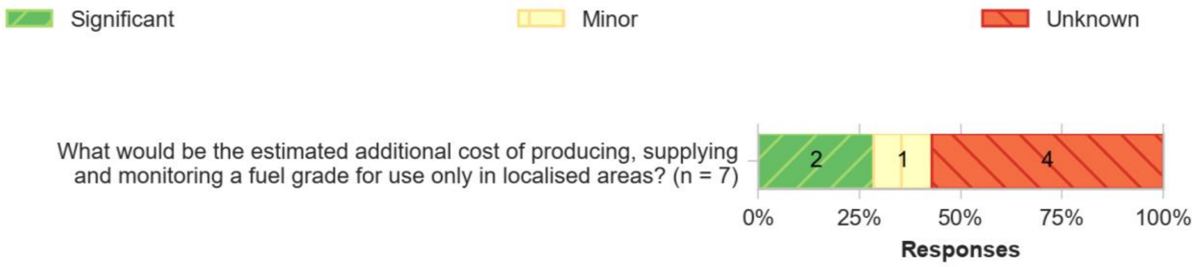
Some fuel producers stated that it should be up to local and national governments to decide if they legislate further improvements in fuel grade, and as such Article 6 should be retained. A further opinion put forward was that Article 6 may help to facilitate the usage of fuels of more stringent environmental standards on the EU market for both petrol and diesel. Specific fuels already utilised in different Member States were referenced, including EC1 fuel in Sweden, and B100 and rapeseed oil standards in Germany. One fuel supplier stakeholder commented that advanced fuels such as paraffinic diesel can offer exhaust benefits in diesel vehicles which run mainly in populated areas or NRMM which operate in confined spaces.

ACEA stated that the flexibility of Article 6 could lead to fragmentation of the market but highlighted that the flexibility would more likely be utilised predominately for captive fleets used in specific circumstances rather than to cause a change to general market fuel quality. As such, they support Article 6 which may be seen as a useful flexibility for the future.

Costs for fuel suppliers

Fuel producers/suppliers were asked to estimate additional costs for producing, supplying and monitoring a fuel grade for use only in localised areas. Figure 9-3 shows that there was no clear consensus on the cost of supplying additional grades of fuels locally. Some comments were provided that costs could potentially be high due to the likely small volume of the new fuel and the segregation of the fuel supply leading to high costs per volume of fuel marketed.

Figure 9-3: What would be the estimated additional cost of producing, supplying and monitoring a fuel grade for use only in localised areas?



Impact on emissions

There is the potential for fuels of more stringent environmental quality to help to improve air quality in local areas, most notably urban areas where air pollution impacts are most significant due to high pollutant concentrations and high population. More than 70% of EU citizens live in urban areas, and although for most air pollutants there has been progress in reducing concentrations, in 2018 15% of urban citizens were exposed to PM_{10} above EU limit values set by the Ambient Air Quality Directive ***(EEA, 2020)***. As outlined in Section 4, both bioethanol and biodiesel lead to lower emissions of PM compared to their mineral counterparts, as well as oxides of sulphur although these are less significant for localised health impacts. Impacts on NO_X emissions are less conclusive and so fuels are less likely to contribute to improvements in this area.

Localised usage of higher blends of biofuels in captive fleets therefore has the potential to facilitate PM concentration reductions from transport in the future, as Article 6 has currently not been used. This could help to compliment other localised measures which are already being rolled out in Europe and often target NO_X emissions specifically, such as UVARs (Urban Vehicle Access Regulations) which restrict vehicle movements in cities, including low emission zones, toll schemes and congestion charges, and bans on specific vehicle types in localised areas.

The FQD evaluation found that Article 6 is considered to be a last resort measure after other more cost effective local measures. Low emission zones restrict vehicles on the basis of exhaust emission standards and are widely implemented across the EU. Extensive research has been undertaken into the effectiveness of low emission zones implemented across Europe (Transport and Environment, 2019). Studies assessing the impact of low emission zones implemented across Europe have found reductions in NO_X concentrations ranging from 4% to a maximum of 32% in Madrid (Transport and Environment, 2019). The UK government has found that low emissions zones are one of the most effective type of measure for driving NO_X emission reductions through policy affecting vehicle owners (Ricardo, 2016). UVARs and low emission zones work by either encouraging owners to upgrade their vehicles to low emission vehicles, or by discouraging vehicle trips into the zone.

9.4 Conclusions

Article 6 has been considered by two Member States but implemented by none. The majority of stakeholders have indicated that Article 6 should be retained as it provides local and national governments with the option of legislating for more stringent fuels. This has been commented to be of greatest potential for captive fleets where different fuel grades can be used without causing fragmentation to the wider market. In the context of other localised measures for air pollution from the transport sector such as low emission zones and other types of UVARs, Article 6 could provide an additional measure particularly for abatement of PM emissions, concentrations of which continue to exceed emission limit values across Europe. However, this could be associated with additional costs for limited production and localised supply of specialised fuel grades.

10 SHOULD THE PROVISIONS ON METALLIC ADDITIVES BE CHANGED?

10.1 Background

Policy background

The FQD has banned the use of lead, limited manganese content in fuels, and requires labelling that indicates when a fuel includes metallic additives. The FQD Article 8a put the 2mg/l limit on manganese in place to limit the presence of methylcyclopentadienyl manganese tricarbonyl (MMT), an additive used in some markets to raise the RON of fuels.

The inclusion of metallic fuel additives (MFAs), and subsequent release into the environment following combustion, can have an adverse impact on human health and the environment. The potential impact is affected by the type and concentration of fuel additives and the conditions of exposure (European Commission, 2017).

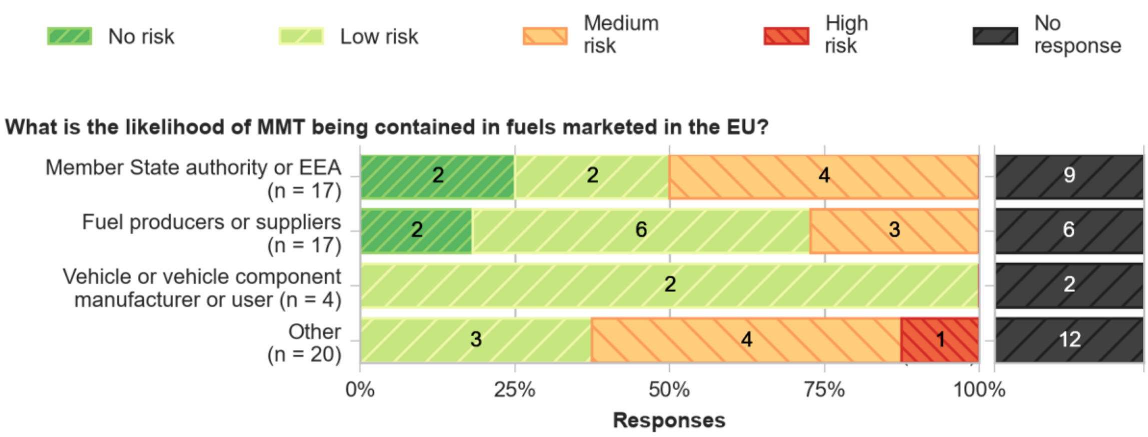
In response to RED II and other ambitions and commitments to reduce emissions, the EU fuels market is entering a period of potential transition, with the possible introduction of a wider variety of fuel types and blend components which may benefit from additive use. Therefore, it is appropriate to consider the impacts of restricting further metallic additives in fuels through the standards in the FQD.

Information gathered for the FQD Evaluation suggests that the costs associated with control of MMT may not be proportionate to the risk of MMT being used. The evidence on the costs of the necessary monitoring and the potential for take up of MMT will be explored, considering the current situation and future fuel composition developments.

Current and future use of MMT in the EU

In the stakeholder questionnaire, the majority of respondents indicated that there is no risk or a low risk of MMT being contained in fuels marketed in the EU (Figure 10-1). Respondents noted that the use of MMT is primarily limited by the restriction in the FQD. Some fuel producers and public authorities stated that EU refineries do not add any metallic additives to fuels. Some also highlighted that fuel producers in the EU would not use MMT due to potential damage to vehicles/engine components, and the availability of viable alternatives to boost octane. Afton Chemical stated in the workshop that it did not believe MMT use would increase in the EU due to opposition by most stakeholders in the automotive industry.

Figure 10-1: Questionnaire responses to the question: 'what is the likelihood of MMT being contained in fuels marketed in the EU?' (n = 56)



The 2019 Worldwide Fuel Charter (WWFC) notes that the manganese limit of 2 mg/l makes the use of MMT redundant, since it is no longer effective as an octane booster at these levels (WWFC, 2019). In the stakeholder workshop held for this study, ACEA noted that the 2 mg/l limit leads to practically zero use of MMT in the EU, although it would have preferred a complete ban to have been implemented. The FQD Evaluation also showed that Member States were not aware of any MMT use. Despite this, the evaluation concluded that despite the fact that MMT is not likely to be used in the absence of the limit, the limit is still valuable as a safeguard.

Although the FQD limit on manganese prevents significant use of MMT in the EU, MMT is still used in other regions (ILT, 2018). The main risk of MMT being contained in fuel marketed in the EU therefore comes from imported fuels. While the current limit prevents the use of MMT as an octane enhancer in the EU, it allows the potential for trace amounts of MMT in imported fuels, for example from contamination of tankers. The French Ministry of Ecological and Inclusive Transition noted in the questionnaire that even though the risk of EU refineries using MMT is low, the risk of imported fuels containing MMT is a reason to keep the current FQD limit in place, and the implementation of a complete ban could help to reduce amounts in imported fuels.

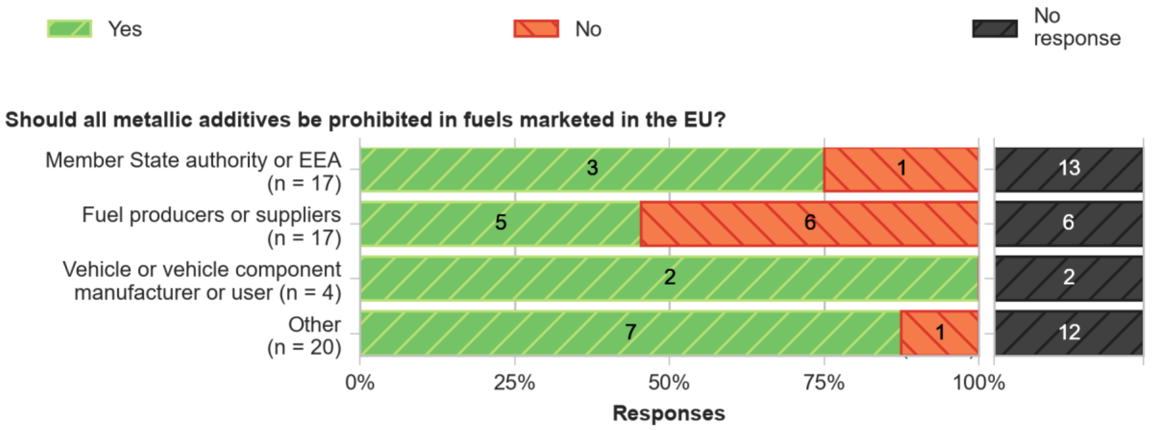
Current and future use of other metallic additives in the EU

The main MFA other than MMT with relevance to the EU in 2020 is ferrocene, being raised by stakeholders in both questionnaire responses and workshop discussions. Ferrocene can be used as an octane enhancer but has been shown to cause harm to oxygen sensors and catalysts (WWFC, 2019). The questionnaire and the stakeholder workshop showed that several stakeholders agreed that there is a need to assess ferrocene and that there is widespread consensus that it is harmful. Stakeholders further noted that there may be justification for a ban.

ACEA remarked in the stakeholder workshop that the use of additives (including ferrocene) as a cheaper way to boost octane is increasing. The Technical Committee of Petroleum Additive Manufacturers in Europe (ATC) notes that the increasing uptake of bio-ethanol in petrol and FAME in diesel will have effects on a variety of aspects of engine performance and underlines that additives could play a valuable role in helping prevent unwanted impacts (ATC, 2013). This was echoed by some questionnaire respondents, which stated that additives may be introduced in fuels in the EU due to the possible shift to high-octane petrol and to increased biofuel components.

Stakeholders were asked in the questionnaire if they believed that all MFAs should be banned in fuel marketed in the EU. Of those that responded, the majority believed there should be a ban, with the most named reason being in relation to detrimental impacts on vehicles, human health and environment.

Figure 10-2: Stakeholder responses to the question : "Should all metallic additives be prohibited in fuels marketed in the EU?"



Some stakeholders stated that there should be evidence of harm to environment, health and engines before a ban is put in place. The WWFC and some workshop attendees supported the view that it would be inappropriate to ban metallic additives without substantive data. The stakeholders suggested that a risk assessment using the EC methodology that demonstrates the safety of a metallic additive's use at a specified maximum concentration (without adverse impacts on vehicles performance or the environment) should be required before an MFA can be used in a fuel in the European market. The nature of this risk assessment and the EC methodology is described in the box below.

Article 8a (4-6) of the FQD specifies that fuels marketed in the EU must be specifically labelled 'contains metallic additives' at the point of sale when MFAs are used in the fuel. A concern raised by one stakeholder in the questionnaire was that the labelling requirement can sometimes not be applied by retailers because they are either not aware of any MFAs in the fuel or not aware of the labelling requirement.

Environmental and health risk assessment of metallic fuel additives

Article 8a of the FQD required the European Commission to develop a test protocol[28] to assess the risks for the environment and health from the use of MFAs in fuels. As discussed in the European Commission's report[29] to the European Parliament and Council, this methodology was used to assess the possible sources of emissions linked to MFA, the possible exposure pathways and the results and implications. The conclusion states that it is apparent that there is a potential impact on health and the environment by the use of MFA and that the developed methodology may be used by any party interested to in order to evidence the establishment or revision of limit values for MFAs in the FQD (European Commission, 2013). The European Commission also published the final report[30] detailing the development of the risk assessment methodology (European Commission, 2013).

Current and future use of non-metallic additives in the EU

While the focus of this study is with regard to the importance of metallic additives, literature and stakeholder inputs also highlighted concerns about the use of non-metallic additives that may be harmful to vehicles, human health and environment.

Non-metallic additives that were discussed in the stakeholder questionnaire and workshop include N-methyl-aniline (NMA) and Santa Barbara amorphous (SBA) which are added to petrol to increase its octane number, and both have been linked to adverse effects on engine parts. They fall under the broader category of non-traditional petrol additives (NTGAs) which also includes acetone, methylal and methyl acetate. NTGAs are not in the list of recommended oxygenates in the EN 228 standard, and their use are restricted by the Euro 5/6 standards (2209/2014): Regulation 715/2007 (ACFA, 2014).

Methylal is used to extend fuel output or to bypass methanol blending limits, its effectiveness is limited and it can cause worsened fuel efficiency (ACFA, 2014). NMAs have been show to cause gum formation, seal swell, shorter induction times, heavier copper strip corrosion and may result in higher NO_X.

Deposit control additives (sometimes referred to as 'detergents') were highlighted by ACEA as additives that were welcome by manufacturers in the stakeholder questionnaire. When used properly, deposit control additives can help minimise deposits which lead to increased emissions and negatively affect vehicle performance (WWFC, 2019). Deposit control additives are typically based on amines (ATC, 2013).

Corrosion inhibitor additives can be used to reduce corrosion of vehicle fuel systems and fuel distribution (Bromberg & Cheng, 2010). Corrosion inhibitors include amines, carboxylic acids and anhydrides (ATC, 2013). The WWFC notes that corrosion inhibitors that do not interfere with fuel quality through formulation or reaction with sodium may be used in fuels (WWFC, 2019).

[28] https://ec.europa.eu/clima/sites/clima/files/transport/fuel/docs/fuel_metallic_additive_protocol_en.pdf

[29] https://www.europarl.europa.eu/registre/docs_autres_institutions/commission_europeenne/com/2013/0456/COM_COM(2013)0456_EN.pdf

[30] https://ec.europa.eu/clima/sites/clima/files/transport/fuel/docs/bio_report_en.pdf

10.2 Policy options

The following policy options have been identified for assessment:

(a) Limits

1. Counterfactual: No changes to the provisions on metallic additives.
2. Implement a complete ban on MMT.
3. Implement a general ban on metallic additives.
4. Require that all metallic additives confirm lack of harm through the risk assessment following the test methodology[31] developed by the European Commission, before being allowed in fuels marketed in the EU.

(b) Monitoring

1. Counterfactual: Retain the current monitoring requirements for MMT in fuels.
2. Amend the wording of the Directive to refer to the use of MMT in petrol instead of in fuels, and consequently remove the requirement for monitoring MMT content in diesel.
3. Simplification of MMT monitoring requirement to allow for it to be conducted at a qualitative rather than quantitative level.

10.3 Analysis

Environment and human health impacts

MFAs can be emitted from tailpipes and enter the environment leading to risk to human health and the environment. To assess the health and environment risks of MFAs, the European Commission published a report showing a thorough assessment of all impacts from different MFAs in 2013 (European Commission, 2013). The report identified and categorised different metallic additives and carried out a risk assessment including emissions during the life cycle, hazard assessment and exposure assessment. The use of MMT was found to be associated with toxic effects on the nervous, respiratory and reproductive system and was linked to behaviour changes and nervous system effects (European Commission, 2013) (ICCT, 2009). Ferrocene is the main metallic additives currently believed to be in use, with use increasing according to stakeholders and concern around health impacts. This additive was assessed in European Commission (2013) and found to have harmful effects from short and long-term exposure including lung inflammation and liver damage.

A number of additional metallic additives were also assessed for hazardousness although these are not currently utilised in the market. The development of new fuel additives including metallic additives is ongoing particularly in the landscape of the development of new vehicle engines and fuels. A complete ban on metallic additives would prevent any potential health and environmental risks of these future products but would also prevent the beneficial functions for which they are developed. It is for this reason that the risk assessment methodology was developed on the basis of exposure pathways and hazardousness.

Metallic additive manufacturers historically disputed the environmental impacts of MMT (ATC, 2013). Afton Chemical stated in the stakeholder workshop that there are both harmful and beneficial impacts of the use of MMT in fuels, as evidenced in numerous studies. A risk assessment following the EC methodology was carried out and concluded

[31] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0456&from=EN

that MMT in fuel up to 18 mg Mn/l does not affect vehicle performance or have significant human health or environmental impact, and disputing the need for the 2mg/l limit (Jackson M. & Sanders M., 2016).

Vehicle compatibility and emissions

The FQD Evaluation found that vehicle manufacturers advise against the use of MFAs due to risks to engines and emission control systems and that the use of fuel containing MFAs could invalidate vehicle warranties. Stakeholders responding to the questionnaire of this study highlighted the risks associated with MMT and other additives with regard to vehicle damage, particularly to the engine, emission control systems or exhaust cleaning devices. ACEA underlined that allowing such metallic additives (or nitrogen-based chemicals) would lead to repair and replacement costs of damaged components for vehicle owners or manufacturers. The Swedish Transport Agency stated that the risks of damage to the exhaust aftertreatment systems was far greater than any potential benefit of these MFAs.

According to the Worldwide Fuel Charter (WWFC), metallic additives that form ash or contaminants can degrade sophisticated exhaust emission control equipment (WWFC, 2019). The WWFC highlights this as being a specific issue with manganese from MMT which will remain and coat the engine, catalyst and exhaust system, thereby irreversibly and cumulatively resulting in higher emissions and lower fuel economy. Ferrocene is also described as causing premature failure of engine systems (WWFC, 2019). The adverse effects of Ferrocene on components were echoed by ACEA, Afton Chemical, Neste and several other stakeholders in the workshop and questionnaire.

In contrast to other stakeholders, The ATC states that metal-based additives show clear performance and emission benefits for engines, if used for applications such as particulate traps, octane boosters, valve seat protection and combustion improvers. Increasing uptake of bio-ethanol in petrol and FAME in diesel will have effects on a variety of aspects of engine performance and additives could play a valuable role in preventing vehicle compatibility issues of these fuels. As with regard to health and environmental impacts, stakeholders not in favour of a complete ban stated that the engine-related concerns should be confirmed by risk assessment rather than the putting in place of a complete ban.

MMT Monitoring Regime and potential changes

The FQD Evaluation indicated that the costs associated with monitoring MMT may not be proportionate to the risk of its use in the EU, with 4 out of 17 Member States indicating that monitoring costs are high. The consensus of stakeholders in this study has indicated that MMT is not currently utilised in the EU for the purpose of increasing octane rating, due to the 2mg/l eliminating its effectiveness for this purpose. It was also widely stated by stakeholders that even in the absence of the current limit, stakeholder views on the negative impacts of MMT on health and the environment as well as on vehicle engines would prevent its uptake. As such, there is the potential for revising the current monitoring regime in order to reduce costs. However, an issue raised by stakeholders in this study is that, while MMT is not used in Europe, there is potential risk of fuels contaminated with MMT entering Europe in imported fuels. This would go undetected if there is a reduction in monitoring requirements of MMT in petrol.

The evaluation and the stakeholder questionnaire responses in this study noted however that MMT is only relevant to petrol and is not used in diesel (European Commission, 2017). However, Article 8a requires monitoring of MMT in all fuels, including diesel. Amending the wording of Article 8a to only require the requirement for monitoring for petrol would eliminate the need for monitoring of MMT in diesel fuels and therefore reduce the costs for fuel suppliers and national competent authorities.

10.4 Conclusions

The current manganese limit of 2mg/l has effectively banned the use of MMT as an octane booster in the EU. The continued presence of the limit on manganese, despite low expectation of use of MMT in EU if the limit was removed, serves as a safeguard. This is also the case as, despite the lack of use in EU industry, there is continued risk of MMT contaminated fuel imports. Findings of a study utilising the European Commission's risk assessment methodology for metallic additives suggests that there will be little additional environmental benefit from going further than the 2mg/l limit to an outright ban.

Although a complete ban of MMT would appear to have small additional environmental and health benefits relative to current provisions, it is the opinion of the majority of stakeholders that a complete ban of metallic additives as a whole should be implemented in order to minimise impacts on the environment and vehicles. Ferrocene is the metallic additive that is currently available for market with negative impacts on health as well as engine components which a ban of metallic additives would prohibit. In the very least, there was widespread support from stakeholders for the investigation into ferrocene due to its known impacts. In addition to this, there is for a possibility that other fuel additives may enter the market in future with a risk that these may have negative impacts on vehicles, human health and the environment. This is particularly the case with the current shifting landscape of fuels and engines. While a ban of metallic additives would prevent negative health and engine impacts of these additives, it will also prevent the benefits for which they are developed. Certain stakeholders have therefore argued that it is preferable to utilise the Commission's risk assessment procedure to demonstrate harm for specific additives, rather than banning all metallic additives.

Policy Option	Environmental Impacts	Vehicle Compatibility Impacts	Other Economic Impacts
Complete Ban of MMT	**o/+** Potential reduction in trace amounts of mercury contained in fuels imported to the EU with associated reduction in health impacts	**o/+** Potential reduction in trace amounts of mercury contained in fuels imported to the EU with associated reduction in engine impacts	**o** No significant changes
Complete Ban of Metallic Additives	**o/+** Prevention of ferrocene usage with associated reduction in health impacts. Potential prevention of usage of metallic additives not yet developed and prevention of associated health impacts.	**o/+** Prevention of ferrocene usage with associated reduction in engine impacts Potential prevention of usage of metallic additives not yet developed and prevention of associated impacts on engines (Both positive and negative).	**o/-** The prevention of usage of all future metallic additives will have uncertain wider economic impacts.

Policy Option	Environmental Impacts	Vehicle Compatibility Impacts	Other Economic Impacts
Risk Assessment Required for new additives	+ The utilisation of the risk assessment methodology can identify additives that are harmful before they are brought to market.	+ The utilisation of the risk assessment methodology can identify additives that are harmful before they are brought to market.	+/- Costs associated with undertaking and checking the risk assessment methodology, however, can result in potential benefits if additives are found to be not harmful and provide other benefits.

11 Should more parameters from the industry standard EN 228 be introduced into Annex I and from EN590 into Annex II?

11.1 Background

Policy background

While the FQD sets important requirements to limit harmful emissions from petrol, such as limits on sulphur, oxygen, ethanol and vapour pressure, the EN 228 standard also sets performance related and other quality standards, such as density, oxidation stability, existent gum content and copper corrosion, as show in Annex A. Similarly, the diesel EN 590 standard goes beyond the FQD parameters, adding specifications for the flash point, cetane index, cold filter plugging point, viscosity, ash content, water content and total contamination, among others, as shown in annex B.

All fuel suppliers in the EU observe CEN standards EN 228 and EN 590. CEN members[32] are bound to give to these European Standards the status of a national standard, either by publication of an identical text or by endorsement. However, the adoption of CEN standards within national legislation is voluntary and, hence, compliance with all requirements under EN 228 and EN 590 is not necessarily compulsory. Based on the EEA Fuel Quality report for 2018 (EEA, 2020), BG, CZ, DK, EL, LT, LU, MT, SE applied the EN 228 and EN 590 standards to national legislation. Further consultation with relevant authorities through FuelsEurope and UPEI confirmed that diesel and petrol are monitored against all EN 228 and EN 590 parameters in a vast majority of EU Member States (see Table 11-1), with most countries fully or almost fully adopting EN 228 and EN 590 standards in their national legislation.

[32] Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom

Table 11-1: Level of alignment of fuels sold in Member States with EN 228 and EN 590 standards

Member State	Compliance with EN 228 and EN 590 standards	EN 228 and EN 590 standards incorporated in national legislation
AT	Yes	Yes
BE	Yes	Yes
BG	Yes	Yes
CY	Yes	Unknown
CZ	Yes	Yes
DE	Yes	Yes
DK	Yes	Yes
EE	Yes	Yes
EL	Yes	Yes
ES	Yes	Yes
FI	Yes	Unknown
FR	Yes	Yes
HR	Yes (*)	Unknown
HU	Yes	Yes
IE	Yes	Unknown
IT	Yes	Yes
LT	Yes	Yes
LU	Yes	No
LV	Yes	Yes
MT	Yes	Yes
NL	Yes	No
PL	Yes	Yes
PT	Yes	Yes
RO	Yes	Yes
SE	Yes	Unknown
SI	Yes	Yes
SK	Yes	Yes

Source: Survey and interviews with stakeholders

Note: (*) In their response to the stakeholder survey, the Croatian authority reported partial compliance of 76-99% of fuels

Current level of compliance

Even though Member States tend to control the quality of petrol and diesel against EN 228 and EN 590 standards, respectively, non-compliant fuels do enter the EU market according to CEN/TC 19. The following causes are associated to lack of compliance:

- **Seasonality**: During transition periods from winter to summer grades and vice-versa, it is more difficult for some traders or suppliers to supply all filling stations on specification at the correct moment. According to UPEI, in some cases, the seasonal specifications for fuels are not known because there is no national annex, or it is not incorporated in the legislation (e.g. NL and LU). It should also be noted that non-compliance may also be related to cost differences between winter and summer specifications. For petrol, winter quality is cheaper than summer quality due to vapour pressure requirements. This means that it is common to observe winter quality petrol after the date of specification change according to the standard. As for diesel, summer specification is associated to lower production costs, so the reversed behaviour is observed.
- **Less intense monitoring**: Some properties (e.g. water content, cold filter plugging point and cloud point or distillation characteristics) tend to be less rigorously controlled by the Fuel Quality Monitoring System (FQMS) and are normally not checked on a batch-by-batch case or at every delivery as they normally rely on appropriate manufacturing.
- **Supply chain contamination:** Contamination during the logistic chain may cause some of these properties to go out-of-specification when finally delivered to the vehicle. For example, a small contamination of petrol in diesel will cause the flashpoint of diesel to be too low. This happens when the discharging at the retail station is not well managed.
- **Imported fuels**: Imports from outside the EU, especially from Russia and the Mediterranean areas, which are delivered as EN-compliant, tend to be less reliable.

CEN/TC 19 also stated that besides the issues above mentioned they have received indications that density, water content, total contamination and oxidation stability tend to be slightly out-of-specification sometimes, mainly for diesel blends. However, they also mention they have no indications that vehicles have been impacted heavily by these fluctuations.

A 2017 report published by Concawe based on results of an independent fuel quality survey for 17 EU Member States (Concawe, 2017) suggests that non-compliance levels may be very low. The results indicated that the fuels that were tested complied with specifications in the CEN standards. This underlines again that the alignment of fuel quality with the CEN standards is already widely applied in practice.

Relevant parameters

For petrol, the EN 228 standard sets specifications for the following parameters (excluding those also specified in FQD Annex I): density @ 15°C, oxidation stability, existent gun content (solvent washed), copper corrosion (3hr @ 50°C) and appearance.

The WWFC discusses different fuel quality parameters from the viewpoint of engine and vehicle manufacturers (WWFC, 2019). However, the WWFC does not highlight any of the specifications listed above as major concerns in terms of fuel quality.

For diesel, the EN 590 standard sets specifications for the following parameters (excluding those also specified in FQD Annex II): flash point, cetane index, cold filter plugging point (winter/summer), viscosity at 40°C, copper strip corrosion (3hr @ 50°C), carbon residue, ash content, total contamination, water content, oxidation stability, lubricity and filter blocking tendency.

Based on the parameter descriptions in the WWFC, flash point, cetane index, water content and oxidation stability are parameters that could be considered to be relevant for the objectives of the FQD.

The **flash point** is the temperature at which a fuel or material will ignite if an ignition source is present. Ethanol may be added to diesel to render e-diesel. Although there is not much current use of e-diesel, some concerns were raised about the significantly lower flash point for e-diesel compared to regular diesel (WWFC, 2019). Although the concerns mainly affect safety concerns around fuel handling and storage, vehicle and engine manufacturers are also concerned that e-diesel may damage vehicle parts.

The cetane number, which is set in the FQD, is tested by combusting fuel, which will reflect cetane improving additives. By contrast, the **cetane index** is designed to give an approximation for natural cetane using a calculation based on measured fuel properties (fuel density and distillation temperatures). The WWFC does not recommend increasing cetane by more than 10 numbers over natural cetane using additives. This is because artificial cetane affects vehicle performance differently than natural cetane which can lead to inconsistent results and may affect emissions (WWFC, 2019). Therefore, the cetane index limit can be used to avoid excessive additive dosage in fuel.

Excess levels of **water** in diesel will lead to corrosion and microbial growth. Increased FAME-blended diesel is a concern because FAME absorbs more water, thus is more susceptible to water contamination which results in corrosion and microbial growth.

Absence of good **oxidation stability** can lead to fuel quality issues for biodiesel blends even at 5%. Biodiesel (FAME) inherently has poor oxidation stability due to its chemical composition, which can easily be oxidised after production and during storage. Precautions must be taken, such as stability enhancing additives such as butylated hydroxytoluene (BHT). The WWFC believes that even the EN590 minimum 20 hours oxidation stability is inadequate to prevent corrosion in metal parts.

11.2 Policy options

Definition of policy options

A number of parameters not regulated by the FQD have been identified as important for consideration from the EN standards, particularly with respect to higher biofuel usage. The literature review has suggested that oxidation stability is particularly important when considering increasing biofuel content in petrol, due to protecting metal parts from corrosion. Flash point is particularly relevant for ethanol, which when added to diesel to create e-diesel results in a very low flash point, with associated safety concerns. FAME absorbs more water than conventional diesel, and excess water can cause corrosion. This makes the control of the water content more relevant in diesel blends with high FAME content.

The following policy options have therefore been identified for exploration, based on the literature review and consultation:

- Counterfactual: Maintain existing parameters of specifications in the FQD.
- Introduce specifications for the following parameters from EN 228 and EN 590 into the FQD.
    - Oxidation stability (petrol and diesel)
    - Flash point (diesel)
    - Cetane index (diesel)
    - Water content (diesel)

- Introduce specifications for all parameters of the EN 228 and EN 590 standards into the FQD.

Against the counterfactual, the option to introduce oxidation stability, flash point, cetane index and water content specification from the EN 228 and EN 590 into the FQD is meant to reinforce the quality control of these parameters in view of the increasing use of biofuels. This aims to prevent the segmentation of the EU market and potential incompatibility issues associated with an inconsistent control of these parameters across the EU.

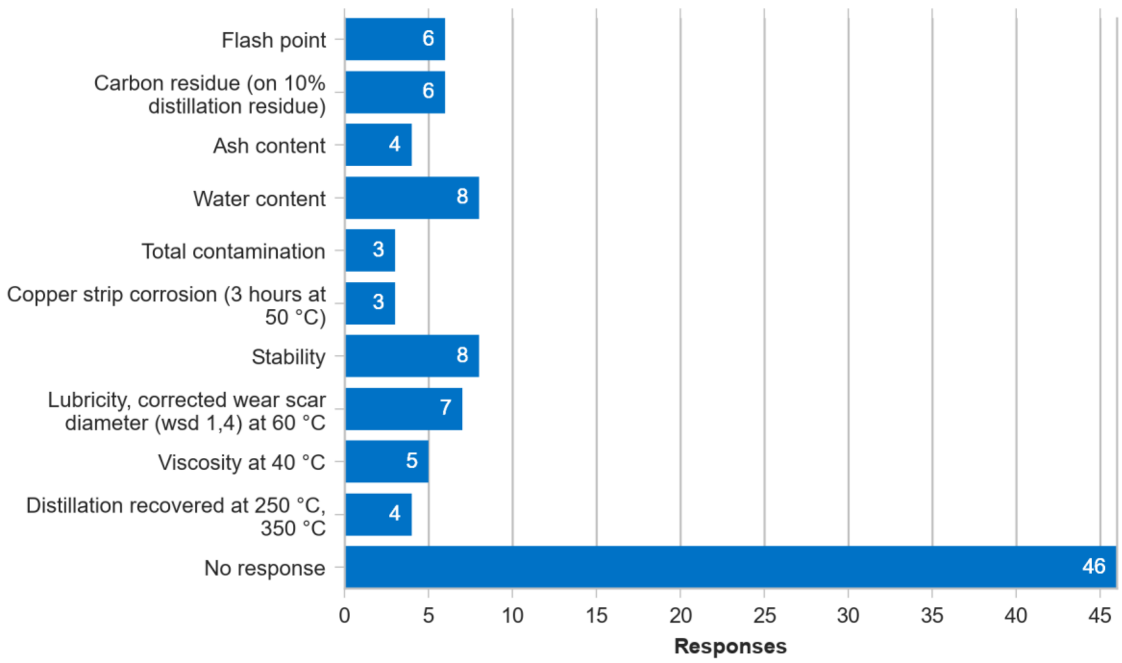
The second policy option ensures full consistency between the FQD and CEN standards. CEN standards 228 and 590 contain the specifications in the FQD and other technical specifications. Each update is agreed by working groups of experts and not via a legislative process. This means that a full alignment would mean that the technical decision on CEN parameters and the legislative process related to the FQD would have to be fully coordinated.

In both cases, if additional parameters in the CEN standards were introduced into the FQD, these parameters would have to be monitored and reported by Member States in accordance to Article 8 of the FQD (EEA, 2020). This means that additional CEN parameters would have to be analysed for all the fuel samples requested by the Fuel Quality Monitoring System (FQMS) in accordance with the EN14274 standard or other national FQMS in place.

Stakeholder views on the definition of policy options

The questionnaire asked what parameters covered by CEN standards EN 228 and EN 590 that are not already included under the FQD should be introduced to the FQD. The view on the addition of the parameters to the FQD differed significantly between fuel producers or suppliers and other respondents (predominately Member States). A lot of respondents picked none of the parameters and responded with a comment arguing that no new parameters should be introduced to the FQD. This is reflected in the low response rate to the question, as shown for diesel and petrol in Figure 11-1 and Figure 11-2, respectively.

Figure 11-1: What parameters covered by the CEN standard EN 590 that are not already included under the FQD should be introduced to the FQD for diesel?



Fuel producers or suppliers generally had the view that parameters covered by CEN standards do not need to be introduced to the FQD. One reason provided is that the FQD should not focus on raw materials and processes, but instead products, with another that the FQD should only refer to standards rather than set technical rules. Furthermore, fuel producers and suppliers underline that FQD parameters should focus on health and environment, while the parameters currently managed by the CEN are technical parameters. To change the standards is a faster process than changing an EU Directive, which is why the technical parameters should remain within the CEN standard. A further point made is that the different climatic conditions in different Member States would complicate the introduction of technical parameters. One Member State also voiced concern about the additional cost of monitoring additional parameters.

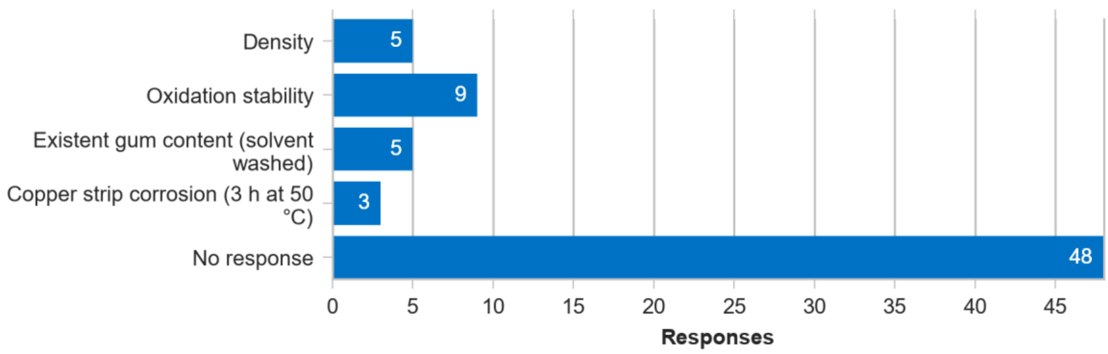
A response from an independent fuel advisor focuses mainly on the introduction of an oxidation stability parameter to the FQD, acknowledging the benefits this could bring as the inclusion of FAME makes diesel fuels less stable. Although noting that if the objective of the FQD is to only be concerned with environmental parameters, then additional ones do not need to be introduced. ACEA raised issues around carbon residue, ash content, oxidation stability and viscosity, noting that the parameters should be introduced to the FQD to improve engine performance and operability. A fuel additive manufacturer also noted in the stakeholder workshop that as a result of the increasing addition of oxygenates to petrol and diesel, it would make sense to add an oxidation stability specification.

ACEA and NESTE noted that the FQD should not adopt the minimum limit set for density in the EN 590 standard as this would restrict the blending of lighter components such as synthetic and paraffinic diesels. This would be counter-productive and does not hold any health or environmental protection benefits.

NESTE and a fuel additive manufacturer also noted that introducing a specification for the Cetane Index would be unsuitable for fuel containing either FAME or HVO and would also pose a challenge for BTL or PtX-based fuels.

The CEN noted in the stakeholder workshop that the concerns about the flash point of e-diesel highlighted in the WWFC are related to logistical transport safety, not to vehicle performance or emissions. They therefore did not believe that e-diesel made at the filling stations would result in any issues.

Figure 11-2: What parameters covered by the CEN standard EN 228 that are not already included under the FQD should be introduced to the FQD for petrol?



The view on the introduction of parameters EN 228 for petrol is fairly similar to that for diesel. Most fuel suppliers or producers have provided similar responses, selecting none of the parameters and commenting that no new parameters should be included.

The CEN highlighted that the concern over oxidation stability does not apply to petrol to the same extent it applies to diesel. They further elaborated that they found no oxidation stability issues with petrol and, further, have difficulties finding non-stable products to assess their test methods.

Other notable views include the comment that limits for metal content (particularly for ferrocene), which is discussed in detail in section 10, should be added to FQD (by an independent advisor for the fuels sector). The strengthening of parameters regarding oxidation stability was also suggested (by a vehicle/vehicle component manufacturer), which diverges from the CEN's comments on petrol's oxidation stability noted in the paragraph above.

ACEA noted a few potential changes in its contribution, amongst which was a comment noting that oxidation stability affected vehicle operability. ACEA also refers to the potential to consider introducing new limits such as a PM-Index, parameters to limit some of the heavier aromatic chains beyond just a total aromatics limit, and revising the distillation curve limits, which currently only set minimum levels at two points. These new limit suggestions were all made with regards to potential ultra-fine particle emissions reduction.

The literature and questionnaire findings both indicated that most stakeholders, except for vehicle manufacturers, did not think that parameters covered by CEN standards should be adopted by the FQD. One of the main arguments given was that the FQD and CEN standards have different aims, where the FQD focusses on health and environment and the CEN standards focus on technical parameters. One respondent noted that the FQD FAME limit is mostly based on technical considerations and that, therefore, there should be scope for the FQD to include a parameter for oxidation stability as FAME contents increase. Further suggestions were made about including other parameters and that some parameters in the CEN standards should be relaxed.

11.3 Analysis

Although CEN standards are mostly incorporated in national legislations for fuel quality, anecdotal evidence from stakeholders suggests that some CEN parameters beyond the scope of the FQD tend to be less intensely monitored within the Fuel Quality Monitoring System (FQMS). This is associated with difficulties in ensuring 100% compliance for some parameters linked to EN 228 and EN 590 specifications due to reasons mentioned described in section 11.1. Hence, including further CEN parameters into the FQD would have impacts on fuels composition and the EU fuels market to the extent that the policy change affects monitoring and compliance levels with CEN standards.

The obligation to monitor and report additional CEN parameters along with current FQD parameters as per Article 8 could somewhat increase the monitoring intensity of these CEN parameters within FQMS of some Member States. However, since CEN standards are widely adopted in national legislations of Member States, the additional monitoring activity on these parameters is likely to be rather marginal. In addition, fuels marketed in the EU have been found to have a high level of compliance with CEN standards with remaining non-compliance linked to some specific seasonal and logistic issues that are difficult to overcome for all samples. Thus, any additional monitoring is expected to lead to marginal changes in compliance levels. Overall, the impact of including further CEN parameters into the FQD is not expected to significantly affect the fuel quality across the EU.

Impacts on vehicle compatibility

As discussed in section 11.1, certain parameters not regulated by the FQD are relevant for vehicle compatibility particularly with regard to the increased use of biofuels. FAME absorbs more water and inherently has poor oxidation stability, which means that oxidation stability and water content become more important in the light of increasing use of FAME in diesel. Non-compliance with oxidation stability and water content specifications may cause issues with engine compatibility due to corrosion. On the other hand, the flash point could be an issue for ethanol use in e-diesel, with potential safety issues mostly related to fuel handling and storage. In this sense, it could be argued that regulating these parameters through the FQD would help to support a more consistent uptake of biofuel blends across the EU and prevent potential incompatibility or safety issues linked to those parameters.

However, as discussed above, the inclusion of these parameters in the FQD is not likely to lead to significantly higher levels of compliance. This means that no significant impact on the quality of fuels with higher FAME blends or e-diesel are expected as a result of introducing parameters from EN 228 into Annex I and EN 590 into Annex II of the FQD.

Economic impacts

The incorporation of CEN parameters into the FQD may imply administrative costs for suppliers and authorities linked to additional testing and reporting requirements. One public authority and an independent fuel advisor highlighted in the stakeholder survey that the alignment would be a challenging process, requiring increased testing and monitoring efforts for every parameter added and would reduce the flexibility of fuel suppliers.

Regarding additional costs for fuel producers and suppliers, CEN outlined in an interview that some parameters are measured and controlled by fuel producers and suppliers on a regular basis. Introducing an additional monitoring requirement for these would not result in significant additional costs beyond some extra administrative costs. For example, fuel density control is required for other existing internal reporting procedures.

However, some other parameters such as appearance, copper strip corrosion or oxidation stability are less likely to be measured as part of the manufacturing process since they are already informed by other parameters. These parameters are expected to be out of specification only sporadically but incorporating these into the FQD would result in extra testing costs for suppliers.

Furthermore, some of these tests at the production stage need a long time before they deliver a result. Waiting for test results may lead to delays that could result in additional operational costs for producers. This effect could be alleviated through faster testing techniques, but these would require investment and R&D.

Besides additional testing by producers, public authorities may also need to meet additional testing and reporting requirements as part of FQD reporting obligations. The FQD Evaluation study found that current reporting and sampling obligations for competent authorities are associated with costs within the range of €173k – €640k per year, based on feedback from six Member States. These estimated annual costs include all fuel testing costs, as well as costs related to outsourcing or contracting fuel monitoring. Should the number of parameters to be monitored and reported increase, costs for authorities may grow proportionally. Based on this, the option to introduce oxidation stability, flash point, cetane index and water content specification from the EN 228 and EN 590 into the FQD may increase costs for authorities by up to 15% (€26k-€96k), while the full alignment may represent an increase of up to 50% (€87k-€320k). However, these estimates are uncertain as they are based on a small sample size. Furthermore, the Evaluation's estimated annual costs could not be split into fixed and variable costs, thus potentially leading to an overestimate.

Some Member States suggested in the FQD Evaluation that the integration of the CEN standards may lead to greater harmonisation of the single market. Similarly, some fossil fuel and biofuel producers and suppliers noted that the different use of CEN standards in some Member States may fragment the biofuel market due to the supply of different blends. However, in light of the wide adoption of CEN standards in national legislations of

Member States and high compliance rates, the additional impact of considered policy options on the EU fuel internal market is not considered significant.

11.4 Conclusions

The inclusion of CEN standard is purely a matter of widening the scope for better alignment and cooperation between FQD and CEN standards, combining operational reasons (CEN) and environmental reasons (FQD) for setting requirements. CEN are decided based on technical criteria, so including them in the FQD may lower this flexibility.

Since the majority of Member States have already aligned legislation for fuels sold with the respective standards, an alignment would not lead to any impacts with regards to vehicle compatibility or environment.

It would only make sense to include CEN standards in the FQD if a significant monitoring inconsistency is expected in light of higher biofuel blends, for which there is no strong evidence. In this context, only oxidation stability and water content could be considered for diesel, although no new parameter would be needed for petrol.

The economic impacts of an alignment would be based on increased monitoring and reporting costs that the new parameters would require.

Policy	Environmental Impact	Vehicle compatibility Impact	Economic Impact
Inclusion of CEN parameters relevant for biodiesel (e.g. water content, oxidation stability)	**o** No significant impacts	**o** No significant impacts	**-** Additional monitoring and reporting costs
Alignment with all CEN parameters	**o** No significant impacts	**o** No significant impacts	**-** Additional monitoring and reporting costs

12 SHOULD THE MINIMUM RON FOR PETROL BE INCREASED?

Increasing the minimum Research Octane Number (RON) of petrol can result in improved efficiency of high-tech engines already in the fleet and provide further opportunity for engine manufacturers to optimise future engine designs. An increase in efficiency has the benefits of reducing fuel consumption and carbon emissions. However, increasing RON requires changes in the petrol production. Therefore, it is also important to consider the implications for refineries with respect to changes in costs, energy use and emissions. There may also be implications for EU/non-EU trade balance. A further aspect is the potential saving for fuel suppliers if only a single grade of petrol is marketed.

12.1 Background

Policy background

Currently, the FQD sets a minimum RON of 95.0 in petrol, but fuels with RON of 98.0 are also commonly marketed in European markets. A footnote in the FQD allows Member States to place petrol with a RON of 91.0 on the market, although this is a negligible share of the total volume sold (around 0.1% of petrol sales in volume).

Current use of higher octane petrol

Higher octane petrol (HOP) is already marketed within the EU due to demand from consumers able to benefit and willing to pay the premium.

As presented in Table 12-1, the majority of petrol sold in 2018 had a RON of 95, accounting for 82.9% of petrol sales in volume. Furthermore, 14.0% of sales were reported as 95 < RON < 98 (95-98) and 3.0% of petrol sales were RON > 98. Note that some Member States reported selling no RON 95, but mostly selling RON 95-98, while other Member States reported no sales of RON 95-98, but sales of both RON 95 and RON 98. Compared to the shares in 2014, the share of RON 95 (82% in 2014) as well as RON 95-98 (12% in 2014) increase while RON 98 has slightly decreased (6% in 2014). An overview of total petrol sales for the different grades are shown in Table 12-1.

Table 12-1: Petrol sales in the EU in 2018, by Research Octane Number (RON)

Petrol grade	Share over total petrol volume sold
Total petrol RON=91 E5	**0.1%**
Total petrol RON=95	**82.9%**
of which E0	6.7%
of which E5	67.0%
of which E10	9.2%
Total petrol RON 95-98	**14.0%**
of which E0	0.5%
of which E5	10.9%
of which E10	2.4%
Total petrol RON>98	**3.0%**
of which E0	0.9%
of which E5	2.0%
of which E10	0.1%

Source: (EEA, 2020)

Expected direct and indirect efficiency gains from HOP

All European petrol cars are required to be able to operate with 95 RON petrol, however some vehicles have the capability to run more efficiently on higher RON grades (Concawe, 2019). Petrol's octane rating or number measures how prone a fuel is to auto-ignite, which may cause a knock or other engine noise, as well as engine damage. Each engine is designed for a fuel with a particular octane rating, so that if a lower octane rating fuel is used, it can result in knocking. The use of a higher octane petrol will not cause issues (WWFC, 2019), other than those associated with higher ethanol blends.

Octane rating has both direct and indirect impacts on engine performance. The direct effect occurs when the engine is operating at high load. Higher octane rating requires a lower spark retardation to avoid knocking, which increases engine efficiency. For an engine to improve efficiency with a high-octane fuel it needs to have an active knock control system, and it needs to be knock-limited with 95 RON under at least some conditions (i.e. the compression ratio is higher than will allow optimum combustion phasing). These have both been standard in mainstream passenger-car petrol engines for vehicles with start-of-production at least 10 years ago. 20 years ago, active knock control was less common, and production calibrations and compression ratio selection were more conservative as a result. Roughly, vehicles older than 10 years would not see a benefit from HOP in terms of fuel efficiency, but no negative effects are expected either on the engine performance or on durability. Considering that the average age of passenger cars is 10.8 years[33], higher RON petrol would lead to direct efficiency gains for a significant share of the current passenger vehicle fleet.

Direct measurable benefits are likely to still occur up to 102 RON with most modern petrol engines. An EU-funded study[34] reports that Euro 6 series-production vehicles calibrated for 95 RON improved their fuel efficiency by 1-4% using RON 102 petrol (E20) in comparison with the RON 95 (E10) reference fuel. Overall fuel efficiency gains in modern petrol engines will increase with higher power requirements within the duty cycle.

The octane rating is also a key factor in engine design and calibration and hence it will have an indirect effect on engine performance. Improvements in engine technology have come through a variety of high-tech developments, a majority of which result in engine operation with higher loads. Higher octane petrol enables higher compression ratios (CR) and other efficient powertrain designs, such as downsizing, downspeeding, cylinder deactivation and hybridisation while maintaining acceptable levels of spark retardation at high loads. The efficiency benefits of optimizing an engine for higher octane fuel will vary depending on the baseline fuel octane number, engine compression ratio, degree of downsizing and other factors (WWFC, 2019).

This indirect impact is larger than the direct effects of octane rating because a higher compression ratio would produce efficiency benefits over the entire engine operating map, while direct impacts on the current fleet only occur during knock-limited operation (i.e. at high loads). Efficiency gains for optimised vehicles would be approximately twice those for conventional (non-optimised) vehicles.

Increasingly stringent CO_2 standards aim to promote technology-neutral improvements in the fuel efficiency of road vehicles in line with climate goals for the road sector. The evolution in powertrain technology to comply with CO_2 targets would benefit from the use of higher octane petrol as a reference fuel in type approval tests, as this would incentivise the adoption of optimised technologies for HOP to meet CO_2 targets.

Effect of oxygenates

An increased use of oxygenate will impact the RON of fuels on the market. For example, increasing the amount of methanol or ethanol in a fuel will increase the RON. This would enable refineries to use a blend stock with a lower octane number, which are typically cheaper to produce. Further blend components and their respective octane numbers are shown in Table 12-2.

[33] https://www.acea.be/statistics/article/average-age-of-the-eu-motor-vehicle-fleet-by-vehicle-type

[34] https://horizon-magazine.eu/article/why-raising-alcohol-content-europe-s-fuels-could-reduce-carbon-emissions.html

Table 12-2: Research octane numbers of different fuels.

Fuel type	Neat RON	Blending RON
Ethanol	108 – 109	120 - 135
ETBE		110 - 119
TAEE		105 - 112
Methanol	107 - 109	127 - 136
MTBE		115 - 123
TAME		111 - 116

Source: (IEA-AMF, 2020)

Note: Octane numbers are blended on a volumetric basis using the blending octane numbers of the components. True octane numbers do not blend linearly, thus it is necessary to use blending octane numbers in calculating the octane number of the blend. Blending octane numbers are refinery specific and have been estimated from empirical correlations that have been developed over the years.

As shown in Table 12-3, for higher octane petrol in the EU, refineries typically increase the proportion of ethers rather than ethanol. In fact, the average ethanol content is higher for RON 95 petrol compared to that of higher octane blends. The current use of oxygenates to increase RON may not be directly extrapolated to a scenario with a single RON 98 grade, but it shows the important role of ethers in achieving higher octane petrol blends.

Table 12-3: Average share of ethanol and ethers for petrol blends in 2018 in the EU

Petrol grade	Share of ethanol	Share of ethers
Petrol RON=95 E5	3.4%	3.9%
Petrol RON 95-98 E5	1.7%	6.8%
Petrol RON>98 E5	1.7%	10.4%

Source: (EEA, 2020)

12.2 Policy options

Definition of policy options

The following policy options have been identified for exploration, based on the literature review and consultation:

1. Counterfactual scenario: Maintain the minimum RON for petrol at 95
2. Increase the minimum RON for petrol to 98
3. Increase the minimum RON for petrol to 102

Additional HOP grade

In the counterfactual scenario, where the current minimum RON for petrol is kept at 95, the use of HOP with RON higher than 98 may not increase substantially (Concawe, 2020). Some stakeholders consider that another option could be to keep the current minimum RON at 95 but include an additional grade for HOP (RON 102, for example) with separate specifications in the FQD. It should be noted that defining the standards for a separate HOP grade is not part of the scope of the study.

As a way of illustration, this option may contribute to the development of a market for HOP, by providing more clarity on the HOP framework to the market and promoting the adoption of engine technologies tailored to HOP. However, the extent to which an additional HOP grade would lead to a higher demand for HOP remains unclear.

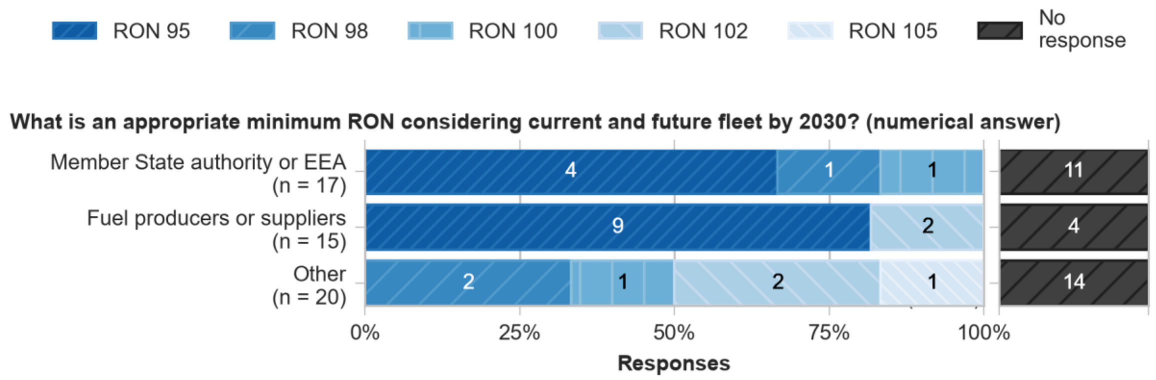
Should this option be implemented, the expected impacts of the policy options included in this study (i.e. increasing the minimum RON to 98 or 102) would be lower (both in terms of costs and benefits), as the demand for HOP in the baseline would be somewhat higher than that of our counterfactual scenario.

Stakeholder views on the definition of policy options

The FQD evaluation notes that Member States have given no indication of wanting to increase minimum RON (European Commission, 2017).

As part of the survey performed for this study, stakeholders were asked what they believed an appropriate minimum RON would be considering the current and future fleet by 2030. As shown in Figure 12-1, most respondents (13 out of the 23 who responded) selected 95 as the appropriate minimum RON. This was followed by 3 out of 23 considering 98 as the appropriate minimum RON and 6 out of 23 selecting a minimum RON higher than 98 (i.e. 100-105). Of the 13 respondents selecting 95 as the appropriate RON, 9 were fuel producers or suppliers, which accounted for 77% of the responses by fuel producers or suppliers. Biofuel producers were more in favour of increasing the minimum RON. Vehicle manufacturers had some split views, while some manufacturer groups and organisations such as ACEA expressed their support to increase the minimum RON, others such as the organisation of automotive suppliers CLEPA were in favour of the status quo. However, there was a consensus among vehicle manufacturers on the need to increase the use of HOP.

Figure 12-1: What is an appropriate minimum RON considering current and future fleet by 2030?



Source: Stakeholder survey for this study

In justifying the RON chosen, the main reasons mentioned for a minimum RON of 95 were: that it is currently the major grade; that increasing the minimum RON would lead to increases in emissions from refineries; and that it would lead to increased costs for the end-consumer. Furthermore, several respondents emphasized that a 95 minimum RON would leave room for the marketing of higher RON fuels if a market develops for it. They further noted that demand for high octane fuels would likely increase significantly by 2030 as high efficiency ICEs become more common.

Several of the stakeholders that considered a minimum RON greater than 95 appropriate referenced a range of studies to justify their position. Two stakeholders referenced the Worldwide Fuel Charter (WWFC) for Gasoline and Diesel Fuel (WWFC, 2019), which describes a high-octane petrol (HOP) that would address anticipated regulations for emission controls in the future. Furthermore, the WWFC describes the likely efficiency gains and full cycle CO_2 benefits of a RON 102 fuel if it is used under the right conditions and in a high efficiency engine.

Since the ACEA is one of the contributors to the WWFC, its response builds on the above by stating that a regulatory signal that RON 102 petrol will become the EU's main grade would encourage manufacturers to ramp up investments and development of high-performance engines with increased efficiency and CO_2 emissions. The ACEA goes on to note that use of such high-octane petrol could be restricted to new engines if it is achieved through increased ethanol content, e.g. E20, or it could be available for all petrol engines if the high octane is achieved through ether or other oxygenates.

12.3 Analysis

12.3.1 Environmental impacts

Impacts on energy efficiency and GHG emissions from vehicles

An increased RON would lead to some efficiency gains in the existing fleet and full efficiency gains in new vehicles optimised for higher RON. As per recent measurements in modern petrol engines over current legislative drive-cycles (Concawe, 2020):

- Fuel economy benefits associated with an increase of RON from 95 to 102 would be between 1.8% and 3.7%, with the lowest benefit being seen over the NEDC drive cycle, and the greatest over the chosen RDE cycle.
- The simulation results also indicate a linear improvement in the fuel consumption benefit between RON 95 and RON 102, meaning that an increase from RON 95 to RON 98 would lead to efficiency gains between 0.8% and 1.6%.
- When the compression ratio is increased, allowed by the fuel's anti-knock behaviour, the fuel economy benefit between RON 95 and RON 102 raises up to ~5%.

For modelling purposes, the efficiency gains in Table 12-4 have been assumed:

Table 12-4: Fuel efficiency gains from HOP

Vehicle age	Fuel efficiency gains of RON98 compared to RON95	Fuel efficiency gains of RON102 compared to RON95
Pre 2010	0	0
Post 2010	1.1%	2.7%
Post 2025	2.1%	5.0%

Source: Ricardo analysis

Results from PRIMES-TREMOVE modelling of these efficiency gains for the respective vehicle ages are presented in Table 12-5, indicating the overall reduction in EU27 emissions.

Table 12-5: Impacts on CO_2 emissions (tank-to-wheel) in 2030 from passenger cars compared to the MIX scenario

Option	CO_2 Emission reduction (%) vs. MIX reference scenario	CO_2 Emission reduction (Mt CO_2) vs. MIX reference scenario
Option 1 – Minimum 98 RON	0.4%	1.3
Option 2 – Minimum 102 RON	0.9%	2.9

Source: PRIMES-TREMOVE model

Impacts on energy efficiency and GHG emissions from fuel production

The Concawe study (Concawe, 2020) finds that the most economical way to produce HOP is through blending optimisation and imported oxygenates (i.e. not produced on-site). This pathway to increase RON leads to limited increases in well-to-tank GHG emissions associated with the refining system. It should be considered that while the changes in the refinery process needed lead to higher energy intensity, the overall demand for petrol would decrease because of higher fuel economy. The lower production volume would tend to offset the absolute increase in GHG emissions from fuel production.

Based on this, the Concawe study finds net GHG emission savings when considering impacts on both well-to-tank and tank-to-wheel emissions. The increased GHG emissions from the refinery process (well-to-tank) represent only 9 – 14% of the GHG emission savings from vehicles (tank-to-wheel).

Accounting for the increase in emissions from the fuel production process and the decrease in emissions from vehicles, there would be a net savings of around 1.2 $MtCO_2$ for a minimum RON of 98 or 2.6 $MtCO_2$ for a minimum RON of 102 in 2030 on a well-to-wheel basis. These are slightly lower than tank-to-wheel emission reduction in 2030 shown in Table 12-5.

The monetised benefits in terms of net climate change costs from road transport, including fuel economy gains at the point of use but also increased energy consumption during production, are shown in Table 12-6.

Table 12-6: Monetary benefit from CO_2 emission reduction from road transport on a well-to-wheel basis in 2030 compared to the MIX scenario (Million euros 2015)

Option	Savings in climate change costs (Million euros 2015)
Option 1 – Minimum 98 RON	118
Option 2 – Minimum 102 RON	275

Source: Ricardo analysis

Impacts on air pollution

Fuel efficiency gains associated with the use of HOP are also expected to reduce air pollutant emissions, assuming the same emission factors for HOP. Results from PRIMES-TREMOVE are presented in Table 12-7 and Table 12-8. These suggest relatively small impacts on air pollution.

Table 12-7: Impacts on air pollutants in 2030 from passenger cars compared to the MIX scenario

Option	Change in air pollution from passenger cars vs. MIX scenario		
	NO_X	**$PM_{2.5}$**	**SO_x**
Option 1 – Minimum 98 RON	-0.03%	-0.003%	-0.4%
Option 2 – Minimum 102 RON	-0.07%	-0.006%	-1.0%

Source: PRIMES-TREMOVE model

Table 12-8: Monetary benefit from air pollution reduction in 2030 compared to the MIX scenario (Million euros 2015)

Option	Benefit in air pollution damage costs from road transport vs. MIX scenario (Million euros 2015)			
	NO_X	**$PM_{2.5}$**	**SO_x**	**Total**
Option 1 – Minimum 98 RON	3.59	0.92	0.07	**4.06**
Option 2 – Minimum 102 RON	8.38	0.40	0.17	**9.48**

Source: PRIMES-TREMOVE model

12.3.2 Vehicle compatibility impacts

The use of a higher octane petrol will not cause compatibility issues on existing vehicles (WWFC, 2019), other than those associated with higher ethanol blends, which are not considered.

Stakeholders noted that although existing engines could use the RON 102 fuel, most of the current fleet would not benefit from efficiency gains. Finally, it was noted that the minimum RON of 95 still leaves room for marketing of RON 102 and the development of HOP is not prevented by the current FQD limit.

12.3.3 Economic impacts

The increased minimum RON of petrol would lead to additional production costs for suppliers but also to fuel efficiency improvements for road users. It should be noted that efficiency gains perceived by road users would somewhat depend on how the higher RON is achieved. Whilst new engines designed to run on HOP will show an increase in thermal (energy) efficiency, consumers buy and measure their efficiency on a volumetric basis. If the HOP contains higher ethanol blends up to 10%, then volumetric energy is reduced.

A recent Concawe study (Concawe, 2020) shows that an evolution towards a higher production of HOP is feasible at EU level. The study estimates that a 50% demand for HOP RON 102 could be met with a price difference between HOP RON 102 and RON 95 petrol of 33-66 $/tonne (i.e. around 7% increase from the RON 95 price), depending on the Brent crude oil price. This represents an additional production cost of 4.1 – 8.2 €/tonne/RON point (on average from RON 95 to RON 102). This cost is driven by the additional oxygenates required, which are more expensive than the BOB, and increased production costs of refinery components. The latter are associated with additional constraints on the refining system, as no additional capacity is considered for this level of demand.

A 100% demand for HOP 102, however, would require full adoption of E10 in all EU regions and investment in additional capacity of production units (Concawe, 2020). The Concawe study expects additional capacity would also be required for ETBE/MTBE production, alkylation and reformate spitters. This would increase the cost to around 5.9 – 11.8 €/tonne/RON point, considering the same variation on the Brent crude oil price. Hence, increasing RON from 95 to 102 would increase petrol production costs by 10% approximately, should additional capacity be needed.

The average historical (2010–2017) octane value in the US Gulf Coast is estimated at around 10.1 €/tonne/point of RON (Concawe, 2019). This value falls within the above range of costs for a full uptake of HOP and it is considered as our default value for modelling purposes.

Results from PRIMES-TREMOVE on fuel consumption costs are presented in Table 12-9. The model considers that additional production costs are fully passed-through to end users, such that final consumption costs are the juxtaposition of two effects: first, the higher price of HOP and, second, the lower fuel consumption associated with fuel efficiency gains of HOP. The net effect in 2030 is an additional cost for consumers, which means that the effect of additional production costs dominates over fuel consumption savings.

Table 12-9: Impacts on fuel consumption costs from road transport in 2030 compared to the MIX scenario (million Euros 2015)

Option	Additional fuel consumption costs (Million Euros 2015)	% Change in fuel costs
Option 1 – Minimum 98 RON	893	0.2%
Option 2 – Minimum 102 RON	2,084	0.6%

Source: PRIMES-TREMOVE model

A large amount of the petrol produced in Europe is exported (nearly 50 Mt per year compared to a total demand of 79 Mt per year in 2014). The EU market of petrol and petrol components is particularly integrated with other markets in the US Gulf Coast and in West and North Africa (Concawe, 2019). As indicated above, the HOP would be mostly achieved via blending, rather than any change to the production of the blend stock for oxygenate blending (BOB). Hence, production of petrol with the lower octane would also continue for the domestic market and no major impacts are expected on exports.

The FQD Evaluation found that while multiple blends with different RON parameters could potentially lead to inconsistencies for the single market, this issue was not observed or reported. In this sense, converging to one main RON specification may not have major impacts on the single market.

Stakeholder views

As part of the survey for this study, stakeholders were asked what the implications of increasing the minimum RON might be. Overall, stakeholder comments are in line with our assessment above.

Figure 12-2 above illustrates the responses of the 25 respondents that answered the question. This shows that the majority of respondents (60%) responded that increasing the minimum RON would lead to increased costs to petrol production, while 44% responded that there would also be implications for EU refining compared to the rest of the world. An engineering service provider noted that a higher minimum RON for petrol would lead to an increase in costs, however this would mainly be due to the higher renewable fuel content rather than an increase in refining costs.

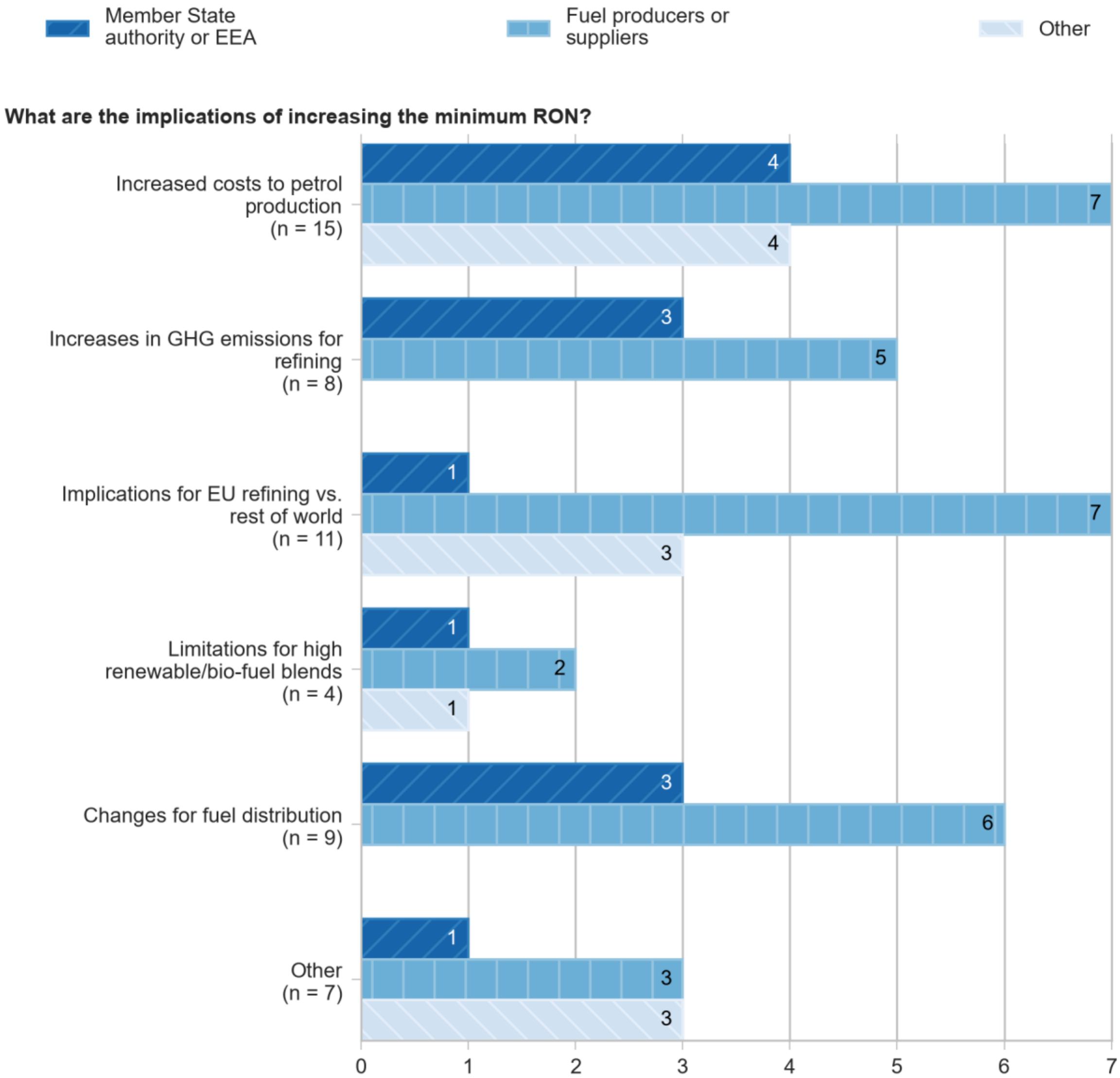
Some respondents noted other implications next to the ones listed in the questionnaire. One respondent noted that increasing the minimum RON would give bio-ethanol and other octane-enhancing biofuels a competitive advantage ahead of other renewable fuels.[35] A further respondent noted the increased costs to consumers, although this would likely fall under the increased production costs category.

Two biofuel producers noted that increasing the minimum RON would result in higher ethanol and oxygenate incorporation in petrol, thus leading to decreasing GHG intensity and reducing dependence on fossil fuels. Furthermore, increasing minimum RON would drive improvements in powertrain technology and lead to development of more efficient engines designed to run on high-octane petrol to reduce emissions and fuel consumption. The respondents also favour a revision of oxygen content limit to ensure fuel suppliers can meet the higher RON standards with oxygenated compounds rather than undesirable products. Cefic highlighted the potential 1-2% increase in average efficiency per one RON

[35] It should be noted however that the legislation would still neutral as it is not specifically singling out certain biofuels. These biofuels would get an advantage because they enable cars to be more efficient, but there are other ways that HOP could be achieved, even if less likely.

increase, referencing Concawe (2019), and underlines that both refiners and car manufacturers have supported the introduction of HOP.

Figure 12-2: What are the implications of increasing the minimum RON (n=56)? Multiple selections possible.



Source: Stakeholder survey for this study

12.4 Conclusions

Increasing minimum RON to 102 would lead to efficiency gains of around 5% for new petrol vehicles. A proportion of those gains would also apply to existing vehicles. Overall, this would lead to 0.9% lower CO_2 emissions from all passenger cars in 2030 compared to the MIX scenario. Increasing the minimum RON to 98 is estimated to decrease CO_2 emissions by 0.4% by 2030. The lower petrol consumption would also lead to reductions in air pollution emissions, of a similar percentage for SO_X as for CO_2, but only to a negligible amount for NO_X and PM.

A Concawe study shows that the petrol production in Europe could adapt in the short-term to a market share for HOP of around 50% by increasing oxygenates in petrol blends, but a full uptake of HOP to comply with the higher minimum RON would require full adoption of E10 in all EU regions and investment in additional capacity of production units. A full uptake of HOP with RON 102 would represent an increase in the cost of petrol by around 10% (per unit of energy consumed). The lower fuel consumption associated with HOP efficiency gains would partially offset the additional fuel costs, but total fuel costs would increase by around 0.6% for a minimum RON 102 and by around 0.2% for a minimum RON 98.

The current ether limit of 22.2% for petrol provides flexibility to increase the RON of petrol with no need for a protection grade and no difficulties in meeting vapour pressure limits. However, an optimal HOP blending from the cost perspective may need both ethanol and ether content to increase. An E10 grade allows for a RON102 petrol. The majority of Member States would not have difficulties in complying with vapour pressure limits for E10 ethanol blends, but countries that applied for an ethanol-related derogation could still need to have this waiver.

Overall, both policy options considered do not appear to lead to cost-efficient outcomes by 2030, as additional fuel costs would outweigh savings in terms of climate change and air pollution costs. However, the adoption of a higher minimum RON is not expected to lead to vehicle compatibility issues.

Policy	Environmental Impact	Vehicle compatibility	Economic Impact
Option 1: Increase the minimum RON for petrol to 98	**+** CO_2 emission reduction from passenger cars in 2030: 0.4% Savings in external costs from climate change and air pollution: 122 million Euros	**O** No significant impacts	**-** Additional fuel costs in 2030: 893 million Euros
Option 2: Increase the minimum RON for petrol to 102	**+** CO_2 emission reduction from passenger cars in 2030: 0.9% Savings in external costs from climate change and air pollution: 284 million Euros	**O** No significant impacts	**-** Additional fuel costs in 2030: 2,084 million Euros

Source: Ricardo analysis

13 Should the vapour pressure derogations for summer petrol be maintained?

13.1 Background

Policy background

The volatility of a fuel is a key characteristic to ensure good operation of engines. It can influence the performance, as well as the emissions of a vehicle. The most common measurements of volatility are vapour pressure, distillation and vapour/liquid ratio. The vapour pressure of petrol is controlled seasonally to reflect how different ambient temperatures affect volatility. At high temperatures, the vapour pressure needs to be limited to control evaporative emissions. At low temperatures, a vapour pressure that is too low will hinder the starting and warm-up performance of engines. Therefore, both minimum and maximum vapour pressures are specified in the EN228 standard (WWFC, 2019).

The FQD sets a maximum vapour pressure limit of 60kPa for summer petrol to control evaporative emissions from petrol. However, it also permits a derogation from the vapour pressure limit of summer petrol if Member States can provide justification, as set out in FQD Article 3(4) and (5). The first of the two possible derogations (Article 3(4)) allows Member States to increase the maximum vapour pressure to 70kPa if they have low summer temperatures. If the first derogation is not applied, Member States can request a derogation for bioethanol blends (Article 3(5)), allowing an increase in vapour pressure to a maximum 60kPa plus the waiver percentage defined in Annex III of the FQD, as shown in Table 13-1.

Table 13-1: The FQD vapour pressure derogation allows the vapour pressure to be limited to 60kPa plus the waiver set for the fuel's bioethanol content.

Bioethanol content (%v/v)	Vapour pressure waiver permitted (kPa)
0	0
1	3.65
2	5.95
3	7.20
4	7.80
5	8.00
6	8.00
7	7.94
8	7.88
9	7.82
10	7.76

Source: FQD Annex III

The Guidance Note on Member State requests for exemptions from the FQD summer vapour pressure limit (European Commission, 2009) outlines what the European Commission requires to grant a derogation. The derogations have to be requested separately and include a duration. The request should include forecasts for the petrol quantities supplied in the Member State, including associated bioethanol contents if applicable. The first criterion to be met is an assessment of the direct socioeconomic problems caused by implementing the vapour pressure limit of 60kPa. The second criterion is that the Member State must provide realistic predictions on their compliance with air quality and pollution legislation with regards to VOCs, ozone and benzene.

Table 13-2 presents an overview of which Member States had been granted a derogation by the European Commission before the end of 2020 for either placing summer petrol with a vapour pressure of 70kPa on the market due to ambient summer temperatures or for placing summer petrol with a vapour pressure according to Annex III of the FQD on the market due to bioethanol content. All derogations granted are set to expire by the end of 2020.

Table 13-2: Derogation granted to Member States for the summer petrol vapour pressure limits by 2020.

No derogations (60kPa)	Derogation for ambient summer temperature (70kPa)	Derogation for ethanol content (60kPa + Annex III)
Austria, Belgium, Cyprus, Czechia, Germany, France, Greece, Hungary, Italy, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia	Denmark, Estonia, Finland, Ireland, Latvia, Sweden	Bulgaria, Spain

Source: Evaluation of the FQD (European Commission, 2017)

At the time of writing this report, new derogations for Ireland and Sweden had been approved on the basis of low summer temperatures, while a bioethanol-related waiver had been granted to Spain. From their side, other countries including Portugal, Latvia and Denmark have requested this derogation, but the outcome is still to be decided at the time of writing this report. This suggests an ongoing demand for the derogations by some Member States.

The submitted derogation requests (most from 2010) contain useful information on the costs and benefits of the vapour pressure limits and can contribute to the evaluation of the potential impacts of withdrawing the derogation. The main points raised by Member States in their derogation requests are presented below and more information on the derogation decisions for different Member States is presented in Annex D.

The derogation requests by Member States outline two main barriers to limiting vapour pressure to 60kPa. The first reason stated in some applications is that the refineries in the Member States would need investments in the scale of tens of millions of Euro to introduce equipment to lower vapour pressure of petrol. Furthermore, the lowering of the vapour pressure would require increased imports of low volatility components, such as ETBE, to blend with the petrol. In the case of the bioethanol derogation, one Member State (ES) noted that it would require the derogation while it increased its capacity for ETBE production, which would eventually allow replacing ethanol. The second reason some Member States noted is that they do not have their own petrol refining resources and therefore rely on imports, which would significantly increase in cost if the derogation were not granted. Addressing the aspect of air quality, Member States provided estimates for the increase in non-methane volatile organic compounds (NMVOC) expected from a granted derogation which ranged from 0.1% to 0.3% of total NMVOC emissions.

Furthermore, the Member States were seen to not be at risk of non-compliance with the national emissions ceiling for NMVOC (NEC).

Findings from the evaluation and previous studies

The FQD Evaluation states that the derogations for vapour pressure of petrol blended with bioethanol and the low summer ambient temperature are cost efficient when considering the cost savings and impacts associated with the derogations (European Commission, 2017). Based on estimations given by Member States, a minimum of €637 million in capital costs and €247 million in operating costs are saved in the EU due to the derogations. Most stakeholders noted that the derogation can lead to some increased costs in terms of air quality emissions, which are however outweighed by the overall economic savings. These results should be caveated, as evidence from Member States may be weighted towards identification of the costs to refineries without sufficient consideration of the benefits to the environment. It should be noted that damage cost valuations for VOCs are less well developed than for other National Emission Ceilings Directive (NECD) air pollutants.

The FQD Evaluation also notes that in the case of an ethanol blend and in order to meet the vapour pressure requirement of Annex I during summer periods, in general, refineries have to deliver a blend stock for oxygenate blending (BOB)[36] with lower vapour pressure (unless the waiver of Annex III is granted), leading to additional costs. Therefore, it is necessary for fuel manufacturers to supply a different BOB for the production of E0 than for E5, E10 (since bioethanol impacts on vapour pressure, see section below), which may lead to additional administrative and distribution costs. However, this is not very problematic as regards E5 and E10, as the BOBs that have to be used are very similar. It may lead to additional costs for those supplying E0, however this grade is not widespread throughout the EU. Also on this issue, the FQD Evaluation notes that some stakeholders stated that the supply of different BOBs to comply with vapour pressure requirements is leading to a less harmonised single market. In addition, stakeholders also note that since the derogations for bioethanol blends are only applied in specific countries, this leads to differences in the market as different vapour pressures are required in different regions.

The FQD Evaluation shows little or no indication that removing the derogation granted for Member States with low summer temperatures would be beneficial. However, some stakeholders noted a limited effectiveness of derogations granted for petrol blends with bioethanol content to promote higher bioethanol blends. The FQD Evaluation sees this derogation as an instrument for the transition to E10 in countries where compliance with the vapour pressure limits is an issue. Bulgaria is now marketing E10 petrol and has not applied for the derogation after 2020. However, the recent application from Spain and Portugal for a derogation for bioethanol content seems to indicate an ongoing demand for this provision, which may be related to the more ambitious climate targets and the increasing need to blend bioethanol.

Similarly, a previous study for the Commission (European Commission, 2012) found that lowering the summer vapour pressure limit of petrol without ethanol from 70kPa to 60kPa for Member States that have been granted a derogation due to low summer temperatures would cost between €22.9 to €43.7 (Euros 2015) per kg of abated VOC, while the monetary benefits of abatement in either case would range from 0.98 to 2.9 €/kg (Euros 2015).

Petrol blends containing ethanol or ethers

The resulting vapour pressure from the addition of ethanol to BOBs does not reflect the simple linear combination of the vapour pressures of both components. By itself ethanol has a very low vapour pressure, however the final vapour pressure of the blend could be either higher or lower than that of the BOB, depending on temperature and ethanol

[36] Petrol blending components intended for blending with oxygenates to produce finished reformulated petrol

concentration. Low ethanol concentrations (below about 10% by volume) and typical ambient temperatures will result in vapour pressures exceeding the BOB's vapour pressure (WWFC, 2019). The highest vapour pressure is reached at around 5-6% ethanol content.

Ethers are also very commonly blended at the refinery as a component for petrol whilst ethanol is blended at the distribution terminal. MTBE and ETBE are the most commonly used ether oxygenates, followed by TAME and TAEE[37]. About half of all biofuel blended into petrol in the EU is currently in the form of bio-ETBE. Ethers also have relevant effects on the vapour pressure.

Ethers are a low vapour pressure component that can be blended into petrol. For example, the blending vapour pressure of pure ETBE is 28kPa (Wallace, et al., 2009). However, unlike for ethanol, there is a linear behaviour when blended, which means that the vapour pressure of the petrol blend can be lowered by adding ether. This improves the predictability of the vapour pressure resulting from the blend.

Adding ETBE or other ethers as a component of the BOB helps to produce a predictable low vapour pressure BOB suitable for ethanol addition at the distribution terminal, making it easier for refineries to meet the fuel specification limit of 60 kPa defined in the Fuel Quality Directive. The ability to stabilise or lower the vapour pressure will especially be beneficial in the warmer EU countries of the Mediterranean Region where heat increases the volatility of the fuel.

13.2 Policy options

The following policy options have been identified, based on the literature review and consultation:

1. Counterfactual: Maintain the derogations for vapour pressure limits of summer petrol.
2. Remove the derogation allowing waivers for Member States with low summer temperatures to increase the summer vapour pressure limit from 60kPa to 70kPa.
3. Remove the derogation allowing vapour pressure waivers for petrol blends containing ethanol.

13.3 Analysis

Petrol blend components

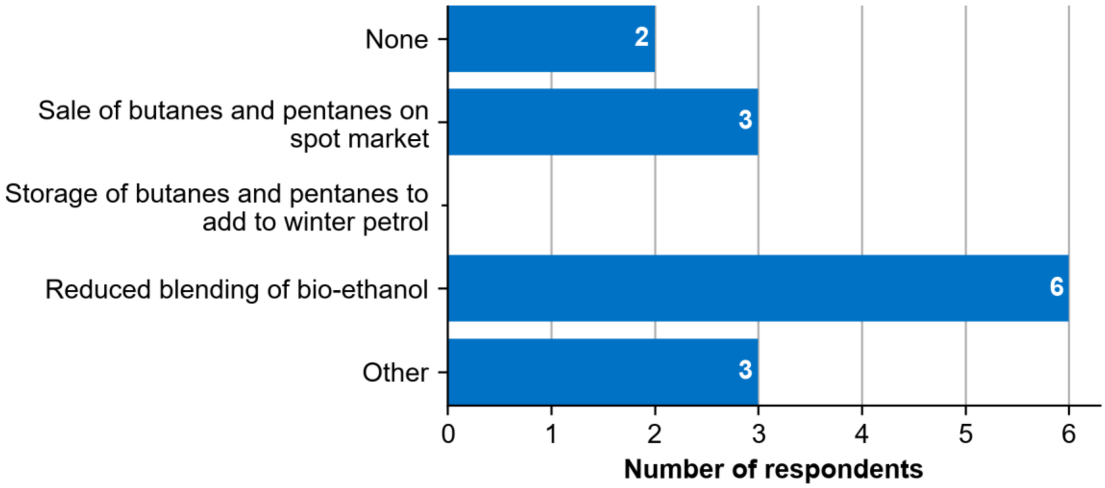
Reducing BOB vapour pressure requires the removal of high volatility molecules from petrol blends, mainly butanes and pentanes. The removed amount of butanes and/or pentanes are sold on the spot market. Another possibility would be to store removed butanes and/or pentanes for winter blending, but this was not considered by stakeholders as a likely option. Commonly, this process is complemented with blending ether components (e.g. ETBE and other ethers) to further control the vapour pressure and improve other parameters (e.g. RON). Another alternative would be to reduce the content of ethanol (or bio-ethanol) to control the vapour pressure.

Stakeholders were asked what the most likely response would be to enable supply of petrol with a summer vapour pressure of 60 kPa rather than 70 kPa if the derogation was withdrawn, as shown in Figure 13-1. Of the 11 stakeholders that responded to the question, most (6) stated that a reduction in bio-ethanol content would be the most likely outcome, while three noted other possible responses. One of these specified that the import of petrol components might be an outcome. A further respondent outlined why they did not believe that reduced blending of bio-ethanol would occur on the basis that the

[37] https://www.sustainablefuels.eu

blending is driven by mandatory Member States' obligations and that bio-fuel can be blended in petrol in its ether form (ETBE and/or TAEE), which would have a beneficial impact on volatility.

Figure 13-1: If the summer vapour pressure waivers are not granted, what is the most likely response to enable supply of petrol with a summer vapour pressure of 60 kPa rather than 70 kPa (n=11)?



Source: Stakeholder survey for this study

13.3.1 Environmental impacts

Air pollution

The vapour pressure of petrol affects the emissions of NMVOC during the fuel distribution and from the vehicle fleet. Emissions associated with the distribution of petrol include evaporation from bulk storage tanks, service station tanks and vehicle refuelling. Emissions from the vehicle fleet are essentially due to breathing losses through the tank vent, but the latter represent a very small proportion of total NMVOC emissions since the introduction of carbon canisters (EEA, 2019). NMVOCs contribute to the formation of ground-level (tropospheric) ozone, and certain species such as benzene and 1,3 butadiene are directly hazardous to human health. Tropospheric ozone is a powerful greenhouse gas and air pollutant harmful to human health, agricultural crops and ecosystems.

A previous study (European Commission, 2012) used the EMEP/EEA air pollutant emission inventory guidebook to estimate that a reduction of the summer vapour pressure from 70kPa to 60 kPa would reduce NMVOC emissions from both the supply chain and the vehicle fleet by 14.5%.[38] Similarly a derogation of the bio-ethanol derogation would be associated with a reduction in vapour pressure from around 68 kPa to 60 kPa, which would reduce NMVOC emissions by 11.5%.

A recent study for Denmark (Plejdrup, 2020) estimated that fuel consumption during the summer period represents 31% of the yearly consumption. This share is deemed

[38] The 2012 study (European Commission, 2012) considered emission factors from the EMEP/EEA inventory guidebook 2012 assuming a Petrol Vapour Recovery (RVP) efficiency of 90%, which is above the 85% efficiency required by Directive 2009/126/EC (Stage II Petrol Vapour Recovery). Commission Directive 2014/99/EU subsequently adapted Directive 2009/126/EC to technical progress with regard to the use of Standard EN 16321-2:2013 to measure petrol vapour capture efficiency but did not change the efficiency level requirement. Hence, emission included in the 2012 study can be considered as valid values

representative to assess air pollution impacts in Member States where the derogation related to low summer temperatures applies, for which the summer period runs from the start of June until the end of August. For the rest of Member States, the summer period runs from the start of May until the end of September. Considering monthly petrol consumption in Spain in 2019 from the CORES database[39], the summer period represents 45% of the petrol consumption. This share is considered when assessing air pollution impacts for the ethanol-related derogation.

Based on this, the impacts of changes in the derogations (options 2 and 3) on NMVOC emissions are assessed. We have included Member States that had a derogation for low summer temperature until 2020 and for Spain and Portugal, which have applied for a derogation for bioethanol content in 2020. It should be considered however that only Ireland, Sweden and Spain have an approved derogation for low summer temperature at the time of writing this report, hence total future impacts on NMVOC may be overestimated by including other Member States. Results are shown in Table 13-3. Avoided damage costs from NMVOC emissions are taken from the 2019 Handbook on external costs from transport (European Commission, 2019) for each country.

Table 13-3: Impacts on air pollution impacts from removal of derogations (Costs in Euros 2015)

Option	Member State	Expected NMVOC reduction per year (ktonnes) (*)	Reduced emissions over total NMVOC emissions (%)	Air pollution cost savings per year (thousand euros)
Remove derogation for low summer temperatures	Denmark	0.28	0.24%	426
	Estonia	0.06	0.28%	19
	Finland	0.23	0.27%	92
	Ireland	0.17	0.16%	295
	Latvia	0.09	0.22%	35
	Sweden	0.40	0.30%	283
	Total	**1.24**	**0.24%**	**1,149**
Remove derogation for bioethanol content	Spain	1.13	0.18%	794
	Portugal	0.81	0.52%	404
	Total	**1.29**	**0.25%**	**1,197**

Source: Ricardo analysis

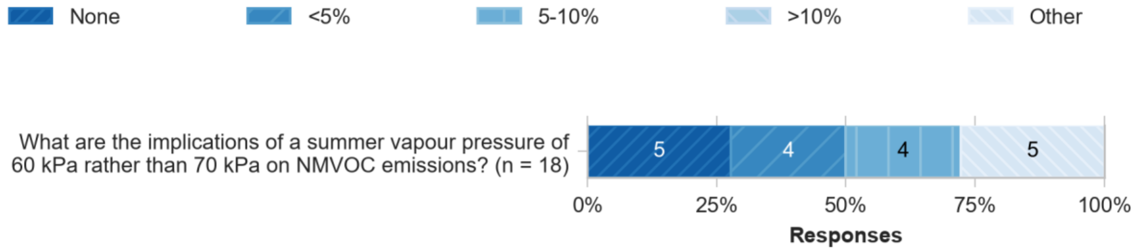
Note: (*) Expected NMVOC reduction is based on emission factors from the 2012 study and the share of fuel consumption during the summer period as described above

Survey respondents were asked what the possible implications of a summer vapour pressure of 60 kPa rather than 70 kPa for NMVOC emissions from petrol supply would be.

[39] https://www.cores.es/es/estadisticas

The 18 responses are shown in Figure 13-2 and illustrate that the responses of the stakeholders questioned diverge on this question.

Figure 13-2: What are the implications of a summer petrol vapour pressure of 60 kPa rather than 70 kPa for NMVOC emissions from petrol supply?



Source: Stakeholder survey for this study

The European Chemical Industry Council (CEFIC) lauded the 60 kPa limitation in the FQD for taking an important step in fighting air pollution and stated that it believed the vapour pressure limit should be kept in place.

Use of bioethanol

The removal of the current derogation for bioethanol content (Option 3) could potentially lower the use of bioethanol in countries that have applied for this derogation. In addition, as ethanol tends to increase the vapour pressure of petrol blends, a reduction in the use of bioethanol could also be a response to the repeal of the derogation for low summer temperature (Option 2). However, this effect would be limited by the target imposed by the Renewables Energy Directive to increasingly use renewable fuels in petrol blends.

A respondent to the survey notes that outside of the seven countries (including UK) that have been granted waivers due to low temperatures, only two countries (i.e. Spain and Bulgaria) have been granted the ethanol-related waiver, which demonstrates that bio-ethanol and its ether forms have been used without any problem in the majority of Member States.

Table 13-4 shows the uptake of ethanol in petrol blends in Spain and Bulgaria after the implementation of the ethanol-related waiver for vapour pressure. The use of bioethanol in Spain is still low and has slightly decreased in 2018, compared to 2014. In contrast, Bulgaria markets fuels at E10 and has slightly increased the ethanol content of their fuels. According to the FQD evaluation, Bulgaria reported vapour pressure exceedances in 2014. However, in 2019, no exceedances of the petrol fuel quality limits were reported (EEA, 2020).

While the ethanol-related derogation seems to have been effective in contributing to the transition towards E10 in Bulgaria, it has not led to a higher use of bioethanol in Spain. In light of these results, removing the derogation is not likely to limit the uptake of biofuels. However, a Spanish fuel supplier highlighted during the workshop for this study that the derogation of the vapour pressure has been a key element of the biofuels market in Spain by allowing direct blends of ethanol during the summer periods. Spain has been granted a derogation for bioethanol content from 2020 onwards, which indicates ongoing difficulties to meet the vapour pressure limits for bioethanol blends in areas with high temperatures in summer.

Table 13-4: Evolution of ethanol content in countries with a vapour pressure derogation for bioethanol blends

Member State	Fuel	Average ethanol content (%)		Average ether content (%)	
		2014	2018	2014	2018
Bulgaria	Unleaded petrol RON 95 E10	6.6	7.6	4.8	4.5
	Unleaded petrol RON≥98 E10	7.2	8.0	9.3	8.4
Spain	Unleaded petrol min. RON=95 (<10 ppm sulphur) E5	1.1	1.0	10.7	9.0
	Unleaded petrol RON > 98	0.5	0.2	14.5	13.4

Source: (EEA, 2020)

Groundwater contamination

The use of ethers raises concerns with groundwater contamination and, hence, this effect needs to be investigated in light of the potentially higher use of ethers to control vapour pressure. Organoleptic aspects are the primary concern of groundwater contamination by ethers because of their low taste and odour thresholds (Thornton, et al., 2020). A Concawe study (Concawe, 2012) detected ether in some natural waters and in the European air, but generally at concentrations at least 1 order of magnitude lower that the relevant taste and odour thresholds, and 5 to 8 orders of magnitude lower concentration than the relevant health criteria, with the exception of localised point-source spill and release events. The lower solubility of ETBE compared to MTBE could mitigate the risk of groundwater contamination. Overall, groundwater contamination may not be a major issue despite the potential increase in the use of ethers as long as the risk of point-source spills is mitigated through appropriate control measures.

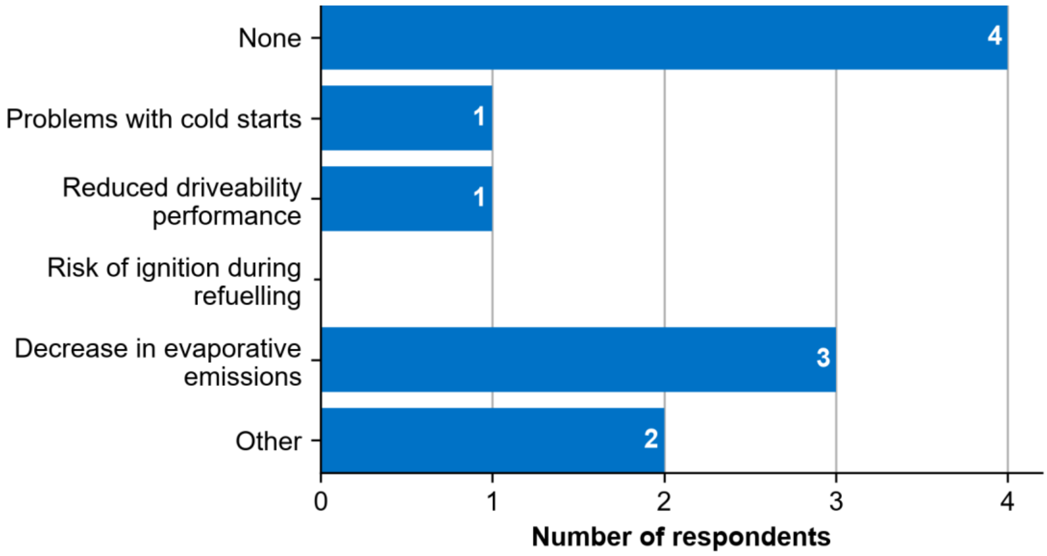
13.3.2 Vehicle compatibility impacts

The combination of low vapour pressure with low ambient temperatures affects the vehicle’s starting and driveability. These driveability issues might be more significant for blends with high ethanol content. This is due to the further decrease in vapour pressure of the petrol/ethanol blend close to the minimum required values (European Commission, 2012).

A recent study (WWFC, 2019) found that for high ambient temperatures E10 petrol blends have a higher vapour pressure relative to E0, but at lower temperatures, the vapour pressure goes below that of E0. The effect could be significant and prevent an engine from starting at very cold temperatures. In light of these results, at low temperature, with equivalent ethanol content, a higher vapour pressure would be preferable. In this sense, removing the derogation of the vapour pressure limit for low summer temperatures could potentially cause a decrease in the winter vapour pressure especially for high ethanol blends. This may lead to driveability issues at very cold temperatures.

The questionnaire asked respondents what the implications of a summer petrol vapour pressure of 60 kPa rather than 70 kPa would be for existing vehicles in the EU. The responses to the question are shown in Figure 13-3. Only one responded expected problems with cold starts and reduced driveability.

Figure 13-3: What are the implications of a summer petrol vapour pressure of 60 kPa rather than 70 kPa for existing vehicles in the EU?



Source: Stakeholder survey for this study

13.3.3 Economic impacts

Achieving a lower vapour pressure would impact fuel producers in Member States where the derogation applies. The first reason given by Member States in their applications is that the refineries would need investments in the scale of tens of millions of Euro to introduce equipment that could lower vapour pressure of petrol. These investments are related to the need to expand existing refinery capacity (e.g. distillation towers, alkylation units). In addition, the disposal or trade of the additional butanes and pentanes would imply a loss in revenue for refineries as these molecules are likely to have to be sold at a substantially discounted price relative to their value if they remained in the petrol blend.

Furthermore, the lowering of the vapour pressure would require increased imports of low volatility components, such as ETBE, to blend with the petrol. In the case of the bioethanol derogation, one Member State (ES) noted that it would require the derogation while it increased its capacity for ETBE production, which would eventually allow replacing ethanol. The second reason Member States noted is that they do not have their own petrol refining resources and therefore rely on imports, which would significantly increase in cost if the derogation were not granted.

The 2012 study (European Commission, 2012) estimated that the additional costs of producing a fuel with a vapour pressure of 60 kPa instead of 70 kPa were between 2.7 and 3.8 €cents/litre (Euros 2015) for non-blended petrol and between 7.3 and 12.4 €cents/litre (Euros 2015) for petrol with 10% ethanol. This difference is due to the need to further reduce the vapour pressure of the BOB when blended with ethanol. Spain reported additional production costs within the range of 3 to 4 €cents/litre.

Additional production costs for refineries as reported by Member States in their latest approved submission are summaries in Table 13-5 below.

Table 13-5: Additional production costs from the removal of the derogation (Euros 2015)

Option	Member State	One-off costs (million euros)	Ongoing annual costs (million euros)
Remove derogation for low summer temperatures	Denmark	156	0
	Estonia	n/d	n/d
	Finland	104	n/d
	Ireland	40	5.5
	Latvia	n/d	n/d
	Sweden	88	0
Remove derogation for bioethanol content	Spain	n/d	183

Source: Commission implementing decisions on requests for a derogation

Note: Reported cost values in the derogation requests have been converted to Euros 2015

As a response to the stakeholders survey, the European Chemical Industry Council (CEFIC), representing fuel oxygenate (i.e. ethers) producers, stated that it believed that the derogation for ethanol-containing petrol vapour pressure should be removed as it only supports one type of fuel, thereby creating a distorted market. However, since only ethanol blending is problematic in terms of vapour pressure, allowing the waiver for only ethanol does not specifically prevent or penalise the use of other blend components such as ethers.

13.4 Conclusions

The derogations for low summer temperatures and bioethanol blends appear to be still efficient in light of the estimated benefits in NMVOC emissions and the additional costs reported by Member States. While NMVOC damage savings are in the order of thousand euros per year, additional production costs to decrease vapour pressure are in the order of million euros per year.

The derogation for bioethanol blends, however, has been unequally effective towards increasing bioethanol content. While the derogation seems to have contributed to the successful transition to E10 in Bulgaria, the ethanol content in Spain has not increased substantially. However, there seems to be an ongoing demand for this derogation in Spain and Portugal. This may indicate persistent difficulties in increasing bioethanol blends during the summer period in some countries with high summer temperatures, as reported by some stakeholders. However, since the major increase in vapour pressure is for an ethanol content of around 5-6%, it is unclear whether these Member States would still require investments in the transition from E5 to E10.

In the current status, the derogation is in control of the Commission as it decides based on environmental and economic issues whether to grant it or not. If the Commission sees any change with the environmental penalty and the economic gain trade-off, it is at liberty to grant or decline the application. This guarantees the efficiency of the granted derogations as long as the socioeconomic assessment reported by Member States are accurate.

Overall, our analysis finds no evidence that the derogation for low summer temperatures should be reviewed. Conclusions regarding the bioethanol-related waiver are however more nuanced. In light of the ongoing demand for this derogation and especially if current applications show persisting future difficulties with higher ethanol blends, this derogation could be maintained. In any case, the Commission has full control to decline this derogation if there is no evidence on positive socioeconomic impacts.

Table 13-6: Summary of impacts for options related to vapour pressure derogations

Policy	Environmental Impact	Vehicle compatibility	Economic Impact
Option 2: Remove the derogation allowing waivers for Member States with low summer temperatures to increase the summer vapour pressure limit from 60kPa to 70kPa	**+** Air pollution savings: around 0.02 - 0.4 million Euros per year per Member State	**-/ o** Potential driveability issues for high ethanol blends at very low temperatures	**-** One-off costs: 40 - 156 million Euros per Member State Annual costs: 0 - 5.5 million Euros per year per Member State
Option 3: Remove the derogation allowing vapour pressure waivers for petrol blends containing ethanol.	**+** Air pollution savings: around 0.4 - 0.8 million Euros per year per Member State	**o** No significant impacts	**-** Annual costs: 183 million Euros per year per Member State (ES)

Source: Ricardo analysis

Note: The summary of impacts refers to Member States that have previously applied for a derogation and, hence, might re-apply in the future

14 Should the derogation of sulphur content for outermost regions/ Mayotte be continued?

14.1 Background

The FQD sets out various limits on fuel quality, which may be difficult to comply with for outermost regions with limited access to the single market due to their remoteness, small size, climate or economic characteristics. The FQD allows Member States to permit a higher sulphur level in petrol and diesel in the outermost regions. The FQD Evaluation identified that only France takes up this option, and only for Mayotte. It is noted that "*France states that the derogation is still relevant and is allowing fuel supply to Mayotte to continue without incurring significant additional costs which would hamper the local economy.*" The derogation allows Mayotte to place petrol on the market with a maximum sulphur content of 50 mg/kg, instead of 10 mg/kg.

According to information gathered in the evaluation, Mayotte imports fuels from a variety of locations, including Singapore and Africa. It also found that fuel supplied from La Reunion does meet the FQD standards, but most other imports do not. If Mayotte were to import all fuels from La Reunion it would require a direct tanker ship fuel link, which could increase the sale price by €0.2 per litre. This would have a significant impact on Mayotte's population and economy (European Commission, 2017).

Spain commented in the FQD Evaluation that it would not require the derogation for sulphur content for Tenerife, as the island has a refinery and is fully integrated in Spain's fuel supply logistics.

14.2 Policy options

The following policy options have therefore been identified for assessment:

1. Counterfactual: Maintain the option for derogation from the limit on sulphur content in petrol and diesel in outermost regions.
2. Maintain the derogation only for Mayotte.
3. Remove the derogation for all outermost regions.

14.3 Analysis

Member States with outermost regions were contacted in order to establish the extent to which the derogation is currently used, and what would be the impacts of removing the derogation. France, Portugal and Spain were contacted for bilateral interviews. A summary of the findings of this investigation is shown in Table 14-1.

Table 14-1 Results of interviews with MS on outermost region derogation

Member State	Summary of status of derogation
Spain	The Spanish Ministry of Ecologic Transition commented that they have consulted this issue internally and concluded that removing this derogation would not have any impact on the fuel consumed in Canary Islands, as the fuel supply chain in the Canary islands is fully integrated with the Spanish and EU market. This would also not lead to any negative impacts with regard to national legislation.
France	The French Bureau of Petroleum Logistics and Alternative Fuels confirmed that Six French outermost regions are recognized: one overseas collectivity (Saint-Martin), as well as five overseas departments and regions (Martinique, Réunion, Mayotte and Guadeloupe, Guyana). In these departments, the same regulations as in Metropolitan France apply. The FQD applies and fuel quality controls are regularly done. There is no derogation of sulphur content in place. This therefore contradicts the findings of the FQD Evaluation and indicates that the outermost region derogation is not actually needed or used in Mayotte.

Member State	Summary of status of derogation
Portugal	Portugal did not respond to the invitations to engage in this study. Information found in the FDQ Evaluation indicates that the outermost region derogation is not currently utilised in Portugal and as such there would be no impacts associated with its removal.

14.4 Conclusions

The outermost region derogation is not used in any Member States. Spain and France have responded to this study and indicate that there is no need for the derogation, and its removal would not lead to any negative effects. Portugal did not respond to the study, however according to information found in the FQD Evaluation, the outermost region derogation is not used by Portugal.

15 Overall Conclusions

The findings of this study identify the following considerations for potential amendment to the FQD:

- **Raising of limits on FAME to 10%** could facilitate greater renewable energy uptake and other environmental benefits. While the current limit is found to not prevent the achievement of RED II targets, this change would facilitate increasing take up of FAME in diesel as an available option for meeting the targets.
- **Implementation of a protection grade for B7** could enable the marketing of higher blends of FAME without incurring large costs for vehicle owners. Consideration could be given to including a threshold for size of retailer required to market the protection grade as a means of avoiding excessive cost to smaller or independent fuel retailers from marketing multiple grades.
- **Extending the coverage to higher strength blends of alternative fuels, by updating the reference to petrol and diesel CN codes**, would support consistent quality of these fuels in the single market. There would be benefits in defining specifications for these fuels with regard to certain parameters, most notably vapour pressure in the case of higher ethanol blends, and oxidation stability and water content for higher blends of FAME.
- **Extending the coverage to gaseous fuels** would support consistent quality of these fuels in the single market. The most important parameters for specification are: sulphur content, Wobbe index and methane number to ensure vehicle compatibility and for minimising negative impacts on the environment.
- In the case of **metallic additives**, the majority of stakeholders are in favour of an outright ban due to their impacts on health, the environment, and vehicle engines and emission control systems. Ferrocene is the main metallic additive that industry is currently concerned with. Current provisions have effectively banned the use of MMT as a RON booster in the EU, but a metallic additive ban may provide further benefits with regard to trace amounts in imported fuels. Metallic additive manufacturers argue that the existing risk assessment protocol that has been developed by the European Commission, in response to Article 8a,should be utilised in favour of an outright ban.
- **Article 6** provides an additional option for local authorities to improve local air quality. While it is considered to be a more expensive measure than other local measures, and it has not currently been implemented by other Member States, its value as a potential measure is clear with stakeholders.
- **Alignment of the fuel specifications for NRMM gas-oil with on-road diesel, including FAME content,** would provide more certainty on NRMM fuel quality to the industry and allow further synergies in engine and aftertreatment technologies with those applied to on-road vehicles. Alignment is expected to have very small direct environmental impacts and minor cost increases, given that a significant proportion of NRMM fuel is already aligned with on-road diesel.
- **Production costs of increasing the minimum RON from 95 to 98 or 102 outweigh the environmental benefits** in terms of carbon and air pollutant emissions reduction. This does not prevent the adoption of alternative policies to promote the uptake of HOP such as a separate petrol specification.
- **Removing vapour pressure derogations for Member States with low summer temperatures** would not be cost-effective; increased production costs are clearly higher than potential benefits associated with NMVOC emissions reduction.

- **Retaining the vapour pressure derogation for ethanol content** would allow for the ongoing demand for this derogation from a few Member States and especially if applications show persisting future difficulties with higher ethanol blends. In any case, the Commission is at liberty to grant or decline future applications if there is any change with the environmental penalty and the economic gain trade-off.
- Regarding **the alignment of FQD specification for petrol and diesel with CEN standards**, the analysis found that since a large majority of Member States have already aligned legislation for fuels sold with the respective standards, alignment in the FQD is expected to have a negligible effect. Such an alignment would only be beneficial if a significant monitoring inconsistency is expected in light of higher biofuel blends, for which no strong evidence was found. Should some parameters be aligned, only oxidation stability and water content could be considered for diesel, and no new parameter would be needed for petrol.
- The **outermost region derogation** is not used in any Member States, and its removal would not lead to any negative effects.

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ANNEXES

The annexes are in a separate document. The list of annexes is shown below.

- Annex A – Parameter specifications in EN 228, EN590 and EN589 standards
- Annex B –CEN specifications for diesel, biodiesel and paraffinic fuels.
- Annex C – Vapour pressure derogation request information

ANNEX A PARAMETER SPECIFICATIONS IN EN 228 AND EN 590 STANDARDS

Unleaded Petrol EN 228:2012 standard

Note: All **bolded** parameters are specified in the FQD. The non-bolded parameters are not specified.

Property	Units	Limits	
		MIN	MAX
Research Octane Number, RON	**-**	**95.0**	**-**
Motor Octane Number, MON	**-**	**85.0**	**-**
Lead Content	**mg/l**	**-**	**5.0**
Density @ 15°C	kg/m³	720.0	775.0
Sulphur Content	**mg/kg**	**-**	**10.0**
Manganese Content			
until 2013-12-31	**mg/l**	**-**	**6.0**
from 2014-01-01 onwards	**mg/l**	**-**	**2.0**
Oxidation Stability	Minutes	360.0	-
Existent Gun Content (solvent washed)	mg/100ml	-	5.0
Copper Corrosion (3hr @ 50°C)	rating	Class 1	-
Appearance	-	Clear and bright	-
Hydrocarbon Type Content			
Olefin Content	**% v/v**	**-**	**18.0**
Aromatics Content	**% v/v**	**-**	**35.0**
Benzene Content	**% v/v**	**-**	**1.0**
Oxygen Content	**% m/m**	**-**	**2.7**
Oxygenates Content			
Methanol	**% v/v**	**-**	**3.0**
Ethanol	**% v/v**	**-**	**5.0**
Iso-Propyl Alcohol	**% (m/m)**	**-**	**2.7**
Iso-Butyl Alcohol	**% (m/m)**	**-**	**2.7**
Tert-Butyl Alcohol	**% (m/m)**	**-**	**2.7**
Ethers (5 or more C atoms)	**% (m/m)**	**-**	**2.7**
Other Oxygenates	**% (m/m)**	**-**	**2.7**

Sulphur Free Diesel EN 590:2013 standard

Note: All **bolded** parameters are specified in the FQD. The non-bolded parameters are not specified.

Property	Units	Limits	
		MIN	MAX
Density @15°C	**kg/m3**	820.0	**845.0**
Flash Point	°C	55	-
Cetane Number		**51**	-
Cetane Index		46	-
Cold Filter Plugging Point			
Winter	°C note 2	-	-15
Summer	°C note 2	-	-5
Viscosity at 40°C	mm2/s	2.000	4.500
Polycyclic Aromatic Hydrocarbons	**% (m/m)**	-	**8.0**
Sulphur Content	**mg/kg**	-	**10.0**
Copper Strip Corrosion (3hr @ 50°C)	rating	-	Class 1
Carbon Residue :			
(on 10% Distillation Residue)	% (m/m)	-	0.30
Ash Content	% (m/m)	-	0.01
Total Contamination	mg/kg	-	24
Water Content	mg/kg	-	200
Manganese Content			
until 2013-12-31	-	-	6.0
from 2014 to 01-01 onwards	**mg/l**	-	**2.0**
Distillation			
% (V/V) Recovered at 250°C	% (V/V)	-	< 65
% (V/V) Recovered at 350°C	% (V/V)	85	-
95% (V/V) Recovered at	°C	-	**360**
Oxidation Stability	g/m3	-	25
Oxidation Stability	h	20	-
Lubricity, Corrected Wear Scar Diameter			
(WSD 1,4) at 60 °C	µm	-	460
Fatty Acid Methyl Ester (FAME)	**% (V/V)**	**-**	**7.0**
Filter blocking tendency	-	-	2.52

LPG (Automotive) EN589:2018 Standard

Property	Unit	Limits		Test method[a] (See Clause 2, Normative references)
		Minimum	Maximum	
Motor octane number, MON		89,0		Annex B
Total dienes content [i]	% (m/m)		0,5	EN 27941 DIN 51619
1,3 Butadiene	% (m/m)		0,10	DIN 51619
Propane content [g,i] until 2022-04-30 from 2022-05-01	% (m/m)	 20 30		EN 27941 DIN 51619
Hydrogen sulphide		negative		EN ISO 8819
Total sulfur content (after odorization) [j]	mg/kg		30	prEN 17178 ASTM D6667
Copper strip corrosion (1 h at 40 °C)	rating	class 1		EN ISO 6251
Evaporation residue [b]	mg/kg		60	EN 15470 EN 15471 EN 16423
Vapour pressure, gauge at 40 °C [c]	kPa		1 550	EN ISO 4256 EN ISO 8973 and Annex C
Vapour pressure, gauge, min 150 kPa at a temperature of: [d,e] - for grade A - for grade B - for grade C - for grade D - for grade E	°C		 - 10 - 5 0 + 10 + 20	EN ISO 8973 and Annex C
Water content [f]		pass		EN 15469
Odour [h]		unpleasant and distinctive at 20 % LFL		See 6.3 and Annex A

[a] See also 6.5.1.
[b] See also 6.5.2.
[c] See also 6.5.3.
[d] For the purpose of this standard EN ISO 8973 together with Annex C shall be applied at the indicated temperatures. For internal routine quality control purposes, the values as given in the informative Annex D may also be used.
[e] See also 6.1.
[f] See also 6.2.
[g] A test method on MON and/or on the performance of LPG in the engine is under development. As soon as such a test method is available a revision with the aim of withdrawing the minimum propane content requirement will be initiated.
[h] National safety requirements have to be followed in any case and may overwrite this standard.
[i] See also 6.5.4.
[j] See also 6.5.5. ASTM D6667 is intended to be no longer referenced when sufficient data on EN 17178 is available.

ANNEX B CEN SPECIFICATIONS FOR DIESEL, BIODIESEL AND PARAFFINIC FUELS

Property	Units	FQD	B7	B10	B100	HVO/XTL
Standard			EN590	EN 16734	EN 14214	EN 15940
Density @15°C	kg/m3	820-845	820-845	820-845	860-900	765-800
Flash Point	°C	-	>55	>55	>101	>55
Cetane Number		>51	>51	>51	>51	>70
Cetane Index		-	>46	>46	-	-
Cold Filter Plugging Point						
- Winter	°C	-	<-15	-	-	<-15
- Summer	°C	-	<-5	-	-	<-5
Viscosity at 40°C	mm2/s	-	2.0-4.5	2.0-4.5	3.5-5.0	2.0-4.5
PAH	%m/m	<8.0	<8.0	<8.0	-	<0.1
Sulphur Content	mg/kg	<10.0	<10.0	<10.0	<10.0	<5.0
Copper Strip Corrosion (3hr @ 50°C)	rating	-	Class 1	Class 1	Class 1	Class 1
Carbon Residue (on 10% Distillation Residue)	%m/m	-	<0.30	<0.30	-	<0.30
Ash Content	%m/m	-	<0.01	<0.01	-	<0.01
Total Contamination	mg/kg	-	<24	<24	<24	<24
Water Content	mg/kg	-	<200	<200	<500	<200
Manganese Content	mg/l	<2.0	<2.0	<2.0	-	-
Distillation						
- %V/V Recovered at 250°C	%V/V	-	<65	<65	-	-
- %V/V Recovered at 350°C	%V/V	-	>85	>85	-	-
- 95%V/V Recovered at	°C	<360	<360	<360	-	<360
Oxidation Stability	g/m3	-	<25	<25		<25
Oxidation Stability	h	-	>20	>20	>8	>20
Lubricity, (WSD 1,4) at 60 °C	µm	-	<460	<460	-	<360
Fatty Acid Methyl Ester (FAME)	%V/V	<7.0	<7.0	<10	<96.5	<7.0

ANNEX C VAPOUR PRESSURE DEROGATION REQUEST INFORMATION

This Annex summarises the reasoning behind the vapour pressure derogation requests for which information was published.

The following derogations were granted for the period until the end of 2020:

- **Denmark** is unable to produce suitable quality petrol with low enough vapour pressure from its refineries without addition of MTBE, however Denmark cannot add MTBE due to potential contamination to drinking water. Danish refineries would need to invest €150 million in new installations, specifically for fluid catalytic cracking (FCC), and import more low volatility components to produce fuel that meets the vapour pressure limits. Applying the derogation leads to an estimated 285 tonne increase of VOC emissions, accounting for 0.3% of total VOC emissions, which would not lead to non-compliance with the national emissions ceilings (NEC).

- **Estonia** does not have petrol refining resources and is therefore entirely dependent on imports. Requiring imports of specific low vapour pressure petrol grades would lead to increasing consumer prices due to additional productions costs to producers. The derogation leads to an increase of approximately 40 tonnes of NMVOC, accounting for around 0.1% of total VOC emissions.

- **Ireland** has one petrol refinery, which is limited in its configuration as it does not contain a fluid catalytic cracking (FCC) conversion facility. Furthermore, Ireland's petrol supply relies to 60% on imports, mostly from the UK. Ireland estimates additional costs of €18 million per year for its refinery to produce petrol with a vapour pressure of 60kPa.

- **Latvia**, similar to Estonia, has no petrol refining resources and therefore relies on imported petrol, mostly from Lithuania. Since Lithuania has a vapour pressure derogation in place, the import prices of petrol would increase as a consequence of not providing the derogation since the production costs would increase. The estimated increase in NMVOC emissions due to a vapour pressure limit of 70kPa was estimated to be 0.1-0.15% of the total NMVOC emissions, indicating no risk of non-compliance with the NEC.

- **Lithuania** provided data on its low ambient summer temperatures and referred to the impacts on vehicle driveability and safety, especially pointing to the old petrol-engine car fleet (most of them manufactured from 1986-1995) requiring petrol with a higher petrol vapour pressure. Lithuania further provided a summary of economic and technical impacts to justify the use of petrol with vapour pressure exceeding 60kPa during the summer period. According to the request, the production of petrol with vapour pressure reduced by 10kPa would increase the price of petrol by €4.5-€7.5/t (the average price of petrol in Lithuania was €1.19/l in April 2010, equivalent to around €1,600/t).
- **Sweden** indicated in its derogation request that its refineries have always produced petrol with a vapour pressure limit of 70kPa and would therefore require significant investments to change its facilities. Furthermore, Swedish petrol sales in 2010 included 4% E85, which would not reach the minimum vapour pressure if the pre-blend petrol had a reduced vapour pressure of 60kPa. The estimated costs of required changes to each refinery is €22 – 34 million and would take three to five years to implement.

Furthermore, the reduced vapour pressure requirement would require increased imports of alkalyte, MTBE or ETBE.

- **Spain** requested the 'bioethanol' derogation allowing increasing the maximum summertime vapour pressure when bioethanol is blended with petrol. The allowed increase varies according to precise ethanol content specified in Annex III of the FQD. Spain was planning to use at least 5% ethanol blend corresponding to 8 kPa maximum permitted increase. In its request, Spain noted that it was technically possible to produce lower vapour pressure petrol but it would come at a cost estimated between €120 and €240 million per year or €0.015 to €0.03 per litre for refineries. Due to increased need for ETBE instead of bioethanol and increased imports of feedstocks, this would result in a €0.03 to €0.04 per litre price increase for consumers. The 18% if annual petrol sales contain ethanol, which would fall under the vapour pressure derogation, would require that Spain produce lower vapour pressure petrol pre-blends for ethanol blends, which would hinder the efficient functioning of its supply infrastructure. Spain's estimate for the increase in NMVOC emissions was 0.04 – 0.06% of total NMVOC emissions.

- **Bulgaria** requested a derogation for vapour pressure of petrol blends containing ethanol, noting production cost increases of €3 million per year, alongside a €7 million investment. Bulgaria's domestic producer plans to modify its production facility to start producing ETBE starting in 2019, which is less volatile. Therefore, the requested derogation deadline of 2020 fits this schedule as the ETBE will then be used as ethanol and the derogation will no longer be necessary.

The following derogations were granted for the period after 2020:

- **Ireland** was the first Member State for which a derogation was approved for the period up to the end of 2030. Similar to the previous derogation request, Ireland noted that it has one petrol refinery, which is limited in its configuration as it does not contain a fluid catalytic cracking (FCC) conversion facility, which prevents it from producing low vapour pressure petrol. Furthermore, Ireland's petrol supply relies to 68% on imports (2017 consumption), mostly from the UK. Since Ireland is planning to increase bioethanol content from 5% in 2020 to 10% in 2030, an even lower vapour pressure blendstock would be required. Ireland estimates an investment cost of €42 million to reconfigure its refinery and an additional €5.2 to €6.4 million annual cost of importing low vapour pressure blendstock.
- **Sweden** was granted a derogation till end 2030: reducing petrol vapour pressure from 70kPa to 60kPa would require importing blending components. Three refineries operate in Sweden with different configurations and different constraints for petrol components leading to increased dependence on imports. Sweden indicated that the production of a lower volatility petrol would require investments in the amount of about 30-40 million EUR for each refinery.
- **Spain** applied for the 'bioethanol' derogation, asking for a permission to apply the maximum limit of 68 kPa, instead of 60kPa till end 2023 while projecting to remain compliant with the NMVOC emissions ceiling for the same period. Without waiver, Spain would require introducing a separate manufacturing stream to produce a lower volatility petrol pre-blend in summer which would imply several undesirable socio-economic implications, such as, non-optimised distribution system, duplication of storage and blending facilities with estimated additional costs amounting up to €1.6 million per installation (Spain operates 39 storage terminals), difficulties of exporting unwanted quantities of manufactured pre-blend components. Spain estimates that the

total additional cost of implementing this option would amount to between €80 and €200 million a year.

- **Latvia** applied for a derogation till end 2030 No petrol refineries operate on Latvian territory with petrol imported mainly from Lithuania (64%) and Finland (33.5%), countries where a vapour pressure derogation is in place. Without derogation, it would be very challenging for Latvia to reorient the import flow and logistics for the small quantities of summer petrol to comply with the 60kPa vapour pressure leading to a cost increase of up to 15 USD per tonne supplied petrol.
- Derogation requests were also submitted by **Portugal, Denmark, Finland, Estonia** and **Lithuania**; however, no decisions were published at the time of writing (May 2021).

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