DNV·GL

MARITIME

GLOBAL SULPHUR CAP 2020

Know the different choices and challenges for on-time compliance

SAFER, SMARTER, GREENER

CONTENTS

INTRODUCTION

The global 0.5% sulphur cap will be introduced in 2020, and up to 70,000 ships may be affected by the regulation according to IMO estimates.

Stricter limits on sulphur (SO_x) emission are already in place in Emission Control Areas (ECAs) in Europe and the Americas, and new control areas are being established in ports in China. As a result of the increased international attention to air pollution, a growing number of shipowners are beginning to weigh their options to ensure compliance.

They face a choice of switching from heavy fuel oil (HFO) to marine gas oil (MGO), burning ultra-low Sulphur HFO/hybrid fuel, retrofitting vessels to use alternative fuels such as LNG or installing scrubber systems which allow them to continue operating on regular HFO.

To assist in navigating both the regulatory landscape and the alternatives for compliance, this guidance paper aims to provide an introduction to the choices and challenges ahead. We recommend starting planning and acting as soon as possible, to ensure compliance in the most cost-efficient way.

REGULATIONS

SO_X REGULATIONS

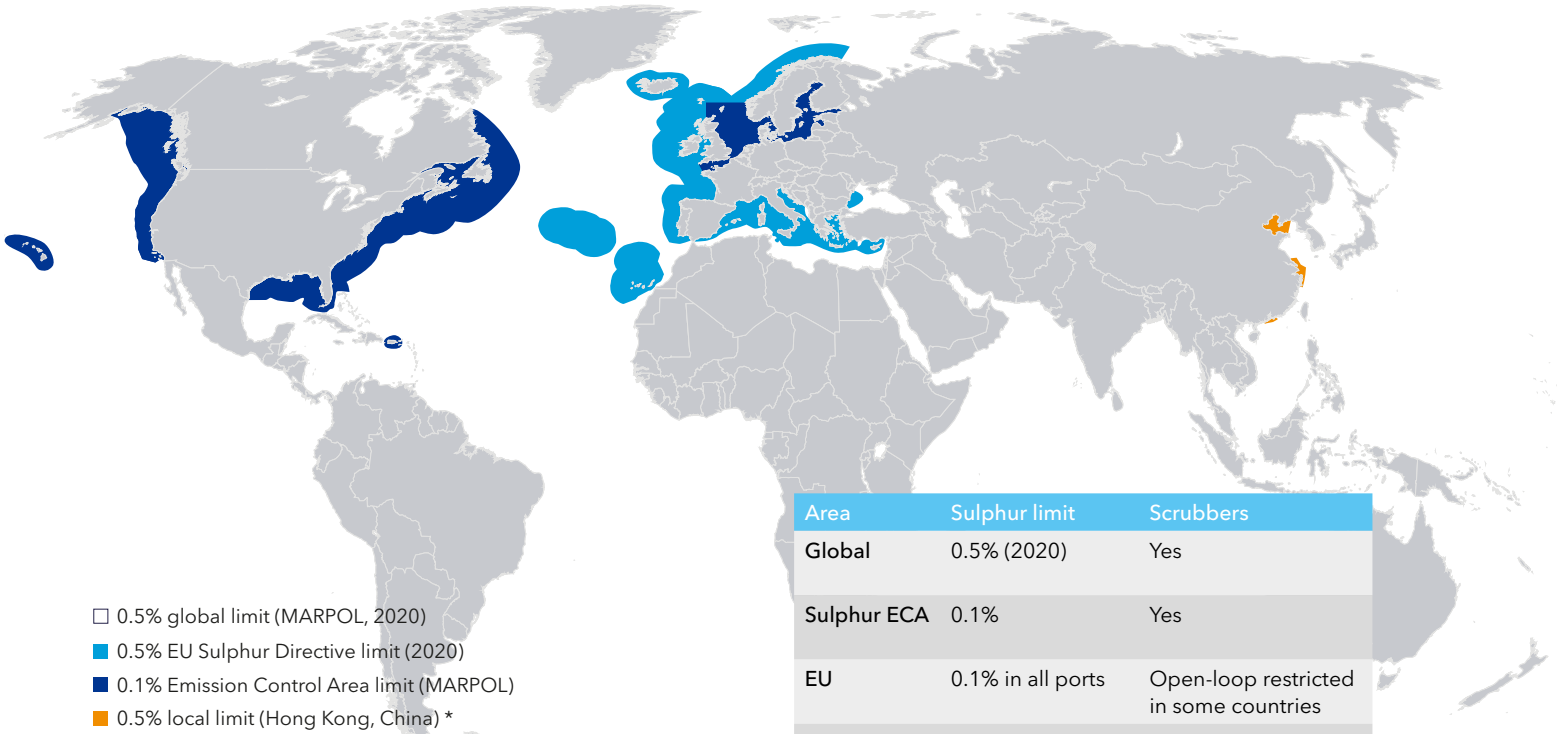
After a review of the outlook of the availability of compliant low sulphur fuel oil in 2020, the IMO has decided that the global fuel sulphur limit of 0.5% should enter into force in 2020. This requirement is in addition to the 0.1% sulphur limit in the North American, US Caribbean, North Sea and Baltic Emission Control Areas (SECA).

A complicating factor is the regional and local regulations, which in some cases stipulate stricter requirements and in others, prohibit certain compliance options.

The **European Union** Sulphur Directive stipulates a maximum 0.5% sulphur content for ships in all EU waters by 2020, and a 0.1% limit in ports. In certain EU countries, it should also be noted that the Water Framework Directive is putting constraints on the discharge of scrubber water. Belgium and Germany have in essence prohibited the discharge of scrubber water in most areas, severely constraining the operation of open-loop scrubbers. Other EU countries are following suit to a lesser or greater degree, with no common EU practice likely to be agreed.

Currently **Hong Kong** has a 0.5% sulphur limit for vessels at berth. China has recently published regulations for domestic SECA-like requirements in the sea areas outside Hong Kong/Guangzhou and Shanghai, and in the Bohai Sea. China is taking a staged approach, initially requiring maximum 0.5% sulphur content in fuel burned in key ports in these areas, gradually expanding the coverage, and culminating in applying the requirements to fuel used in the sea areas from 2019 onward. There is the possibility that the requirement will be tightened to 0.1% in 2020, and that a formal ECA application may be made to IMO.

California's Air Resources Board (ARB) enforces a 0.1% sulphur limit within 24 nautical miles of the Californian coast. The regulation does not allow any other compliance options than low sulphur marine gas or diesel oil (DMA or DMB). A temporary research exemption may be granted allowing the use of a scrubber. The application has to be sent before entering Californian waters. A sunset review is expected in 2018 which may conclude that the ECA regulations are sufficient.



- 0.5% global limit (MARPOL, 2020)
- 0.5% EU Sulphur Directive limit (2020)
- 0.1% Emission Control Area limit (MARPOL)
- 0.5% local limit (Hong Kong, China) *

* Note that China and Hong Kong may go down to 0.1% before 2020

Area	Sulphur limit	Scrubbers
Global	0.5% (2020)	Yes
Sulphur ECA	0.1%	Yes
EU	0.1% in all ports	Open-loop restricted in some countries
China	0.5% in selected areas	Yes
California	0.1% within 24 nm	No, only through research exemption

ENFORCEMENT

It is presently not clear how the global sulphur cap will be enforced. The only current experience is with the limits applied in the Emission Control Areas, in particular the 0.1% limit in force from 1 January 2015, and the EU Sulphur Directive.

Mostly the challenge has been related to the fuel-switch process, but with more experience gained and improved training, these issues have disappeared. There is no evidence of large-scale deliberate non-compliance. Veritas Petroleum Services reported that the share of the marine distillates sample increased from 25% to 40% with the 0.1% sulphur limit in ECAs. As part of the application of the EU Sulphur Directive, the following issues have been raised for shipowners and operators to be aware of.

- **Handling fuel samples:** Representative fuel samples should be forwarded in clean, properly marked and sealed bottles to a laboratory for testing. The laboratory should be accredited for fuel oil analysis according to ISO 17025 to ensure reliable and correct results. The sampling frequency is increased, with Member States being obliged to check approximately 10% of all individual ships calling at EU ports for compliance with the EU Sulphur Directive.

- **Reporting:** Storing inspection data from samples and surveys is an issue that has been solved by establishing a software platform for reporting and sharing this information with all Member States (Port States). It is an extension of the European Maritime Safety Agency's (EMSA) Thetis data system, called "Thetis-S".

- **Awareness and training:** Another important issue is to raise awareness for fuel switching and sulphur control inspection. Various parties offer training sessions for inspectors and crews. Along with publications, they can help you and your crew to learn about the potential safety risks of the fuel changeover procedure and how to avoid such risk.

- **Port State Control:** Port State Control inspectors also need to be qualified. Only PSC personnel with sufficient knowledge about fuel systems, machinery and fuel sampling should be authorized to carry out the on-board inspections.

- **Targeted controls:** "Remote Sensors" or "in situ" SO_X emission monitoring are being tested as options for checking compliance with the regulation. So-called "sniffers", installed in planes or fixed on bridges or harbour entries, are capable of indicating whether compliant fuel is used while the exhaust plume of the ship is passing the sniffer. This could help PSC target their sampling better and increase the number of ships that are checked for compliance with the sulphur directive in their port. Ports in Sweden, Denmark, Germany and the Netherlands already use this type of "sniffer" technology. However, this will not replace on-board fuel sampling, as for enforcement purposes Port State Control is legally obliged to rely only on physical fuel samples.

The sulphur cap of 0.50% planned for 2020 will have a more significant effect on shipping costs. Our calculations show that they could increase between 20% and 85%, depending on the assumptions regarding speed, fuel price and ship size. The relatively large margin is due largely to the uncertainty surrounding the availability of low sulphur ship fuel.

REDUCING SULPHUR EMISSIONS FROM SHIPS – © OECD/ITF 2016

If the global cap is implemented in 2020, and if fuel costs stay at the current low levels which have applied since the dramatic fall in oil prices during 2015, a mandatory switch to low sulphur fuel would mean that bunker costs would return to their 2014 peak. But if by 2020, as some predict, oil prices increase to something approaching US$ 70 a barrel (still well short of the peak in 2014), it has been estimated that the differential between compliant and residual fuel could spike by as much as US$ 400 a ton.

International Chamber of Shipping

OPINIONS ABOUT THE SULPHUR CAP

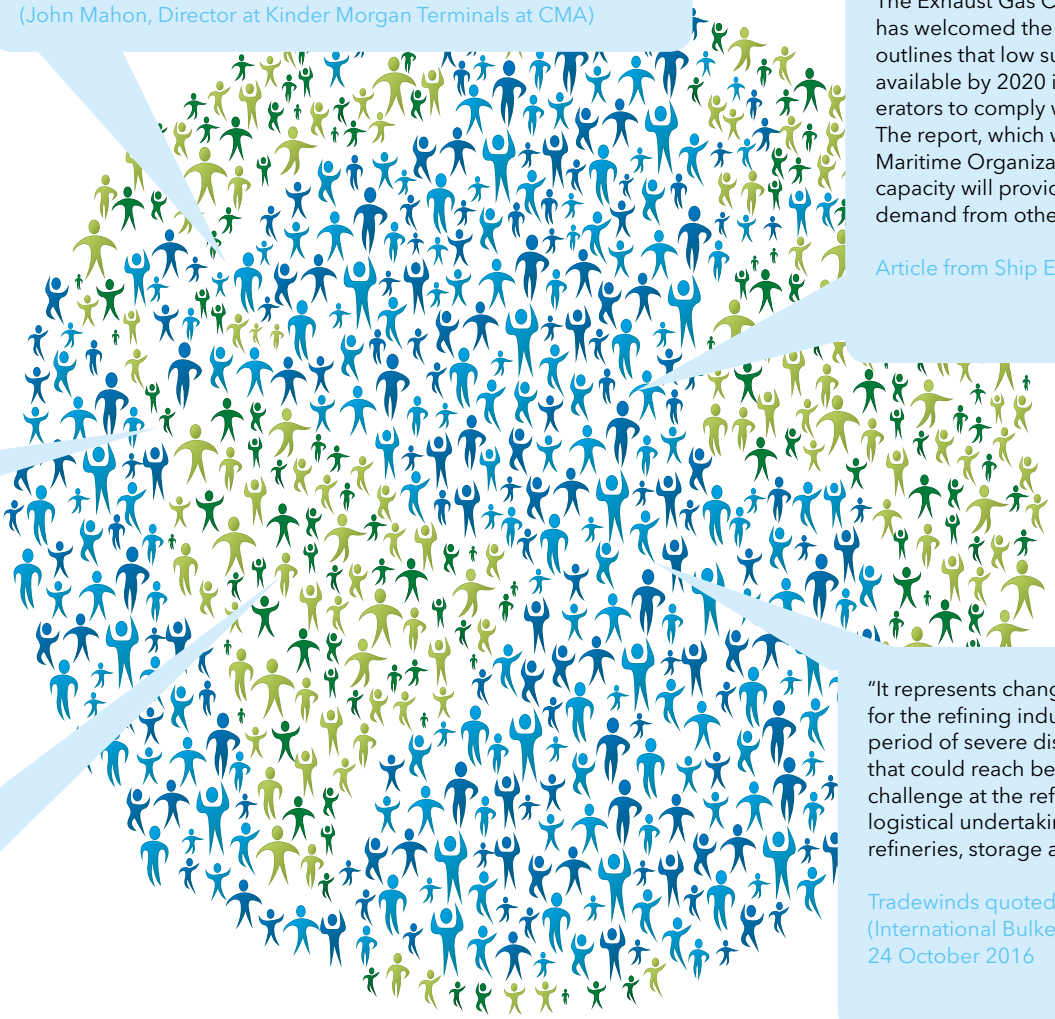
The debate prior to IMO's decision became very heated. Two commissioned studies concluded differently on the availability of low sulphur fuels in 2020, leading to an extensive debate regarding the assumptions and possible consequences for shipping.

Predicting the availability and in particular the price of fuels in the future is a difficult task with numerous assumptions being made. Below is a small collection of the various opinions by stakeholders in the maritime industry.

Despite the IMO deemed the availability of low sulphur fuel to be sufficient, several stakeholders questions this. Hence, uncertainties when it comes to both fuel price and availability remain an isssue for the industry. DNV GL has tried to illustrate these uncertainties in the further description of possible compliance options and case studies.

There is very little interest in the refining community that I've seen in fixing the resid problem. If they are going to fix the problem, they're going to make a lot more diesel and distillate, which has a lot more value to them.

Article from Ship&Bunker, 7 September 2016
(John Mahon, Director at Kinder Morgan Terminals at CMA)



The Exhaust Gas Cleaning Systems Association (EGCSA) has welcomed the findings from a CE Delft study that outlines that low sulphur marine fuel will be sufficiently available by 2020 in order to allow shipowners and operators to comply with the 0.5% global sulphur fuel cap. The report, which was commissioned by the International Maritime Organization (IMO) shows that the refining capacity will provide enough low sulphur marine fuel as demand from other sectors for distillates has slowed.

Article from Ship Efficiency Review, 15 July 2016

"It represents change on an un-precedented scale for the refining industry, and would likely result in a period of severe disruptions and market distortion that could reach beyond shipping. Aside from the challenge at the refineries, this will also be a huge logistical undertaking involving transport between refineries, storage and delivery vessels"

Tradewinds quoted a statement from IBIA (International Bulker Industry Association), 24 October 2016

HOW DOES THE GLOBAL SULPHUR CAP AFFECT SHIPPING?

AVAILABLE FUELS AFTER 2020

Shipowners and operators should start considering:

- Which fuel should their vessel use?
- Are the fuels available where the vessel will operate?
- What will the cost implications be?

As there are a variety of options to consider, planning and implementing should start as soon as possible.

HFO (3.5% S) will be available, though compliance will require the installation of exhaust gas cleaning systems. Compliant fuels and distillates will be on the market, but will be more expensive and have different operational issues. Alternative fuels, such as LNG, are and will be available, but requires investments and the price fluctuations are different from conventional fuel. Other fuels such as methanol or ethanol may be an alternative where such fuels are available, and in the far future, a hydrogen fuel cell combined with battery technology could be viable for use in the marine industry.

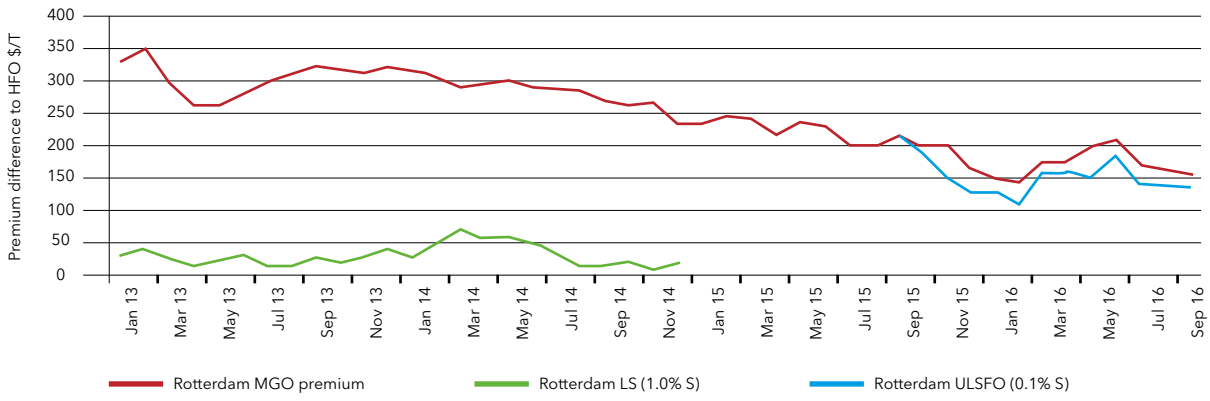
There is, however, some uncertainty in the industry whether there will be a sufficient amount of compliant fuels available, how this will affect fuel oil prices and, not least, how the enforcement of the sulphur cap will be carried out.

Experience from SECA implementation

Experience from the SECA areas that came into force in 2015 show that the majority of operators have opted for the fuel switch from HFO to MGO, with just a small percentage having chosen to use HFO with exhaust gas cleaning or LNG as fuel. This is expected, as scrubbers require a costly retrofit and the industry has questions regarding technological maturity and operational limitations, and LNG is mostly relevant for newbuilds. In particular, larger vessels do not spend a significant amount of time in ECAs to justify an expensive investment. In addition, where charters are paying for the fuel, there is no or little incentive for an owner to invest in equipment for running on cheaper fuel as he will see no return on the investment.

In 2015, a distinct change in deliveries of international marine bunkers within Europe was observed. While demand for residue bunker oil fell by around 10%, marine gas oil deliveries grew by as much as 50%. Despite higher demand, the premium MGO prices

Low sulphur fuel premiums



remained unchanged, whereas the blended, hybrid 0.1% fuel oil was priced around 10% lower than distillates.

This is why the increased cost of operating in ECAs was essentially driven by the increased cost of switching from a lower-grade fuel (HFO 1% S) to a higher-grade fuel (MGO 0.1% S), rather than the price increase of MGO triggered by higher demand. Will there be a similar effect from the global cap in 2020, or will we see some other mechanisms influencing the prices?

Possible price development

Implementation of the global sulphur cap continues to generate countless discussions about future low sulphur fuel availability as well as its possible price development.

Predicting the future fuel price is indeed a challenging task. A transition to a higher-grade fuel will most likely result in elevated fuel costs for the industry.

The cost of different grades of fuel has been closely correlated; however, such correlation should not be used for the future predictions. Increased blending will lift the demand for distillates, subsequently changing the historic correlation and most likely driving the prices upwards. As a result, we may observe a widening gap between two competing fuel solutions, with HFO (combined with scrubber) setting the bottom price and MGO representing the upper level.

> During the implementation of the SECA areas, the majority of operators simply switched to MGO/MDO fuels. If we follow the same pattern again, increased MGO prices are inevitable in the short term.

Nevertheless, as the production of low sulphur-blend hybrid fuels (0.5% S) is gradually introduced, we may observe the prices of distillates eventually levelling off. However, if a substantial price differential between the traditional HFO and the compliant fuels persists over time, the alternative solutions, such as scrubbers or using LNG as fuel, may prove to be the preferred solution.

WHAT ARE THE OPTIONS?

The time to implementation is short, and operators who are investigating options other than a fuel shift to MGO need to have their strategies ready for actions to take and options to choose between.

There is no one-size-fits-all solution, and the best option very much depends on vessel type, size of vessel, operational patterns and which fuels are available in the short and long term. For options requiring a retrofit, it is also important to consider the complexity of installation, possible off-hire and the remaining lifetime of the ship.

HFO with SO_X scrubber

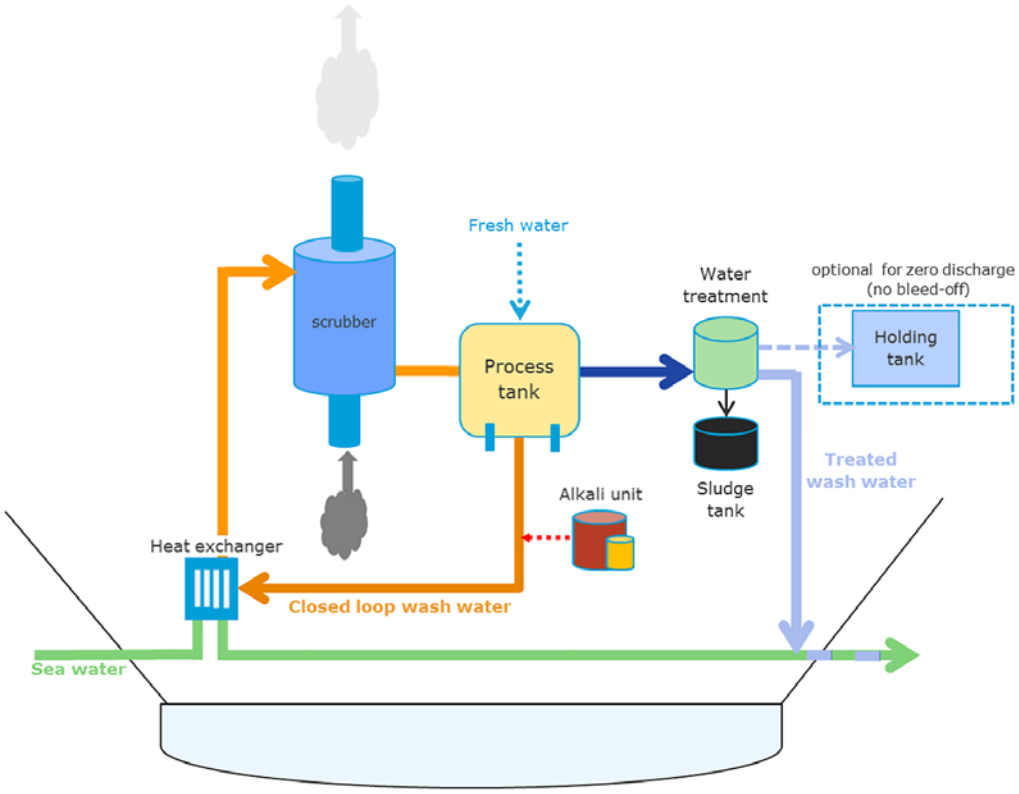
HFO will still be an option after 2020. This might be an alternative for owners who are concerned about price increase and availability of compliant fuels. However, to be in compliance, it will require the installation of exhaust gas cleaning technology commonly known as SO_X scrubbers. No changes will have to be made to the engines or fuel treatment plant, but the installation of a scrubber could be complex, especially for retrofits. There is a significant investment cost for the exhaust gas cleaning plant, and there will also be operational expenses related to increased power consumption, need for chemical consumables and sludge handling.

Will the scrubber manufacturers in the short term have the capacity to produce and install sufficient amount of systems on vessels to make it a common sight at sea? In the long run, if the price difference between high and low sulphur fuels is high and maintenance proves to be manageable, scrubbers may become a widespread technology.

Scrubber technologies

There are two technologies available today: dry and wet systems. The wet systems are by far the most predominant. Within the wet systems there are three alternatives: open loop, closed loop and a hybrid system that can operate either as a closed- or open-loop system.

In addition, one can choose between multi-inlet scrubbers, allowing for exhaust from more than one emission source or a single-inlet scrubber that serve only one engine. The technology is suitable in most cases for retrofitting vessels as well as for newbuildings.



Principal sketch of closed-loop scrubber

All known scrubber concepts have the potential to meet both the 0.5% and 0.1% criteria.

The optimal scrubber type for a given ship depends on the machinery configuration, operational profile and the routes of the vessel, such as time spent inside/outside areas and harbours with restrictions against wash water discharge. In addition, there are weight and space considerations that have to be taken into account, especially for retrofitting on existing vessels.

Open-loop systems use seawater, which is alkaline by nature in order to wash out the SO_X in the exhaust. The resulting waste water must meet MARPOL requirements before being discharged. However, if a vessel occasionally sails through waters with a slightly more acidic pH-level, such as rivers or brackish waters, a hybrid (open/closed loop) solution could be considered. Another drawback of open-loop-only systems is that several ports in Europe and the port of New Haven in the United States presently prohibit the release of open-loop water. Other ports may implement similar regulations in the future.

For vessels operating inside areas where discharge to sea is restricted, closed-loop or hybrid systems are necessary.

Closed-loop systems use wash water mixed with chemicals, such as caustic soda, to boost the alkalinity of the wash water, which is then recirculated through the system and partially purged. Currently, hybrid scrubbers are the most popular solution, followed by open-loop systems. Closed-loop scrubbers are installed on ships sailing mainly in fresh water or low-alkalinity areas, such as the Great Lakes in the United States.

The main differences between a scrubber designed for the global cap of 0.5% sulphur content and the SECA restriction of 0.1% sulphur content will be the amount of water used in the cleaning process and the amount of chemicals for the closed-loop system. The scrubber tower is designed for the exhaust flow and will not be much affected by what fuel is used. For vessels operating both inside and outside ECAs, operational modes for both 0.5% and 0.1% sulphur cleaning is advised.

DNV GL can help you make the right decision by assisting with feasibility studies, cost-benefit analyses with risk assessments with regard to installation on newbuilds as well as for retrofits. DNV GL has also performed technology qualification projects for the major scrubber suppliers.

Distillates
Switching to distillate fuel will mean a significant increase in fuel cost and may also require upgrading to the fuel treatment plant due to the significantly lower viscosity of the fuel.

New low sulphur fuels (0.5% S)
Low sulphur compliant hybrid fuels are expected to be available, as refineries gear up their plants. De-sulphurisation is costly and refineries may opt to refine higher grade fuels rather than invest in de-sulphursation systems. Some stakeholders in the industry are concerned if the supply of de-sulphurised fuels will cover the demand by 2020, leaving the world fleet to rely on MGO or distillate blends.

In the aftermath of the implementation of the SECA areas, compliant blends of fuel are on the market to serve the 0.1% restriction. It is expected that new blends to comply with the IMO 0.5% sulphur cap will be introduced. It is also expected that many of the same issues regarding the SECA blends will also emerge with these new fuel blends. Typical issues with the SECA blends have been that they are more sensitive to storage, handling and compatibility. Diligent use and handling of these types of fuel are important for successful operation. Quality control when bunkering to ensure that on-spec fuel is received will be important. Mixing fuels may cause flocculation of asphaltenes even in small quantities in the treatment system.

The use of the new hybrid fuel should be carefully considered and planned (with fuel suppliers, makers of engines, purifiers, filters, etc.) so the new fuel will not cause any risk to ship and engine safety!

LNG as fuel
With the IMO 0.5% sulphur cap, it is expected that LNG as fuel will gain a more favourable position as a marine fuel. LNG as fuel is now a technically proven solution, and LNG bunkering infrastructure is developing rapidly. While conventional oil-based fuels will remain the main fuel option for most existing vessels in the near future, the commercial opportunities

HFO WITH SCRUBBER

+

- Can use conventional HFO
- Possible for retrofit
- Reduces particulate matter as well as SO_x

−

- Initial investment (US$ 2-10 m)
- 3-5% fuel penalty
- Requires space for scrubber tower and supporting systems
- Requires chemicals (closed loop)
- Requires integration with ship's power management system
- Requires monitoring

DISTILLATE FUEL

+

- Useable for most engine configurations

−

- Higher fuel cost
- May create operational issues due to low viscosity of the fuel

of LNG are interesting mainly for newbuilds, but in some cases also for conversion projects. Taking the leap to LNG should only be made on the basis of the best possible information and a thorough analysis.

Besides the commercial aspects, the main argument for choosing LNG as a ship fuel and in the replacement of conventional oil-based fuels by LNG is the significant reduction in local air pollution – ranging from emissions of SO_x and NO_x to particulates (PM). The complete removal of SO_x and PM emissions and a reduction of NO_x emissions of up to 85% by using LNG is a strong argument for the use of LNG, especially in the ECAs. In addition, LNG can also to some extent reduce CO_2 emissions, up to 25%. As a fuelling option, LNG offers multiple advantages to human health and the environment. It also has a positive impact on the Energy Efficiency Design Index (EEDI) of the ship.

Today, gas engines cover a broad range of power outputs. Concepts include gas-only engines, dual-fuel four-stroke and two-stroke, and are thus suitable for all types of vessels.

DNV GL has contributed significantly to the evolution of LNG as ship fuel over the past 15 years. This long involvement has resulted in our in-depth and proven advisory service portfolio, and has given us a leading role in the classification of gas-fuelled ships. LNG as fuel is ready to set course, and we can help you succeed.

Other alternative fuels

There are a variety of emerging fuels that could be considered. The most predominant are methanol, different types of biofuels and LPG. These are considered to have very little impact on the market as a whole, but are alternatives that can be considered where supply is readily available. Apart from some of the biofuels, changing to these types of fuel will need special adaptive engines and fuel treatment systems.

NEW COMPLIANT FUELS

- Useable for most engine configurations

- Unknown fuel cost
- Not on the market (no track record)
- Uncertain availability
- May create operational issues due to off-spec fuel or incompatibility (ref. ECA hybrid fuels)

LNG AS FUEL

- Has good environmental performance
- Can reach Tier III performance
- Positive impact on EEDI

- High investment cost (US$ 3-30 m)
- Costly to retrofit
- Large regional variations in LNG price
- Methane slip in exhaust
- Requires space for tank
- Some engines types need additional systems to reach Tier III

FUTURE TRENDS

With the global 0.5% sulphur limit entering into force in 2020, DNV GL expects that there will be an increasing demand for scrubbers. Will the yards and makers have sufficient capacity to handle the demand?

Even if suppliers and yards gear up, we believe that there will be a few thousand scrubber installations by 2020, requiring the rest of the fleet to rely on compliant fuel.

The number of ships using LNG as fuel is increasing, and more and more infrastructure projects are planned or proposed along the main shipping lanes. In line with this dynamic development, DNV GL expects LNG to grow even more rapidly over the next five to ten years. At the same time, LNG is commercially attractive and available worldwide in quantities able to meet the fuel demand of shipping in the coming decades. LNG as fuel is especially expected to increase for vessels frequently operating in the North American and North European waters with existing or upcoming NO_x requirements. An increase in compliant fuel prices relative to LNG will encourage operators to invest in LNG.

Alternative fuels, such as methanol and biofuels, are expected to only be able to serve a minor share of the market. They will be an alternative in some local areas, where the supply fits trading patterns for vessels.

Looking farther into the future, hydrogen as fuel with fuel cell technology combined with batteries is an emerging alternative.

WHAT TO DO

2020 is rapidly approaching. Strategies and plans for how to react to the 0.5% sulphur cap need to be addressed soon in order to have the best competitive edge on the market. DNV GL has calculated scenarios for three different ship types, each with three different ages and trades.

A cost comparison between a scrubber, LNG and a range of compliant fuel alternatives are shown for a newbuilding for each ship type. The scenarios are general, and the conclusions will vary depending on the assumptions that are used. DNV GL can further offer ship-specific calculations for your vessel or fleet as part of our advisory services.

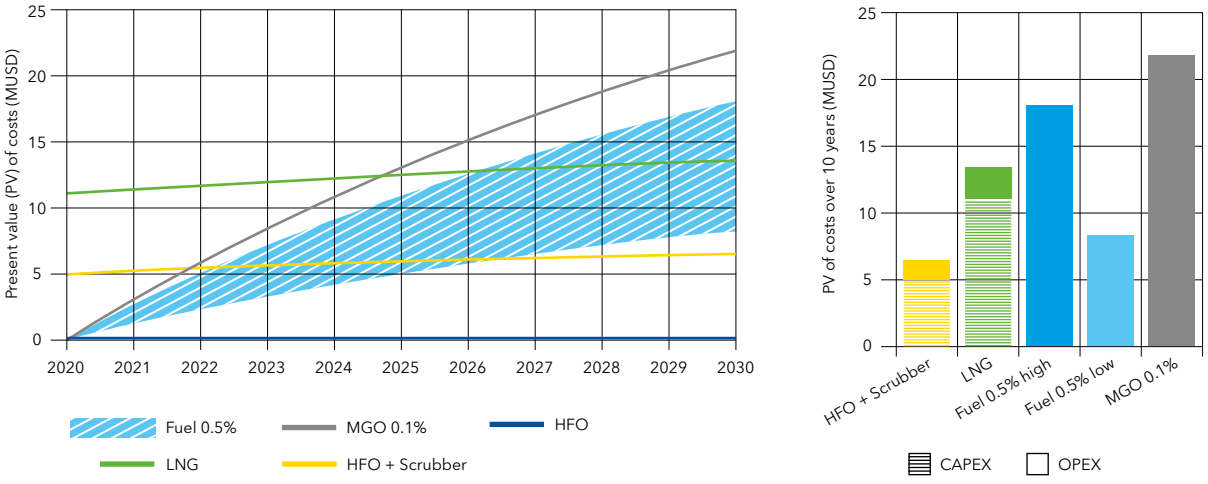
The cost comparisons are based on the difference between HFO and the alternatives, where the HFO is the base case and set here at $300. Running on HFO with a hybrid scrubber is shown with an investment for installing the scrubber and increased operating costs. The compliant fuel is shown as a range, where the lower side represents an increase in fuel cost of 30% or $90 above the HFO price and the upper end represents 80% or $240 above the HFO price. It should be noted that the absolute price spread of the alternative fuels will vary with variations of HFO prices. For operation within ECAs a 0.1% ECA compliant fuel is used with a high price estimate 100% or $300 above the HFO price. The LNG alternative has an investment cost and a running cost based on an assumed LNG price. The LNG price is set differently for the different ship types due to the amount of LNG needed. It is expected that larger amounts of LNG ordered will result lower prices. The prices are set respectively above HFO:

Tanker: **10%**
Container: **5%**
Bulk carrier: **15%**

TANKER

	Tanker 1	Tanker 2	Tanker 3
Age	3	13	To be built
Operating profile	High speed (15 knots)	Low speed (11 knots)	High speed (15 knots)
ECA exposure	Medium	Low	High
TC / spot (...who pays for fuel?)	TC (long term)	Spot	TC (long term)
North America trade?	NO	NO	Yes
Solution 1	**Hybrid fuel** 0.5% outside ECA 0.1% in ECA	**Hybrid fuel** 0.5% outside ECA 0.1% in ECA	**Hybrid fuel** 0.5% outside ECA 0.1% in ECA + EGR/SCR (Tier III)
Solution 2	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA + EGR/SCR (Tier III)
Solution 3			**LNG** + EGR/SCR (Tier III)*

Accumulated cost compared to HFO baseline



The graph shows a comparison between today's situation, running on traditional HFO, and a future case where a scrubber, LNG or compliant fuel is used.

A newly built Aframax tanker running on conventional non-compliant HFO with a scrubber will need an extra initial investment for the scrubber system of around $5 million. Compared to using a compliant fuel, the payback time, depending on how the compliant fuel cost varies, will be from 2.5 to 6 years.

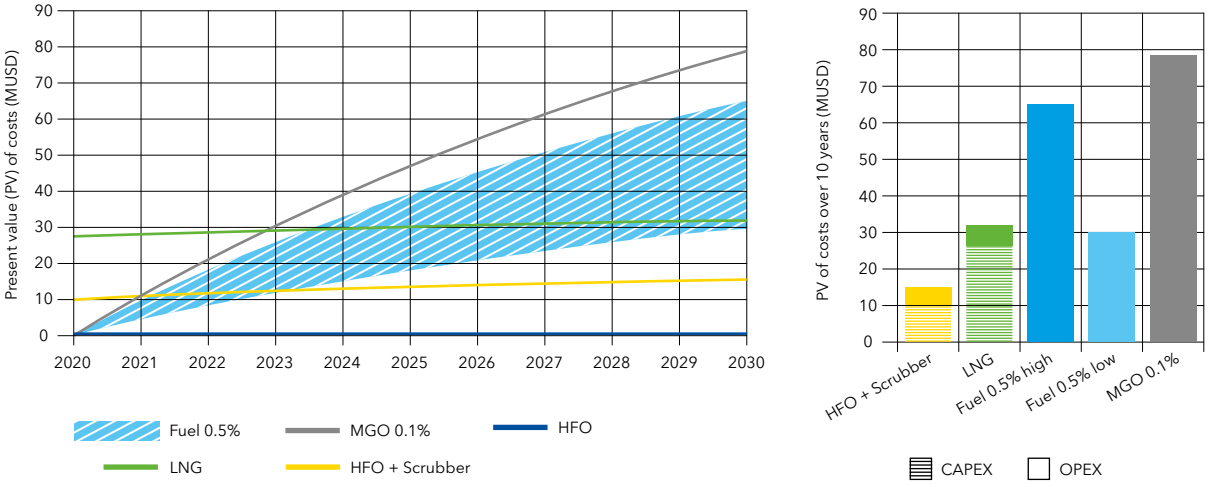
Similarly, if an LNG alternative is chosen, the initial investment will be about $11 million and the payback time may vary from 6 to well beyond 10 years. With the payback times estimated, the scrubber alternative should be feasible both for newbuildings and retrofits. One must expect a somewhat higher initial cost when retrofitting a scrubber system on an existing vessel, while the LNG alternative appears to be less interesting both for new and existing vessels.

* Using LNG as marine fuel removes 85-90% of NO_X in the case of low-pressure engines (2- and 4-stroke), while for a high-pressure engine

CONTAINER VESSEL

	Container vessel 1	Container vessel 2	Container vessel 3
Age	3	13	To be built
Operating profile	Operating at design condition	Operation at lower speeds than designed for	Operating at design condition
ECA exposure	Medium	Low	High
North America trade?	No	No	Yes
Solution 1	**Hybrid fuel** 0.5% outside ECA 0.1% in ECA	**Hybrid fuel** 0.5% outside ECA 0.1% in ECA	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA + EGR/SCR (Tier III)
Solution 2	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA	**LNG** + EGR/SCR (Tier III)*
Solution 3	**LNG?**		

Accumulated cost compared to HFO baseline



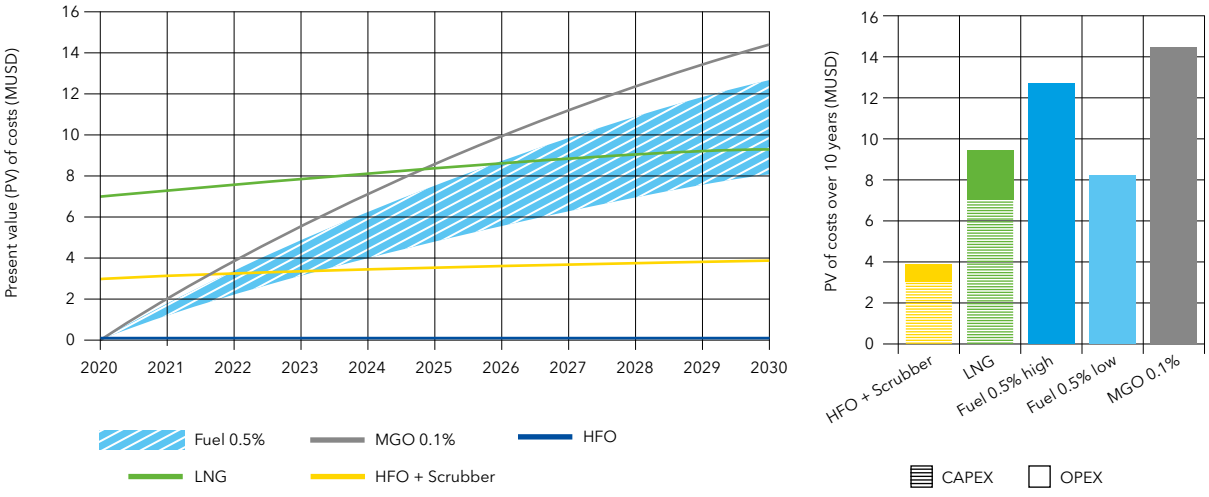
A new 19,000 TEU container carrier running on conventional non-compliant HFO with a scrubber will need an extra initial investment for the scrubber system of around $10 million. Compared to using a compliant fuel, the payback time, depending on how the compliant fuel cost varies, will be from 1 to 3 years. Similarly, if an LNG alternative is chosen, the initial investment will be about $28 million and the payback time may vary from 4 to just beyond 10 years. With the payback times estimated, the scrubber alternative will be feasible both for newbuildings and retrofits. The short payback time for the scrubber alternative is a result of the large amount of fuel these types of vessels use. LNG may be an alternative and should be considered for new vessels. However, it appears to be fuel-price sensitive for retrofitting existing vessels, though, it may still be sensible to consider LNG as fuel for vessels that have a high degree of exposure in North American and other NECAs.

without further emission abatement systems, NO_x removal is typically 40% to 50% when operating on LNG, hence requiring EGR or SCR.

BULK CARRIER

	Bulker 1	Bulker 2	Bulker 3
Age	3	13	To be built
Operating profile	Normal speed profile	Normal speed profile	Medium /high speed
ECA exposure	Medium	Low	High
North America trade?	No	No	Yes
Solution 1	**Hybrid fuel** 0.5% outside ECA 0.1% in ECA	**Hybrid fuel** 0.5% outside ECA 0.1% in ECA	**Hybrid fuel** 0.5% outside ECA 0.1% in ECA +EGR/SCR (Tier III)
Solution 2	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA	**HFO + Scrubber** 0.5% outside ECA Scrubber 0.1% in ECA +EGR/SCR (Tier III)
Solution 3			**LNG** +EGR/SCR (Tier III)*

Accumulated cost compared to HFO baseline



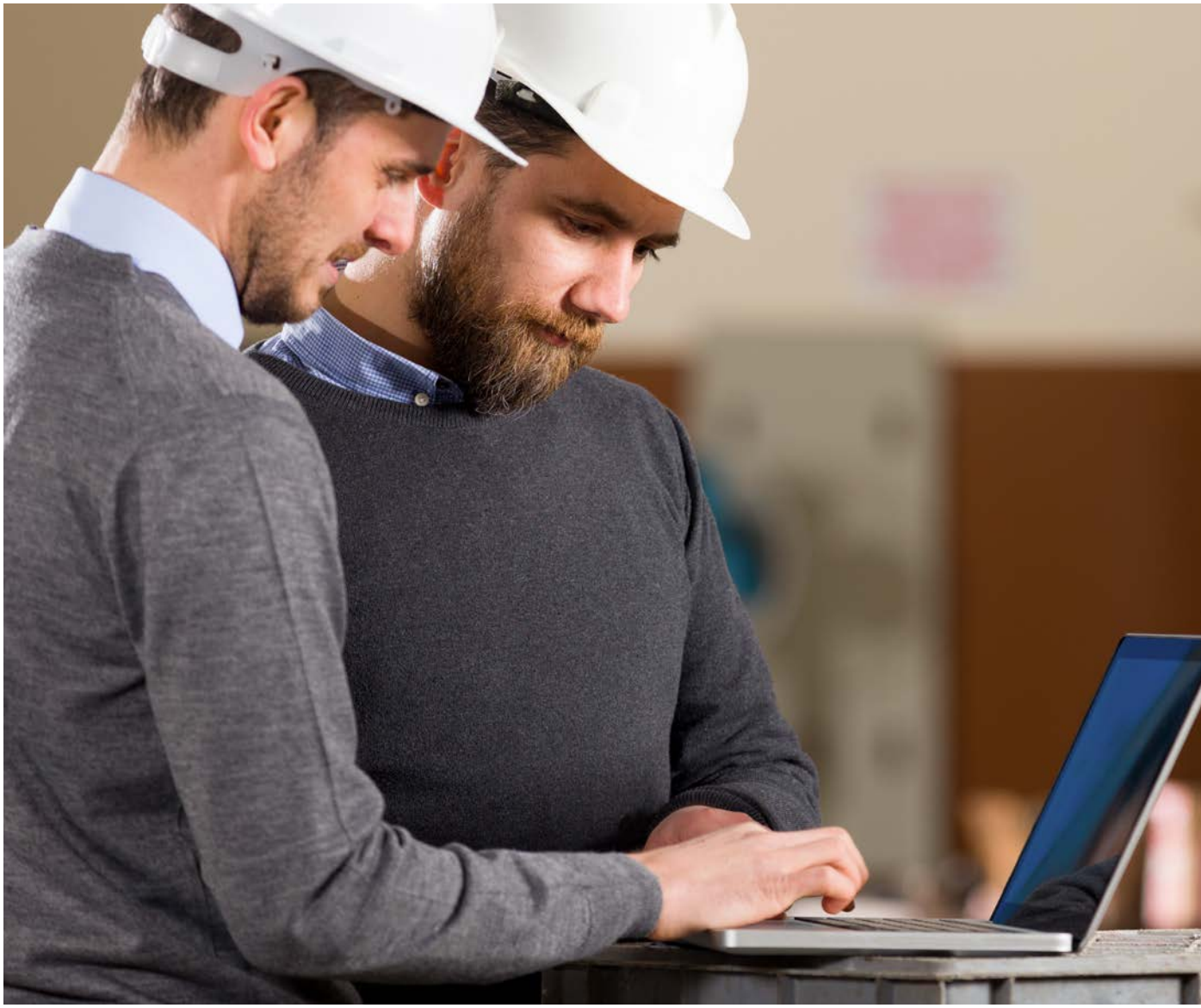
A new Handymax bulk carrier running on conventional non-compliant HFO with a scrubber will need an extra initial investment for the scrubber system of around $3 million. Compared to using a compliant fuel, the payback time, depending on how the compliant fuel cost varies, will be from 2 to 3.5 years. Similarly, if an LNG alternative is chosen, the initial investment will be about $7 million and the payback time may vary from 6 to well beyond 10 years. With the payback times estimated, the scrubber alternative should be feasible both for newbuildings and retrofits. The LNG alternative is much more sensitive to the price differences between HFO compliant fuel and LNG, but may be an alternative with a high degree of exposure to trade in North American and other NECAs.

DNV GL SUPPORT

Keeping up to date with global and local environmental legislation is challenging. To minimize future operational risk, it is hence important for shipowners to thoroughly consider a strategy for compliance.

With its long-standing maritime expertise in regulatory affairs, operational experience and technical innovation, DNV GL is prepared to support our customers to overcome this challenge. We provide a wide range of services and support to ensure regulatory compliance in the most cost-effective way.

For more information, please contact your Key Account Manager or use our DATE service (Direct Access to Technical Experts) via My DNV GL **my.dnvgl.com.**



CLASS SERVICES

Based on years of experience, DNV GL has developed several class notations to support the switch to low sulphur fuels, preparing shipowners for lower sulphur limits and more. The notations are briefly described below.

Gas Ready notation

LNG as ship fuel is spreading rapidly through the maritime world. To be more flexible and competitive, you need to ensure your newbuilding is ready for future LNG conversions. Based on the experience we have gained from our LNG Ready Service, as well as the 50 LNG-fuelled vessels we already have in class with our Gas fuelled notation, we have developed the new Gas Ready notation. This notation enables you to ensure that a future LNG-fuelled version of your vessel complies with the relevant safety and operational requirements. It also helps you specify and quantify the level of investment you are making at the newbuilding stage.

The basic notation – with nominators D and MEc – GAS READY (D, MEc) – verifies that the vessel is in compliance with the relevant rules in terms of its overall design for future LNG fuel operations, and that the main engine can be converted or operate on gas fuel.

You can also choose to add extra optional levels to the newbuilding under the notation – putting the vessel further along the LNG track and thereby speeding up and simplifying a later conversion.

Scrubber Ready

DNV GL has created a class notation to help shipowners prepare their newbuildings for the installation of a scrubber. It ensures that the necessary preparations are in place for a smooth and cost-efficient scrubber retrofit at a later stage. The notation can be awarded to ships that have planned and partly prepared for the installation of an exhaust gas cleaning system (EGCS) for the removal of SO_x at a later date. The notation identifies the general type and category of scrubber systems that can be installed on the vessel. It also details the level of scrubber readiness, with the minimum scope attesting that the space available and future installation arrangement meet class and statutory requirements. This can be expanded to include more extensive preparations, through to a complete review of the scrubber documentation according to main class rules, including the certification and installation of piping and subsystems. For shipyards, working with the Scrubber ready standard gives an easy framework within which to offer future-ready ship designs to the market.

DNV GL has published different studies and guidance brochures on low emission and alternative fuels such as:

- In Focus: The future is hybrid
- Managing sulphur limits
- Cost and benefits of alternative fuels
- LNG as ship fuel

These can be downloaded at: dnvgl.com/publications.

Gas Fuelled notation

The Gas Fuelled notation's requirements cover all aspects of the gas-fuel installation, from the ship's gas-fuel bunkering connection all the way up to and including all gas consumers. The rules are applicable to installations where natural gas is used as fuel. Other gases are subject to special consideration. The class notation is mandatory for any newbuilding being built with gas as fuel, either with gas-only or dual-fuel concepts.

Low Flashpoint Liquid (LFL) fuelled

Methanol is a low flashpoint liquid (LFL) fuel that is gaining interest in the market because it does not contain sulphur and is therefore suitable for meeting the existing 0.1% SO_x Emission Control Area requirements. Methanol has a flashpoint of about 12 degrees Celsius, and vessels will be assigned the additional notation LFL FUELLED to demonstrate their compliance with the safety requirements set out in the industry-first rules published by DNV GL in June 2013.

DNV GL was the first classification society to publish LFL rules and sees methanol as part of the future energy mix for shipping. As well as having low SO_x and NO_x emissions, a methanol fuel system is easy to retrofit on a ship.

DNV GL has been involved in newbuilding projects from the early design stage, working together with the shipowner, engine maker and yard to ensure an equivalent level of safety to that of a conventional fuel oil system. DNV GL has made use of its long experience with LFL cargo handling on chemical tankers and offshore supply vessels designed to transport low flashpoint cargo and its experience with alternative fuels from 15 years of working with gas-fuelled ship installations. This is a mandatory class notation for ships using methyl alcohol or ethyl alcohol as fuel.

ADVISORY SERVICES

DNV GL Advisory can support customers in a variety of services of services for assisting with the upcoming the upcoming fuel shift. For optimized compliance, we provide low sulphur decision-making support tailored to your specific conditions, operation and requirements.

To comply with stricter environmental regulations and limit costs, shipowners need to evaluate alternatives to traditional fuels and technologies. But which option is best for a ship's actual operational setting?

As marine and industrial engineers, economists and environmental specialists, DNV GL has the deep knowledge across multiple disciplines to offer reliable solutions.

We advise the maritime sector on environmental regulations and compliance options, we measure and benchmark your environmental performance, support you in making the best business decisions on environmental technology, and help turn environmental performance into a marketing advantage.

As a designated technical advisor for various governmental initiatives to reduce ship emissions, we have deep knowledge of the regulatory policies and technical solutions.

If incidents damage the fuel systems and other related systems, we can help alleviate the problem. We have a wide range of experience with troubleshooting, both on a design level and on board the ship. DNV GL engineers can help customers to find root causes for the problem and recommend modifications to reduce future damage in terms of costs and/or even off-hire.

For more information, please contact
environmentadvisory@dnvgl.com

Our services in environmental technology and alternative fuels include:

Fuel changeover calculator (FCO)
DNV GL's ship-specific FCO plots a complex numerical simulation of the fuel changeover process from conventional HFO to ultra-low sulphur fuel oil, which is typically marine gas oil (MGO). It promises a very accurate calculation and potential cost savings compared to a linear model, and also takes into account recommended maximum temperature change per minute. The FCO also offers a comprehensive package to account for documentation requirements. Receive more information at: https://www.dnvgl.com/maritime/advisory/Fuel-change-over-calculator.html

ECA support
We offer strategic advice on solutions for ECA compliance, including assistance in choosing and implementing technologies for reducing emissions and remaining in compliance in a cost-effective manner.

Emission analyses and assessments
We conduct tailor-made studies on fuels, technologies, regulations, emissions and environmental accounting, policy instruments and activity-based ship data (AIS) for you.

LNG intelligence portal (LNGi)
Through our LNG intelligence portal, we offer comprehensive insights into worldwide LNG bunkering availability and market data on LNG as fuel for ships.

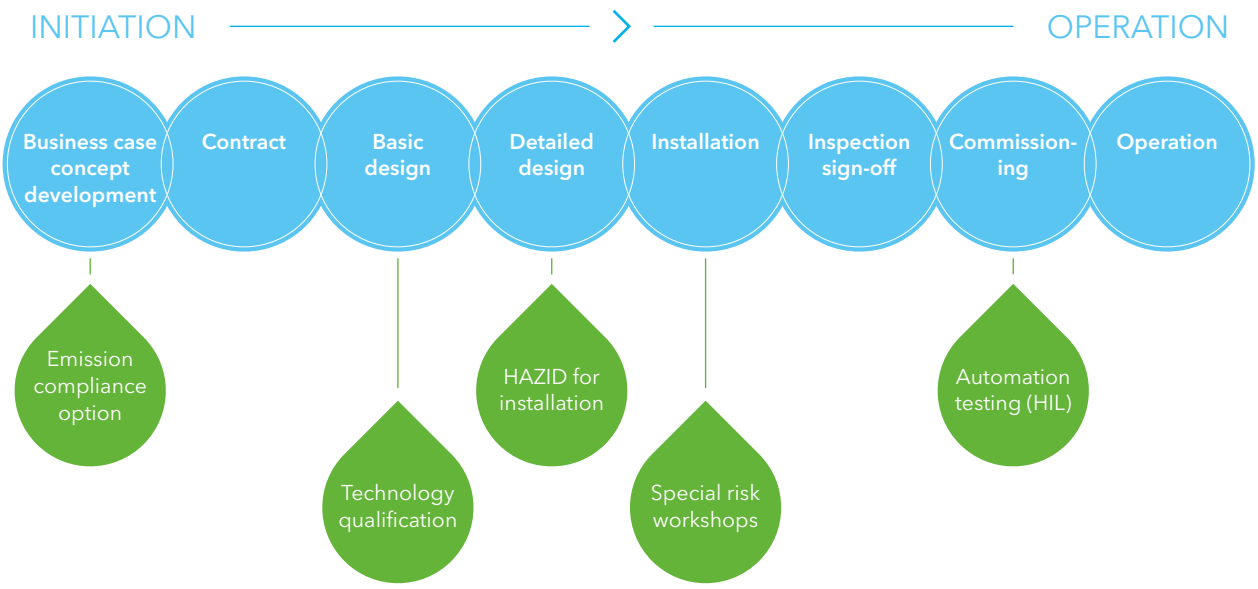
Feasibility studies
The evaluation of the technical feasibility and financial attractiveness of environmental technologies or fuels, such as LNG (LNG Ready), scrubbers, biofuel, battery systems, hydrogen, ballast water, VOC management, waste and waste water technologies.

Technology qualification
Determination of whether a solution is fit for its given purpose. Risk identification and risk reduction through failure mode, effect and criticality study (FMECA), hazard identification study (HAZID) or hazard and operability study (HAZOP).

Triple-E
Triple-E is an environmental and energy efficiency rating scheme for ships. As an independent verification tool, it measures a vessel's environmental performance, covering management, operation and design.

Control system software testing
The verification and testing of control system software using Hardware-in-the-Loop (HIL) technology will result in safer and more reliable automation systems and shorter commissioning times due to less software issues. Any control system can be tested, e.g. EGCS/scrubber, SCR, LNG as fuel, energy management system, ballast water treatment system.

Advisory services provided by DNV GL



DNV GL ACADEMY

The DNV GL Academy offers a training course designed to help overcome the challenges the challenges of fuel switching in ECAs by discussing the issues related to the change-over in detail.

Air pollution from ships in practice
The course objective is to gain advanced knowledge about exhaust emission legislation, abatement technology and alternative fuels.

Low sulphur fuel – basics and experience
Participants will gain detailed knowledge for managing the international requirements regarding sulphur reduction for ship newbuildings and ships in service.

Gas as ship fuel
The course will give participants an overview about the current developments in the field of gas as ship fuel.

SO_X Exhaust Gas Cleaning (EGCS) – in practice
Become familiar with different SO_X EGCs technologies available on the market, and understand applicable requirements regarding SO_X EGCs according to MARPOL Annex VI & MEPC.259(68).

For more information, please visit our training web page: **www.dnvgl.com/maritime-academy**

ABBREVIATIONS

ECA	Emission Control Area
EEDI	Energy Efficiency Design Index
HFO	Heavy Fuel Oil
LFL	Low Flashpoint Liquid
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
NECA	NO_X Emission Control Area
NO_X	Nitric Oxides
PM	Particulate Matter
SECA	SO_X Emission Control Area
SO_X	Sulphur Oxides
ULC	Ultra-Low Compliant Fuel Oil
ULSHFO	Ultra-Low Sulphur Heavy Fuel Oil

SAFER, SMARTER, GREENER

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DNV GL
Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. Operating in more than 100 countries, our professionals are dedicated to helping our customers in the maritime, oil & gas, energy and other industries to make the world safer, smarter and greener.

DNV GL is the world's leading classification society and a recognized advisor for the maritime industry. We enhance safety, quality, energy efficiency and environmental performance of the global shipping industry – across all vessel types and offshore structures. We invest heavily in research and development to find solutions, together with the industry, that address strategic, operational or regulatory challenges.