PAPER ON EMISSION LEGISLATION

(NRMM IN INLAND NAVIGATION AND SULPHUR GAP FOR SEAGOING VESSELS)

THE EFFECTS AND IMPLEMENTATION OF NRMM IN ESTRIN AND PROPULSION EVALUATION IN INLAND NAVIGATION

General remark

Chapters to which addition/changes to the previous versions of this paper are added as per December 2022, are marked blue, as are the respective changed Alinea in the chapters

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INTRODUCTION

Originally this first issue of this paper was written shortly after the implementation of the NRMM in order to inform parties in the inland navigation sector about what the NRMM is all about and the consequences in relation to inland navigation propulsion systems.

In line with the NRMM in December 2018 the Renewable Energy Directive 2018/2001/EU (RED II) entered into force. The Fuel Quality Directive (FQD) was introduced and the Green Deal was agreed upon by various parties, including shipowners, inland navigation associations, shippers and banks, in order to achieve an accelerated reduction of emissions in sea- and inland navigation. All this had severe consequences for inland navigations propulsion systems in relation to emission reduction. In this paper also information concerning the impact of the implementation of emission regulations was incorporated.

Since 2018 quite a lot has happened in inland navigation with respect to looking for alternative fuels and new propulsion systems.

Generally the inland navigation vessels before 2018 were all propelled by diesel engines. One has to bear in mind that diesel engines in inland navigation have a lifespan of 15 to 30 years, mostly pending on power range.

This means that introducing new innovative propulsion system will take years to be developed, but implementation of these new propulsion systems to replace the existing diesel engines, will take much longer and will depend on investment costs and the available alternatives.

In the meantime, reduction of CO_2 emission and other emissions like nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO) and hydrocarbons (HC), in inland navigation on the short time is only possible with using alternative(bio)fuels in the combustion diesel engines and /or installing catalyzers and/or particle filters.

It must be clear that using alternative fuels in the combustion diesel engines is no more than an intermediate step in reaching the final goal for 2050, being zero emission for the propulsion of inland vessels.

This paper tries to give insight in current legislation concerning emission and technical requirements, possible alternative fuels and their consequences, alternative propulsion systems being developed, and pilots being started, also with their respective consequences. This is an ongoing process and with this paper IVR tries to keep parties informed and up to date about the various developments in inland navigation. That's the reason why this paper is periodically update to keep track with the latest developments.

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THE LEGISLATION

FUEL QUALITY DIRECTIVE (FQD)

There are currently 2 regulations that regulate the addition of bio to inland navigation propulsion fuels as of 1-1-2022. Namely the transposition of the revised **Renewable Energy Directive** (RED II) and Article 7 of the **Fuel Quality Directive** (FQD) 2009/30/EC of 23 April 2009. These regulations sies for a sustainable continuation of the system of annual emission reduction obligation.

Fuel Quality Directive (FQD)
The Netherlands has been addressed by the European Commission concerning the Fuel Quality Directive (FQD) as it was not yet been implemented for the Dutch fuel suppliers although it was obliged to do so as of 1-1-2022. In principle, inland fuel suppliers should have complied with the Fuel Quality Directive (FQD) from 01.01.2019. This means that suppliers must reduce the CO_2 footprint in the fuel chain by 6%. Fuel suppliers must add at least 6% biofuel to their diesel, or compensate for this by purchasing Renewable energy units (REUs). This percentage will not periodically change over the coming years. This directive should have been implemented throughout the EU, but The Netherlands, Belgium and Germany interpreted the legislation differently as to why implementation of this regulation has not yet taken place. After being summoned the Netherlands intended to implement the FQD as of 1-1-2022, when at least 6% bio must be added to the present diesel or compensated for by means of renewable energy points (HBE's)[1].

RENEWABLE ENERGY DIRECTIVE 2018/201/EU (RED II)

In November 2016, the European Commission published its 'Clean Energy for all Europeans'[2] initiative. As part of this package, the Commission adopted a legislative proposal for a recast of the Renewable Energy Directive.[3] In the context of the co-decision procedure, a final compromise text[4] among the EU institutions was agreed in June 2018. In December 2018, the revised renewable energy directive 2018/2001/EU (RED II) entered into force.

In RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%. The Commission's original proposal did not include a transport sub-target, which has been introduced by co-legislators in the final agreement: Member States must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy.

The Directive 2009/28/EC specifies national renewable energy targets for 2020 for each country, taking into account its starting point and overall potential for renewables. These targets range from a low of 10% in Malta to a high of 49% in Sweden.

EU countries set out how they plan to meet these 2020 targets and the general course of their renewable energy policy in national renewable energy action plans.

The Dutch Ministry of Infrastructure and Water Management investigated whether inland navigation could be added to the RED II share obligation at European or national level. Separately, the use of biofuels (blends) in inland navigation can increase, as fuel suppliers are looking for additional outlets to meet the increasing obligation for road transport.
Under RED II, the Ministry has a draft energy transport decision for the period 2022 to 2030 for consultation, of which implementation of increased use of biofuel in inland navigation per 1-1-2022 is part.

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1 Ultimately it was decided mid December 2021 by the Dutch Government not to implement the FQD until at least the 1st January 2023..

2 Reference is made to Clean energy for all Europeans package (europa.eu)

3 Reference is made to the Proposal for a recast of the Renewable Energy Directive.

4 Reference is made to Final compromise text among the EU institutions

In line with Red II inland navigation fuel suppliers who supply fuel to inland shipping without excise duty, the Dutch bunker companies are given the administrative obligation to keep track of the number of Renewable Fuel Units (HBE's). A HBE is created when an amount of 1 GJ (gigajoule) of renewable energy has been supplied to the Dutch transport market and is registered (entered) in the Energy for Transport Register (REV). In this register, companies can than "book" renewable energy supplied to transport.

The Netherlands planned to, as per January 2022, demand a mix-up rate of 16.4% in the inland navigation diesel of which 7% being FAME and the rest HVO, which will increase annually in accordance with the Energy Transport Decree in connection with the implementation of Directive (EU) 2018/2001.
Amendment of the Energy Transport Directive in connection with the implementation of Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources and on the implementation of the Climate Agreement, regulates as in article 3.1 below the percentage steps for the use of renewable fuels

Article 3 1.

The part of the energy content of the supply to final consumption, referred to in Article 9.7.2.1, first paragraph, of the Law, whereby the number of renewable fuel units is rounded up, is for the calendar year:

- 2022: 17.9 %
- 2023: 18.9 %
- 2024: 19.9 %
- 2025: 21.0 %
- 2026: 22.3 %
- 2027: 23.6 %
- 2028: 25.0 %
- 2029: 26.5 %
- 2030: 28.0 %

In 2021, the Environmental Management Act and the Energy Transport Directive were amended partly to introduce the reduction obligation for inland shipping on the basis of the Fuel Quality Directive. This directive stipulates that fuel suppliers must achieve a 6% CO_2 reduction in the chain through the use of biofuel through their deliveries.

In view of the requirement of introduction of the renewable energy directive 2018/2001/EU (RED II), discussions have been held in recent months with Belgium, Germany and the European Commission in order to guarantee a level playing field. These discussions showed that Belgium and Germany are not unsympathetic to the introduction of the reduction obligation and support the sustainability task for inland shipping.
In Germany in particular, however, decision-making still needs to take place at political level, after which legislation needs to be adapted in the event of a positive decision. It is excluded that this will be arranged as of 1 January 2023. The chance of evasive behavior of Dutch inland vessels to bunker abroad (bunker tourism) remains too big. Bunker tourism also does not contribute to the climate objectives. As such The Netherlands have decided not to implement RED II and FQD as of 1-1-2023, but postponed them until further notice, pending on the results of agreeing on an acceptable EU wide available bio-blend and joint implementation in the Netherlands, Germany and Belgium.

This, in view of Dutch authorities, does not jeopardize its climate objectives of the Fuel Quality Directive, because the Netherlands has implemented higher ambitions via road transport.
These currently compensate for the sustainability task about the fuels delivered to inland shipping.

The Dutch government intended to take a first step towards the reduction of 5 PJ from the Climate Agreement with the implementation of the Fuel Quality Directive for inland shipping. The introduction of this directive would reduce 3.5 PJ (0.26 Mega tons) annually. This step is not being taken now. It might be more likely to achieve the reduction of 5 PJ from the Climate Agreement through the implementation of the updated Renewable Energy Directive (RED III) in the context of the Fit for 55 package. This directive is expected to be transposed by 1 January 2025. The RED III offers opportunities to make agreements with the relevant countries and thus achieve a simultaneous and comparable implementation. The aim is to have all modes of transport contribute to the energy transition by using renewable fuels. The Dutch government has started the consultation process about the implementation of the RED III with Belgium and Germany.

Presently the Dutch government is reviewing RED II. The overarching objectives of the revision of RED II are to increase the consumption of energy from renewable sources by 2030, a more integrated energy system, and to contribute to climate and environmental objectives, including the protection of biodiversity, addressing intergenerational concerns about global warming and biodiversity loss. This revision of RED II is crucial to achieve the tightened climate target.

The above resulted that as per 1-1-2023 the implementation of Directive (EU) 2018/2001 will still not be executed. Outcome of the Panteia research for a good and for all parties acceptable EU wide available bio fuel in 2023 will be awaited. More information on the research of Panteia and IVR's contribution can be found in this paper in chapter Alternative fuels – FAME (fatty acid methyl ester) page 33.

THE GREEN DEAL

Within the Green Deal, the Dutch government has in 2019 reached agreements with various parties, including shipowners, inland navigation associations, shippers and banks, in order to achieve an accelerated reduction of emissions in sea- and inland navigation.

This Green Deal set out the following targets for inland navigation for 2024:

1. To have developed a new European guidance toolbox that encourages the achievement of the stated ambitions without the need for the government to impose mandatory emission standards per ship for 2030 and 2035.
2. A reduction in CO_2 emissions of at least 20% compared to 2015.
3. A 10% reduction in the emission of environmental pollutants from inland navigation compared to 2015.

The first goal for inland shipping is that it must emit at least 40% less CO_2 in 2030 and be "virtually climate neutral" by 2050.

The Ministry of Infrastructure and Water Management will provide subsidies to enable this transition as much as possible.

NON-ROAD MOBILE MACHINERY (NRMM)

First steps to reduce the inland navigation propulsion emission started in 2003 with the introduction of emission requirements CCR-I followed in 2007 with the introduction of the CCR-II emission requirements respectively in 2003 and 2007. Then it became quiet for a while. Although CCNR-III and CCNR-IV requirements were discussed, these requirements never materialized.

Regulation (EU) 2016/1628 (NRMM) on requirements relating to emission limit values for gaseous and particulate pollutants and type-approval for internal combustion engines installed in non-road mobile machinery, became effective 14th September 2016.

New main and auxiliary engines for an inland vessel currently have to meet emission requirements for Non-Road Mobile Machinery (NRMM) or from the Central Commission for the Navigation of the Rhine (CCNR). Current standards for inland navigation are known as NRMM Phase IIIA and CCR-II respectively. These two standards are almost identical, with the difference being that the CCNR standards come from Strasbourg (CCNR) and the NRMM standards from Brussels (European Union). Due to mutual recognition, both standards are currently valid.

The NRMM emission requirements are known as **Stage-V**. These are the requirements of the European Union for the air emissions of various 'non-road' mobile machines, such as locomotives, construction machines, lawn mowers, and also to inland vessels. These different machines are in turn divided into different categories, with separate categories for main engines (IWP) and auxiliary engines (IWA) for inland navigation. Requirements are set for various Green House Gas Emissions, as are; nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO) and hydrocarbons (HC). These new requirements will apply to new engines under 300 kW that will be placed on the market from 2019. And from 2020 for new motors of 300 kW and higher.

In order to make natural gas engines possible, the new requirements include that the emission of hydrocarbons (HC) for gas engines may be higher. Where this is 0.19 g/kWh for a full diesel engine, this can be up to 6.19 g/kWh for a gas engine, depending on the percentage of gas used. The regulations for dual-fuel engines (gas and diesel engines) will be further elaborated in this paper.

These new requirements will lead to a drastic reduction in air emissions from inland navigation: NO_x by 70-84% and PM by 92.5% lower than CCR-II. In addition, after implementation in 2020, the European Commission will report to the European Parliament and the Council of the EU on the feasibility of further reductions in emissions, for example with regard to hydrocarbons in gas engines and the number of particulate matter and NO_x in the engines.

The NRMM Regulation sets out limit values for carbon monoxide emissions (CO), hydrocarbons (HC) and nitrogen oxides (NO_x) for inland waterway engines. In addition, in addition to requirements for the maximum weight of particulate matter (PM), it has also been chosen to impose standards for the number of solid particulate particles (PN). No_x emissions by 70-84% and PM are 92.5% lower than current requirements for CCR-II engines.

Ability	CO	HC	NOx	Pm (particulate mass)	Pn (particle number)
Kw	**g/kWh**	**g/kWh**	**g/kWh**	**g/kWh**	**#/kWh**
19≤P<75	5	(HC+NOx≤4.70)		0,3	–
75≤P<130	5	(HC+NOx≤5.40)		0,14	–
130≤P<300	3,5	1	2,1	0,1	–
P≥300	3,5	0,19	1,8	0,015	1×10^{12}

The entry into force of the Regulation (EU) 2016/1628 (NRMM) of the European Parliament and of the Council of 14 September 2016 on rules on emission limit values for pollutants and particulate matter and type-approval for mobile machinery not intended for road, amending Regulations (EU) No 1303/2016 1024/2012 and (EU) No 1024/2012 167/2013, and amending and repealing Directive 97/68/EC, means that as of 1-1-2019 for engines with a power of power from > 19kW to < 300 kW for new-build vessels, they must meet the new requirements (also known as Stage-V) and after 1-1-2020 for engines with a power of > 300 kW for new-build vessels.

There were transitional provisions if engines met the conditions for 'transitional engine'. These 'transition engines' may be built in/accepted for 18/24 months respectively, i.e. until 31-12-2020 for engines < 300 kW and until 31-12-2021 for engines > 300kW.

There are several categories of engines based on the type approval. This depends on whether it is a propulsion or auxiliary engine (incl. bow thruster engines) with a fixed or variable speed.

The manufacturer shall ensure the type-approval. The requirements for this are detailed in the NRMM. Even when they are 'transitional' engines.

In fact, NRMM means that manufacturers of diesel engines should **not** be allowed to market engines which do not have type-approval after 1-1-2019 and 1-1-2020 respectively.

In order to obtain a Stage-V type-approval for an engine, manufacturers must have the engines go through specific test protocols to demonstrate that the engines meet the NRMM emission requirements in the various simulated operating conditions. This is a costly business for engine manufacturers.

Over the years, several engines which met the different emission requirements (applicable at the time) have been developed and delivered in inland navigation, namely:

- Pre-CCR engines from before 2002
- The CCR1 engines, installed between 2002 and 2007
- The CCRII engines, installed between 2007 and 2020
- The Stage-V engines to be delivered after 1-1-2020

Depending on the type-approval, an engine can run on different fuel types, based on the reference fuels complying with CEN standards EN590 or EN15940. Also on other commercially available fuels, e.g. B100 (EN 14214:2012+A1:2014), B20 or B30 (EN16709:2015).

Important here is; The permitted fuels are indicated in the type-approval of the engine. Meaning; the use of a different type of fuel revokes the type approval and an amendment to the type approval is required.
Only the manufacturer may submit such a request for an amendment, which must be made to the approval authority which granted the original type-approval.
This also means that when a vessel with a type-approved engine, be it a CCR II or a Stage-V, starts running on a fuel that is not included in the type-approval, the type-approval expires, and the engine is actually **no longer** allowed to be used with that particular fuel!

It is therefore important that the fuel to be used continues to comply with the reference fuel used in the type-approval. The addition of, for example, a methanol injection or any other additive or substance, means that the type approval is cancelled.
It should also be noted that several (in manufacture, type and power), different engines are often installed on board inland barges for propulsion, auxiliary power and bow thruster propulsion. It is certainly not to be ruled out that these different engines have different or no bio additions in their type approvals with each a different interpretation of the in the type approval permitted fuel.

Emission classes of engines
It must be noted that there is quite some difference in what is possible within the various emission classes (CCNR and Stage-V) with regard to the fuels to be used within the type-approval /emission legislation and within the "experience" of engine manufacturers with "the right measures".

The table below from the TNO report TNO 2020 R11455 of November 2020 gives an overview.

Table 1: Officially admitted bio fuel blends and alternative bio fuels

	Pre CCR < 2002	CCR I 2002 - 2007	CCR II 2007 - 2020	Stage-V > 2020
According to engine emission legislation	Not regulated	• Max. 7% FAME, B7 • This can be added with approx. 30% HVO. • Total max 37% bio fuel (volume base). This means a mix of 7% FAME, approx. 30% HVO in the diesel. This remains within the EN 590 specifications		• Max 8% FAME, B8 • High blends to 100% with FAME possible if tested for type approval with this. • 100% HVO • 100% bio LNG • Synthetic blends, for instance GTL+FAME.
According to engine manufacturers	Hardly information available. Sometimes small problems with >B7	• Always B7 • With the implementation of the appropriate measures often B20-B30 cabn be used.	• Always B7 • With implementation of the appropriate measures mostly capable of handling B20-B30. Sometimes 30% to 100% HVO can be used.	No information yet.

In the 2020 R11455 TNO report of November 2020, TNO notes that CCR II engines are often resistant to B20 to B30. For CCR I and older engines this is unclear.

However, it appears from the above that the engine manufacturers believe that the use of B20 / B30 (20% or 30%) bio addition can only be "with the right measures". An inventory needs to be made which “right measures” are required and whether these measures differ from different type-approval engine and manufacturer.

Implementation in technical regulations[5]

As regards the Technical Regulations in inland navigation, the ROSR (legislation for vessels on the Rhine) and directive 2006/87 EC (for vessels on all other EU inland waterways) were merged into ES-TRIN 2017 as of 7 October 2018. ES-TRIN is evaluated and adjusted every 2 years.

ES-TRIN 2019 is the European standard for the adoption of the technical requirements for inland waterway vessels by 1-1-2020.

ES-TRIN 2019 states that internal combustion engines must meet the requirements of Regulation (EU) 2016/1628.

[5] How to deal with the implementation of NRMM rules in inland navigation is regulated in ES-TRIN 2019 Article 9.

Internal combustion engines of the categories are;

a) IWP,
b) IWA,
c) NRE with a reference capacity of less than 560 kW or
d) engines recognized as equivalent in accordance with Regulation (EU) 2016/1628.

Definitions:

Category **IWP** engines means:

- Engines with a reference power of 19 kW or more, used or intended for direct or indirect propulsion exclusively in inland waterway vessels;
- engines used instead of engines of category IWA provided that they comply with Article 24(8) of the Regulation (EU) 2016/1628;

Category **IWA** engines means:

- Auxiliary engines with a reference power greater than or equal to 19 kW which is exclusively used for inland waterway vessels;

Category **NRE / NRS** engines means:

- Engines for non-road mobile machinery which are intended and suitable for, whether or not over the road, to move or to be moved, which are not excluded under Article 2(2) and which are not are included in another category defined in points 2 to 10 of this paragraph;
- Engines with a reference power of less than 560 kW used instead of
- Stage-V engines of categories IWP, IWA, RLL or RLR;
- engines for auxiliary railway vehicles and auxiliary engines for trainsets and locomotives, depending on their characteristics.

Note:

1. A variable speed engine of a particular category may be used in place of a constant speed motor of the same category.
   Variable speed engines of category IWP used to operate at constant speed shall also comply with Article 24(7) or Article 24(8), as applicable.
2. Engines for auxiliary railway vehicles and auxiliary engines for trainsets and locomotives shall be included in accordance with their characteristics.

Conformity

The conformity of the engines should be demonstrated by a type-approval.

The engines must be indicated on the ship certificate. This means that an inspection body (for the Netherlands these are the Private Institutions (Pi's) and Class must establish that the engine complies with the required emission on the basis of the type of approval, the installation in accordance with the type of approval checks, issue an installation declaration and ensures that the new engine is entered into the vessel's certificate.

Stage-V Standards

Stage-V emission limit values for engines in non-road mobile machines (category NRE) are shown in Table 4.

These standards apply to diesel engines (CI) from 0 to 56 kW and to all types of engines above 56 kW. Engines of more than 560 kW used in generator sets (NRG category) must meet the standards set out in Table 5 (NRSC and NRTC test cycles).

Table 4
Stage V emission standards for nonroad engines (NRE)

Category	Ign.	Net Power	Date	CO	HC	NOx	PM	PN
		kW		g/kWh				1/kWh
NRE-v/c-1	CI	P < 8	2019	8.00	7.50[a,c]		0.40[b]	-
NRE-v/c-2	CI	8 ≤ P < 19	2019	6.60	7.50[a,c]		0.40	-
NRE-v/c-3	CI	19 ≤ P < 37	2019	5.00	4.70[a,c]		0.015	1×10^{12}
NRE-v/c-4	CI	37 ≤ P < 56	2019	5.00	4.70[a,c]		0.015	1×10^{12}
NRE-v/c-5	All	56 ≤ P < 130	2020	5.00	0.19[c]	0.40	0.015	1×10^{12}
NRE-v/c-6	All	130 ≤ P ≤ 560	2019	3.50	0.19[c]	0.40	0.015	1×10^{12}
NRE-v/c-7	All	P > 560	2019	3.50	0.19[d]	3.50	0.045	-

[a] HC+NOx
[b] 0.60 for hand-startable, air-cooled direct injection engines
[c] A = 1.10 for gas engines
[d] A = 6.00 for gas engines

Stage-V Regulation introduced a new limit for emissions of particle numbers.

The PN limit is designed to ensure that a highly efficient particle control technology, such as wall flow particle filters, is used on all the engine categories involved. The Stage-V Regulation also tightened the mass-based PM limit for different engine categories, from 0.025 g/kWh to 0.015 g/kWh.

Table 5
Stage V emission standards for generator set engines above 560 kW (NRG)

Category	Ign.	Net Power	Date	CO	HC	NOx	PM	PN
		kW		g/kWh				1/kWh
NRG-v/c-1	All	P > 560	2019	3.50	0.19[a]	0.67	0.035	-

[a] A = 6.00 for gas engines

Phase III A (CCR II) standards introduced emission limit values for engines used in inland waterway vessels, Table 6. Engines are divided into categories based on displacement (swept volume) per cylinder and net output power. The engine categories and standards have been harmonized with US standards for ship engines.

There are no phase III B or phase IV standards for vessels.

Table 6
Stage III A emission standards for engines in inland waterway vessels

Category	Displacement (D)	Date	CO	HC+NOx	PM
	dm^3 per cylinder		g/kWh		
V1:1	D ≤ 0.9, P > 37 kW	2007	5.0	7.5	0.40
V1:2	0.9 < D ≤ 1.2		5.0	7.2	0.30
V1:3	1.2 < D ≤ 2.5		5.0	7.2	0.20
V1:4	2.5 < D ≤ 5	2009	5.0	7.2	0.20
V2:1	5 < D ≤ 15		5.0	7.8	0.27
V2:2	15 < D ≤ 20, P ≤ 3300 kW		5.0	8.7	0.50
V2:3	15 < D ≤ 20, P > 3300 kW		5.0	9.8	0.50
V2:4	20 < D ≤ 25		5.0	9.8	0.50
V2:5	25 < D ≤ 30		5.0	11.0	0.50

The emission limit values for inland waterway vessels have been significantly tightened under the Stage V Regulation (Stage V).

The limits of phase V, Table 7, apply to propulsion engines (IWP) and auxiliary engines (IWA) of more than 19 kW, including engines of all types of ignition.

Table 7
Stage V emission standards for engines in inland waterway vessels (IWP & IWA)

Category	Net Power	Date	CO	HC[a]	NOx	PM	PN
	kW		g/kWh				1/kWh
IWP/IWA-v/c-1	19 ≤ P < 75	2019	5.00	4.70[b]		0.30	-
IWP/IWA-v/c-2	75 ≤ P < 130	2019	5.00	5.40[b]		0.14	-
IWP/IWA-v/c-3	130 ≤ P < 300	2019	3.50	1.00	2.10	0.10	-
IWP/IWA-v/c-4	P ≥ 300	2020	3.50	0.19	1.80	0.015	1×10^{12}

[a] A = 6.00 for gas engines
[b] HC + NOx

NRMM -some questions

Under what conditions can transitional motors be installed?[6]

Instead of an Stage V IWP, IWA and equivalent engines, a transitional engine can be installed on board a barge provided:

1. The production date of the vessel not older than 18 months after the start of the transitional period (being 30.6.2020 for P < 300 kW and 30.6.2021 for P ≥ 300 kW); and
2. The engine complies with the last entry into force emission limits as defined in the relevant legislation applicable on 5 October 2016 (being RVIR CCNR II or Directive 97/68/EC); and
3. The engine has not been marketed later than 24 months from the applicable date for placing on the market as indicated in Annex III of the Directive (EU) 2016/1628 (being 1.1.2021 for P < 300 kW and 1.1.2022 for P ≥ 300 kW); and
4. The vessel did not enter the market later than 24 months from the applicable date for the placing on the market as indicated in Annex III of the Directive (EU) 2016/1628 (being 1.1.2021 for P < 300 kW and 1.1.2022 for P ≥ 300 kW); and
5. The engine Manufactured Is before the start of the transition period (Being 1.1.2019 For P < 300 Kw And 1.1.2020 For P ≥ 300 (kW).

The transitional period for NRE engines, used instead of IWA and IWP, shall be the same as applicable to the IWA and IWP engines (same dates as above).

Note: the last applicable emission limits as defined in Directive 97/68/EC of 5 October 2016 are:
1. In the case of propulsion and auxiliary engines of more than 560 kW:
   - V (37 kW ≤ P) - EU-stage IIIA
2. In the case of auxiliary engines under 560 kW:
   a) For variable-speed engines, the categories
      - K (19 kW ≤ P < 37 kW) - EU stage IIIA
      - P (37 kW ≤ P < 56 kW) - EU stage IIIB
      - R (56 kW ≤ P < 130 kW) - EU stage IV
      - Q (130 kW ≤ P ≤ 560 kW) - EU stage IV
   b) For engines with a constant speed the categories
      - K (19 kW ≤ P < 37 kW) - EU stage IIIA
      - J (37 kW ≤ P < 56 kW) - EU stage IIIA
      - I (56 kW ≤ P < 130 kW) - EU stage IIIA
      - H (130 kW ≤ P ≤ 560 kW) - EU stage IIIA

What modifications to engines are allowed?[7]

A modification that does not result in change of emission related parameters, including drawings and descriptions included in the approval type information package, is permitted.

Additionally, an engine must be installed in accordance with the manufacturer's installation guidelines. Failure to comply can be seen if they are not compliant (not meeting the type of approval) of the engine.

[6] *Reference is made to: Directive (EU) 2016/1628, Article 3(33), Article 3(32), Article 58(3)(5)(6) and (7)*
[7] *Reference is made to: Directive (EU) 2016/1628, Articles 8, 9 and 10*

When a person modifies an engine in such a way that it no longer meets the emission requirements laid down in the type-approval, that person is responsible for regaining a type of approval or re-complying with the emission requirements for the motor category or sub-category.

When an importer/ distributor modifies the engine in such a way that it may be that the engine meets the emission requirements as laid down in the type of approval is at stake, the importer/distributor will be seen as the manufacturer (Original Equipment Manufacturer (OEM)) and thus become fully responsible for obligations such as warranty, product description, liability) as a manufacturer, including compliance with the emission requirements as laid down in the type approval.

If an OEM or instance acting as an OEM does not follow the manufacturer's instructions or makes adjustments to the engine which negatively affects engine emissions, this OEM will be seen as a manufacturer and thus fully responsible for obligations as a manufacturer, including compliance with emissions requirements as laid down in the type of approval.

The engine manufacturer may carry out modifications to the engine in such a way that the engine becomes a different type of approval from that manufacturer, even if the engine with its properties is going to belong to another category or sub-category. The engine manufacturer is responsible for meeting the engine applicable type approval, including the necessary emission markings on the engine.

Using another fuel as indicated in the type of approval or addition to the fuel, also results in a change in the type of approval.

Adjustment of type approval[8]

A modification/modification of an engine type that changes one of the data included in the information package, including fuel, drawings and descriptions, requires that type approval be changed.

Only the engine manufacturer, as holder of the type of approval, requests such a change. This comes from the type approval authority (in The Netherlands this is the RWD) which originally certified the engine type. If the approval authority finds that inspections or tests should be repeated for the submission of a change, it shall inform the manufacturer accordingly. Where the data contained in the information package has been changed without the need to repeat inspections or tests, such an amendment shall be called a 'revision'. In other cases, it is called an extension and the extension of the type approval number should be indexed.

If the production of the original engine type is to continue in addition to the modified engine type, the modified engine type may need to become an additional engine type. In the case of an engine family, if the parameters of the modified engine type remain within that of the engine family, the additional engine type may be added to the engine family and retain the same type approval number with or without indexation. The Extension number depends on whether additional tests were needed.

If there is no engine family or if the modified engine does not fit within the family parameters, a new type approval must be granted. Same goes, as already stated, when a different fuel or fuel additive is used which is outside the fuel specs of the type approval, mostly being the EN590 fuel specification.

[8] *Referenced to: Directive (EU) 2016/1628, Article 3(50), 8 and 27 in line with Chapter VI and the Implementing Directive (EU) 2017/656, Annex I including the Annexes*

When using more than 7% FAME

When bio is added outside the 7% max. of FAME within the EN590 specifications used as scope for the NRMM type approval of engines, the engine needs to have type approval for the FAME % used. So when 50% FAME is added to the diesel, the type approval has to be done with this 50%. If type approval is granted, lower % of FAME can be used, but not higher. If higher is required new type approval / proof that the engine with a higher % of FAME is within the NRMM emission requirements has to be submitted.

When using alternative fuels

Regulation (EU) 2016/1628 has prescribed "standard" fuels for certification.

All engines must be certified on at least one of below stated fuels, or combinations:

- diesel
- petrol
- petrol/oil mixture, for two stroke spark ignition (SI) engines
- natural gas/bio methane;
- liquid petroleum gas (LPG);
- ethanol.

Other "fuels, fuel mixtures or fuel emulsions" may be certified, in addition to one (or more) of the one of the standard fuels, but require demonstration of conformance to NRMM emission requirements.

Certification of engines to fuels is laid down the detailed requirements are set out in delegated act (EU) 2017/654, Annex I, stating:

- The permitted range of market specifications of the "standard" fuels are laid out.
- For each "standard" fuel there is a reference fuel specification to be used for certification test (Annex IX).
- There are additional options for engines operated on natural/bio-gas, or a combination including natural/bio-gas and a liquid fuel (dual fuel)
    - universal fuel range engine.
      This covers a wide range of high (H) and low (L) calorific value gasses;
    - restricted fuel range engine.
      This cover engines certified for either high (H) or low (L) calorific gas;
    - fuel-specific engine.
      This can be used for LNG where the quality and calorific value of the gas is further restricted.

Within Regulation (EU) 2017/654 for certification of engines to different fuels there are also procedures for certification of 'dual-fuel' engines.

A 'dual-fuel engine' means an engine that is designed to simultaneously operate with a liquid fuel and a gaseous fuel, both fuels being metered separately, the consumed amount of one of the fuels relative to the other one being able to vary depending on the operation.[9]

There are various type of dual-fuel engine defined depending on the gas energy ratio and whether they can run on liquid only. Certification is complex and often required testing on two gaseous fuels.

To be permitted to run on liquid only in normal operation they must have a liquid only certification in addition to the dual fuel certification.

A "service mode" can be permitted that temporarily allows engine to be exempted from requirements of Regulation (normally emergency operation on liquid fuel only).

[9] *(EU) 2016/1628 , Article 3.18*

A “service mode” means a special mode of a dual-fuel engine that is activated for the purpose of repairing, or of moving the non-road mobile machinery to a safe location when operation in the dual fuel mode is not possible.[10]

All other combinations of fuels need to follow article 35 of Regulation (EU) 2016/1628. Type approval of engines operated simultaneously on a combination of more than one liquid fuel and a gaseous fuel or a liquid fuel and more than one gaseous fuel shall follow the procedure for new technologies or new concepts given in article 35 of Regulation (EU) 2016/1628.[11]

In relation to article 35, a manufacturer may propose an alternative method of demonstrating meeting (at least) the environmental protection requirements of the regulation where the certification techniques of the Regulation cannot be applied.

An article 35 approval is:
- valid for a minimum of 36 months;
- only valid in the Member State that issued it;
- other member state Approval Authorities may also choose to accept it;
- subject to authorisation by the Commission (by implementing act), at which point, if approved it would apply across the EU.

There is no time scale and there are specific instructions in the event it were not approved.

FIELD TEST FOR NON-CERTIFIED ENGINES

The procedures to obtain a EU type-approval for alternative fuel engines is regulated in Regulation (EU) 2016/1628. The regular procedure to be followed for this is described in article 35. However, there is also a procedure for pilot projects as described in art. 34(4) Regulation (EU) 2016/1628.

The latter Article 34(4) states that engines for which no EU type-approval has been granted in accordance with Regulation (EU) 2016/1628 may be temporarily placed on the market for field tests for:
- 24 Months on notification of the Approval Authority.
- A Further 24 months on request to the Approval Authority.
- Special documentation and labelling requirements.
- At end of test engine must be brought to a certified specification or removed from the market.
- Ownership shall remain with the engine manufacturer during the test period under Annex XI of Delegated Regulation (EU) 2017/654 (does not prevent financial arrangement).
    - This might create problems for inland waterways because of a possible conflict with national law.

Situation according Dutch law (concerning ownership remaining with manufacturer)

Under Dutch law, as soon as the engine is built into the ship, the engine becomes part of the ship. The principle of verification applies here (Article 3:4 of the Dutch Civil Code and the judgment in tug Egbertha[12]). This means that the shipowner becomes the owner of the engine as soon as it is built into the ship. Since the ownership under Annex XI of delegated regulation (EU) 2017/654 must remain with the engine manufacturer during the test period, this therefore constitutes a conflict with Dutch law.

[10] *(EU) 2017/654 Article 1.38*
[11] *(EU) 2017/654, Annex VIII, (1 P3)*
[12] ECLI:NL:HR:1936:158

The verification cannot be interfered with by a (Delegated) Regulation. Under private international law, the starting point is that property law issues relating to movable and immovable property are governed by the law of the country where the property is located (lex rei sitae).

With regard to ships registered, the questions who is the owner of a registered ship and what rights in rem rest on it are answered in accordance with the law of the state where the ship was registered when the relevant right arose (Article 10:127 paragraph 2 of the Dutch Civil Code). This right also determines what is a component of an item (Article 10:127 paragraph 4 of the Dutch Civil Code). If a ship has not yet been registered, the lex rei sitae applies on the basis of case law.
How this should be approached and dealt with throughout the EU needs to be further sorted out.

EUROMOT is identifying where the certification techniques of the regulation cannot be applied and is working on guidance for members on alternative techniques to facilitate the use of Article 35. Single fuel hydrogen is the first priority, due to its relevance for construction equipment.

ENGINES OF PLEASURE CRAFT[13]

Engines for recreational craft not defined in EU Directive 2013/53/EU and which are not excluded from the scope of Directive (EU) 2016/1629 by operating normally on tidal water and which only temporarily sail on inland waterways are subject to the requirements of Regulation (EU) 2016/1628.

In short; The propulsion plant of recreational craft sailing on the EU should also meet NRMM emission requirements in the case of new construction or replacement after 1-1-2020 and therefore need to be equipped with Stage-V engines.

AFTERTREATMENT SYSTEMS

According to Regulation (EU) 2016/1628 , an after-treatment system necessary to meet the applicable emission limit values is part of the engine. EU type-approval is granted as a single unit for the entire system.

A single entity (OEM) must take responsibility for the type-approval and placing on the market of that fully approved unit. Only combinations in accordance with EU type-approval are allowed. It is not permitted to market an engine without the necessary type-approval and then to set up an exhaust post-treatment system without type-approval of the entire system in accordance with the requirements of Regulation (EU) 2016/1628 and 2017/654.

Any additional after-treatment or other devices installed in the exhaust system shall **not** be considered as part of the engine's emission control system and shall not be considered when inspection of an engine for the conformity with type-approval of Regulation (EU) 2016/1628. Additional equipment installed should not violate the installation of the engine manufacturer requirements, for example exceeding the exhaust backpressure limits.

EXCHANGE ENGINES

Definition 'exchange engine' means an engine that:

1. only used to replace an engine already on the market and is mounted in mobile machines not intended for the road,

and

2. meets an emission phase lower than that applicable to the date on which the engine is replaced;

[13] *Reference is made to: Directive (EU) 2016/1628, Article 2*

REPAIR OF ENGINES[14]

When is a repair of a propulsion engine so extensive that the repaired engine should be considered a replacement engine? Is the replacement of the engine block considered a simple repair or as a replacement for the engine in particular?

In accordance with Chapter 24 of the ROSR (or Chapters 24 and 24a of Directive 2006/87/EC), replacement engines could only be installed until 31 December 2011 and under certain conditions.

Under ES-TRIN 2017, Article 9.01, fourth paragraph, the installation of replacement engines ('exchange engines') is expressly prohibited.

This results in the following question: which repairs are allowed on an existing propulsion engine installed on board a ship, especially with regard to the replacement of parts?

Answer:
Allowed repairs are;

- Repairs carried out in accordance with type-approval and the existing type of approval process report of engine characteristics are, and
- Provided that the identity of the repaired engine can be traced back to the engine originally placed on the market and installed on the vessel, where no new engine is created by that repair.

Explanation:
This option provides for the need to set a limit to what is considered a repair and in this way enables the competent authority to check.
The owner of the ship must be able to provide evidence regarding the traceability of the engine and the repairs carried out on this engine. This option is entered by the following arguments;

- EU regulations are based on the criterion of placing on the market (Directive 97/68/EC, Regulation (EU) 2016/1628).
  A repair should not lead to the marketing of a new engine. If the identity of the engine remains unchanged, the engine can be used and restored to infinity.

- Where an engine has been placed on the market in accordance with Regulation (EU) 2016/1628, Directive 97/68/EC or before this Directive, there is no restriction on the repair or reconstruction of an engine with parts or parts to the extent that the original specifications of the engine emission control system are respected.

- The origin of the parts (including the engine block) does not affect, but these components must comply with the manufacturer's specifications to comply with type-approval.

Note:
An engine should also be considered as a replacement engine if, as a result of a repair, it should be classified in another engine category in accordance with the NRMM Regulation.

IMPLEMENTATION PROBLEMS / QUESTIONS[15]

With implementation of the NRMM in the inland navigation sector quite some questions arose with respect to the wording of the legislation, interpretation and more detailed explanation.

[14] Reference is made to Chapter 9, in particular Article 9.01 - Repair of an existing engine and a replacement engine
[15] Reference is made to CCR's and EOROMOT's FAQ, which is available at https://www.cesni.eu/wp-content/uploads/2018/11/FAQ_Engines_en.pdf

For this reason CESNI in close cooperation with EUROMOT, set up a standard Frequently Asked Questions (FAQ) which is published on the CESNI website. As of July 2021, an amended version of the FAQ, drawn up by EUROMOT in collaboration with CESNI, has been published.[16]

Due to COVID-19 delivery problems of newbuilt vessel hulls from non-EU countries occurred, due to which the timely installation of still CCR2 engines, the old emission types which could still be installed in the transitional period being 30.6.2020 for P < 300 kW and 30.6.2021 for P ≥ 300 kW.

This meant that a solution had to be found for vessels which should be ready before the expiration of the first transition period being 30.6.2020 for engines with an output of < 300 kW. The CCNR has concluded that revision of Regulation (EU) 2020/1040 was required. The transition period for engines with an output of < 300 kW was adapted taking in account the effects of COVID-19. This added 12 months to the transition deadlines for engine of less than 300 kW, making the deadlines the same for all categories. The NRMM for this reason was required and as such the FAQ was adapted to inform parties interested.

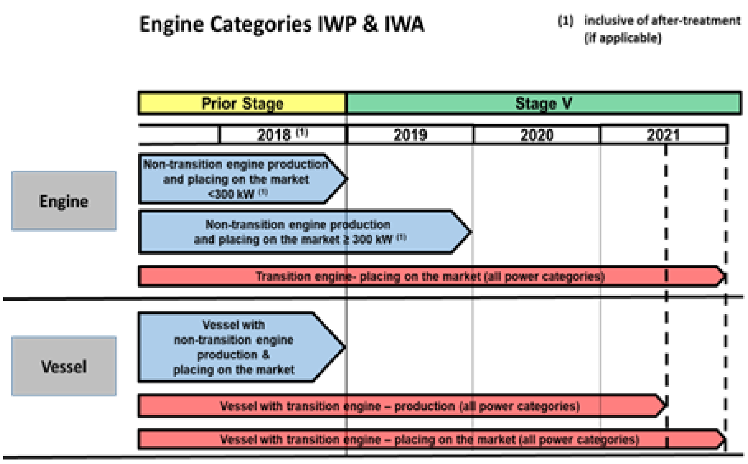
For engines with > than 300kW, a postponement has also been granted until 31 December 2021 as of July 2021. Reference is made to the amended REGULATION (EU) 2016/1628 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 September 2016, which provides for an extension of the transitional period for engines above 300 kW of six (6) in Article 58.

This also means the quite a number of CCR II type approved engines were still installed after 30-6-2020 and for engines of > 300kW after 30-6-2021. It has to be born in mind that in general diesel engines in inland navigation have an expected lifetime of about 25 years, making it, from an investment and depreciation point of view, more difficult to change over to extensive emission reduction or a zero emission propulsion installation to achieve the set emission reduction targets for 2030.

Some information about the engine transition is explained in FAQ 6 as stated below[17]:

FAQ 6. - Under what conditions may transition engines be installed on board inland navigation vessels?
Instead of Stage V IWP, IWA and equivalent engines, a transition engine can be installed on board an inland navigation vessel if:

- the production date of the vessel – (see answer 5) is not later than the 30th of June 2021; and
- the engine complies with the latest applicable emission limits defined in the relevant legislation applicable on 5 October 2016 (meaning RVIR CCNR II or Directive 97/68/EC); and
- the engine is placed on the market not later than 31st December 2021; and
- the inland navigation vessel is placed on the market (see question 11) not later than 31st December 2021; and
- the engine was produced before the beginning of the transition period (meaning 1st January 2019 for P < 300 kW and 1st January 2020 for P ≥ 300 kW).



The transition periods applicable to NRE engines, to be used in place of IWA and IWP, are those applicable to IWA and IWP (same dates as above).

[17] Reference: Regulation (EU) 2016/1628, Article 3, sub 33), Article 3(32), Article 58(3)(5)(6) and (7) as amended by Regulation (EU) 2040/1040".

Note: the latest applicable emission limits defined in Directive 97/68/EC on 5 October 2016 are:

1. In case of propulsion engines of all powers and auxiliary engines of more than 560 kW:

- V (37 kW ≤ P) - EU-stage IIIA

2. In case of auxiliary engines no greater than 560 kW:

a) for engines with variable speed the categories

- K (19 kW ≤ P < 37 kW) - EU stage IIIA
- P (37 kW ≤ P < 56 kW) - EU stage IIIB
- R (56 kW ≤ P < 130 kW) - EU stage IV
- Q (130 kW ≤ P ≤ 560 kW) - EU stage IV

b) for engines with constant speed the categories

- K (19 kW ≤ P < 37 kW) - EU stage IIIA
- J (37 kW ≤ P < 56 kW) - EU stage IIIA
- I (56 kW ≤ P < 130 kW) - EU stage IIIA
- H (130 kW ≤ P ≤ 560 kW) - EU stage IIIA

For further information on the use of propulsion engines for auxiliary power[18], as well as engines used as part of an integrated electrical, hybrid or other alternative propulsion system[19] reference is made to Regulation (EU) 2016/1628, Article 4, Article 24(8) and Regulation (EU) 2016/1628 Annex IV (table IV-5).

With respect to the FAQ's, reference is made to CESNI's and EUROMOT's FAQ publications, which is available at https://www.cesni.eu/wp-content/uploads/2018/11/FAQ_Engines_en.pdf

Note: The use of NRE / EURO VI engines in place of IWP / IWA engines is described under question 16. Moreover, a dedicated guide[20] for the procedure to marinize such engines was published by CESNI.

[18] Reference: Regulation (EU) 2016/1628, Article 4, Article 24(8)
[19] References: Regulation (EU) 2016/1628 Annex IV (table IV-5)
[20] Reference is made to Guide for the procedure to marinize NRE type machinery and equivalent engines like truck engines (EURO VI) and checking the eligibility for installation of these engines into inland navigation vessels available at https://www.cesni.eu/wp-content/uploads/2019/10/Guide_marinisation_en.pdf

<u>AMENDED LEGISLATION (ES-TRIN 2023)[21]</u>

As of 1 January 2024, ES-TRIN 2023 will enter into force, which will include changes to be the use and installation of Lithium-ion batteries on board inland vessels. As it takes some time before ES-TRIN 2023 enters into force it might be that some more minor changes will be implemented before 1-1-2024.

These amendments and additions concern the following provisions in ES-TRIN (2023/1):

The draft standard incorporates the various amendments identified by the CESNI/PT Working Group in its summary CESNI/PT (21) 1 rev. 3. These amendments concern in particular the following areas:

- Low flashpoint fuels and fuel cells,
- Life jackets,
- After-treatment systems,
- Waste water collection,
- Permanently installed firefighting systems for protecting objects,
- Passenger vessels,
- Recreational craft,
- Electric propulsion engines aft of the aft-peak bulkhead,
- Repair of engines in service,
- Retractable wheelhouses,
- Radar navigation installations and rate-of-turn indicators,
- Updating of references to the ES-RIS 2023/1,
- Special anchors with reduced mass,

but also editorial corrections.

<u>Concerning aftertreatment systems</u>:
Article 9.09 is amended as follows (marked grey):

a) (1) is worded as follows:

"1. The ~~exhaust gas~~ after-treatment systems shall not impair the safe operation of the craft, including propulsion system and power supply, nor block the exhaust system."

b) (2) is worded as follows:

"2. When the ~~exhaust gas~~ after-treatment system of internal combustion engines, which ensure the main propulsion of a craft, is equipped with a bypassing device, the bypassing device must comply with the following conditions:

a) In the event of a failure of the ~~exhaust gas~~ after-treatment system, the activation of the bypassing device must allow the craft to continue to make steerageway under its own power.

b) In the event of activation of the bypassing device, the by-pass device control system shall trigger an acoustic and optical alarm signal in the wheelhouse.

c) A by-pass device control system shall record in non-volatile computer memory all incidents of engine operation with use of the bypassing device. The information shall be readily available for the competent authorities."

[21] Reference is made to document CESNI/PT (21) 1 rev. 2 of 15th March 2022.

c) *(5) is worded as follows:*

"5. The requirement of (1) shall be deemed to be fulfilled when the vessel is equipped with

a) a second independent propulsion system (even if that second system also includes an ~~exhaust gas~~ after-treatment system) allowing the craft to continue to make steerageway under its own power; or

b) an after-treatment system with a bypass device according to (2); or

c) for a vessel with only a single-engine propulsion system, an alarm system allowing warning of the malfunctioning of the after-treatment system, combined with possibility to override the automatic shutdown of the engine, to continue operation for at least 30 minutes in order to reach a safe berth."

Concerning repair of engines in service:

1. Article 9.10 hereafter is added after Article 9.09:

"**Article 9.10 *Repair of engines in service***

1. Engine repairs are permitted provided that:

a) they are consistent with the type approval and existing engine parameter protocol;

b) the identity of that repaired engine is traceable such that the original engine that was placed on the market and installed on the vessel can be identified.

If the repairs result in the entire engine being replaced, the requirements of Article 9.01(2) shall apply. In particular, if a different identification number is assigned to the engine, it shall then be deemed to be a newly installed engine.

2. When carrying out maintenance or repair of an internal combustion engine with replacement of components, the person or company who carried out such maintenance or repair must provide a report which includes:

a) date of maintenance or repair,

b) description of maintenance or repair work done, including condition of engine before repair and reason for the repair,

c) list of components which were replaced or used on the engine, with the specifications of these installed components which show that the engine still complies with the type-approval,

d) confirmation of compliance with the engine manufacturer's instructions and the engine parameter protocol referred to in Article 9.05(1) after maintenance or repair,

e) when appropriate, the information displayed on the identification plate of the engine pre-repair and post repair,

f) when appropriate, supporting pictures."

The adding of article 9.10 will give more insight in repairs and maintenance carried out at the engines on board.

TAXONOMY[22]

General

Currently, some Member States have labelling schemes in place. These existing schemes are built on different classification systems for environmentally sustainable economic activities.

Given the political commitments under the Paris Agreement and at EU level, it is likely that more and more Member States will introduce labelling schemes or impose other requirements on financial market participants or issuers with regard to promoting financial products or corporate bonds as environmentally sustainable.

In such cases, Member States would use their own national classification systems to determine which investments qualify as sustainable. If those national labelling schemes or requirements use different criteria to determine which economic activities are considered environmentally sustainable, investors would be discouraged from investing across borders due to difficulties in comparing different investment options.

In addition, operators wishing to attract investments from across the Union would have to meet different criteria in different Member States in order to qualify their activities as environmentally sustainable. The absence of uniform criteria would therefore increase costs and significantly discourage market participants from accessing cross-border capital markets for the purpose of sustainable investment.

In order to address existing barriers to the functioning of the internal market and to prevent such barriers from arising in the future, Member States and the Union should be required to apply a common concept of environmentally sustainable investments when introducing requirements at national and Union level in relation to financial market participants or issuers for the purposes of labelling financial products or corporate bonds that are be placed on the market in an environmentally sustainable way. In order to avoid market fragmentation and harm to the interests of consumers and investors due to divergent notions of environmentally sustainable economic activities, national requirements that financial market participants or issuers must meet in order to market financial products or corporate bonds as environmentally sustainable should build on the uniform criteria for environmentally sustainable economic activities. Such financial market participants and issuers include financial market participants that make environmentally sustainable financial products available and non-financial undertakings that issue environmentally sustainable corporate bonds.

Appropriate technical screening criteria should be established for the transport sector, including for mobile assets. Those screening criteria should take into account the fact that the transport sector, including international shipping, accounts for almost 26 % of total greenhouse gas emissions in the Union. As stated in the Action Plan on Financing Sustainable Growth, the transport sector represents around 30 % of the additional annual investments needed for sustainable development in the Union, for example to increase electrification or support the transition to cleaner modes of transport by promoting modal shift and better traffic management.

The Commission should continue the existing expert group on sustainable finance of the Member States and give it a formal status. The tasks of that expert group will include advising the Commission on the appropriateness of the technical screening criteria and the platform's approach in developing those criteria. To that end, the Commission should keep Member States informed through regular meetings of member states' expert group on sustainable finance.

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[22] Related documents: Commission Delegated Regulation (EU) 2021/2139 of 4th June 2021,Taxonomy Regulation 2020_0852_EN_TXT / 210803-sustainable-finance-platform-report-technical-screening-criteria-taxonomy-annex_and Annex 1 Climate Change DA 20210604, Annex 2 Climate Change DA 20210604 / REGULATION (EC) No 1893/2006 of 20 December 2006 establishing the statistical classification of economic activities NACE Rev. 2 / Regulation (EEC) No 3037-90 old on NACE code / Regulation (EC) No 1165-98 old on NACE code / Regulation (EC, Euratom) No 58-97 old on NACE code / Regulation (EEC) No 3924-91 old on NACE code / Regulation (EC) No 1172-98 old on NACE code Regulation (EC) No 530-1999 old on NACE code / Regulation (EC) No 2150-2002 old on NACE code / Regulation (EC) No 450-2003 old on NACE code / Regulation (EC) No 48-2004 old on NACE code / Regulation (EC) No 808-2004 old on NACE code / Regulation (EC) No 1552-2005 old on NACE code

IVR is of opinion that the different labelling schemes throughout the EU should be combined/converted into **one** EU wide accepted standard emission label based on unified criteria.

Inland navigation Emission Achievement Label

Currently, an Inland Shipping Emission Achievement Label will be introduced in the Netherlands as of 1-1-2022.
For new engines (up to 20,000 operating hours), the manufacturer provides the necessary specifications to apply for a label. For older engines (more than 20,000 operating hours), a measurement must be made by a certified measuring company for which the costs are approximately EUR 6,000.
If both new and older engines are installed on board, the label is valid until the first engine has reached 10,000 operating hours after issuing your label.
For older engines, the label is valid for up to 10,000 operating hours. After that, another measurement must be carried out by a certified measuring company. The label is valid for 10,000 operating hours
For new engines, the label is valid up to 20,000 operating hours. After that, another measurement must be carried out by a certified measuring company. The label is valid for 10,000 operating hours.
If both new and older engines are installed on your ship, your label is valid until the first engine has reached 10,000 operating hours after issuing your label.
New engines come with a technical specification from the manufacturer. The specifications are valid for the label up to 20,000 operating hours. After that, these motor(s) must be measured every 10,000 operating hours by a certified measuring company.
From the moment of issue date (see label), you must specify your operating hours in the portal every three months.
If 1 or more engines are equipped with an aftertreatment system with Urea, you must report your Urea consumption every 3 months via the portal. This consumption must be demonstrated with purchase invoices.

The information to be provided by the owner is:

1. Entering Ship Data (L X B, Tonnage, M3, Passengers, etc.)
2. Entering Engine Data (all engines on board above 19Kwh.)
3. Documentation to be uploaded:
    1. Measurement reports of certified companies (for engines above 20,000 operating hours)
    2. Datasheets from the engine manufacturer (for engines under 20,000 operating hours)
    3. Bunker vouchers
    4. Photographs of engine time positions (not older than one week, if no hour meter is present, copies of the sailing time book are necessary. These are delivered via info@binnenvaartemissielabel.nl)
    5. Copies of Ureum purchase (if applicable aftertreatment system or Stage V engines)
    6. Copy of the declaration of incorporation (from CCR2 engines, otherwise an invoice/proof of which engine is built in)
4. Annual reporting should consist of
    1. annual fuel consumption of entire ship
    2. What types of fuel (HVO, FAME etc.)
    3. Operating hours per year per engine

Currently, realization does not yet find land in the Netherlands, due to, among other things, the high costs, lack of incentives for a lot of administration for the owner.

IVR is of the opinion that the threshold to a label is too high and awareness of the need in inland navigation is still lacking.

IVR has, in order to remove the barriers and to achieve the simplest possible awareness, developed a CO_2 calculation tool within the IVR inland vessels database. Based on his ship data, the owner can view in the database what his current propulsion engine emission is and what the results with regard to emissions are when using different types of fuels, adding percentages of bio and also installing, for example, a catalyst and / or a particulate filter and or a Stage-V engine. The calculation is automatically generated and results are shown in graphs in comparison with the average current inland shipping emission, and thus gain more insight into the possibilities and consequences.

A low-threshold calculation method that provides insight into the possibilities without already making investments.

The methodology of the IVR emission calculation tool is based on the European GLEC Framework, which is more or less accepted as a standard.

1. Purpose of the taxonomy

Just to meet its 2030 climate and energy targets and mitigate climate change, the EU faces an investment gap of €350 billion per year. In addition, further additional investments to achieve the EU's broader environmental objectives are estimated at €100 to €150 billion per year. To close these investment gaps, the financial sector must play a key role in reorienting flows to support the transition to a more sustainable economy. However, such a reorientation of capital flows requires a common understanding between all investors, financial institutions and companies across the EU of what constitutes a "sustainable investment".

As a result, a uniform EU-wide classification system ('the EU taxonomy') for sustainable economic activities was set up to steer green investments towards those activities that are essential for achieving the objectives of the European Green Deal. The EU taxonomy creates an operational list of economic activities with technical screening criteria, which determine in which cases each economic activity makes a substantial contribution to an environmental objective. The EU taxonomy results, inter alia, in:

1. Creating a uniform and harmonized classification system that provides investors, companies, policy makers and financial institutions with a common language about what is considered to be an activity that makes a substantial contribution to an environmental objective;
2. Creating transparency and certainty in environmental sustainability for investors and helping to shift investments where they are most needed;
3. Protects private investors against greenwashing;
4. Helping companies to become taxonomy-aligned;
5. Reduce market fragmentation and barriers to cross-border capital flows by applying a single, uniform taxonomy system instead of different taxonomies in the Member States;
6. Providing the basis for further policy development in the area of sustainable finance, including standards, labels and any changes to prudential rules. (prudential supervision is supervision aimed at promoting the financial soundness of financial institutions.)

2. Taxonomy approach explained

The European Commission (EC) will adopt the EU taxonomy as a set of delegated acts under the Taxonomy Regulation, based on advice from external experts from the public and private sectors and on the basis of a transparent process involving stakeholders, using robust methodologies and scientific evidence. For this purpose, as required by the Taxonomy Regulation, the European Commission has established a Platform for Sustainable Finance (PSF), a new expert group, the Technical Working Group (TWG), which replaces the Technical Expert Group (TEG) and advises the European Commission on the further development of the taxonomy.

The Taxonomy Regulation (Article 3) defines six environmental objectives:

1. climate change mitigation;
2. adaptation to climate change;

3. the sustainable use and protection of water and marine resources;
4. the transition to a circular economy;
5. pollution prevention and control;
6. the protection and restoration of biodiversity and the ecosystem.

On **1 January 2022**, a first Delegated Act on sustainable activities for climate change adaptation and mitigation entered into force.[23]

A second delegated act mainly covering the remaining environmental objectives 3-6 (and some additional criteria for environmental objectives 1-2) will be adopted on the basis of the platform's recommendations.

As such, the Platform has been mandated to focus on and make recommendations to the Commission on TSC for the second draft delegated act on sustainable activities for environmental objectives 3-6.

3. Calculation methodology

For each activity, the magnitude of its impact in relation to the objective was assessed, measured using a set of indicators (e.g. SO_x, NO_x and PM for pollution prevention and control).

The potential for improvement (i.e. the potential to reduce that impact) for the same set of indicators was then assessed. For each impact indicator, two scores were assigned to the activity (for impact and for improvement potential).

They were multiplied to obtain a combined score for that indicator. The greater the impact of an activity, the higher the priority to be given to it for that objective.

However, an activity with a high impact and low reduction potential should not be prioritized, as the possibility of making a substantial contribution to the achievement of the environmental objective is limited. So the higher the improvement potential, the higher the priority. The use of a score that combines both impact and reduction potential (aggregated across each of the indicators for the target) is therefore appropriate.

It was then possible to aggregate the different combined scores for each activity across indicators (with specific weighting factors). The overall score for each activity reflects the impact and improvement potential for all relevant impact indicators for the objective under consideration.

Based on this multi-criteria analysis score, a ranking (or sequence) of activities for each objective was produced. Illustrative sequences were generated using a series of weighting factors.

As calculation method looks at the EEOI (Energy Efficiency Operational Indicator). The EEOI provides a tool to calculate the operational energy efficiency of a ship. The EEOI is not yet mandatory and therefore its calculation is not necessary. The accuracy of the calculated EEOI depends on the data used to calculate it. EEOI is expressed in the CO2 index can be based on different cargo units depending on the ship type: [gCO2/t•nm], [gCO2/TEU•nm], [gCO2/m³•nm], [gCO2/lane m•nm], [gCO_2/pax•nm]. (nm = nautical miles)
EEOI = tons of CO2 /ton*nm ......

$$EEOI = \frac{Fuel_{consumed} \cdot c_{Carbon}}{Cargo_{transported} \cdot Distance_{sailed}}$$

Initially, the TWG mandate focused on developing technical screening criteria for environmental objectives 3-6 with only minor additional criteria for environmental objectives 1-2. The priority economic activities of the mandate were divided between the following eight different sectors:

[23] COMMISSION DELEGATED REGULATION (EU) 2021/2139 of 4.6.2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives

1. Agriculture, forestry and fisheries;
2. Mining and processing;
3. Production;
4. Energy;
5. Construction and buildings + ICT + Emergency services;
6. Transport;
7. Restauration and remediation + tourism;
8. Water supply, sewerage and waste management.

The first proposal for technical screening criteria was discussed with amongst others, IWT the undersigned and other experts, resulting in below printed Revision of shipping taxonomy mitigation criteria post-2025 in which the resulting changes are colored orange and those still with second thoughts and comments by the group of experts (not stated in detail below) are colored green.

"

Climate mitigation criteria - Inland vessels

3.3. Manufacture of low carbon technologies for transport

Description of the activity

Manufacture, ***financing***, repair, maintenance, retrofitting, repurposing and upgrade of low carbon transport vehicles, rolling stock and vessels.

The economic activities in this category could be associated with several NACE codes, in particular C29.1, C30.1, C30.2, C30.9, C33.15, C33.17, *N77.34* in accordance with the statistical classification of economic activities established by Regulation (EC) No 1893/2006.

An economic activity in this category is an enabling activity in accordance with Article 10(1), point (i), of Regulation (EU) 2020/852 where it complies with the technical screening criteria set out in this Section.

Technical screening criteria Substantial contribution to climate change mitigation

The economic activity manufactures, repairs, maintains, retrofits[24], repurposes or upgrades:

(...)

6.8. Inland freight water transport

Description of the activity

~~Purchase,~~ Financing, leasing, rental and operation of freight vessels on inland waters, involving vessels that are not suitable for sea transport. The economic activities in this category could be associated with several NACE code H50.4 in accordance with the statistical classification of economic activities established by Regulation (EC) No 1893/2006. Where an economic activity in this category does not fulfil the substantial contribution criterion specified in point (a) of this Section, the activity is a transitional activity as referred to in Article 10(2) of Regulation (EU) 2020/852, provided it complies with the remaining technical screening criteria set out in this Section.

Technical screening criteria Substantial contribution to climate change mitigation

[24] For points (j) to (m), the criteria related to retrofitting, ***repair, maintenance, repurposes or upgrades*** are covered in Sections 6.9 and 6.12 of this Annex.

1. The activity complies with one or more of the following criteria[25]:

(a) the vessels have zero direct (tailpipe) CO2 emission;

(b) where technologically and economically not feasible to comply with the criterion in point (a), until 31 December 2025, the vessels have direct (tailpipe) emissions of CO2 per ton kilometer (gCO2/tkm), calculated (or estimated in case of new vessels) using the Energy Efficiency Operational Indicator[26], 50% lower than the average reference value for emissions of CO2 defined for heavy duty vehicles (vehicle subgroup 5- LH) in accordance with Article 11 of Regulation 2019/1242.

(c – new) *The yearly average greenhouse gas intensity of the energy used on-board by a ship or a company's fleet during a reporting period[26] shall not exceed the limits set below:*

- *76.4 gCO2e/MJ from 1 January 2025;*
- *61.1 gCO2e/MJ from 1 January 2030;*
- *45.8gCO2e/MJ from 1 January 2035;*
- *30.6 gCO2e/MJ from 1 January 2040;*
- *15.3 gCO^2e/MJ from 1 January 2045;*
- ***Xg****CO2e/MJ from 1 January 2050.*

(d – new) *Vessels derive 100% of the energy used onboard from fuels or other energy carriers which achieve at least 80% greenhouse gas emission savings compared to their fossil fuel equivalent on a Well-To-Wake basis*

2) Vessels are not dedicated to the transport of fossil fuels.

3 – new) *The undertaking shall refer to the criteria in point 1) for the classification of its revenues and its operational expenses (OpEx). For the purpose of reporting the taxonomy alignment of its capital expenditure (CapEx) the undertaking shall refer to the portion of CapEx that complies with the technical screening criteria defined in the manufacturing section 3.3 – letter k)*

6.9. Retrofitting of inland water passenger and freight transport

Description of the activity

Retrofit and upgrade of vessels for transport of freight or passengers on inland waters, involving vessels that are not suitable for sea transport. The economic activities in this category could be associated several NACE codes, in particular H50.4, H50.30 and C33.15 in accordance with the statistical classification of economic activities established by Regulation (EC) No 1893/2006. An economic activity in this category is a transitional activity as referred to in Article 10(2) of Regulation (EU) 2020/852 where it complies with the technical screening criteria set out in this Section.

Technical screening criteria Substantial contribution to climate change mitigation

1. The retrofitting activity achieves one or more of the following:

a) ***Reduces*** fuel consumption of the inland ***passenger*** vessel by at least ***15 %*** expressed ***per unit of energy*** per ***complete journey (full passenger cruise)***, as demonstrated by a comparative calculation for the representative

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[25] *The criteria refer to operational requirements. The requirements are covenanted in the financial and contractual agreements between financial institutions/asset and owners/operators and reported ex post minimum annually. Fulfilling of the operational criteria will be evidenced via relevant policies and procedures by vessels operators, or via relevant contractual obligations on the vessels charters/ operators posed by vessel owners.*

[26] *The greenhouse gas intensity of the energy used on-board by a ship shall be calculated as the amount of greenhouse gas emissions per unit of energy according to the methodology and default values specified in Annexes I and II below. From the date of entry into force of the FuelEU Maritime Regulation, these Annexes should be updated accordingly.*

navigation areas (including representative load profiles ***and docking***) in which the vessel is to operate or by means of the results of model tests or simulations.

a 1 (new) ***Reduces fuel consumption of the inland freight vessel by at least 15 % expressed per unit of energy per ton kilometer, as demonstrated by a comparative calculation for the representative navigation areas (including representative load profiles) in which the vessel is to operate or by means of the results of model tests or simulations.***

b) (new) enables vessels to derive 100 % of the energy used onboard from fuels or other energy carriers which achieve at least 80% greenhouse gas emission savings compared to their fossil fuel equivalent on a Well-To-Wake basis, have the ability to plug-in at berth and are equipped with plug-in power technology;

4. Vessels retrofitted or upgraded are not ***exclusively*** dedicated to the transport of fossil fuels

This document still has to be finalized and agreed upon by the EU Committee before it becomes final.

FuelEU MARITIME

FuelEU Maritime is part of the Fit for 55 package directed at shipping. The goal of FuelEU is to reduce greenhouse gas (GHG) emissions of ships' when travelling to, from or within the EU. FuelEU takes into account all greenhouse gas emissions (not only CO_2) from the entire supply chain ('well-to-wake'), and aims to increase the use of Renewable and Low-carbon Fuels (RLF).

These fuels should represent 86-88% of the international maritime transportation fuel mix by 2050 to contribute to the EU's targets. The production and distribution are addressed in the Renewable Energy Directive (RED) and the Alternative Fuels Infrastructure Directive (AFID) respectively.

FuelEU Maritime applies to all vessels:

- of any flag above 5.000 GT [27] travelling to, from or at berth in ports in the EU
- Energy used at berth in an EU port
- 100% of energy used in intra-EU voyages
- 50% of energy used on extra-EU voyages

When will FuelEU take affect?

FuelEU will take effect as per January 1, 2025. The European Council adopted the General Approach.

It includes:

- Beginning January 1, 2025, applying to all ships above a gross tonnage of 5,000 whose purpose is transporting passengers or cargo for commercial purposes.
- Shore power requirements.
- The use of renewable and low-carbon fuels, and the extent to which they count towards GHG intensity reduction targets.
- Governance and enforcement.
- Specification about the verifier role.

The yearly greenhouse gas limit under FuelEU Maritime will be based on the average onboard greenhouse gas intensity of the fleet in 2020 – to be determined by the EU Commission.

[27] Several organizations are lobbying to reduce the limit to 400 GT in order to 'level the playing field'

Annual reduction targets will become more ambitious up to 2050 to reflect developments in low-carbon fuel technology and availability. Reduction targets will start at approximately 2% by 2025, and increase exponentially to 75% by 2050.

As a goal-oriented measure, FuelEU Maritime will be neutral in terms of fuel preference.

Shipping companies will need to calculate emissions per unit of energy used on board, based on their reported fuel consumption and the emissions factors of their respective fuels. It should be noted that FuelEU Maritime adopts a 'well-to-wake' approach to assessing a fuel's emissions factor. For the average shipowner, this means the impact and costs will be higher compared to other regulations such as EU ETS.

The emission intensity of biofuels and biogas, among others, will be determined using the RED Directive, whereas fossil fuels should be assessed using FuelEU Maritime's default emission factors.

Passenger ferries and containerships at berth in an EU port will be required to connect to an onshore power supply (OPS) as of January 1, 2030. Exemptions will be allowed in certain emergency situations, or for ships at berth for under two hours.

However: As for now FeulEU is presently not applicable for inland navigation.

PRESENT INLAND NAVIGATION FUELS

Almost all inland vessels have used gas oil as a fuel since the introduction of the diesel engine. It was only in 2013, as part of projects to reduce emissions from inland vessels, that the first tanker was put into operation whose propulsion is fully LNG-electric. With this application, emissions of carbon dioxide (CO2) and nitrogen oxides (NOx) have been reduced by more than 25% and 80% respectively.

Awareness to reduce emission in the inland navigation industry had already set in and new emission legislation required new propulsion types and alternative fuels.

Below an overview is given of the presently fuels and alternative fuels being look into to be added to, or totally replace diesel.

Vignette Oil Shipping Foundation (VOS)

In the Netherlands, the VOS Foundation has been in existence since 1990. Participation in the foundation means that the bunkering companies trade fuel that meets at least the current VOS specification. The VOS Foundation monitors this.

The addition of biofuel to inland diesel has been happening to a limited extent since 2011.
Inland navigation mainly uses fuel which meets the VOS ULS 2011 standard. This standard has been indicated by VOS that it aims for a zero FAME (bio) content. Due to logistical reasons, a certain FAME percentage content cannot always be prevented. The maximum FAME percentage is equal to the EN 590 fuel standard.
As of 1-1-2020, VOS is has changed to the VOS ULS 2020vs2 fuel quality, which assumes for the bio-addition the EN 590 standard of up to 7% FAME.

Besides the VOS ULS 2011, a lot of diesel has been sold in the years without FAME addition (being called "B0"). According to research, the percentage of this diesel B0 in inland navigation in 2019 and 2020 would have been 74% and 78% respectively. So actually in 2020 4% less bio addition as in 2019.

EN 590

The EN 590 fuel (being a diesel standard developed for road traffic) allows up to 5% bio-addition (B5).

Over time, an EN 590 B7 has been released in which the percentage of bio is 7% (the B7).

With respect to the EN 590 fuel reference is also made to the adopted Regulation (EU) 2017/654 of 19 December 2016 supplementing Regulation (EU) 2016/1628 of the European Parliament and of the Council with regard to technical and general requirements concerning emission limit values and type-approval for internal combustion engines for non-road mobile machinery (NRMM).

The current combustion engines that can still be installed in inland vessels must be equipped with a Stage-V type approval.

Regulation (EU) 2016/1628[28] of 14 September 2016 lays down the requirements relating to emission limit values for gaseous and particulate pollutants and type-approval for internal combustion engines installed in non-road mobile machinery.

[28] Regulation (EU) 2016/1628 amending Regulations (EU) No 1024/2012 and (EU) No 167/2013, and amending and repealing Directive 97/68/EC (1), and in particular Article 24(11), points (a), (b) and (c) of Article 25(4), Article 26(6), Article 34(9), Article 42(4), Article 43(5) thereof, and Article 48.

In Annex I - Requirements for other specific fuels, fuel mixtures or fuel emulsions of Regulation (EU) 2016/1628 is under I- Requirements for engines running on liquid fuels is Indicated:

Article 1.2.2.1.

In addition, unless the engine manufacturer complies with the requirement set out in point 1.2.3, he shall not indicate at the time of EU type-approval that an engine type or engine family may run in the Union on fuels available on the market other than those complying with the requirements of this point: (a) for petrol: Directive 98/70/EC or CEN standard EN 228:2012. Lubricating oil may be added according to the manufacturer's specifications;

a. for petrol: Directive 98/70/EC or CEN standard EN 228:2012. Lubricating oil may be added according to the manufacturer's specifications;
b. for diesel (excluding gas oil for non-road machinery): Directive 98/70/EC of the European Parliament and of the Council or CEN standard **EN 590:2013**;
c. for diesel (gas oil for non-road machinery): Directive 98/70/EC together with a cetane number of not less than 45 and a FAME content not exceeding 7,0 % v/v.

Article 1.2.3.

If the manufacturer allows engines to run on fuels available on the market other than those referred to in point 1.2.2, for example B100 (EN 14214:2012+A1:2014), B20 or B30 (EN16709:2015), or on specific fuels, fuel mixtures or fuel emulsions, he shall not only comply with the requirements of point 1.2.2.1, but shall also take all of the following measures:

a. specify in the information document set out in Commission Implementing Regulation (EU) 2017/656 (2) on administrative requirements the commercially available fuels, fuel mixtures or fuel emulsions on which the engine family may run;
b. demonstrate that the parent engine can meet the requirements of this Regulation for the declared fuels, fuel mixtures or fuel emulsions;
c. ensure that for the declared fuels, fuel mixtures or fuel emulsions, including mixtures of declared fuels, fuel mixtures or fuel emulsions, and for the commercially available fuel referred to in point 1.2.2.1, the requirements for in-service monitoring laid down in Commission Delegated Regulation (EU) 2017/655 (1) on the monitoring of in-service engines are complied with.

As such EN 590 is the fuel spec. which has to be used for achieving a Stage-V type approval.

This also means that **no other fuel** outside the spec. of the EN 590 can be used in case of a Stage-V type approved engine.

ALTERNATIVE FUELS

BIO FUELS

It's the Dutch authority's intention to increase of amount of added bio to inland navigation diesel in line with the implementation of Directive (EU) 2018/2001 and the Fuel Quality Directive (FQD) 2009/30/EC of 23 April 2009 .

Types of biofuel[29]:

With high blends of bio and diesel, there are considerable limitations in practice due to the (often less good) fuel properties and the regulations:

- The methyl esters are usually limited to at most B20 or B30 (20% respectively 30% methyl esters), depending on the engine type.
- For HVO, but this varies per engine type. In practice, HVO30, HVO50 and HVO100 (30%, 50% and 100% HVO respectively) have often been used in recent years.
- Waste-based biodiesel is a distilled product using i.e. animal slaughter waste as bio product.

It should also be noted that blends are sometimes delivered without even shipowner's knowing, which means that he is confronted with bio-addition without being able to take measures to prevent problems in advance. Of course, with all the consequences that entails.

FAME (fatty acid methyl ester)

FAME is produced from vegetable oils, animal fats or waste cooking oils by transesterification, where various oils (triglycerides) are converted into methyl esters. This is the most widely available form of biodiesel in the industry and is often mixed with regular diesel. The marine fuel specification standard ISO 8217:2017 contains additional specifications (DF grades) for distillate marine fuels with up to 7.0 volume % FAME. FAME diesel mixtures with up to 30% BTL content are also used in automotive applications and referred to as B20 or B30. International standards: EN 14214, ASTM D6751, EN 590.

Quality of FAME

It has already been indicated that the most commonly used biodiesel components are methyl – and ethyl esters of vegetable oil and of used vegetable/animal oil and fats.

The problem, however, is that the raw materials for the applied FAME can vary greatly by location and by country. Inland navigation is a cross-border industry, where given the potential impact of FAME's quality, it should actually be European-wide identical.

The FAME used for blending should meet specification requirements of EN 14214 or ASTM D6751. The fact however is that there are considerable quality differences within the same technical specification, EN14214, which must be met. There is no obligation for unambiguous good quality for FAME throughout the EU.

The cost aspect also plays a big role in this. To be precise, possible internationally more limited available high quality FAME will be more expensive than the lower quality.

Two groups of diesel substitutes are distinguished, namely:

[29] Reference is also made to DNV'-GL's publication Using Biodiesel in marine diesel engines" of October 2020 and TNO's report TNO 2020 R11455 of November 2020.

Fatty Acid Methyl or Ethyl Esters
Fatty Acid Methyl or Ethyl Esters, also often referred to as **FAME** or **FAEE.** The variants are often indicated by the raw material, followed by the letters ME of Methyl Ester:

1. UCOME: Used cooking oil methyl ester;
2. SME: Soybeans Methyl Ester;
3. RME: Rapeseed Methyl ester;
4. PME: Palm Oil Methyl Ester;

and

Hydrated Plant Oil (HVO)
HVO is a so-called paraffin diesel, which is often made from the same raw materials as the first group, but has a different process.
These diesel substitutes can be used more or less directly in a diesel engine in a high blend or pure biofuel.

FAME (Fatty Acid Methyl Esters) is the cheapest and mostly used solution for this alternative diesel part and is made by turning oils – such as cooking oil – into fatty acid esters.

Fatty acid esters come mainly from palm oil. This is one of the cheapest types of FAME where, however, the palm oil can already solidify at room temperature.

All problems of blending (FAME) and biofuel must be avoided and it is therefore essential that strict regulations and high quality requirements are established for the blended FAME to ensure that the presence of SMGs (saturated Monoglycerides) and SGs /ASG (Sterol Glucosides/acylated sterol glycosides) is limited. The solubility of both substances in FAME and fuel is very limited and is currently directly associated with the slamming of the filters (in addition to microbiological contamination) and engine failures on board our ships. The presence of SG, ASG and/or SGS is currently **not** limited by DIN EN 14214.
The concrete question therefore arises: how can it be ensured that the right processes and steps are carried out in the process of digestion/refining to ensure that these components are reduced and failure is prevented?

The mixing is (yet) not an obligation for inland navigation, however, to comply with the agreements of the Climate Agreement and to achieve the mixing obligation for the other sectors (road traffic), may be mixed in inland navigation which may include as Reduction.
"Previously, crops were used as soy and palm oil, because they were fully available. Recently, these food crops may or may no longer be used as biofuel for sustainability reasons and, for example, the aforementioned used frying fat is used as a base. As a result, the fuel composition changes, because properties of substances in detail are different.
The composition can also change due to changes in the fossil part of the fuel, because it may have a different origin (from Russia, Norway, Saudi Arabia to the US) and is therefore not constant.
From the environmental point of view, adding bio-component and the decrease in Sulphur in diesel are great developments. However, in practice, biodiesel and the decrease in Sulphur do cause problems.

For inland navigation, the use of Hydrotreated Vegetable Oil (HVO) and biodiesel currently seem to be the most obvious options.
Biofuels can be mixed without problems and no modifications to the engine seems to be needed. Biodiesel can be added to diesel without problems, if added to a certain limit. This is already happening a lot in road transport. Although there presently problems start to emit.

As stated above biofuels do also have their negative sides to which serious attention should be paid. Switching over to any type of biofuel or adding of bio should always only be done after detailed consultation with the engines manufacturer.
It should be taken into account that adding bio or other components to the original fuel type, might create conflict with warranty conditions of the manufacturer and may even result in losing engine's emission stage level certification according the NRMM regulations and NRMM's certification.

The VOS ULS 2011 is a specification specifically used for inland navigation. The VOS ULS 2011 specification is broadly the same as the EN590 specification but focused on inland navigation. The fact is that in the new VOS ULS 2011 gas oil it is not always prevented for logistical reasons. For the VOS ULS 2011 gas oil is aimed at a maximum FAME percentage equal to the EN 590 (0.30% v/f).
The minimum amount of bio to be added in inland gas oil can range from 5 to 7 %, resulting in possible damage (blockage filters by bacteria formation). It is unclear what the legal policy will be with regard to the maximum of this addition in inland navigation. The fact is that the addition of max. 10 % bio in road traffic petrol has already caused problems. From commercial consideration and CO2 compensation it is interesting for suppliers to add bio.

Although the supplied (bio) fuels all have to meet European specifications, problems are more and more frequently experienced. This might very well be that the overflow of bio is unofficially mixed with gasoil for inland navigation.

In 2018, 72% of the annual commitment (8.5%) filled by waste streams. In this, used cooking oil (UCO) with 56% a large share. These waste streams are used for biodiesel. What is striking is that relatively few different raw materials are used and that the origin of raw materials has a stronger international character than in crops is the case. In The Netherlands, the cooking oil used for organic has a greater origin outside Europe.
It however seems that with regard to the determination of HBE's of renewable energy supplied, such as from used cooking oil will be kept outside this system of marketable HBE's and bio in which cooking oil has been added will not be rewarded with an HBE.

It should also be noted that mixtures are sometimes supplied without the knowledge of the shipowner, which means that he is faced with bio-addition without being able to take measures to avoid problems in advance. Of course, with all the consequences that entails.

The motion on the investigation into the risks was submitted by Mahir Alkaya of the SP and Roelof Bisschop of the SGP. The motion as adopted reads:
"
Motion by BISHOP and ALKAYA
Presented 20 May 2021
The House, after hearing the deliberations, noting that the government intends to include inland navigation under the blending obligation for biofuels;

- *whereas blending biodiesel can pose risks to marine engines and no targeted research has yet taken place;*
- *whereas, according to the government's plan, inland navigation is confronted with the regular, high blending rate and associated price risks in one go; calls on the government to commission a study in the short term on the risks 2000s of different types of biofuels for marine engines in inland navigation;*

calls on the government, in consultation with sector organizations, to examine how the introduction of the blending obligation in inland navigation can be carefully designed, and to inform the House about this before the consideration of the intended draft decision for the revision of the Energy Transport Decree."

Their motion not to maintain the blending obligation as long as safety, suitability and durability are not guaranteed was also adopted. They also pointed out that enforcement and compliance on the biofuel supply chain is complex and susceptible to fraud.

Actions IVR

On the basis of consultations with the Minister previously held by IVR and a number of market parties, in which IVR, also on behalf of insurers, informed the Minister that IVR is in favor of sustainability and greening in inland shipping.

IVR has informed the Minister that although RED II is a European directive and thus gives Member States their own discretionary power to integrate and interpret the directive in national legislation, IVR is of the opinion that, given the international nature of the inland navigation sector, things should also be considered in a European perspective.

IVR shares the opinion of CBRB/BLN that the first step that should now be taken by the Ministry, concerns the release of research funds. An independent technical investigation into the consequences of biofuels on different types of engines are not only desirable but necessary in this whole discussion.

In contrast to road traffic, there is indeed no blending obligation for Dutch inland navigation to this day. Since 2011, minimal, but also random bio fuel has been added. However, this often concerns less than 5% biofuel. The TNO report indicates that at the moment only 30% would sail on biomixing. From information from the market, this number seems to be even lower. Furthermore, the VOS (in accordance with which specification the Dutch fuel suppliers often supply their fuel) stated in its specifications for the VOS that the FAME percentage in its fuel delivered as of 2011 spec. VOS ULS 2011 (Ultra Low Sulphur) indicated that the VOCs strive for a zero FAME content. Due to logistical reasons, a certain FAME content cannot always be prevented. The maximum FAME percentage is equal to EN 590. The max. percentage fame was in the 2011 spec. only 0,3 % v/v.

VOS in the most recent new inland fuel from 01.01.2020 has also switched to ULS 2020vs2 fuel quality, which for the bio addition equals the EN 590 standard of up to 7% FAME.

As 2nd step, (after completion of the independent and technical research) IVR indicates (based on the research results) which FAME quality should be used, which, given the significant quality differences within the same technical specification EN14214 should be stricter.

IVR shares the view that blending biofuel should not lead to any safety risk for inland navigation.

Apart from the major differences within the current FAME spec. in IVR's opinion, there is still a lot of uncertainty about the availability and availability of an equal quality biodiesel as well as HVO in the Netherlands and certainly within Europe.

That is why IVR also advocates checking the delivered fuel quality by means of a standard automatic sampling during bunkering, in order to be able to determine incorrect deliveries and to find out the source but also to be able to monitor and control the spec. used.

There must therefore be unambiguous but above all clear information to inland shipping about the required quality and blending of biodiesel. As well as clear information on the inevitable necessary measures to be taken on board to prevent malfunctions and damages.

Undeniably, the use of bio-diesel will have a cost-increasing effect on inland shipping, due to the necessary good care, increased filter use and decrease in the service life of fuel pumps and injectors and decrease in the service life of fuel pumps and injectors and thus a higher maintenance frequency of the engines. Not to mention the higher consumption and higher fuel costs.

IVR therefore argues that the proposed biodiesel with max. 16.4% organic (consisting of max. 7% FAME diesel and 9.6% HVO) and 9.6% HVO) must be available throughout the EU. This is to prevent problems in other countries after bunkering of other fuel.

Finally, it can be noted that the TNO report TNO 2020 R11455 of November 2020 report TNO 2020 R11455 of November 2020 on the use of biodiesel in inland navigation contradicts the TNO report MON--RPTRPT--033033--DTSDTS--20072007--01813 issued by TNO with regard to the introduction of bio and low sulfur fuel in inland shipping.
IVR has also indicated to the Minister that other initiatives such as setting up a guarantee fund might also be worthwhile to be considered.

IVR has indicated with respect to the Terms of Reference (ToR) that, in the opinion of IVR, the objectives should be that there is clarity about:

- Safe navigation when using biofuel
- The degree of corrosion of tanks and fuel system
- The degree of damage risk, wear and tear and possible shortening of the service life of the engine and after-treatment installation components
- Availability and unequivocal quality of biofuels within the EU
- Guaranteed quality of the biofuels to be supplied
- Price and maintenance consequences (good care, possibly increased filter use and possibly reduced maintenance intervals for engine and after-treatment installation.

As additional research questions, IVR has indicated that the following questions should be part of the ToR, namely:

1. Is admixture with FAME possible and within what specifications would the quality requirements of the FAME spec. in order to prevent problems with pollution, oxidation, formation of monoglycerides and glycosides, flake formation, corrosion of tanks?
2. Will the from point 1. resulting FAME spec. be EU-wide available?
3. To what extent can the government give guarantees with regard to the minimum required specifications of the bio-admixtures to be delivered throughout the EU within the desired percentages of bio-admixture (B5 / B7 / B20 / B30, or in combination with a part of the admixture of HVO admixture with or only HVO), or adequate quality control of the delivery;
4. How does the government view quality control, does representative sampling become a requirement for government delivery? And if so, what are the consequences of this?
5. If not EU wide the same quality or in any case biofuel is not available in certain admixture and therefore inevitable mixing of various types of fuels and qualities in the fuel tanks will arise, what is the impact on the fuel system, the pollution, the combustion and therefore the damage risk, wear and service life of various engine and aftertreatment plant components?
6. Clarity about the maintenance, wear and service life impact of using bio for both the fuel tanks, the fuel system, the engines and the aftertreatment installations, based on the various proposed bio-percentages and fame/ bio components to be used in the fuel.
7. In what way does the government provide good open information of the research results to the market and information about the measures to be taken, good family care, tank cleaning, etc.

8. To what extent is taking a legally representative sample (automatic sampling) necessary to maintain good quality feasible and necessary?
9. Can engine manufacturers indicate in writing which fuel (bio admixture (type and max. percentage)) can be used without problems in their type of engines and do they then remain within the EN 590 spec. and their emission certification, in and out of warranty and if not why not?
10. What are the consequences according to the engine manufacturers (in writing) when using various percentages of bio-fuel at maintenance intervals and components lifetime when using bio admixture and to what extent, per type of admixture %.
11. What is the availability of e.g., HVO nationally and internationally and what are the cost consequences compared to FAME bio-admixture percentages (B5 / B7).
12. Will/can the government guarantee delivery of the right quality?
13. Can the FAME spec. (EN141112) be adjusted or the possibly permitted FAME blending quality which lead to fewer problems are enforced by the government / governments within the EU? If not, how does the government / suppliers expect to be able to meet the quality of bio-admixture (FAME and/or HVO or another bio-admixture) which will follow the bio-admixture specification resulting from the research?
14. To what extent is the government prepared to reach an agreement with other EU memberships for international guaranteed quality and supply guarantees of good FAME / bio-admixture? And to what extent does the government consider this feasible in the short term and if not in the short term, which term or EU-wide?
15. Can/will, if it must be concluded that bio-admixture with FAME due to the broad spec. of FAME and the inability to change this in the short term (before 1-1-2022) or the FAME spec required for a good bio-admixture. introduction of RED II / revision of the Energy Transport Decree to be postponed?
16. How does the government foresee the realization of the close involvement of market parties promised by the Minister during the investigation and implementation thereof?

The government has awarded the additional research to NEN with the objective of reporting before the end of October 2021. IVR realizes that the available time, partly in view of the holiday periods, is a very limited one to arrive at thorough research and results because long-term effects must also be investigated and also clarity about an EU-wide quality supply, control and possible adjustment of the FAME specifications to be used within the bio-diesel mixture for inland navigation EU-wide.
At the Minister's commitment, IVR will continue to be closely involved in this investigation.

Status (November 2021):

Recently, the Dutch government shared the following documents with the House of Representatives (2nd Chamber). Energy Transport Decree (RED II) calendar years 2022 to 2030 | House of Representatives of the 2nd Chamber. It has to be noted that already now a revised version of RED II being RED III is being discussed in which the percentage steps increase to reach the 2030 emission reduction goal by adding bio will be more challenging, also because of the delay of implementing RED II. Implementation of RED III is foreseen to be 1-1-2025.

In summary, this means that from 1 January 2022 inland navigation would not yet be covered by the annual obligation to add the percentage of biofuel, but would be postponed to 1/01/2023. However, inland navigation will fall within the scope of the Fuel Quality Directive (FQD) 2009/30/EC of 23 April 2009.

Since 2013, inland shipping has already been covered by the sustainable energy system. From 2022, fuel suppliers will also have an obligation to our sector. Based on the Fuel Quality Directive, a reduction obligation is a requirement (this was already an obligation a few years ago, but the Dutch government has not implemented this in regulations).

The reduction obligation means that it is demonstrated annually that fuel suppliers reduce the CO_2 footprint in the fuel chain **by 6%.** However, this, as stated before, will not increase annually as is intended by RED II, which provides for an annually increased % of the organic addition.
They demonstrate this in the Netherlands by submitting REU's (renewable energy units) for the reduction obligation. The fuel suppliers can achieve the reduction within the sector by, for example, supplying biofuel or by purchasing the REU's themselves in other sectors such as road (until 2025). It is therefore **not** an obligation to use renewable energy (biofuel) in the sector, but to pay for a contribution to make transport more sustainable. It is not yet clear whether the fuel suppliers will purchase the REU's themselves or will add 6% organic. Just like the financial consequences of either are still clear. Discussions take place with the fuel suppliers.

For the time being, we have to wait and see the results of the research that is currently being carried out by NEN. The Dutch government has decided to (for the time being) abandon the intention to bring inland navigation under the scope of the annual obligation (and thus the blending of biofuel up to 16.4%). Although the reduction obligation applies (by the fuel suppliers to 6% according to FQD). This gives more time for the research that is being carried out for the time being.

IVR advised the fuel suppliers by HBE's themselves and waited for the outcome of the NEN investigation before actually adding bio.

After the research has been completed, the plan is to discuss the results of this research with the various stakeholders (including IVR).

Status November 2022
The annual obligation to add the percentage of biofuel, but would be postponed to 1/01/2023, however for reasons stated in this paper, this again will be postponed until agreement on an EU wide acceptable blend is achieved with Germany and Belgium.
To agree on an EU wide acceptable blend, as stated above the Dutch government has authorized the start-up talks with all parties interested, such as users, engine manufacturers, bunkerers, blenders, associations of shipowners and IVR in order to establish the specs and percentages of bio which are acceptable for use in inland navigation for all parties concerned, including supply and quality control of this spec.

Two meetings have taken place and input has been given by parties present, of which engine manufacturers regretfully were not able to attend, to Panteia with respect to views regarding questions to be answered such as:
1. What are the current experiences with the blends?
2. Which (renewable) fuels are used in inland navigation?
3. What experiences do you have? Think of operational use & safety, but also delivery and price
4. Which ones are suitable and which are less suitable? What are the points of attention for each of the fuels?

And the general question to the participants: Describe which renewable fuel(s) can be safely used in inland navigation (and which cannot), and why?

In the meantime the Dutch government has started talks with Belgium and German authorities to agree on an EU wide use of this specific inland bio-fuel.

Technical challenges of bio-fuels (use of bio components (Fame) to diesel)

It's known that the use of biofuels also can create technical problems on board which need to be addressed. Problems occurring are:

Addition of bio components to diesel

Unlike road traffic, there is no additional obligation for Dutch inland navigation to date nor in the most EU countries.

Since 2011 in inland navigation one started slowly with diesel fuel with an added bio-component, but never more than 5% Fame. The focus of the suppliers was to limit the added amount of bio as much as possible.

Vos specs even stated: "*VOS strives for a zero FAME content. Due to logistical reasons, a certain FAME content cannot always be prevented. The maximum FAME percentage is equal to the EN 590 (being 5% FAME)*". It's estimated that in 2019 only 30% of the fuel bunkered in Dutch inland navigation contained some % of Fame. In 2011 also Sulphur % in fuel was strongly reduced (Sulphur content has been reduced from 1000 ppm to 10 ppm.). This reduction of Sulphur makes the diesel fuel scraper and reduces lubrication. IVR published a comprehensive report on this in 2010 on the potential consequences and risks of reducing Sulphur content in inland waterways. 30

Biodiesel attracts up to eight times more moisture than normal diesel. Moisture is a first source of possible problems. How does moisture (eventually water) get into the fuel tank now?

Temperature fluctuations, dark spaces, long storage (e.g. after a winter) and poor sealing of the fuel filling opening ensure that moisture/condensation is given a chance. Now there's always a percentage of moisture in fuel. Diesel can absorb up to 0.02% water, without losing quality. If there is more 0.02% moisture in the diesel, this will slowly sink to the lowest point of your fuel tank. Too much moisture reduces the lubricating effect of the diesel fuel and will eventually lead to bacterial growth. Bacteria are recognizable as a black sludge. This bacterial growth must be removed from the diesel before they can clog the fuel filter. If fuel filters become completely clogged, your engine will no longer run, with all the consequences.

Microbial growth:

Bacteria and mold may grow if condensed water accumulates in biodiesel fuel. Microbial growth leads to excessive formation of sludge, clogged filters and piping. Frequent draining of tanks and the application of biocide in the fuel may reduce or mitigate microbial growth.

Filters clogged by bio-addition causes poor combustion and thus problems in the combustion chamber of the engine, which can lead to serious damage. It has also been shown in practice that atomizers have a shorter life span, break down more often, with poor combustion resulting in possible engine damage. The life of filters by adding bio is also greatly shortened. It is not yet clear what the bad combustion does with the emission, but it certainly does not improve. Long term effects are not yet known.

Oxygen degradation:

Biodiesel can degrade over time, forming contaminants of polymers, and other insolubles. Deposits in piping and engines could form compromising operational performance. In advanced stages, this could lead to increased fuel acidity, which could result in corrosion in the fuel system and accumulation of deposits in pumps and injectors. It is therefore recommended not to bunker the fuel for long-term storage before use, but to treat the fuel as fresh goods and to use it within a relatively short period of time. Adding antioxidants to the fuel at an early stage may improve the ability of a somewhat longer time of storage without degradation.

30 "The possible consequences and risks of reducing Sulphur content"- 2010

Low temperature:
Biodiesels in higher concentration usually have a higher cloud point than diesel (depending on feedstock), leading to poor flow properties and the clogging of filters at lower temperatures. It is therefore important to know the product's cold flow properties and to keep the storage and transfer temperatures above the cloud point.

Corrosion:
This is most critical for biodiesel in higher concentration (B80-B100). Some types of hoses and gaskets could degrade, leading to loss of integrity and interaction with some metallic material such as copper, brass, lead, tin, zinc, etc. It could also result in an increased formation of deposits. Hence, it is important to verify that these components in the fuel system are endurable and can be used together with biofuel.

Possible degeneration of rubber sealings, gaskets and hoses:
It is important to verify that these components in the fuel system are endurable and can be used together with biofuel.

Conversion:
Biodiesel has shown to have a solvent property, so when switching from diesel to biofuel it is expected that deposits in the fuel system will be flushed, clogging fuel filters. It is recommended to flush the system and/or to monitor filters during this period.

Consequences of a new standard specification ranges of bio (Fame);
Issues to be dealt with when it's clear which new standard of specification ranges of bio (Fame) can be safely used are:

Quality control
How to make sure that the quality is consistent throughout the EU throughout the supply chain? And how will this be effected when bunkering (e.g. automatic representative samples whilst bunkering)?

Availability
Will there be enough of the respected bio-fuel available throughout the EU for inland navigation and at what cost?

Creating awareness[31]
Creating awareness with inland navigation bio-fuel users what's required on their part with respect to "good housekeeping". For example with respect to tank cleaning etc.

Technical adaptation
To what extent will, due to the new standard inland navigation fuel, adaptations to the engines be required by manufacturers to fuel system filters injection/injectors, fuel pumps etc.. This might differ per manufacturer and engine type and consultation with manufacturers will be required.

Increasing % of bio periodically
As set by RED II and even more by the upcoming RED III the percentage of bio required to be added will increase periodically. Will this encounter further change of fuel specifications. Will engine type approval need to be reviewed/ re-approved? [32]

Practical obstacles for using FAME

[31] Reference is made to IVR's leaflet on bio-fuels available at https://www.ivr-eu.com/wp-content/uploads/2021/12/IVR-Technical-Leaflet-Addition-of-biofuel_edit-21.12.2021.pdf
[32] Reference is made to chapter WHEN USING MORE THAN 7% FAME of this document

The goal is to use FAME as a bio-fuel addition to diesel with different percentages over the coming years (according to RED II / RED III) and to give owners and manufacturers the choice of using / approving (engines NRMM type approved) different percentages of FAME to be added.

Currently diesel (B0) without any bio component is generally available throughout the whole European Union, whereby it has to be noted that retaining the same quality of diesel throughout the EU is already now a challenge. Let alone what it would be when different percentage of FAME adding would be used throughout the EU. Good quality control would be quite a challenge, apart from the fact that it would require different logistical challenges for bunkerers to be able to supply all these different blends of diesel throughout the EU.

Another challenge is the challenge of finding a better EU wide accepted increase quality specs of FAME and its availability throughout the EU.
In all; this seems an almost impossible task with quite some consequences for owners, also in view of the "good housekeeping" which is required when using FAME diesel blends.[33]

Currently there is one logistical chains for the supply of diesel in inland navigation. When however using different blends with different % of FAME, which %, will also periodically need to change in view of the RED II / RED III requirements, different logistical chains will be required, which will increase the difficulty in quality control, difficulties for owners where to bunker what blend etc..
From a commercial point of view or legislative point of view it, to my opinion will be difficult if not impossible nor realistic to introduce in due time one diesel/Fame blend throughout the EU.

HVO (Hydrotreated Vegetable Oil)

HVO is a very pure and high-quality diesel. It has a slightly lower density (specific gravity) than conventional diesel. As a result, HVO does not meet the EN590 standard for regular diesel, but does meet the new EN15940 specification for paraffinic diesel fuel. Technically, this new type of diesel can be used in almost all modern diesel engines.

HVO or HDRD (hydrogenation-derived renewable diesel) is the product of fats or vegetable oils – alone or blended with petroleum – refined by a hydrotreating process known as fatty acids-to-hydrocarbon hydrotreatment. Diesel produced using this process is often called renewable diesel to differentiate it from FAME biodiesel. The overall production process is typically more costly than for FAME biodiesel, however HVO/HDRD is a drop-in fuel which can be directly introduced in distribution and refueling facilities as well as existing diesel engines without any further modification. During the production process, hydrogen is added to vegetable oil, to create a fuel that is very similar to conventional diesel and that can be used in many medium and heavy engines.

This makes HVO a fossil-free and renewable fuel with enormous advantages in terms of sustainability. HVO gives a very high CO_2 reduction of no less than 90% compared to diesel and lower emissions of harmful emissions such as particulate matter, nitrogen and sulfur.

Characteristics of HVO diesel;
- Completely fossil-free diesel
- Reduces CO2 emissions by 90% compared to regular diesel
- Very low emissions of harmful emissions such as nitrogen and soot

[33] Reference is made to IVR's leaflet on bio-fuels available at https://www.ivr-eu.com/wp-content/uploads/2021/12/IVR-Technical-Leaflet-Addition-of-biofuel_edit-21.12.2021.pdf

- Contains virtually no sulphur particles and aromatics
- Does not contain FAME biodiesel components that can cause contaminated filters
- Is well biodegradable
- Is virtually odorless
- Is more resistant to freezing temperatures. It only freezes at -20ºC
- Has a relatively high cetane number of more than 70
- Has a slightly lower density (specific gravity) than conventional diesel

As stated, HVO does not meet the EN590 standard for regular diesel, but does meet the new EN15940 specification for paraffinic diesel fuel. As such HVO can be used in Stage-V engine as a mixture of HVO and diesel in all % grades, but also for 100%, without affecting the engines type approval.

The renewable diesel HVO can be tracked up to a rate of 30% to 40% and still complies with the specifications. It is identical to GTL, burns good and reduces soot. An 30% increase in HVO in diesel reduces CO2 emissions by about 27%.

HVO can be used without modifications in existing engines. So it seems to be an interesting option for inland navigation. The disadvantage is the higher operating costs because HVO is still more expensive.
Even with the use of biofuels, no NRMM emission requirements are currently met and after-treatment of exhaust gases will be required.

From market research and the information received through the Biofuel Hotline, which was set up at the end of 2020 by IVR, together with CBRB, Royal BLN-Schuttevaer, NOVE and VOS, in order to gain insight into the experiences, problems and work on solutions in the use of biofuels, appears that using HVO gives limited to no problems in diesel engines. Also reference is made to the Port of London report on Emissions and Performance of Alternative Diesel Fuels on PLA Harbour Service Vessel – Kew, available at IVR.

<u>HVO biodiesel disadvantages</u>

- Nitrogen (NO_x)
  Although the emission of CO_2 and soot is greatly reduced, the emission of nitrogen and particulate matter remains virtually the same compared to conventional diesel based on fossil raw materials.
- Limited raw materials
  In theory, HVO biodiesel is produced from renewable substances, but in practice it appears that many of these substances are currently limited in availability. In order to scale up the production of these raw materials, (agricultural) land will have to be extracted and that may contribute to the deforestation of the planet.
- Cost
  Due to the limited raw materials and a relatively complicated production process, the costs of HVO biofuels are currently often higher than those of regular fuels. Nevertheless, traditional refineries can easily be converted once the demand for HVO increases.
- Availability
  Presently a lot of parties, road, train, inland navigation, costal navigation and industry using diesel, are looking for alternatives, of which HVO seems to become the most wanted, causing serious question with respect to availability of HVO for the relatively limited inland navigation market.

<u>Waste-based biodiesel</u>

Waste-based biodiesel is a distilled product that can be directly blended at different percentages or even at 100% (B100) with conventional diesel and is presently starting to be used as a fuel, typically in trucks, buses, vans and cars. It however can also be used in inland navigation diesel engines.

To produce waste-based biodiesel, severely degraded fats & oils are processed to remove impurities. Any free fatty acid present in the oil is reduced to a manageable level limiting issues further down the process. The oil is reacted again, under different conditions, and at this stage the vast majority of the biodiesel is synthesized. Any oil that is not converted at this stage is collected and put back into the process, ensuring a high conversion to biodiesel. The discharges from the previous two steps are collected and then reacted together from which fertilizer and glycerin products are produced. Post-reaction the crude biodiesel is put through a distillation column as a final polish to produce biodiesel of a consistent high quality.

As such Waste-based biodiesel is a fossil-free fuel and quite similar to HVO, but momentarily not yet used in inland navigation, as such no practical use and result / consequences of using Waste-based biodiesel in inland navigation is known.

GTL (Gas-to-Liquids)

GTL is the abbreviation for Gas To Liquid. It is the liquid diesel fuel that is obtained synthetically from natural gas and as such doesn't result in a CO_2 reduction. Natural gas is a fossil fuel that is widely available. The production of GTL is done according to the so-called Fischer-Tropsch process.

The first reactions with using GTL are positive.

The fuel burns more efficiently than conventional, petroleum-based, standard diesel. With the greatest advantage of being less local emissions and less soot.

Product features of GTL:

- Virtually free of sulphur and aromatics
- Clear as water
- Virtually odorless
- High cetane number (75 – 80)
- Non-toxic
- Well biodegradable
- Good Cold Filter Plugging Point (CFPP) properties all year round, better than -20°CGTL
- Can be applied directly without investments in infrastructure or adaptation to diesel engines.

GTL alone is not enough to meet the NRMM emission requirements. Also when using GTL, after-treatment and thus type approval of motor with after-treatment will be required or an exemption will be requested.

The European legislature (CESNI/CCNR) is critical of exemptions. Exemption suffered only for one specific vessel and should be requested through the Commission of Experts (in the Netherlands through the PI's and Class Offices). Unfortunately, the application procedure takes a long time, from at least 1 year to 2.5 years.

The long-term consequences for using GTL in standard diesel engines related to wear, maintenance and life span of the various components is not yet known.

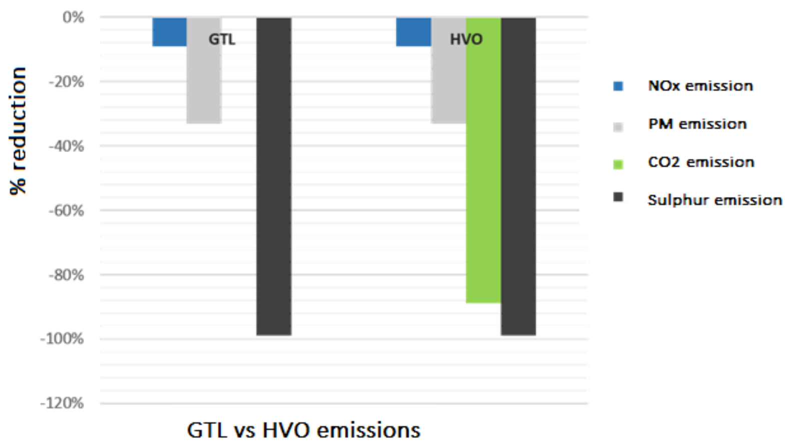
As stated; GTL can be used seamlessly in diesel engine. However, as with any transfer to a fuel other than conventional diesel, older vessels should be used to look for possible fuel leakage by shrinking gaskets. GTL does not contain aromats that ensure the so-called 'seals well' as when using conventional diesel. When another product is then used (with aromas), the gaskets will swell again and no more leakage occur. It is good to check the rubber seals on the engine and the bunker tank for leaks in particular in the first period. Experience shows that older seals in particular can leak.

Ordinary diesel, with bio component, can contain much more water than GTL. So you would think GTL therefore offers less breeding ground. But almost all manufacturers indicate that GTL is as sensitive to bacterial and fungal growth as the other diesels. After all, these bacteria need water to grow in and that water can also end up in GTL. According to EG Fuel, GTL is less susceptible to bacterial formation. Several users endorse this and say in practice that bacterial growth in GTL is less than in ordinary diesel.

Focus point:
It is not clear whether the manufacturer's warranty is maintained when using GTL in new engines. It is important to inquire about this with the manufacturer in good time.

Comparison GTL and HVO diesel
Both products come from the same type of process. This process ensures that unsaturated hydrocarbons are no longer in the fuel. Because these hydrocarbons have been removed from the fuel, this fuel burns much cleaner than normal diesel.
As a result of this cleaner combustion, there is less emission of particulate matter (PM), nitrogen (NO_x) and sulphur particles.
The combustion in the engine of the synthetic fuels is equal to the combustion of fossil diesel. Thus, as already stated, the use of HVO also does not require any adjustment of the motor.
Both products are approved according to the EN15940 standard. Both products have a lower density as fossil diesel. Due to this a lower density, both products also fall outside the EN590 standard. That is why it is important to check with the manufacturer if this fuel can indeed be used.

This graph compares the emission differences of GTL and HVO.



BTL (biomass to liquid fuels)
BTL is a synthetic fuel produced by from biomass by means of thermo-chemical conversion (Fischer–Tropsch process). The end product can be fuels that are chemically different from conventional fuels such as gasoline or diesel, but can also be used in diesel engines. International standards: EN 16709, EN 15940
The Fischer–Tropsch process is used to produce synfuels from gasified biomass. Carbonaceous material is gasified and the gas is processed to make purified syngas (a mixture of carbon monoxide and hydrogen). This process polymerizes syngas into diesel-range hydrocarbons. While biodiesel and bio-ethanol production so far only use parts of a plant, i.e. oil, sugar, starch or cellulose, BTL production can gasify and utilize the entire plant.
BTL is extracted from biomass and HVO from finished vegetable oils. These fuels can therefore be called CO_2-neutral.
BTL is not widely used/available as inland navigation fuel, also because the ongoing discussion on the use of biomass for fuels.

Change GTL

Change GTL is a blend of 20% FAME and 80% GTL.

MARPOL Annex VI Regulation 18, “Fuel Oil Availability and Qualities”, applies to using both fuels derived from petroleum refining and derived by methods other than petroleum refining[34], e.g. biodiesel.
In the latter case, the fuel should, among others, not exceed the applicable sulphur content. Moreover, such fuels should not cause an engine to exceed the applicable NO_x emission limits. Meeting the sulphur limits is normally not a challenge for biofuels, however the NO_x emissions might be higher than with fossil diesel oils, due to possibly high oxygen content.
In order to meet the requirements of MARPOL Annex VI, evidence must be made to confirm that the diesel engine complies with the applicable NO_x emission limits (which depend on the keel laying date of the vessel and the operational area) also when biofuels are used for combustion purposes.

Important for owners and also insurers:

It is not clear whether when using GTL in new engines, the warranty is maintained by the manufacturer. The case is to request this in a timely manner from the manufacturer.

As an alternative to gas oil, the inland waterway entrepreneur could also opt for methanol or the renewable bio-methanol available in the near future, which is no longer different from regular methanol at all. The advantage of methanol is that it burns even cleaner than HVO or biodiesel. To use it, the inland navigation entrepreneur must invest in a renewal of the engine. Another option, further in the future, would be the use of methanol that was created through the Method of Power to Liquid (PTL). This is a chemical process in which a liquid energy carrier can be produced from electricity. It is also called Power to X, solar fuel, e-fuel or wind fuel. However, this process is still under development.

LNG (Liquified Natural Gas)

Methane is the main component of LNG. LNG is lighter than air, liquid at about-163 ºC, flammable, but with a high Self-ignition temperature: 595 ºC (~210 ºC for diesel). LNG does not contain Sulphur (no SO_x emissions).
LNG is a clear, colorless, non-toxic liquid, which occurs when natural gas is cooled to about -160°C. As a result, it shrinks to 1/600th of its original volume and is easier to store and transport.

Liquefied natural gas (LNG) is a type of fuel that is made by cooling natural gas to a liquid state, at which point it becomes easier to transport and store.
LNG meets all new environmental requirements for inland navigation without after-treatment techniques. Indeed, the reduction of harmful emissions is significant: 80% reduction in nitrogen emissions (NOx), 99% in the case of particulate reduction (pm) and CO_2 emissions are also 20% lower.

A focus[35] is methane slip emissions (= unburned methane). It is limited to a maximum of 6.19 grams of HC per kWh in the NRMM Directive for 2019/2020. If the gas engines are further developed and dedicated gas engines are applied, methane emissions can be further reduced.

Without adjustments, the transfer to bio-LNG can also be effortlessly switched. This clean and CO_2-neutral[36] fuel is increasingly emerging and stems from sources such as manure and other organic waste. This allows bio-LNG to be generated locally. Once the production capacity of this fuel is large enough, bio-LNG (also known as LBM) will be the logical successor to LNG.

LNG also requires storage tanks that, if they need to be built into the ship, are also at the expense of the cargo compartment. The alternative is placement on deck. Furthermore, the installation must be equipped

[34] **In this context, synthetic fuels according to EN 15940 are not considered to fall under “fuel oils derived by methods other than petroleum refining”. These synthetic fuels include the subgroups such as Hydrotreated Vegetable Oil (HVO), Biomass To Liquid (BTL), Gas To Liquid (GTL), and Coal To Liquid (CTL) which are different resources converted to fuels through chemical processes.*
[35] Comments National LNG platform
[36] CO_2-neutral refers to something that does not produce any net greenhouse gas emissions, specifically carbon dioxide (CO_2)

with pumps and evaporators. By the way, there is a rapid development towards increasingly compact systems. LNG is therefore particularly interesting for use in new construction. For the smaller engines it remains interesting to exchange the engine. The investment depends at a time on the need and type of solutions offered by the market. In 2011, Wärtsilä de Bit Viking, a product tanker, converted from diesel to dual-fuel powered, was a very far-reaching refit. Conversion is an expensive option that in this case was only possible thanks to subsidization of the switch to the cleaner fuel.

The multi-investment for a vessel on LNG depends heavily on the type of ship, but is about €1.5 million.

Suppliers of gas engines in shipping are plentiful.

LNG has some advantages compared to diesel fuel, including:

- Lower emissions: LNG has lower emissions of certain pollutants compared to diesel fuel, including particulate matter and sulfur oxides.

- Increased efficiency: LNG has a higher energy content than diesel fuel, which can result in increased fuel efficiency and lower operating costs.

However, there are also some disadvantages to using LNG compared to diesel fuel:

- Limited infrastructure: LNG infrastructure, such as filling stations and storage facilities, is not as widespread as diesel fuel infrastructure, which can make it more difficult to access.

- Higher upfront costs: LNG vehicles and equipment can be more expensive to purchase than their diesel counterparts due to the cost of the technology and the need for specialized training.

- Lower energy density: LNG has a lower energy density than diesel fuel, which means that more fuel is required to produce the same amount of energy. This can result in larger fuel tanks and increased weight, which can impact vehicle performance.

- Limited availability: LNG is not as widely available as diesel fuel, particularly in certain parts of the world.

Overall, the decision to use LNG or diesel fuel will depend on a variety of factors, including the specific application, the availability and cost of the fuels, and the regulatory environment.

CNG (Compressed Natural Gas)

CNG is a fuel obtained by compressing natural gas and injecting it into the tank at a pressure of about 200 bar. Natural gas is a fossil fuel and emits CO_2. The combustion of 1 m^3 of natural gas (1 bar, 0 °C) releases approximately 1.8 kg of CO_2. Compared to diesel, the reduction in CO_2 emissions is 9%
CNG is presently mainly used as fuel for motorcars of which the petrol engine is adjusted to also burn CNG or LPG.
Natural gas - unlike diesel - does not ignite by itself. An existing diesel engine can be used, but the gas must be ignited. Two methods are used to ignite the natural gas, namely ignition with an ignition system as with petrol engines, or using the existing diesel injection in which a minimum amount of diesel fuel is used to initiate the combustion of the natural gas. The latter is called dual fuel.
Because the calorific value is lower than that of diesel fuel and combustion is slower, the consumption will be higher than that of diesel, but the engine (due to the slower combustion) also runs quieter.
Currently there are no CNG engines with an NRMM type approval available.

Methanol

Methanol is manufactured from synthesis gas which is a mixture of carbon monoxide and hydrogen with the chemical formula CH_3OH. The raw material of this has been oil or natural gas for the past 40 years. Methanol is an organic chemical compound of the alcohol group of substances. Methanol is mainly used in the petrochemical industry as a raw material for the production of other chemicals such as formaldehyde and acetic acid.

Properties of methanol:

Methanol is a colorless liquid that boils at 64.96 °C and solidifies at -93.9 °C. It forms explosive mixtures with air and burns with a non-luminous flame. It is fully miscible in water. Methanol has a smell similar to ethyl alcohol, the alcohol in alcoholic beverages, but is a dangerous poison. Many cases of blindness or death have been caused by drinking mixtures containing methanol.

Methanol burns in air and forms carbon dioxide and water: $2\ CH_3OH + 3\ O_2 \rightarrow 2\ CO_2 + 4\ H_2O$

A methanol flame is almost colorless. Because of the invisible flame, the burning of methanol should be done with caution.

Benefits of methanol:

Emission:

Methanol as no sulfur oxides (SO_x) and no particulate matter (PM) and depends on the engine settings gives less nitrogen oxides (NO_x) in comparison with the emission during the combustion of diesel oil. The big advantage of methanol is that it does not contain sulfur.

Safety:

Methanol is a relatively safe fuel, which is liquid at ambient temperature and can be bunkered just like diesel oil. Because the temperature at which methanol begins to evaporate (the flash point), is lower than that of diesel oil, additional regulations apply. So you have to take that into account, but that does not stand in the way of large-scale storage & use.

Presently the CESNI-PT working group CESNI-PT-FC, dealing with regulation concerning fuel cells and fuels like nitrogen and methanol are setting up proposals for the use, bunkering and storage on board inland navigation vessels. This is to be decided upon in 2023.

Biodegradability:

Methanol is easily biodegradable in water[37] [] and therefore much less harmful to the environment than petrol, diesel or fuel oil. Methanol discharges at sea spread faster and aquatic plants and bacteria break it down organically easily and quickly, without residue.

Methanol can be used in diesel engines:

Methanol can be used as fuel in a combustion engine. However, the properties of methanol are quite different from diesel oil. Certain parts of existing diesel engines must therefore be adapted when using methanol. To ignite the methanol, just like with a petrol engine, a spark is needed. This ignition energy can be obtained by, for example, injecting a small amount of diesel oil, which is called pilot injection. Other fuels, with just as low auto-ignition temperature as diesel oil, can also be used for this. Given the high reliability of fuel injectors, many engine manufacturers will probably opt for this method.

Aftertreatment:

Methanol does not contain sulfur and less nitrogen oxides and particulate matter are released during combustion than with diesel oil. The limited particulate matter emissions comes from the lubricating oil consumption of the engine and through the pilot injection. So it does not come from the methanol, which

[37] Reference is made to https://methanolfuels.org/about-methanol/environment/

burns clean, which also means that the exhaust gas aftertreatment can be less complex and smaller than with diesel engines.

Disadvantages or methanol:
Energy density:
Methanol has a lower energy density than diesel. It weighs almost the same as diesel oil but contains just under half the energy. As a result, you need more than 2 times as much fuel for the same distance which has to be taken in account in terms of bunker size and weight.

Safety guidelines compared to diesel:
For methanol, different safety requirements apply to bunkering, storage and the fuel supply system due to the lower flash point (11°C versus 52°C of diesel oil). The entire fuel system of a ship must therefore be adapted or designed for the use of methanol. There are also stricter regulations for ventilation and vapor detection, among other things.
Additional methanol treatment measures for handling methanol are required. Methanol can result in poisoning when ingested, in case of contact with the skin or inhalation of methanol vapors. High toxicity can result in blindness with an intake of no more than 10 ml of pure methanol. The intake of 30 ml of pure methanol may be fatal, although the average lethal dose is approximately 100 ml.

Legislation on inland navigation propulsion or auxiliary systems operating on fuels with a flashpoint equal or lower than 55 °C
Presently the CESNI-PT working group CESNI-PT-FC, is dealing with adaptation of Annex 8 of ESTRIN, which originally was meant for LNG only, and is now being adapted with;

- Section I Definitions
- Section II Fuel storage
  - Chapter 1 LNG (original)
  - Chapter 2 Methanol
  - Chapter 3 Hydrogen
- Section III Energy converters
  - Chapter 1 Propulsion or auxiliary systems with fuel cells
  - Chapter 2 Propulsion or auxiliary systems with internal combustion engines using LNG as primary fuel
  - Chapter 3 Propulsion or auxiliary systems with internal combustion engines using methanol as fuel.

It's expected that implementation of these adaptations in ESTRIN will be 1st January 2025.

Greene methanol
There have been important developments to produce methanol that is largely 'green'. Any solid biomass, for example agricultural, urban and industrial waste, can be used to make synthesis gas using techniques similar to its production from coal. More recent developments include a plant in the Netherlands, which uses liquid propane-1,2,3-triol (glycerol), a by-product of the production of biodiesel, from animal fats and vegetable oils, to produce the gas.

Another 'green' route is the use of carbon dioxide. Although the first of such a plant is linked to geothermal energy, it could be used to convert carbon dioxide waste from, for example, lime kilns and steel production into methanol.

The use of methanol in the maritime industry is currently limited to two ro-ro passenger ships and a number of sea transport chemical tankers that use methanol from their cargo as fuel. Some pilots in inland navigation are presently being started.

Methanol can also be used as a fuel in fuel cell systems that power an electric propulsion engine, although the output is still limited and as such at the moment only applicable for small low power systems.

Hydrogen (H_2)[38]

There are several methods for the production of hydrogen, such as:

1. By reforming fossil fuels, for example:
    1. Steam reform, being an endotherm catalytic reaction of light hydrocarbons with water vapor
    2. Partial oxidation is suitable for the reform of heavy hydrocarbons using oxygen
    3. Autothermal reform is a combination of steam reform and partial oxidation that benefits from the benefits of both ways of reforming.
2. By electrolysis:
   Electrolysis is the conversion of electrical energy into chemical energy. In the case envisaged, this means the degradation of water molecules (H_2O) in hydrogen (H_2) and oxygen (O_2) by applying direct current

Properties of hydrogen:

With a boiling temperature of -253 °C and a melting temperature of -259.2 °C, hydrogen is an almost permanent gas. Since the critical temperature at -239.96 °C is also extremely low, a pressure increase to support liquefaction (critical pressure 13.1 bar) is only limited.

With its divers ignition and detonation limit values hydrogen can ignite in a large number of concentrations compared to other fuels. In an incineration process, this would allow very lean air/hydrogen mixtures. The difference between the ignition and detonation limits lies with the type of combustion. Deflagration refers to a subsonic combustion, detonation to a supersonic combustion. The self-ignition temperature of hydrogen is higher than that of other fuels, but the minimum ignition energy is significantly lower.

Hydrogen is a colorless and odorless, nontoxic gas at room temperature. It is extremely light compared to air (kgt = 1.29 kg/m³) and volatile air quickly in.

Hydrogen evaporates easily and spreads through a variety of materials due to the small molecule size. This makes the storage and transport of hydrogen quite complex. To deal with this, special steel or diffusion barrier layers must be used. Moreover, the glare of materials that comes into contact with hydrogen is an important problem.

Hydrogen is a slightly flammable gas that is ideal for its properties as fuel. The handling requires a major concern and compliance with the safety regulations. However, the necessary safety regulations do not have to differ significantly from other fuels, as the hazards are very similar. The necessary training measures, as is the case for LNG tankers, are required for the use of hydrogen.

Hydrogen has a high energy density per kg, but the energy density per volume is extremely low. This means more space is needed for hydrogen as a fuel than for other fossil fuels for the specified sailing route. The same stands for the energy conversion systems where fuel cells require more space than internal combustion engines. In order to increase the volumetric energy density of hydrogen, the hydrogen is compressed or liquified.

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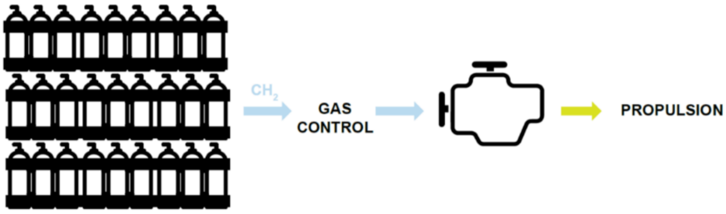
[38] *Reference is made to the feasibility study of Marigreen of October 2018 "perspectives for the use of hydrogen as fuel in inland waterways".*

By compressing hydrogen to high pressures some other features of hydrogen become relevant. The maximum and minimum concentration of gas or vapor that will burn in air is defined as the upper and lower explosive limit (UEL and LEL)[39]. For hydrogen, the LEL is 4% volume and UEL is 75% volume. For reference the LEL and UEL for propane (component of natural gas / cooking gas) are 2,1% and 9,5% volume. To some extent, hydrogen is safer than propane but due to high compression pressure any leakage of highly compressed hydrogen will quickly overcome the LEL in a confined volume. Thus, placement in open air is the preferred solution for compressed hydrogen. Additional concern is hydrogen's low ignition energy. While propane requires 0,25 mJ as minimum ignition energy, hydrogen requires only 0,017 mJ ignition energy. Thus, any leakage of hydrogen needs to be quickly detected and appropriate safety measures need to take place.

The two main variants for transporting and storing hydrogen are under pressure in liquid and gaseous form.



An innovative example of particular importance for shipping is to store the hydrogen in standard intermodal cargo containers as indicated above.

Engine modifications

The conversion of hydrogen to mechanical energy using internal combustion engines seems beneficial for several reasons. In particular, applications that require high propulsion power and low energy consumption for aid companies can benefit from direct conversion.

Most of the propulsion systems currently available in inland waterway vessels are based on internal combustion engines. The use of hydrogen as fuel offers the possibility to adapt existing engine concepts to hydrogen in addition to the new design of engines specifically designed for hydrogen as fuel.

The properties of hydrogen as fuel differ significantly from current fuels, so that various changes in the design of an internal combustion engine are needed.
Customizing to a.o.;

- Injection system
- turbocharger and intercooler
- ignition system
- lubrication system
- Cooling system
- valves control
- Compression ratio
- crankcase ventilation

is necessary.

[39] *The range between the LEL and UEL is known as the flammable range for that gas or vapor. The lower explosive limit (LEL) is the minimum concentration of a specific combustible gas required to fire combustion when in contact with oxygen (air). If the concentration of the gas is below the LEL value, the mix between the gas itself and the air is too weak to spark. The upper explosive limit (UEL) is the maximum level of concentration of the gas that will burn when mixed with oxygen; when the gas concentration is above the UEL value for the gas/vapor, the mix is too "fat" to ignite or explode.*

At the moment, several projects of using hydrogen as an alternative fuel in the inland navigation sector are currently underway. One of these projects is the conversion of the Msc MAAS. This vessel will be converted from a diesel propelled system to hydrogen system by means of hydrogen containers, fuel cells and a fully electric drive resulting in an emission ship without / zero (0) emissions. For this project, reference is made to the next chapter "Containerized energy in inland navigation".

Liquid hydrogen must be stored very cold. That in combination with high outside temperatures in the summer makes boil off gas emission inevitable (the cryogenic temperature is maintained by controlled evaporation of the liquid). All this makes for a complex system. This requires a specially trained crew for safe operation of the system.

Hydrogen can be "packaged" in all kinds of forms. Here we consider only the most promising in the short term: a bundle of high-pressure tanks in a container. In longer perspective, candidates are: as cryogenic liquid, in metal hydrides, in metal hydrogen salts, in organic liquids (LOHC). In addition to formic acid, ammonia and methanol are also substances that can serve as a hydrogen source.

A new development is the use of powdered sodium borohydride (NaBH4) as a hydrogen carrier. Hydrogen (H2) is released from sodium borohydride using ultrapure water. Hydrogen is also released from the ultrapure water. In this way, the amount of hydrogen is doubled. As a result, the energetic density of the powder per kilogram approaches that of diesel.

Hydrogen in a solid carrier powdered sodium borohydride (NaBH4) should make storage of hydrogen more practical for the maritime industry. Powdered sodium borohydride is a white powder that used to be used in detergents. When it comes into contact with water, hydrogen is released with the help of an activator being a highly diluted acid and/or a catalyst. But also the hydrogen atoms from the water atom. So there is actually a doubling of the amount of hydrogen. The energy density of the powder (27 MJ/liter) is relatively high compared to other hydrogen storage forms, and approaches diesel fuel (36 MJ/liter). The powder, with a flash point of 70 degrees Celsius, is also safer to transport and bunker than hydrogen in gaseous form.

The system will be tested next year in the new management vessel of the Port of Amsterdam, Neo Orbis. An additional advantage: it is not as fire-sensitive as hydrogen in containers. But the big question is whether the powder will be affordable. The goal is to limit the costs to 1 to 2 euros per kilo, but whether this will succeed is still the question.

For inland shipping, the option to use tank containers will initially be more obvious.

Hydrogen in powder form is still developing strongly. At the moment, research is still being done into more stable reactions. There are also no industrial developments for upgrading and transporting this substance. Not yet suitable for use at the moment.

It can be concluded that the use of hydrogen as a fuel for inland vessel is still in a pilot phase, but looks promising.

Ammonia (NH_3)

Ammonia can be used in more or less similar fuel tanks as LNG. There is therefore already talk of "retrofitting" LNG ships with ammonia as an option. In that case, bunkering also means pumping LNG through a hose connection. However, the picture is that ammonia will first grow mainly in shipping.

The energy content of a liter of ammonia is at the level of methanol, but is more than one and a half times as large as that of a liter of hydrogen (liquid): about 17 MJ against 10 MJ. Combustion of ammonia yields only water and nitrogen, greenhouse technically harmless compounds and it is a proven technique. Ammonia (NH3) is already liquid at minus 33 degrees Celsius or at a pressure of about nine bar at room temperature. Hydrogen is only liquid at minus 253 degrees Celsius and is often refueled (as a gas) at approximately 300-350 bar or even 700 bar. Transporting ammonia is therefore easier than hydrogen. At 3.2 kWh per liter, the energy density of ammonia itself is about a third of that of diesel (10.9 kWh per liter).

Ammonia burns according to the chemical reaction 4 NH3 + 3 O2 -> 2 N2 + 6 H2O. The important advantage: no CO2 is released. That N2 should not be confused with the nitrogen problem. Nitrogen gas (N2) makes up about 78 percent of the atmosphere and is harmless to organisms. The nitrogen problem is caused by nitrogen compounds such as NO_x and NH_4. NH3 as a fuel has a high calorific value, a very high octane rating and good combustion efficiency.

Technical data	Ammonia	Hydrogen	Petrol	Diesel
Density (g/cm^3)	0,77 (g/cm^3) (liquid)	0.0071 (g/cm^3)	0.73 (g/cm^3)	0.84 (g/cm^3)
Ignition temperature	800 °C	400 °C	530 °C	220 °C
Octane language	110	130	90-98	-
Calorific value	18,510 kJ/kg	120,000 kJ/kg	43,500 kJ/kg	42,700 kJ/kg
Energy density	11.3 mJ/m^3	3.75 mJ/m^3	31.54 mJ/m^3	35.69 mJ/m^3
Ignition energy	680 mJ	0.02 mJ	0.20 mJ	0.63 mJ

Comparison of hydrogen, petrol and diesel with ammonia as pure fuel. Source: Wuhan University of Science and Technology

Ammonia falls under the category of hazardous substances. It is a toxic gas, which has a stimulating effect on the eyes and can cause eye damage and if the concentration is too high, the gas is even deadly. It is also an aggressive liquid that promotes corrosion and reacts directly with water (to ammonia). That is why there are strict regulations for storage and loading.

GLOBAL SULPHUR GAP PER 1-1-2020[40]

From 1st January 2020, the limit for sulphur in fuel oil used on board of seagoing ships operating designated emission control areas (ECAS) was reduced to 0,50% m/m (mass by mass), from 3,50% m/m in order to reduce SO_x emission.

This limit is set in Annex VI of the International Maritime Organization (IMO) of the International convention for Prevention of Pollution from Ships (MARPOL).

To comply, ships can;

- use a compliant fuel oil with a sulphur content of max. 0.50%
- if exceeding the 0,50%, use an Exhaust Gas Cleaning System (scrubber)
- use an alternative fuel such as LNG or Methanol

The main type of “bunker” oil for ships is heavy fuel oil, derived as a residue from crude oil distillation. Crude oil contains sulphur which, following combustion in the engine, ends up in ship emissions. Sulphur oxides (SO_x) are known to be harmful to human health, causing respiratory symptoms and lung disease. In

[40] Information form IMO and Annex IV IMO/MARPOL

the atmosphere, SO_x can lead to acid rain, which can harm crops, forests and aquatic species, and contributes to the acidification of the oceans.

IMO regulations to reduce sulphur oxides (SO_x) emissions from ships first came into force in 2005, under Annex VI of the International Convention for the Prevention of Pollution from Ships (known as the MARPOL Convention). Since then, the limits on sulphur oxides have been progressively tightened.

From 1 January 2020, the limit for sulphur in fuel oil used on board ships operating outside designated emission control areas is reduced to 0.50% m/m (mass by mass).
For ships operating outside designated emission control areas the previous limit for sulphur content of ships' fuel oil was 3.50% m/m.

There is an even stricter limit of 0.10% m/m in effect in emission control areas (ECAS) which have been established by IMO. This 0.10% m/m limit applies in the four established ECAS: the Baltic Sea area; the North Sea area; the North American area (covering designated coastal areas off the United States and Canada); and the United States Caribbean Sea area (around Puerto Rico and the United States Virgin Islands).

Fuel oil providers supply fuel oil which meets the 0.10% m/m limit (such as marine distillate and ultra-low sulphur fuel oil blends) to ships which require this fuel to trade in the ECAs.

For comparison:

Already since January 1st 2011, the maximum sulphur content in gasoil for inland navigation is 0.001% m/m, being 10 mg/kg. In inland navigation mainly EN 590 diesel fuel is used.

Occurring problems[41]
Regretfully there currently is a four- to five-month backlog of vessels that should have been retrofitted by the end of last year. The number of vessels that need to be retrofitted has accumulated so it will probably take until April or May 2020 to complete all scrubber installations. The reasons for the backlog are manifold. Material shortages and limited yard capacity are the biggest issues.

For example, there is only a limited number of manufacturers of GRE pipes in China where most scrubbers are installed. Designers and yards have a high workload of retrofit installations, and lack of staff has doubled the installation time at yards from 40 to 80 days.

From 1 January 2020 vessels must run on very low-sulphur fuel oil (VLSFO) or with scrubbers. If a scrubber has not been installed in time, operators need to switch to VLSFO until a scrubber has been installed and approved.

An even harder deadline is 1 March 2020: from this date on, even the carriage of high-sulphur fuel oil (HSFO) on vessels without scrubbers is prohibited. This means that operators of ships not equipped with scrubbers must remove all HSFO from board and clean the tanks. They will only be allowed to carry HSFO again and use it as fuel after installing a scrubber system.

The price of a scrubber is about 200 USD per tonnes of fuel, long-term precise price predictions are very difficult. Choosing the right material and coatings to avoid corrosion of the piping is essential as well. GRE

[41] Publication DNV-GL 16-1-2020

pipes with a diameter of up to one metre need supporting struts to avoid damage when litres of heavy wash water flushes through them.

Presently already noted problems are leakage and corrosion of SO_x scrubber overboard pipes, sensor failures are also a big concern, and adhering to planned maintenance intervals is of utmost importance. When a sensor fails, the control system can get the wrong data and cause an incorrect or unnecessary operational response.

Misleading sensor data can also falsely suggest that emissions are within limits and only when the emissions are checked by an authority will this be detected. This can lead to high fines and even in some the responsible officer might even be arrested.

Some EU and Chinese ports have fitted sensors at the quayside, and on some occasions, PSC officers equipped with a handheld sensor have boarded to check emissions. In for instance the Netherlands drones are also used in some areas to measure vessel emissions.

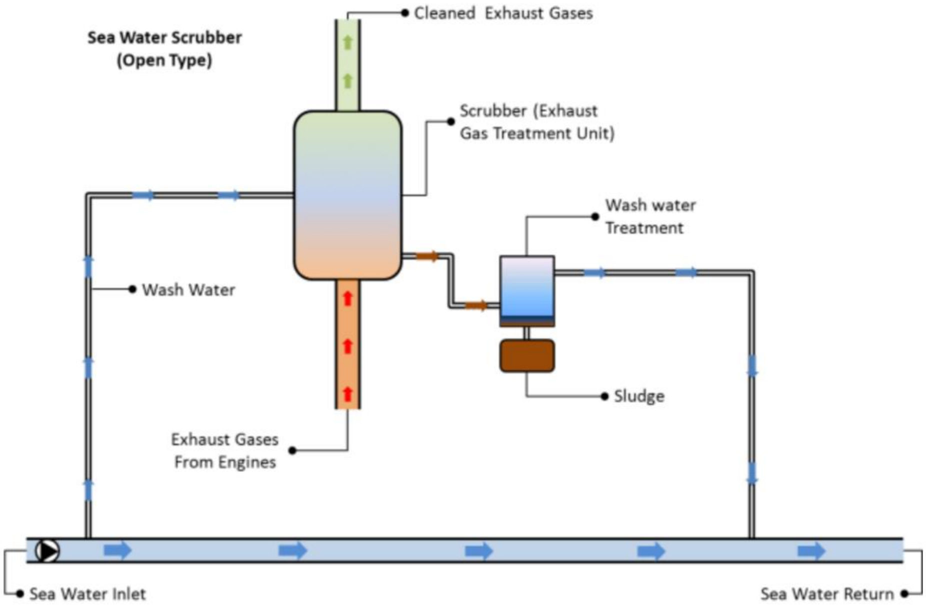
The effects of low sulphur fuel on the engine is also a subject to be looked into, as is the methods / procedures of switching over in time from HSFO to VLSFO when approaching ECAS areas.

AFTER TREATMENT SYTEMS

SCRUBBER SYSTEMS

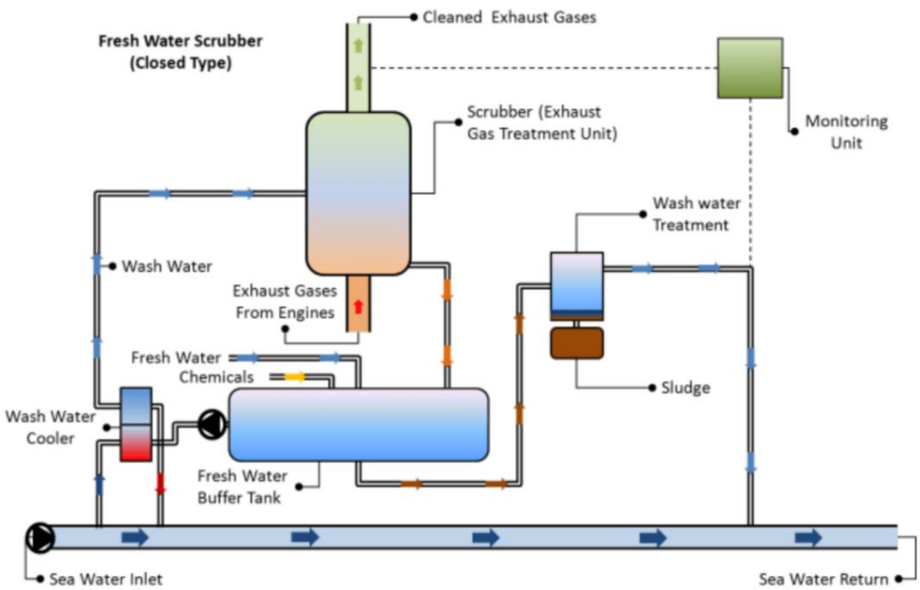
Open type Scrubber

The open type uses sea water to wash the exhaust gases. The wash water is then treated and discharged back to sea, with the natural chemical composition of the seawater being used to neutralize the results of SO2removal. Open seawater typically systems use 45m3/MW h for scrubbing.



Closed type Scrubber

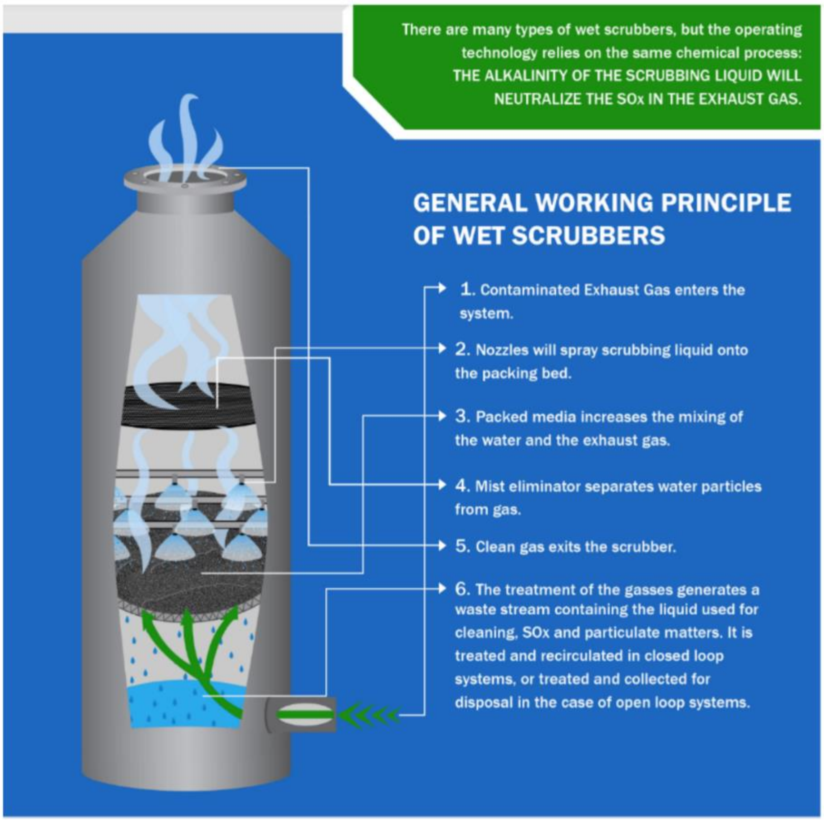
The closed type uses fresh water in “closed” fresh water circuit that is treated with an alkaline chemical such as caustic soda neutralization and scrubbing. The wash water is re-circulated and the losses is made up with additional freshwater. A small quantity of the wash water is bled off to a treatment plant before discharge to sea. Typically closed freshwater systems have a discharge rate of 0.1- 0.3m^3/MW h. The system could also be designed with a holding tank for zero discharge for a certain period.



Hybrid Scrubber

A hybrid is, as the name suggests, some kind of mix between both systems. At Wärtsilä the name is used to identify a system that can run in both open loop and closed loop, enabling flexibility for customers operating in both low and high alkalinity areas. The term "hybrid" is also being used for other products, such as an open loop system where caustic soda (NaOH) is being added to the water to give the alkalinity already in the seawater an extra boost.

General working principle of a wet scrubber



SOOT FILTER

A diesel engine emits soot particles, they are collected in modern diesel engines in a DPF or soot filter. The particulate filter is part of the exhaust system, the soot filter is the component that filters harmful particles out of the exhaust gas. After a certain number of business hours, the soot filter has become full of soot particles. The filter is then automatically burned clean, converting the soot particles into carbon dioxide (water and ash). This clean burn is called regenerating.

Different sensors in or on the filter measure values such as pressure and temperature. The engine computer (ECU or Motor management system) checks these values and when necessary it starts regenerating the particulate filter. In practice, however, we notice that this process, however, is little or nothing.

Soot filter systems often use high-quality and robust Silicon Carbide filter elements. These elements consist of a porous ceramic material in which the channels are sealed around and around on one side. In this way, a very good filtering of the exhaust gases is obtained. In the channels a thin layer is deposited that consists of soot and ash. This thin layer ensures the final fine filtering of the soot particles.

The ash in the exhaust gases comes from the fuel and lubrication oil and remains in the back of the channels while the soot burns. This process is called regenerating.

There are two methods to regenerate the soot stored in the filter:

The first method is to combine the combination of oxidation catalyst (DOC) with a non-coated soot filter. This method is very much applied in the automotive industry and road transport.

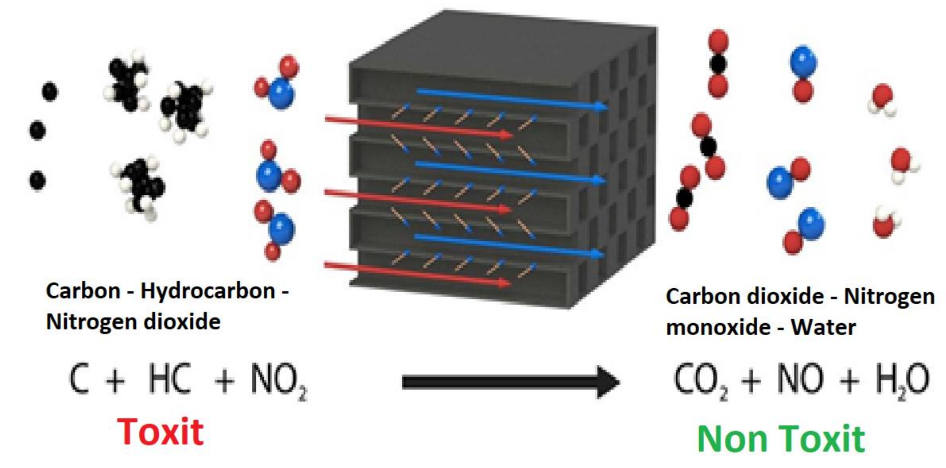
The oxidation catalyst is equipped with precious metal such as platinum or palladium and converts part of the nitric oxide (NO) which is in the exhaust gases into nitrogen dioxide (NO_2). This nitrogen dioxide is normally only formed in the atmosphere.
Nitrogen dioxide is a reactive substance that oxidizes (burns) the soot stored in the particulate filter (carbon and hydrocarbons) to carbon dioxide (CO_2) and water (H_2O).
The design of the oxidation catalyst should be carefully adjusted to the engine to prevent too much nitrogen dioxide from forming.

This can lead to a yellow/brown discoloration of the exhaust gases in certain situations. For this reason, this method of regeneration is usually combined with an SCR system to reduce excess nitrogen oxides.

A great advantage of this method is that the regeneration of soot filters already takes place at low temperatures (between 250-400°C) and, as it were, continuously regenerate. An important plus is that replacement and operating costs are significantly lower than in the second method.

One limitation is that the oxidation catalyst can only be applied with ultra-low sulfur fuel such as EN590. In sulfurous fuel such as DMA or DMX, the oxidation catalyst would prematurely lose its effect by attaching the sulfur to the precious metal.

Chemical reactions NO2 regeneration filter

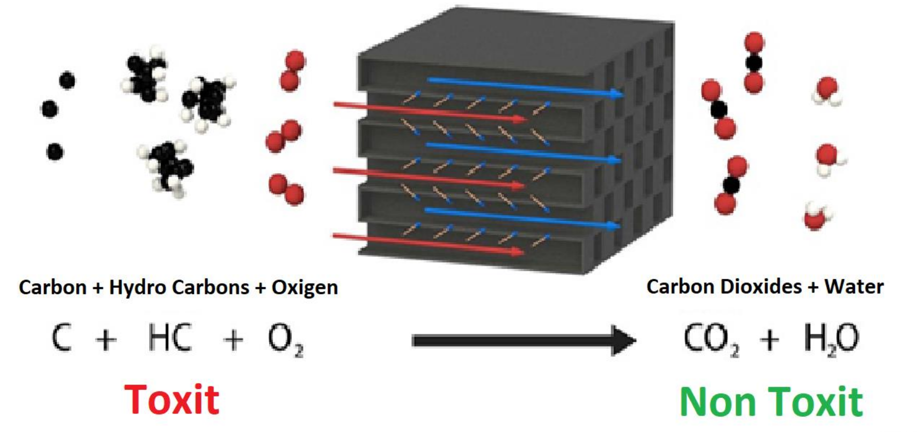


The second method for regenerating the soot filters is to provide the soot filters with a catalytic layer or coating. This layer reduces the oxidation or combustion temperature of the soot stored in the filter. Without this coating, soot would not burn until about 600°C. With the catalytic "sidekick", the oxidation temperature can be reduced to around 350 - 400°C. Because this temperature is higher than the first method, in most cases a form of active regeneration is required, periodically increasing the temperature of exhaust gases with a burner or electrical heating element above 500°C.

The advantage of this method is that certain types of coated soot filters (called cDPF) are reasonably resistant to sulfur. The high regeneration temperatures also allow the sulfur to oxidize and do not remain in the filter.

One drawback is that the coating will have to be replaced relatively quickly and eventually the complete soot filters. In addition to the fact that more frequent active and at a higher temperature, operating costs in this method are higher that with the first method.

Chemical reactions O2 regeneration filter



Disadvantages of a particulate filter may be that the soot filter system functions less well at some point, for example, because the installation does not get to temperature properly (low power sailing) short. Or the soot filter (DPF) is too full of ash particles which means that the storage capacity has become insufficient. The resulting soot and ash accumulation in the soot filter with adverse points as a result:

- Rise in oil levels
- High regeneration frequency.
- Car goes into emergency run (reduced power)
- Higher fuel consumption
- Display or interference memory failures

Causes of this may include:

- Faulty exhaust gas recirculation system (EGR).
- Turbo or turbo control.
- Leakage of inlet air cooling system.
- Air mass gauge measures traffic value.
- Sensors in the exhaust are faulty or give wrong value.
- Extreme pollution of the intake manifold.
- The maximum storage capacity has been achieved by high number of turning hours.

Life of a particulate filter

De lifetime depending on the type of particulate filter. Soot filters that have a catalytic coating last significantly less than filters without this coating.

The life of a catalytic coated soot filter is affected by fuel quality, (sulphur content), lubricating oil quality, exhaust gas temperature, regeneration temperature and mechanical damage during maintenance (rinsing). Depending on your engine, we are happy to give advice on the expected life span.

With an uncoated filter, the influence of fuel and lubrication oil quality is less. Furthermore, the filter is not sensitive to exhaust gas temperature and regeneration temperature. For EN590 inland applications, the expected life span is above 40,000 hours.

SCR Catalyst

There are many types of catalysts. The common SCR catalysts consist of a combination of titan oxide with a very small amount of bound vanadium oxide as active substance. Within this group there are many variations. There are full extrudate catalysts. These consist entirely of active ceramic material. And there are catalysts with metal substrate as a base. In addition, there are thermal-stabilized variants that can be applied again at higher temperatures. Every choice has its downside. Catalysts suitable for low temperatures give a worse NO_x reduction at high temper times and vice versa. The standard SCR catalysts that we apply for EN590 fuel in inland navigation meet between 220 and 520 °C in the temperature area.

For the SCR De-Nox systems, a urea solution is injected into the hot exhaust gases. Urea is a connection between carbon and ammonia. The chemical composition is $CO(NH_2)_2$

Above 200°C, the bound ammonia is released. This ammonia is used to reduce harmful nitrogen oxides.

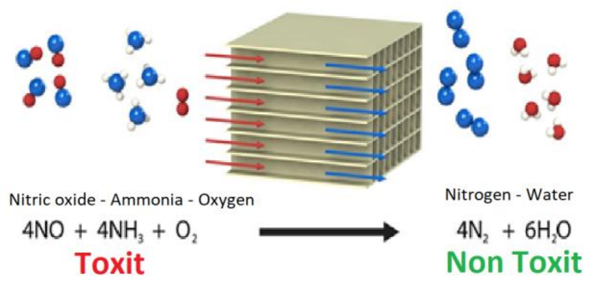
When the combustion temperature increases, the efficiency increases and reduces CO_2 emissions, but emissions of nitrogen oxides are also increasing. At high temperatures, nitrogen can connect to oxygen and form harmful nitrogen oxides.
Because it is virtually impossible to prevent nitrogen oxides from being released at a high combustion temperature, it has been chosen to cause nitrogen oxides to occur in the engine but to capture them before they end up outdoors.

An oxidation catalyst or Diesel Oxidation Catalyst (DOC) is made from very thin corrugated layers of stainless steel with a very thin layer of particles of precious metal such as Platinum and/or Palladium.
This precious metal reduces the oxidation (=combustion) temperature of hydrocarbons (CH) and carbon monoxide (CO). The diesel air and fat soot disappears as a result. An oxidation catalyst becomes active from around 200°C.
In addition, some of the nitric oxide (NO) contained in the exhaust gases will be oxidized to nitrogen dioxide. This last substance can be used to oxidize (burn) the soot stored in the particulate filter into carbon dioxide. In addition, a correct balance between NO and NO_2 ensures a fast and very high NO_x conversion at relatively low temperatures.

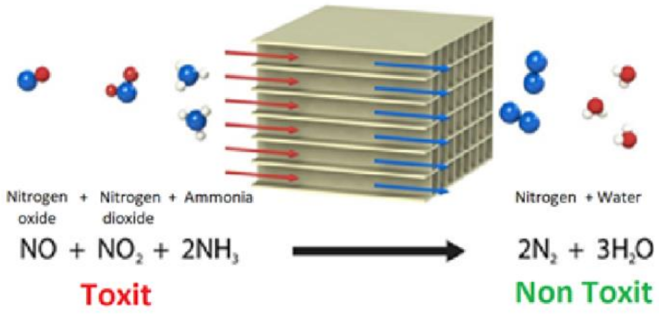
An SCR system reduces harmful nitrogen oxides (NO_x) using ammonia (NH_3) and a catalyst. The term SCR stands for Selective Catalytic Reduction, which means that under the influence of the catalyst material the ammonia reacts only with the nitrogen oxides and therefore not with other substances in the exhaust gases.

The SCR process is complex. For example, there are multiple reactions that ultimately all result in the harmful NO_x being converted into harmless nitrogen (N_2) and water (H_2O).

Standard SCR response



Quick SCR response



When an oxidation catalyst is placed for an SCR catalyst, part of the NO is converted into NO_2. This NO + NO_2 provides an extra quick reaction with NH3 that occurs at low temperature. In the case of too high a conversion from NO to NO_2, more urea would be needed to reduce the NO_x.

Life of a catalyst

A catalyst thus accelerates a certain chemical reaction without the catalyst material itself being consumed. Theoretically, therefore, a catalyst should last indefinitely. The surface of the catalyst is, if you look at it under a microscope, very porous. The NOx and ammonia molecules flow through this spongy surface and react with each other. Now, however, the catalyst is outdated under the influence of temperature and contaminants in the exhaust gases. In fact, the sponge gets clogged and the surface is getting smoother. The activity is thus decreasing.

Urea

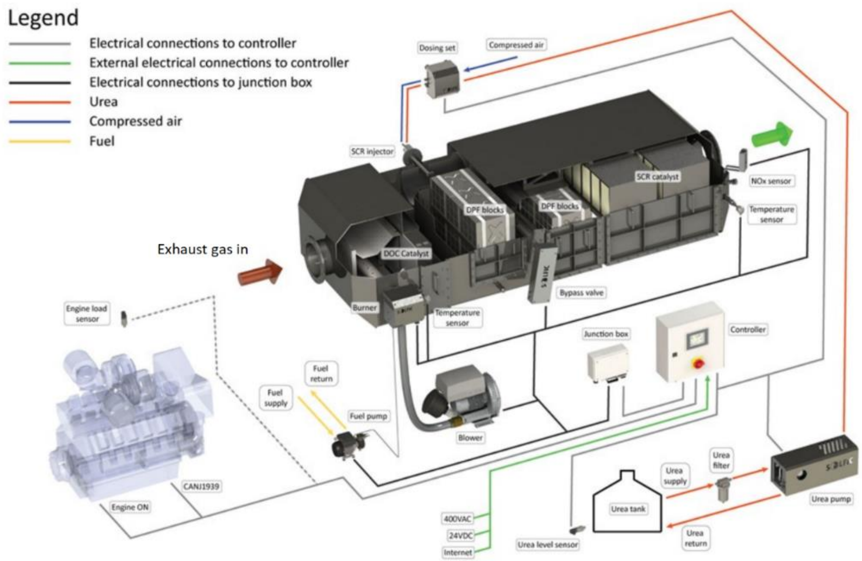
Urea is also known as a basic substance for fertilizer, for example. It also occurs naturally in urine, for example. The urea used in SCR systems has been dissolved in water. A common solution is 32.5% urea in water. Under the well-known brand name AdBlue®, this road transport solution is used. The reason for this is that this solution has the lowest freezing point, namely -11°C. At this temperature, the urea crystallizes and blockages in the injectors and pipes can occur. Another name for the 32.5% solution is also called AUS32 or DEF (Diesel Emission Fluid). The term AdBlue® is a global trademark of the German Automobile Industry Association (VDA) regarding DEF produced in accordance with the ISO 22241 specifications.

In industry and maritime transport, a solution of 40% is common. The advantage of this is that less water needs to be transported for the same amount of urea. It is important that the storage tank does not fall below the freezing or crystallization point of 0°C.

The technology used is called selective catalytic reduction or SCR, in which precise amounts of a liquid are injected into the vehicle's exhaust gases to produce a chemical reaction that neutralizes harmful emissions.

Below is an overview of a combined particulate filter/catalyst installation:

Systeem-overzicht MPAT-Compact



AdBlue® can only be stored in containers of high-density polyethylene, polypropylene or stainless steel. Suitable materials for piping, insulation and sealing:

1. Polyisobutylene (synthetic rubber), free of additives - (for seals and hoses)
2. PFA, PVDF & PTFE (Teflon) free of additives (for sheet covering for chemical equipment / support rings, seals)
3. Co polymers of (P) VDF and HFP (Viton), free of additives - (for the insulation of electrical wires & seals / O-rings)

No materials such as copper, nickel, zinc, soft iron or aluminum can be used.
AdBlue® begins to decompose at a temperature above 30 °C and begins to freeze below -11 °C. Once thawed, the product can be used normally. Urea solution is incompatible with certain materials; it can cause corrosion of metals and also damage certain types of plastics.
AdBlue® must be stored outside direct sunlight between -6°C and 25 °C in a clean and sealed container or dispenser.

When using a catalytic converter and or particulate filter, behind the existing propulsion engine it is important to start using another lubricant. It should minimize the pollution of soot formed from the oil consumed and burned. This lubrication oil meets a LOW SAPS quality.

IMPORTANT FACTS FOR INSURERS

The above gives a statement of the laws and regulations and the emission requirements to be met by engines by 1-1-2019 and 1-1-2020 respectively.

These are particularly stringent requirements for which no engines are actually available for the higher power range per 1-1-2020. For the time being, thanks to the transitional periods (up to 18 months from 1-1-2020), engines of the type CCR II will still be manufactured before the start of the transition period (being 1.1.2019 for P < 300 kW and 1.1.2020 for P ≥ 300 kW) can be placed in new construction vessels. Provided that the date of production of the vessel does not exceed 18 months after the start of the transitional period as described above.
This means that as from 1-1-2023 only Stage-V engines can be installed without any possible exceptions.

Things needing attention:

1. According to Regulation (EU) 2016/1628, an after-treatment system necessary to meet the applicable emission limit values is part of the engine. In other words; the after-treatment plant is an inseparable part of the engine as regards the type of approval of the engine. No other after-treatment plant can be put behind, nor other parts not listed in the type of approval specification. One of the consequences of this is that a product or other type of engine, with, for example, slightly more or less power, in the case of serious damage to the engine, also requires a type of after-treatment plant belonging to that other engine or engine!

2. Every 5 or 7 years, depending on the type of vessel, re-certification must be carried out by a Class Office or Private Institution. This is called an "Interim inspection".
   Article 9.07 of the ES-TRIN 2019 states, with regard to this 'Interim inspection', that the Expert Commission (in the Netherlands is a private institution mandated by IL&T (PI's) and Class Offices) to determine whether ***the built-in engine still meets the technical requirements relating to the emission level of harmful gases and air pollutants, even after it changes or modifications***.
   This is difficult to enforce, since in the 5- or 7-years maintenance of the engines should be performed such as (depending on the number of turning hours) valves set, replace/ repair, replace piston rings, etc.
   In fact, proper verification by the Expert Commission could only take place if such maintenance and/or repair work is carried out exclusively by the manufacturer (the person who has issued the type of approval), indicating that the manufacturer has not made any changes to the engine with regard to the specification/parts specified in the type of approval.
   In short, maintenance should always be carried out by the official manufacturer, which may have (higher) costs consequences.
   This is in ESTRIN 2023, in force 1-1-2024 tackled by the added Article 9.10 - Repair of engines in service, where in sub.2 is stated:
   When carrying out maintenance or repair of an internal combustion engine with replacement of components, the person or company who carried out such maintenance or repair must provide a report which includes:
   a) date of maintenance or repair,
   b) description of maintenance or repair work done, including condition of engine before repair and reason for the repair,
   c) list of components which were replaced or used on the engine, with the specifications of these installed components which show that the engine still complies with the type-approval,
   d) confirmation of compliance with the engine manufacturer's instructions and the engine parameter protocol referred to in Article 9.05(1) after maintenance or repair,
   e) when appropriate, the information displayed on the identification plate of the engine prerepair and post repair,

f) when appropriate, supporting pictures.
It however needs to be awaited how this in practice will work out.

3. If damage is serious, no exchange engine may be built in. Reference is made to the above stated chapter "REPAIRS TO ENGINES" on page 19 of this paper.

4. Because the engine and after-treatment plant form a single whole, the engine day valuation should be taken into account in the future.

5. The damage sensitivity of after-treatment plant in still unknown, so also the cost of the various parts. It is clear, however, that an after-treatment plant requires more attention from the skipper/owner with regard to, among other things, timely replenishment of urea, clean of the catalyzer and the like.

6. Due to the higher costs of a propulsion plant (engine with after-treatment plant) and the long transition, it is to be expected or is there a chance that ships with existing CCR II engines will continue to repair them as long as possible in order to avoid the installation of a more expensive Stage-V engine. What this will mean for the sensitivity of the engines and the costs that may be associated with insurers cannot be estimated, but certainly deserves attention.

7. Existing working vessels did not have to be certified before 1/1/2019, working vessels from after 1 July 2009 must be certified. As of 1-1-2019, all working vessels longer than 20 m or having a displacement of more than 100 m^3 should therefore be certified after 1-1-2019. This means that the engines installed in working vessels after 1 January 2019 with fixed installed engines also have to meet the NRMM emission requirements.

8. Fuel additions, including the addition of a certain percentage of bio, provided not laid down in type-approval, can cause problems with emissions results and therefore in fact also with type approval. This could lead to additions to the fuel obtaining type-approval, warranty e. d. expires.

9. To what extent is the life expectancy of a particulate filter and/or catalyst in relation to the life expectancy of an engine, bearing in mind that the aftertreatment is one with the engine where type approval is concerned?

10. Adding of bio to diesel as well as the increase thereof, even when the fuel is within type-approval specs, special attention should be given to tank cleaning, reduction of water in tanks, tapping off of tanks, regular checking of filters etc. Reference is made to IVR's damage prevention leaflet "Inland navigation fuels per 1st of January 2011" concerning implementation of low sulfur fuels and bio adding. To what extent does this fall under "good housekeeping"? In 2022 IVR again published a technical leaflet "Addition of bio-fuel" to inform about the latest developments in adding bio and the consequences / preventive measures to be taken.

11. When using a SCR catalyst installation, the engine oil needs to be meet a low SAPS quality. This should be implemented in close consultation with the manufacturer of the engine. Not using the correct oil can result in in polluting the catalyst installation and soot filter.

OTHER PROPULSION SYSTEMS

Apart from or precisely by NRMM emission requirements, there have been more and more developments in the field of alternative (cleaner) fuels and alternative propulsion systems, which, according to IVR, also deserves the attention of insurers.

Currently, almost all inland vessels sail on diesel, with the exception of approximately 65 hybrid and 11 LNG vessels. Electric and hydrogen vessels are still in the research and market introduction phase. There are currently three to four engine suppliers offering LNG engines. Liquid biofuels such as FAME, GTL and HVO can be used in conventional inland vessels.

The share of renewable energy (biofuels, green electricity, etc.) in inland vessels is not known, because there is no separate monitoring obligation for it. As a result, the Dutch emission authority cannot make an exact breakdown of the application of renewable energy in different modalities, nor within the modalities.

Affordability[42]

The TCO ("Total Cost of Ownership") of battery-electric inland vessels is (still) considerably higher than that of a comparable diesel inland vessel. This is due to the higher costs of battery containers and the daily loading and changing of such containers. These costs are expected to decrease when scaled up.

The TCO of hydrogen-powered inland vessels is (still) considerably higher than that of a comparable diesel inland vessel. This is caused by the high cost of fuel cells, hydrogen tanks and the hydrogen itself. The costs will probably fall considerably towards 2030. The TCO of inland vessels running on LNG is slightly lower than that of the reference vessel on diesel. Although the purchase costs are higher, fossil LNG is relatively cheap. Bio-LNG is currently still expensive. The TCO of ships on HVO and FAME is slightly higher than that of the reference ship on diesel.

Functional specifications

The range of battery-electric (one-day sailing) and hydrogen inland vessels (one to two days sailing) is much smaller than that of a diesel-powered inland vessel, which can sail twenty days on one tank filling. For LNG inland vessels, this is six to nine days of sailing. With HVO and FAME, the range is the same as that of diesel. A diesel ship has to refuel for about one to two hours to be able to sail for twenty days. Electric inland vessels currently have to charge/bunker for approximately one hour a day. The filling speed of hydrogen is one to two hours per tank filling. The filling times for gaseous fuels and liquid biofuels are comparable to those of diesel. The storage of battery containers and hydrogen tanks takes up a relatively large amount of space.

Each fuel and system have its (technical) advantages and disadvantages. The following is a (as complete as possible) overview of recent developments in this area and will also focus on the points of interest for insurers.

[42] Reference is made to RWS report "Route radar 2019 Innovation Monitor" of 8 October 2020.

CONTAINERISED ENERGY IN INLAND NAVIGATION

Introduction
As mentioned on the previous page, almost all inland vessels run on diesel, with the best of about 65 hybrid and eleven LNG vessels. There are now several engine suppliers that offer LNG engines. Consideration is also being given to the implementation of sustainable biofuels such as FAME, GTL and HVO for use in inland vessels with conventional diesel engines.

The production of Stage-V engines with a higher power by different manufacturers also takes place. For a reference to the currently available type of approved Stage-V engines, please refer to the CCR site https://listes.cesni.eu/2060-nl.html.

Electric and hydrogen vessels are still in the research and market introduction phase, although a number of pilot projects have already been completed, such as the Mcs MAAS with hydrogen-powered fuel cells and the Mcs ALPHENAAR with lithium-ion electric drive. Both in containers and interchangeable.

Mcs MAAS (hydrogen)
The Mcs MAAS is an inland container ship of 109.8 m long, with a width of 11.45 m. The ship sails between the Netherlands and Belgium and can transport 208 TEU containers, originally powered by a conventional diesel engine.

The vessel is equipped with three 275 kW hydrogen PEM fuel cells that provide the primary energy source. In addition, two battery rooms were installed that provide a secondary and tertiary power source. The secondary power is provided by an EST-Floattech battery system on the back line of the ship with a capacity of 210 kWh and the tertiary power by a battery system in an area further on the ship, with a capacity of 294 kWh.

Approximately 450 kg of compressed hydrogen is stored at 300 bar in six/seven Type II cylinders and installed in 2 x 40 ft storage skids installed in the cargo hold. The container are exchanged when the hydrogen is consumed. The cylinders are then filled with hydrogen at a production site and transported by road before being hoisted on board.

The skids contain a pressure reduction facility that brings the cylinder pressure down to 10 bar. The corresponding valves are located in a naturally ventilated valve box on the accommodation side of the skid. The pressure is further reduced to 4 bar by a fixed system installed on board. It is supplied to the fuel cell modules at 4 bar, but is further reduced to 0.3 bar. An acoustic leak detection system has been installed between container and accommodation wall. The installed fire extinguishing systems are approved by DNVGL.

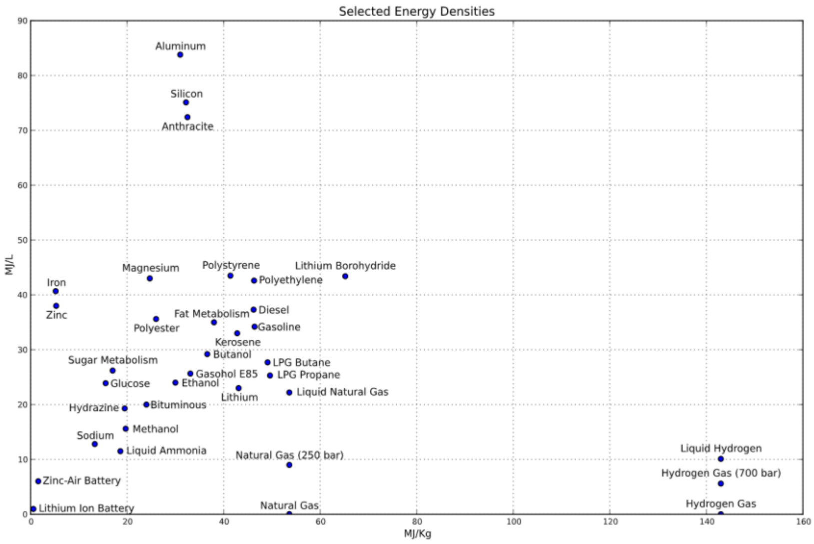
A hydrogen plant is not yet regulated in ESTRIN, but LNG is, namely in Annex 8 in ESTRIN 2019 and Chapter 30 on special provisions applicable to vessels equipped with propulsion or auxiliary systems running on fuels with a flash point equal to or lower than 55 °C. Given that the use of hydrogen is not yet regulated, Mcs MAAS had to apply for a recommendation for the use of hydrogen as a fuel. This RVG recommendation was approved at the RVG meeting in June 2021.

To gain insight into the challenges with regard to retrofitting an inland vessel with hydrogen technology, it is good to look at some characteristics of hydrogen. One of the most influential parameters when designing a ship's propulsion system is the energy volumetric density of the fuel.

Below is the figure with energy density of different fuels and while the energy density of hydrogen per kg is high, the energy density per volume is extremely low. As a result, more space is needed for hydrogen as a fuel than for other fossil fuels for the specified sailing route. The same applies to energy conversion systems where fuel cells require more space than combustion engines.

As such, compressed hydrogen is the most suitable.

Therefore, the Mcs MAAS is equipped with com-primed hydrogen containers and proton-exchange membrane (PEM) fuel cells (FC).



By compressing hydrogen to high pressure, some other characteristics of hydrogen become relevant.

The maximum and minimum concentration of gas or vapor that will burn in air is defined as the upper and lower explosion limits (UEL and LEL). For hydrogen, the LEL is 4% volume and UEL is 75% volume. For reference, the LEL and UEL for propane (component of natural gas / cooking gas) are 2.1% and 9.5% volume.

To some extent, hydrogen is safer than propane, but due to high compression pressure, any leakage of highly compressed hydrogen will quickly overcome the LEL in a limited volume.

Liquid hydrogen must be stored very cold. That in combination with high outside temperatures in the summer makes boil off gas emission inevitable (the cryogenic temperature is maintained by controlled evaporation of the liquid). All this makes for a complex system.

Placement in the open air is therefore the preferred solution for compressed hydrogen. Extra concern is the low ignition energy of hydrogen. While propane requires 0.25 mJ as the minimum ignition energy, hydrogen requires only 0.017 mJ of ignition energy. For example, any leakage of hydrogen must be detected quickly and appropriate safety measures must be taken.

Ms ALPHENAAR (Lithium-ion)

Mobile Energy Containers (MECs)

The ms ALPHENAAR is the first vessel to use interchangeable energy containers for its electric propulsion. These are large lithium-ion batteries in containers (Mobile Energy Containers). These containers have a capacity of approximately 2 to 3 MWh per container. The containers, if they are empty, can be exchanged daily for a charged one. In this way, the ship is almost continuously operationally available.

The shipowners do not have to bear the huge investment of these MECs themselves. They only need to provide an electric drive. This is often used, also in combination with diesel or gas engines. Recently, the company ZES was founded to provide these MECs. The shipowner actually purchases electrical power from ZES at a pre-agreed electricity rate.[43]

[43] Zero Emission Services, launched by the companies ENGIE, port of Rotterdam Authority, ING Bank and Wärtsilä.

Presently there is some discussion where the Lithium-ion battery containers can be placed on board. Presently on board the ALPHENAAR they are placed on automatically coupling contact beds, placed in the cargo hold, with a bulkhead between the containers and the actual cargo hold. For this the ALPHENAAR received a temporary approval from CESNI-PT. Within CESNI-PT hopefully in 2023 it will become clear where these containers are allowed to be placed on board.

Point of attention:
Especially for the system of lithium-ion containers, where the container is not owned by the owner of the vessel and has to be changed frequently and the owner of the ship only pays for the use of the energy, it is important to consider how i.e. is arranged in terms of insurance coverage in case of damage to or due to a broken battery container, because, for example, it has been damaged unnoticed during transport. What if the container is irreparably damaged by a collision, or a fire occurs resulting in damage to the vessel as a result of a technical defect built into the container's control unit?

Flow batteries

A second battery-electric concept concerns the use of so-called "flow batteries". This concept was launched by shipbuilding company Port-Liner, but has not yet been tested in practice. When using flow batteries, "charged electrolyte" is refueled, as it were, which is stored on board in bunker tanks and pumped through the battery [Portliner, 2020].

FUEL CELLS[44]

FUEL CELL FACTS

Fuel cells are energy converters that continuously convert the chemical energy of the fuel, such as hydrogen, (natural) gas or methanol, into electrical energy and thermal energy (heat losses) using an oxidant such as oxygen. The fuel cell can supply electricity as long as suitable fuel is available.

The principle of the fuel cell was invented in 1838, however the first commercial use of fuel cells came more than a century later in NASA space programs to generate power for satellites and space capsules. Since then, the improvement of the fuel cell began and nowadays they are used in many other applications, e. g. for primary and backup power for commercial, industrial and residential buildings and in remote or inaccessible areas. The second most important application for fuel cells is as a power source for vehicles of all kinds.

With fuel cells local emission-free power generation is possible. The comparison of a fuel cell with a conventional internal combustion engine shows that no mechanical stress on components takes place because no fuel is burned. This results in no wear, vibration or generation of noise.

REGULATIONS

The European committee for drawing up common standards in the field of inland navigation (CESNI) does not consider the installation of fuel cells in its current regulation European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN - 2019/1).

The ES-TRIN requires that all electrical installations on board must be designed for a constant inclination of 15°. In addition, the energy supply must in principle consist of at least two energy sources. If one energy source fails, the remaining energy source must be able to provide the required energy for at least 30

[44] Reference is made Interreg Danube Transitional Fact sheet Fuel Cells.

minutes. This means that either the fuel cells have to be divided into (at least) two systems including the fuelling system or a battery with sufficient capacity needs to be implemented.

Classification societies like DNV GL already have guidelines for the installation of fuel cells since 2016. The predecessor Germanischer Lloyd has had regulations for the use of fuel cells since 2002 and they were the first classification society to think about this topic.

Presently the CESNI-PT FC (a CESNI-PT working group focussing on new legislation for hydrogen, methanol and the use of fuel cells on board inland navigation vessels) is hopeful to introduce the new rules for fuel cells and the use and storge of hydrogen and methanol in ESTRIN 2025.

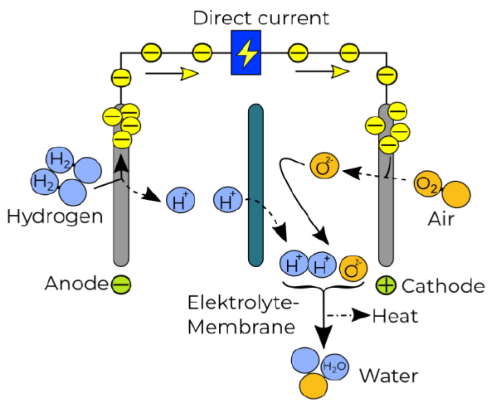
The following diagram shows the basic conversion process in a fuel cell using the example of hydrogen as a fuel.

BASIC WORKING PRINCIPLE OF FUEL CELLS

All fuel cells consist of two electrodes - the anode and the cathode. These are separated by an electrolyte with an ion-permeable mem-brane. After the fuel has been supplied to the anode, it is divided into electrons and protons. The free electrons flow into an outer circuit between the anode and cathode to be used as an electric current. The protons spread through the electrolyte to the cathode. At the cathode, the oxygen from the air combines with the electrons from the outer circuit and protons from the electrolyte. This results in water and heat.

Several fuel cells in a row make up a fuel cell stack. The number of individual cells that are connected in series can be used to variegate the performance of the stack and adapt it to the respective requirements.

All fuel cell types are based on the reaction of a fuel with oxygen. The electrochemical reaction generates basically electricity, heat and water. From the fuel cell, the electricity is provided as direct current (DC). If alternating current (AC) is required for further use, DC from the fuel cell is routed to an inverter is converted there to AC.



CLASSIFICATION OF FUEL CELLS

Basically, fuel cells are classified according to their operating temperature and the type of electrolyte used in the fuel cell. The following fuel cells are particularly interesting for inland waterway vessels:

LOW TEMPERATURE PROTON EXCHANGE MEMBRANE FUEL CELL (LT-PEMFC)

PEMFC uses a water-based polymer membrane as electrolyte, H2 as fuel and O2 as oxidant. The operating temperature is < 100°C. Due to the low temperature, only pure hydrogen can be used in PEMFC. The by-products besides electricity are water and heat. The fuel cell can be started cold without pre-heating to the operating temperature.

HIGH TEMPERATURE PROTON EXCHANGE MEMBRANE FUEL CELL (HT-PEMFC)

If the operating temperature is significantly exceeding than 100°C, PEMFC is used. These can reach up to 200°C and used mineral acid electrolyte instead of a water based one. The fuel cell must first be brought to operating temperature before it functions properly.

SOLID OXIDE FUEL CELL (SOFC)

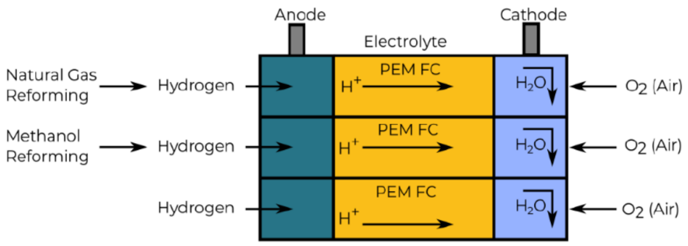
If the operating temperature is significantly exceeding than 100°C, PEMFC is used. These can reach up to 200°C and used mineral acid electrolyte instead of a water based one. The fuel cell must first be brought to operating temperature before it functions properly.

SOFC contains a solid electrolyte. From an operating temperature of approx. 650°C, this so-called oxide ceramic conducts the hydrogen ions through it. Some devices reach a temperature of 1.000°C. SOFC is one of the high-temperature fuel cells. An internal reforming of natural gas to hydrogen takes place in SOFC itself.

Technology	SOFC	LT-PEMFC	HT-PEMFC
Common size	1kW-10 MW	1-100 kW	< 30 kW
Fuel	Hydrogen, Methanol, Natural gas	Hydrogen	Hydrogen, Methanol, Natural gas
Emission	CO_2, low levels of NO_X	-	CO_2, low levels of NO_X
Efficiency	60-65 %	50-60 %	50-60 %

All fuel cell systems produce neither SO2, fine dust particles nor soot. They usually have between 10.000 and 20.000 operating hours, but the fuel cell providers are currently aiming for 30.000h.

Various energy sources can be used as fuel for fuel cells. Often hydrogen, methanol or natural gas is used.



COMPONENTS ON BOARD

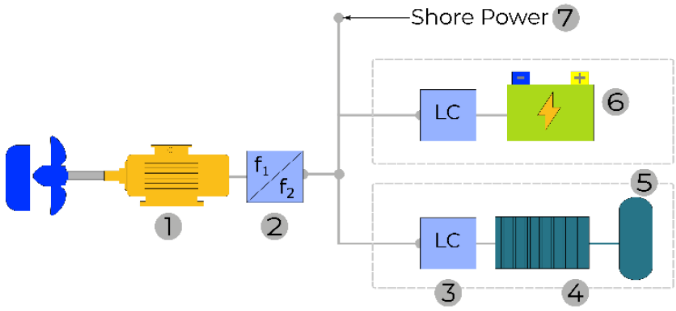
The fuel cell system as a propulsion system for a ship often consists of several components. These include the fuel cell, an electric motor, accumulators and partly a reformer. A negative property of the fuel cell is its own inertia to react. This inertia is balanced by an accumulator. It must also be taken into account that a fuel cell needs some time to reach operating temperature, this time difference is also compensated by the accumulator. The fuel cell supplies direct current, the energy produced is transmitted to an electric motor for propulsion. This electric motor, for example, generates the rotary motion for the propeller shaft. The energy requirements for all electrical equipment on board a ship can be supplied directly from the fuel cell or accumulator without detours. The arrangement of the fuel cell and the accumulator can be either parallel or in series.

TECHNICAL CONCEPT

The electric motor (1) drives the propeller with constant rpm at any load case. Its advantage is a nearly constant efficiency at all load cases. De-pending on the selected electric motor a gear box can be omitted. The frequency converter (2) sup-plies the electric motor with a frequency and volt-age amplitude variable AC voltage.

The converter can be supplied by any AC or DC on board energy grid. The rotational speed of the electric motor is controlled by varying the output frequency.

The main switch board (3) distributes the energy from all sources to all loads. The loads are frequency converters at the propulsion system. The fuel cell (4) provides the base load. The fuel is stored in the tank (5). Peak loads are absorbed by the battery (6) which can be charged either by the fuel cell or via shore power (7).



BENEFITS

- High efficiency at full load and (depending on application) at partial load
- Good controllability
- Good performance extension due to modular design
- Increased comfort (low noise and vibrations)
- Low maintenance

DOWNSIDES

- High development potential
- High investment costs
- Operating experience in field test still low
- Shorter useful life compared to market-dominating products (combustion engine)
- Few suppliers

New types of fuel cells

New types of fuel cells are being developed.

- Proton-exchange membrane fuel cells (PEMFC), also known as polymer electrolyte membrane (PEM) fuel cells, are a type of fuel cell being developed mainly for transport applications, as well as for stationary fuel-cell applications and portable fuel-cell applications. Their distinguishing features include lower temperature/pressure ranges (50 to 100 °C) and a special proton-conducting polymer electrolyte membrane. PEMFCs generate electricity and operate on the opposite principle to PEM electrolysis, which consumes electricity.

- Solid oxide fuel cell (SOFC) is a fuel cell operating with a solid, non-porous oxide (ceramic) as an electrolyte. The ion transport takes place using oxide ions, the catalyst for the ionization of the hydrogen consists of nickel with yttrium-doped zirconium oxide (yttrium-stabilized zirconium). A SOFC usually has a return around 60%. Recent studies also claim that the SOFC can be used with biogas as a fuel[1], which makes the SOFCs very flexible in terms of fuel choice. This type of fuel cell has a high temperature operating area, approx. between 800°C and 1100°C. As a result, no precious metal catalysts (such as platinum) are needed, which ensures that the SOFCs are relatively cheap. This high operating temperature also creates challenges in terms of construction and life of the fuel cell. This also ensures a long start-up time of the fuel cell.

- Direct-methanol fuel cells or DMFCs are a subcategory of proton-exchange fuel cells in which methanol is used as the fuel. Their main advantage is the ease of transport of methanol, an energy-dense yet reasonably stable liquid at all environmental conditions. Whilst the thermodynamic theoretical energy conversion efficiency of a DMFC is 97%. The currently achievable energy conversion efficiency for operational cells attains 30% to 40%. There is intensive research on promising approaches to increase the operational efficiency.

Visible development for implementation in inland navigations is still under investigation in some pilot projects.

OTHER ALTERNATIVE PROPULSION SYSTEMS

Dual fuel engines
These are engines that can run both gas (LNG) and diesel.

LNG Dual Fuel engines have been in use in coastal and sea shipping for more than 10 years. In the meantime, these engines are also supplied for inland navigation. The LNG Dual Fuel engines are specifically designed as a Dual Fuel engine which requires only a limited amount of pilot fuel. Nevertheless, the Dual Fuel engine can run entirely on diesel. As a result, there is a ratio of 1% diesel and 99% LNG.

Various dual-fuel engines have already been installed in inland navigation. This is for the moment often LNG/diesel.

For the use of LNG for propulsion in inland navigation, clear regulations have now been laid down in ES-TRIN 2019 as regards installation, safety requirements, bunkering, crew etc.[45]

These requirements can also be applied to new alternative fuels with a flashpoint of 50 °C or less. However, fuels other than LNG require a recommendation/exemption.

There are already a number of vessels that have the engines running on LNG.

Other types of dual fuel are for instance:
- Diesel / methanol mixture
- Diesel / hydrogen mixture
- Diesel / ammonium

However, one has to bare in mind that according to Fuel Provisions of Regulation (EU) 2016/1628 all engines must be certified on at least one of these fuels, or combinations:
- diesel
- petrol
- petrol/oil mixture, for two stroke SI engines
- natural gas/bio methanol
- liquid petroleum gas (LPG)
- ethanol.

Other "fuels, fuel mixtures or fuel emulsions" (as in dual fuel engines) may be certified, in addition to one (or more) of the one of the standard fuels. Requires demonstration of conformance. This is set out in the co-decision act and not included in the committee procedure, it cannot realistically be changed in the short term.

Use of Euro-6 truck engines
Euro-6 truck engines in principle meet NRMM emission requirements, with which the idea has arisen to also apply these engines in inland waterways.

[45] Reference is made to ES-TRIN 2019 - PART II ADDITIONAL REQUIREMENTS FOR SPECIFIC EQUIPMENT ON BOARD - ANNEX 8 ADDITIONAL PROVISIONS FOR VESSELS POWERED BY FUELS WITH A FLASHPOINT OF 55 °C OR LESS .

Currently, projects are underway to marinize Euro-6 truck engines. This means that the air cooling of the engine present in lorries, for inland waterways in an engine room, the cooling must be converted into a water cooling.

Another important feature of the Euro-6 engine to meet the emission standard is that engine power is controlled by emissions. When the emission gets outside the permitted values, the engine automatically decreases power and will eventually stop.

Inland navigation legislation states that an engine is automatically allowed to fall back into power or stop in the event of a malfunction. Understandably, because if a ship sails into a lock and the engine power suddenly decreases or the engine stops automatically, this can lead to disastrous consequences.

The decrease in power in the case of a deviation in the emission of a Euro-6 engine is automatically electronically controlled. It seems difficult for the time being to adjust this electronic, inland waterway, power reduction in such a way that the engine does not stop in the case of emission change or to have the engine meet the emission requirements without having this electronic power reduction.

It has to be stated that in other EU-countries the interpretation of not allowed automatic power decrease is interpreted differently and no electronic adjustment to prevent this has been implemented and these engines nevertheless obtained type approval from the countries type-approval authorities.

The correct interpretation of this is still under discussion. Recently, the DAF/PACCAR Euro VI MX11 and -13 Stage-V engines were approved for naval application. The MX series more than adequately comply with the IWW Stage V emission legislation. Result: up to 98% less nitrogen oxides, 99% less soot and fuel use (read CO2 emissions) are guaranteed to be 16% lower than that of the previous generation of CCR2 ship diesels.

The state-of-the-art diesel engine comes including an ex-factory after-treatment unit, consisting of an SCR catalyst and DPF particulate filter. To achieve the Euro VI emission levels, the MX engines are supplied including after-treatment unit. This after-treatment unit consisting of an SCR catalyst and DPF particulate filter has very compact dimensions (approximately 750 x 750 x 500 mm), replaces the standard silencer and is virtually applicable in any engine room.

For the MX11 series, the power range is between 220 and 330 kW and for the MX13 between 315 and 319 kW. So still in the somewhat lower power ranges.

Hybrid drive (diesel / electric drive)

Diesel electric or LNG electric propulsion has been enormously in the spotlight lately, with a view to possible fuel savings and emission emissions reduction. A ship with (diesel) electric propulsion has several generator sets on board, which together provide the full power supply of the electrical propulsion. If the maximum power is not fully required, (single) generator sets can be stopped, saving fuel and reducing CO_2 emissions.

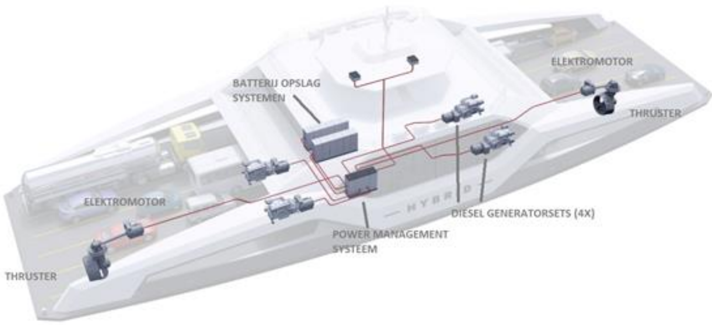
Especially with ships that already need large generators for other large consumers on board, such as large cargo pumps or on-board mesh sets, a diesel/LNG Electric propulsion can be interesting.

However, there are also disadvantages to a (diesel/LNG) electrical propulsion. The investment is a lot higher than with diesel direct propulsion. In addition, the electrical components each have a loss of efficiency, which can amount to around 13% in total.

As with the hybrid shape, generator sets provide the necessary amount of power. Of course, the sets can be switched on or off. The size of the generator sets can be determined as desired. Moreover, it is no longer necessary to put the sets in line with the screw shaft. They can be placed in any place.

The generator sets are powered by diesel or LNG. At the moment, the generator sets mainly still use diesel.

Below is schematically displayed an example of an hybrid drive, being diesel generator sets that provide for the power supply for electric motors drive on the screw shaft/thruster, but there is also a battery storage to be able to sail for a short time without the diesel generator sets.



These systems are more complex and often more expensive than the old diesel engine with flexible coupling, turning clutch, screw shaft and screw. The advantage is that the engines often run a constant speed and can be handled well with low emission and low wear.

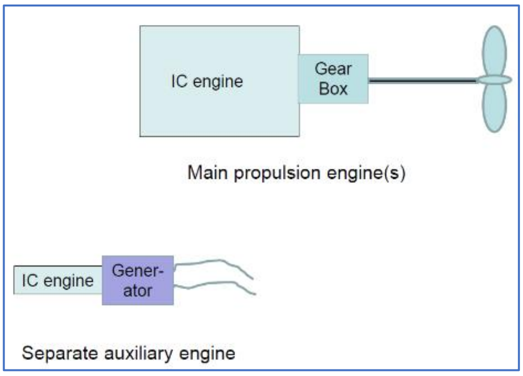
When batteries are also used, special attention to the installation of the batteries with risk analysis will be necessary, including the fire hazard in case of overload or damage to the batteries.

An internal combustion (IC) engine may be used as a power source in conjunction with a part electrified or electrified power train in an integrated (hybrid) power system for a number of reasons:

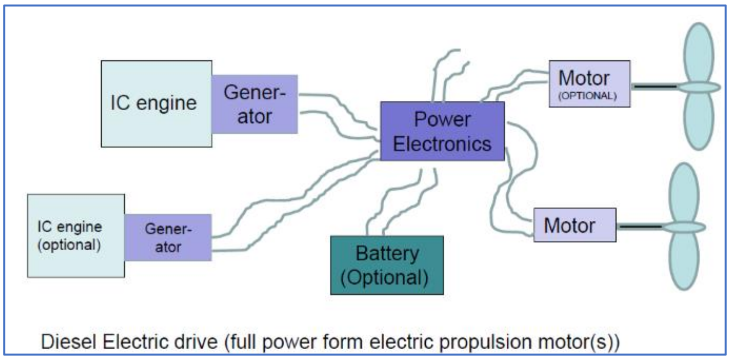
- Increased efficiency (reduced fuel consumption and CO2) in many applications.
- Allows more flexible installation
- Usually high redundancy
- Can allow periods of zero emission operation
- Can overcome limited selection of IC engine available
- Provides auxiliary power efficiently
- Not constrained by the limited energy storage capacity of a fully electrified system.

An overview of systems is shown below:

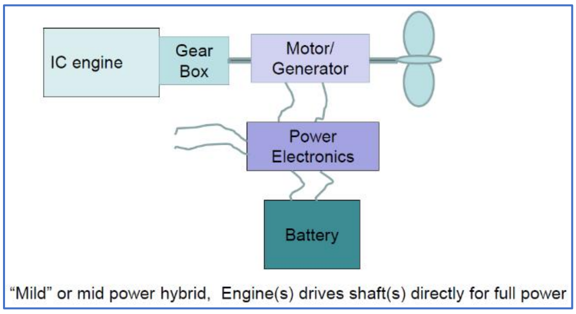
Conventional system



Integrated power system (series)



Integrated power system (Parallel)



The diesel engine must comply with relevant regulations and provide enough power to drive the generator. For the electric propulsion motors different types are applicable. An asynchronous or an synchronous motor.

ASYNCHRONOUS MOTOR

The asynchronous motor is the most widely used industrial motor. It can be connected directly to the three-phase mains and is very robust and easy to build. The asynchronous motor takes its name from the fact that it does not rotate exactly with the mains frequency. It only has a torque if its speed deviates from the synchronous speed. In the operating range, the torque is proportional to this deviation. This type of electric motor is characterized by low investment costs and small dimensions. Its nominal rate of revolutions is usually too high to be used as a direct drive. A gearbox between electric motor and propeller shaft is necessary. The gearbox increases the investment costs, lowers the efficiency of the drive train and could be a point of failure. If the advantages of asynchronous motors and the disadvantages of the gearbox are balanced correctly, a cost and energy efficient drive train can be designed.

SYNCHRONOUS MOTOR

For synchronous motors, the speed of the motor is equal to the mains frequency divided by the number of pole pairs. The rotor of a synchronous motor is permanently magnetized and follows the rotating field of the stator. Usually, the speed is given in revolutions per minute (rpm). This type of electric motor is characterized by high energy efficiency, low nominal rate of revolutions and a good torque/speed characteristic. This motor can be used as a direct drive, without a gearbox between motor and propeller shaft. Its large outer dimensions are disadvantageous like the high investment costs. Using a synchronous electric motor for the propulsion system leads to an efficient drive train with a sensitive control.

INVESTMENT COSTS[46]

With a diesel-electric drive, additional costs incur for the electric motor, frequency converter and extended main switchboard. In the layout of the drive train it is aimed for matching the distribution of power with the operational profile so that diesel generators are either used in their sweet spot or not running.

Exemplary costs:

Generator sets - 350 EUR/Kw

Electric motor - 120 EUR/kW

Installation costs - 30,000 EUR for conversion, wiring and power management, based on the use of already existing installed diesel engine.

[46] Reference is made to the presentation of Interreg Danube Transitional Programme January 2019 Fact sheet Diesel-Electric propulsion.

ECONOMIC OPERATIONS

Depending on the operational profile, diesel-electric propulsion can significantly reduce energy consumption and emissions since it makes it possible to adjust propulsion needs to actual operational conditions. While direct drives have to cover the whole power range, diesel-electric drive trains consist of at least two gensets with suitable distribution of power. This allows using diesel engines more efficiently by switching off a genset when it is not needed. This leads to optimised loads of the engines. Due to the better fuel efficiency of the diesel engines at the optimum load, the operational costs and emissions are decreased with the reduced fuel consumption.

A common example for partial loads is the difference between upstream and downstream sailing. Most downstream sailing vessels only need less than half of the power needed upstream. When the vessel is sailing downstream at least one genset can be switched off. Other ships have an operational profile similar to the left plot below. Here engine loads were measured over several journeys including upstream, downstream and canalized sections without currents. Most of the time the vessel is operating at engine loads of less than half of the installed power. Only on small sections of the waterways and for emergency stops the full power is required.

BENEFITS

- Engines running in their sweet spot
- Low noise and reduced vibrations
- Increased efficiency for suited operational profiles
- Lower emissions of air pollutants
- More flexibility to generate auxiliary energy
- Easier implementation of batteries and fuel cells
- Additional freedom for engine positioning
- Trend to better manoeuvrability
- Highly redundant designs possible

DOWNSIDES

- Additional losses
- Higher weights
- Increased space requirements
- Higher investment costs

General comments on Integrated power systems are:

- There are many possible ways of combining an IC engine into a part electrical drive system for a vessel to create an 'integrated power system'
- Volume for each system are low, in many cases they are a 'one off'
- Other than passenger cars, where thousands of identical products are produced, it has proved impractical to certify such propulsion system as a complete unit
- A system was created for heavy duty trucks but it has never been used to date.
- In the short to medium term emissions certification of the engine as an individual item will remain.
- Certification must be compatible with the requirements of Regulation (EU) 2016/1628 (stage V).

Engines to be used in these systems have to apply to the NRMM regulation where emissions are concerned.

Fully electric drive

At the moment, the first fully electric ship to be powered by PM engines is under construction. In April this year, the ship will be on the way.

The ships are equipped with giant E-power boxes for the drive, each the size of a container of 20 feet (6 meters). They bring the energy to the electric engine. The small ships can sail for 15 hours, the large ones (which have four power boxes on board) would come to 35 hours of autonomy. The batteries can also be exchanged or recharged at container terminals if necessary.

Because there is no longer a classic engine room, some space is ultimately saved: there is an 8% gain compared to a similar classic fossil fuel ship.

Electric motors and batteries are also built into older ships, the so-called retrofitting. The new ships could sail independently, without skipper, although autonomous sailing on most waterways would not be discussed for the time being.

The batteries are still quite pricey, although the developments in this are fast.

LITHIUM-ION ACCUMULATORS

The use of lithium-ion batteries also called accumulators in inland navigation is increasing rapidly to reduce inland navigation’s emission. 'Lithium-Ion' accumulators occur in various substances and have various advantages compared to conventional accumulators (with Lead or Nickel/Cadmium) such as a longer service life due to more charging and discharge cycles and higher energy density, or a lot of energy at a small volume.

Lithium batteries use a liquid lithium-based material for one of their electrodes. Of a Lithium-ion battery, the anode exists out of carbon and the cathode out of lithium metal oxide. The electrolyte between the electrodes consists of organic carbonate compounds, such as ethylene carbonate, to which lithium complexes are attached.

It is known that these accumulators pose a high risk in the case of a misapplication in which a 'Thermal Runaway' can be caused with a fire or worse as a possible result, an explosion.

Risks

1. Fire / explosion
   Lithium, like all alkali metals, is highly reactive and flammable. A lithium fire can be recognized by its brilliant silver flame. Furthermore, lithium can ignite and is potentially explosive when exposed to air and water.
   The core of a lithium-ion fire is the cell itself which is very difficult to reach and even harder to extinguish due to having multiple elements of fire types (metallic, chemical, etc.). It also releases energy to its surroundings and can potentially produce its own oxygen. A battery fire will emit toxic gases. The gases identified so far are carbon monoxide, nitrogen dioxide, hydrogen chloride, hydrogen fluoride, hydrogen cyanide, benzene and toluene. This means all protocols for entering enclosed spaces must be strictly followed.

2. Overheating (Thermal runaway)
   Another risk is thermal runaway. Lithium-ion batteries can blow-up or melt when internal electrical components short-circuit. For example, this can occur due to mechanical problems after an accident, or when the batteries are not installed correctly. Often the cause of these failures is when one portion of the battery gets too hot and cannot cool down quickly enough. This creates a chain reaction generating more and more heat. This effect is called thermal runaway.
   During thermal runaway, the separate battery modules melt, creating heat and as a result the electrolyte material between the anode and the cathode may start to boil. The thermal runaway will eventually cause the battery to self-ignite and might even cause the accumulator to explode.

Legislation
Lithium-ion accumulators are subject to the requirements of European standards EN 62619: 2017 and EN 62620: 2015.

For the use on board inland vessels, installations for Lithium-ion accumulators need to comply with ESTRIN's Article 10.11 Batteries, accumulators and charging equipment.

Prevention

1. Location
   To prevent incidents, installations should be installed according to ESTRIN's requirements (Article 10.11), not to be installed in wheelhouse, accommodation, cargo hold and accommodation, or on passenger ships in passenger compartments, cabins and kitchens and must be well secured and well ventilated.

2. Cooling
   Liquid and air cooling are the only safety systems currently tested and proven to prevent thermal runaway. These active cooling systems prevent batteries from entering thermal runaway by simply extracting more heat than the cells can produce.

3. Fire protection
   For accumulators with a total power of more than 20 kWh, the spaces in which they are installed need to be protected against fire of one or more lithium-ion accumulators protected by A60-type partition walls. Fire protection needs to be approved by an expert. Accumulators with a payload of up to 2.0 kW may also be installed below deck in a cabinet or box. These requirements are not for accumulators with a payload of less than 0,2 kW.

4. Accumulator fires are very hard to extinguish. Early detection is key. Direct injection of foam shows the best heat mitigating results. High pressure water mist protection also provides good heat mitigation at module level.

5. Battery Management System
   The installation needs to be provided with battery management system (BMS), which protects a cell by cutting the power in case of external and internal short circuit, surge, complete discharge, power- and thermal management, and regulating the charging of the cells.

6. Alarm system
   Compartments where accumulators are installed need to be protected against fire from one or more lithium-ion accumulators based on a fire protection concept drawn up by an approved expert.

7. Other issues
   In the market refurbished accumulators are available. However often these do not comply to the EN 62619: 2017 and EN 62620: 2015 standards and the use of refurbished accumulators, although cheaper, should be avoided.

As of 1-1-2020, ES-TRIN 2019 is in force in which the new Chapter 11 includes 'Special provisions for electric drives'. Ships where the electric drive is installed before 1-1-2020 does not have to meet these requirements, as described above. For existing vessels with installed accumulators not all forementioned requirements are legally required. These vessels need to comply with the regulation with newly built craft and/or to the Replacement or Conversion of the parts or areas concerned, at the latest by renewal of the barge certificate after 1.1.2025. However, although when not legally required yet, it is important to abide to forementioned as much as possible to avoid serious incidents.

These exemptions on can be found in ESTRIN Article 10.11 for existing vessels can be found in ESTRIN's article 32.01, 32.02, 32.03, 32.04 and 32.05 for vessels sailing on the Rhine river and in article 33.01, 33.02 and 33.03 for vessels not sailing on the River Rhine.

Currently plans are to take containers with batteries on board to sail without emissions in the urban area. These containers are charged on shore.

In France, trials are currently being done with sodium ion batteries.

With the exception of the material, the operation of a sodium ion battery is similar to that of a lithium-ion battery, but sodium ion batteries will limit a number of limitations of current dominant lithium-ion batteries around the charging speed, fire hazard, life span, use of rare earth metals or production costs. Charging would take only a few minutes and the life span would be 10 years, i.e. three times longer than that of lithium-ion batteries at an equivalent cost. It is still unclear when batteries available for inland waterway with sufficient capacity will be available.

For smaller vessels, such as open canal boats and Amsterdam's canal boats, a full electric drive, partly due to the additional emission requirements imposed by the local authorities, is increasingly applied.

These are smaller relatively low-power drives, often powered by Lithium-ion batteries. Also in the pleasure boating electric drive more and its way. It must be noted that there is still ignorance among owners about the use of lithium-ion batteries and the requirements.

As mentioned, Lithium-ion batteries/accumulators are used for the electric drive.

'Lithium- Ion' accumulators come in various substances and have various advantages over conventional accumulators (with Lead or Nickel / Cadmium) such as a longer service life due to more charging and discharge cycles and a higher energy density, or a lot of energy at a small volume. Lithium-Ion is a collective name for rechargeable accumulators with the free ions of the substance Lithium as the energy carrier. It is known that these accumulators pose a high risk in case of a wrong application where a 'Thermal Runaway' can be caused with the possible result of a fire or even worse, an explosion.

For canal boats of the 'Amsterdam Canal Type', the requirements of the Barge scheme Annex 3.3 apply; reference is made to the ES-TRIN (Annex 1.1a of the same scheme).

Since 7 October 2018, ES-TRIN has been in force for inland waterway vessels. It contains the technical requirements to be met by vessels. For 'Lithium-Ion' accumulators is only described in Art 10.11 paragraph 15 that they must be inspected in accordance with standards EN 62619 and EN 62620. However, no further regulations were included for the installation, installation, maintenance, prevention of a calamity and the fight against a calamity at these accumulators.

In the case of new construction, refurbishment or conversion (N.V.O.), transitional provisions art.32.05 for ships on the Rhine and outside the Rhine should meet the accumulators and requirements, as well as in the case of certificate extension after 1-1-2025. The same applies to the accumulator management system in terms of the monitoring of the accumulators in respect of, among other things, the charging state, thermal management, capabilities management etc..

As of 1-1-2020, ES-TRIN 2019 is in force in which the new Chapter 11 includes 'Special provisions for electric drives'. Ships where the electric drive is installed before 1-1-2020 does not have to meet these requirements, as described above.

Chapter 11, Article 11.01 General provisions state:

1. The main electric drive of a vessel shall consist of at least:
    a) two power sources, regardless of the number of main drives,
    b) a switching device,
    c) an electric drive motor,
    d) the steering adjustments, and,
    e) pending on the construction of the electric main drives the corresponding power electronics.

2. If an electric main drive is equipped only with one drive motor and the vessel does not have any other ship propulsion that ensures sufficient drive power, the main electric drive shall be carried out in such a way that at least in the following situations the movement is ensured at its own power with the necessary maneuverability:
    a) after a failure in the power electronics or
    b) after a failure in the control and control of the of the propulsion installation.

This requires reasonable costly investment.

<u>Amended legislation (ESTRIN2021)</u>

As of 1 January 2022, ESTRIN 2021 will enter into force, which will include changes to be the use and installation of Lithium-ion batteries on board inland vessels.

These amendments and additions concern the following provisions in ES-TRIN: Article 10.11(14), (17) to (19); and ESI-I-2.
The adjustments include, among other things, the definitions from Article 1.01, namely;
3.4'electrical business premises' means a space in which there are parts of an electric drive system such as control cabinets or electric motors and is not a main engine room or engine room;
11.3 'accumulator' means a rechargeable energy source on an electrochemical basis for electrical energy;
and
11.4 'battery' means a non-rechargeable energy source on an electrochemical basis for electrical energy;';

CESNI has decided to keep the current definitions of the two concepts: accumulator and battery for the time being.

Furthermore, the legislation has been adapted with regard to the safety institutions, in view of the risks recognized;
1. risks associated with the accumulator itself and
2. risks associated with the room or cabinet where the accumulators are located (also in relation to the adjacent rooms).

For the first case, the standard EN 62619 already contains a list of risks to which specific requirements should apply: 'fire; bursting/explosion; severe short circuit due to leakage of liquid electrolytes from the cell; release of flammable gases through the ventilation openings; bursting open the housing of the cell, module, battery pack and battery system, exposing the internal components." Also, in accordance with the standard EN 62619 lithium-ion accumulators in article 10.11, sixteenth paragraph, must be equipped with an accumulator management system.

With regard to the second situation, the fire protection concept drawn up by a recognized expert in accordance with Article 10.11, seventeenth paragraph, includes the following: fire protection and the prevention of a thermal runaway (with regard to the room in which the accumulators are set up, with regard to any other devices set up in the same room and with regard to the consequences for other rooms). This concept complements the requirements of standard EN 62619 and the accumulator management system. The accredited expert must, as provided for in ESI-I-2, be an expert in lithium-ion accumulators and fire protection. This fire protection concept must take into account the instructions of the manufacturer of the lithium-ion accumulators and the provisions applicable to alarm systems. In certain cases, no fire protection concept needs to be drawn up.

Apart from this, spaces in which lithium-ion accumulators are installed must be protected by A60 partitions. They must also have mechanical ventilation to open deck.

This 17th paragraph as well as the 16th paragraph of article 10.11 does not apply to accumulators with a charging capacity of less than 0.2 kW.

<u>Application area for lithium-ion accumulators</u>

In principle, the requirements in Article 10.12, second paragraph, apply to all accumulators with the exception of the accumulators in movable equipment and with a charging capacity of less than 0.2 kW.

Article 10.11 currently apply payload as a criterion. However, "capacity" should also be taken into account here. The capacity plays an important role in risk situations and largely determines the choice of the various safety measures. By the way, if several sets of accumulators are set up in the same room, the total power should be taken.

In addition, the charging capacity is controlled by the accumulator management system that is mandatory for lithium-ion accumulators. Modern chargers have a "fast charging function" which means that they always exceed the current limit values. That's true even for small portable devices. Therefore, the payload may no longer be the appropriate criterion in this context.

CESNI, on the proposal of the classification societies, has decided to use the following criterion when applying the specific requirements for rooms in which lithium-ion accumulators are installed: the combined capacity of the lithium-ion accumulators present in the space is equal to or more than 20 kWh.

<u>Arrangement of lithium-ion accumulators</u>

In summary, it can be said that in accordance with ES-TRIN 2019:

- accumulators with a charging capacity exceeding 2,0 kW shall be housed in a special room below deck or in a closed cabinet on deck;
- accumulators with a charging capacity of up to 2,0 kW in a cabinet may be installed both below deck and on deck;
- accumulators with a charging capacity of up to 2,0 kW open, but with protection against falling objects and drip water, may be installed in an engine room, an electrical business premises or any other well-ventilated area.

No accumulators may be accommodated in wheelhouses, dwellings, cargo hold and living areas, or on passenger ships in passenger compartments, cabins and kitchens. This does not apply to accumulators in movable equipment or with a charging capacity of less than 0.2 kW.

CESNI agreed that a "special room" (and not a separate room) for lithium-ion accumulators is adequate. In this room, for example, energy inverters or an electric motor can be set up. However, the fire protection concept must take into account other devices present in the room and the risks associated with them, as well as the fact that it must be possible to enter the room in the event of an emergency.

Traction batteries

On the basis of the first experiences with Chapter 10, it has become clear that there is a need to amend Article 10.11, fourteenth paragraph. Traction batteries, as a rule, require a higher charging voltage and it has been added in the 14th paragraph that instead of the previously mentioned charging voltage of up to 120% of the rated voltage must be ensured, this for traction batteries has been increased to 125%.

ITEMS FOR CONSIDERATION

Above, a (not complete) overview has been given of the latest developments in the field of emission requirements, fuels and propulsion systems in the field of navigation.

This includes a number of cases for insurers, such as;

1. For example, what can be classified as "the engine" in the above sketch of a diesel / hybrid propulsion system in the context of the policy?
2. What is covered by the 'engine' in such a case?
3. Are fuel cells to be considered as “engines” and does the same goes for accumulators?
4. What if the warranty expires through the use of addition and to the fuel, the application of other (cheaper) fuel and/or the type approval expires?
5. What if an engine is damaged in such a way that a new engine needs to be installed and the owner wants a different manufacturer, type or power, so that the after-treatment system also needs to be replaced/adjusted?
6. To what extent are the risks of Lithium-Ion accumulators recognized and incorporated into the policy?
7. Or and to what extent should the relatively limited life span of Lithium-Ion batteries be taken into account in the insurance policy?
8. What when unapproved batteries/accumulators are applied and cause problems / fire?
9. How can insurers respond to an increase in the addition of bio in regular diesel with possible damage consequences?
10. Will the total new installation be reimbursed for the replacement of existing engines due to damage engine including after-treatment plant due to the new legislation?
11. To what extent does it not have timely adds of urea and/or maintenance of the after-treatment plant coverage consequences?
12. How is the liability arranged for the energy containers placed on board?
13. What if the container damage, not being the property of the owner of the ship
14. What if there is damage to the container in the event of a collision, for example,

15. What if a malfunction in the internal container causes equipment causing damage /fire and therefore damage to the ship?
16. What if the ship is damaged when loading or unloading the container to the ship or the container?
17. Presently more or less only diesel (B0) is generally everywhere available throughout the EU. What would be the impact logistical challenges for bunkerers having to supply of require different blends, with different percentage of FAME, its required quality control throughout the EU?
18. How soon could a better EU wide accepted increase quality specs of FAME throughout the EU be achieved?
19. How soon could a better EU wide accepted increase quality specs of FAME throughout the EU be commonly available.
20. What will be the consequences if different blends will not be widely available throughout the EU with respect to owners "good housekeeping"?
21. How well can the logistical for the supply of diesel in inland navigation be periodically adapted when the different blends with different % of FAME, which % will also periodically change in view of the RED II / RED III requirements?

We did not discuss other issues which are a spinoff of the desire/need for more efficient, and environmentally friendlier inland navigation. Developments such as;

- Autonomous sailing
- Vessel train with remotely controlled connections
- Increase of cybersecurity due to more and more automation on board, on shore and within ship to board communication and control.

However each of fore mentioned subject by itself is too complex to in short comment on the consequences for insurers, apart from the fact that most are still in a pilot/research phase. Nevertheless these also are subjects which will need constant follow up and in time evaluation as well.

With respect to the most recent propulsion and environmental related developments, we hope to herewith have given some information and things to think about for the near future.

Henk Arntz BSc
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