New construction of the seagoing vessel 23kTEU and equipment for LNG operation

Ship name	23kTEU_LNG_Schiff
Type	23,000 TEU Ultra Large Container Ship
Shipowner	Hapag-Lloyd AG
Year of construction	2024
Construction period	November 2021 to August 2024

Project concept and objectives of the project

Overall objective of the project

Objective: New construction of the ship 23kTEU_LNG_Schiff and equipping it for operation with LNG as a fuel in accordance with regulations (MARPOL VI)

The aim of the project is to equip the new construction of the 23,660 TEU container ship 23kTEU_LNG_Schiff with LNG for dual-fuel operation.

Special contribution of the project to the reduction of greenhouse gas and air pollutant emissions and to the development of the LNG infrastructure

The planned LNG equipment in the proposed project will enable Hapag-Lloyd to go well beyond the applicable standards. The planned new construction of a ship with dual-fuel use for ship propulsion and electric power generation allows the more environmentally friendly LNG to be used whenever possible, but marine gas oil (MGO) will continue to be available as a secondary fuel. As planned, only about 3.2% of this secondary fuel will be used, as this represents the required amount in which MGO is required as an ignition fuel to ignite the LG in the engine.

This makes a significant contribution to reducing air pollutant emissions and thus to climate, environmental and health protection. Compared to the comparative scenario of a new building for operation with MGO, there is a decrease in the Emissions of SO_x by 99,3 %, of CO_2 by 25 % and of particulate matter by 66 % (see chapters 3.1 and 5.2). While the LNG equipment in the named project helps to fall well below the Union standards with regard to SO_xemissions, there are currently no regulatory requirements from the EU with regard to $CO_2$and particulate matter emissions (see 3.1).

Since 1 January 2020, the sulphur content in marine fuels has been allowed to be only 0.5% globally as well as in EU waters. In the ECA (Emission Controlled Areas) zones, this value is reduced to only 0.1%. [1] Against this background, LNG offers the possibility of reducing emissions of SO_x far below the applicable standards. Compared to the other equipment alternatives to achieve the SO_xrequirements, such as the use of low-sulfur fuels such as marine gas oil (MGO) or the retrofitting of an exhaust gas desulfurization plant (scrubber), the new building with LNG propulsion planned in this project is the most capital-intensive, but also the most environmentally friendly option.

Compliance with the IMO NO_x Tier III requirements applicable to newbuilding in the NECA zones (for ships with keel laying on or after 1 January 2021 u.a.in the Baltic Sea and North Sea) will also be ensured by the installation of an SCR (selective catalytic reduction) system. It should be borne in mind the North American NECA is already implemented.

The newbuild as an LNG ship also enables particularly environmentally friendly characteristics for the ship with regard to the following indices: EEDI value (Energy Efficiency Design Index) and EEXI value (Energy Efficiency Existing Ship Index) as a summary of technical measures to reduce emissions, EEOI (Energy Efficiency Operational Index) as a summary of measures for low-CO_2ship operation, ESI (Environmental Ship Index; Environmental Index for Ships) and SEEMP (Ship Energy Efficiency Management Plan). [3] The newly built ship 23kTEU_LNG_Schiff1 will achieve values in all these classifications that are far below the applicable specifications (see e.B. the IMO specifications for the EEDI value).

A concrete tightening of corresponding EU or IMO standards with regard to emission limits has not been announced at present.

In addition, the equipment for LNG operation may also enable the future use of new fuel technologies, such as .B synthetic LNG, which could be an important step on the way to zero-emission ships. The project thus corresponds to Hapag-Lloyd's sustainability strategy .

In addition, the project will trigger a direct market demand for LNG, which can make a significant contribution to the expansion of LNG infrastructure and the establishment of LNG as a marine fuel. Due to the high fuel consumption of large container ships and their high round trip activity, container ships have a much greater fuel requirement than other types of ships (since downtimes are associated with high costs, the use of container ships is optimized so that the downtimes are as short as possible). This implies not only the expansion of LNG bunker sites and an increase in LNG-powered ships, but also a further development of the regulatory requirements regarding the operation of LNG ships and the establishment of a dealer structure for corresponding components for LNG ships.

Technical innovation of the project:

As part of the equipment for LNG operation, a MAN B&W 11G95ME-C10.5-GI main engine and auxiliary machines from the manufacturer Daihatsu are to be installed, which are suitable for dual-fuel operation and can therefore be operated with both LNG and alternative fuels.

The hull is optimized in cooperation with DNV-GL (formerly FutureShip GmbH) and HSVA (Hamburgische Schiffbau-Versuchsanstalt GmbH) for particularly low consumption.

The main engine is to be equipped with the latest engine technology, the High Pressure Direct Injection technology.

The installation of a Type B Hi-Mn (high manganese steel) LNG tank is planned. This is a new technical development of the DSME shipyard. According to the current state of knowledge, a Type B tank of this size has not yet been installed in any ship.

In addition to the installation of the LNG tank, the installation of a gas treatment system (FGSS) with the aggregates and pipelines for the gas supply of the main engine for ship propulsion and the generator sets for electrical power supply is necessary. The structures specially required for LNG operation also include the gas tank connection room (TCS), the gas treatment room (FPR), the bunker stations on both sides and the fan houses with a blow-off mast (vent mast). Special challenges and a need for innovation arise here, especially in the implementation of the significantly increased safety requirements for LNG operation.L NG (hereinafter also generalized as "natural gas"). Especially due to the size of the tank, a possible leak represents a great safety risk, which must be prevented accordingly. This special safety infrastructure includes, for example.B, special systems such as a drip tray below the LNG tank, the ventilation system of the gas rooms and the double-walled supply lines, the degassing line (Block & Bleed) as well as the inerting by means of the nitrogen system and the gas detectors with compressed air control of the Emergency Shut Down (ESD) valves. Since the named components are not required in a ship running on conventional fuel or MGO or do not require them with the same safety and functional requirements, there is a significant technical risk from the LNG equipment due to the reduced experience associated with it.

Technical and economic challenges:

In the context of container shipping, however, the environmental advantages of the project described above also stand in the way of various special challenges, as well as a corresponding considerable technical and economic risk.

As already mentioned above, the construction of ships for LNG operation in container shipping and especially on this scale is not yet widespread and there is only a small wealth of experience here so far.

Compared to a new ship for operation with marine gas oil (MGO), additional investment costs arise, as on the one hand more expensive LNG-capable components (e.B. LNG tank compared to MGO tank) and on the other hand additional components (e.B. safety infrastructure) must be installed in order to realize a successful LNG operation. These are to be seen in comparison with other cheaper alternatives, such as bunkering with low-sulfur distillates (such as MGO, the reference scenario chosen here) or the use of desulfurization plants (scrubbers), which do not achieve the positive environmental effects of LNG technology, but may be sufficient to meet all applicable and currently specifically announced standards.

Due to the required size of the LNG tank to be installed, which must be chosen significantly larger compared to tanks for MGO or heavy fuel oil due to density and energy content, there is a loss of container storage spaces (and thus loss of revenue) and payload benefits.

The currently partly inadequate LNG infrastructure in Europe and the partly immature regulation regarding bunkering in container ports also restricts the possible operational routes of an LNG container ship.

With regard to commissioning and subsequent operation, the hurdles lie, among other things, in the uncertainties in the handling of crew members with the new safety systems, pressure and temperature monitoring as well as maintenance and bunkering processes. Crew members must be trained accordingly and best practices in ship operations must be developed on board.

In terms of maintenance, the challenge is that the majority of the components are not only significantly more expensive than the components required for operation with conventional fuel or MGO, but are also not yet available as standard in many shipyards or can be procured at short notice (for the recently completed conversion of the A15 Hapag-Lloyd ship BRUSSELS EXPRESS for operation with LNG, for example, many components had to be first developed and as a special solution. == In addition, the maintenance of an LNG ship requires new technical work processes and shipbuilding knowledge and methods, with which there is little experience in most shipyards.

1.1 Purpose of use

After completion of the new construction of the 23kTEU_LNG ship, it is intended to use it under the European flag (possibly German flag) as a pure cargo ship. The currently planned timetable regularly provides for an 80-day round trip from Europe (Hamburg) through the Suez Canal to the Far East (Busan, or Qingdao) and back again. A deployment of the ship in Californian seaports could become possible in consultation with the consortium partners at a later date.

In principle, pure operation with LNG is planned. MGO is to be used only as an ignition fuel as an addition to LNG in the ratio of about 3.2% of the LNG. This is necessary because LNG does not ignite on its own in the type of engine used.

Essential aspects of use:

- As described above, LNG is to be used as a more environmentally friendly fuel whenever possible. Since not only European waters are passed during the tour, but also Asian waters, the project contributes to reducing global air pollution not only in Europe, but also in international waters.

Contribution of the project to the achievement of the funding objectives

The project makes a significant contribution to achieving goals of realizing the climate, environmental and health benefits of LNG and providing an incentive for the use of LNG as a marine fuel, and is thus in line with the Federal Government's mobility and fuel strategy.

The concrete contributions of the project are listed below.

Contribution to the realization of local benefits for climate, environmental and health protection

Shipping is a major emitter of carbon dioxide (CO_2),sulphur oxides (SO_x),nitrogen oxides (NO_x)and particulate matter (PM). However, it represents a comparatively environmentally friendly alternative among the means of transport, as high quantities of goods can be transported. Container shipping offers the potential to significantly reduce environmental pollution. Here, the construction of new LNG container ships shows an effective approach.

Compared to other alternatives, LNG offers the best chance to contribute to improving air quality and the associated human health by significantly reducing emissions, but also to counteract environmental damage, such as acidification and eutrophication of the oceans. These occur particularly in ports and on the coasts, as shipping traffic is generally particularly strong in coastal waters near ports.

In addition to the actual emission values for SO_x, CO_2 and PM, which are significantly lower for LNG compared to alternative fuels, LNG has other significant environmental benefits. When using heavy fuel oil, for example, it is customary to process it only on board in order to comply with the sulphur limits. This results in residual materials (so-called sludge), which pose environmental risks and which have to be disposed of in the ports. [4] In addition, when scrubbers are used for exhaust gas aftertreatment, the washing water used is partly discharged directly into the sea. Environmentally harmful polycyclic aromatic hydrocarbons and heavy metals also end up in the sea. [5] These environmental risks associated with the use of heavy fuel oil and scrubbers can also be avoided by using LNG.

Concrete contribution from Hapag-Lloyd's planned project

Among the fuel alternatives, the new LNG building represents the option with the greatest positive effects on environmental and climate protection. By building a new ship with LNG operation as a more capital-intensive, but at the same time most environmentally friendly alternative, Hapag-Lloyd is significantly exceeding existing Union standards with regard to the emission limit values for SO_x, CO_2 and PM (existing standards such as MARPOL, see business plan, environmental and climate protection regulations in maritime transport.

Significant savings result from the direct use of LNG as a fuel. This results in high energy savings, among other things, from the fact that no steam from the exhaust gas boiler at sea or the auxiliary boiler on the territory or in the port is required to heat heavy fuel oil and thus make it pumpable.

The following savings[6] compared to operating with MGO as a reference scenario can be recorded by equipping the ship with LNG propulsion and have a direct impact on climate and health:

- Decrease in CO_2 by 25 %
- Decrease so_x by 99.3 %
- Decrease in particulate matter by 66 %

With regard to the regulation of sulphur oxide (SO_x)and particulate matter (PM) emissions, MARPOL Annex VI in Regulation[14 [7]] has required a sulphur content in marine fuels and a maximum PM emission of 0.5% for all ships since 1 January 2020. In the SECAs (SO_x emission control areas), which, as with the NECAs, include the North and Baltic Seas as well as the North American coast, a maximum sulphur content of 0.1% is permitted. Within the EU, the so-called Sulphur Directive (Directive EU 2016/802)[8] has also been in force since 2012, which also prescribes maximum values for the emission of SO_x on marine fuels. The emission limit values of the Sulphur Directive coincide with the limit values of MARPOL Annex VI. Only traces of sulfur are contained in LNG, so that the regulatory requirement in this area is exceeded by the use of LNG. For the new 23kTEU_LNG_Schiff with LNG propulsion, a particle emission of approx. 0.07% is expected, so that the regulatory requirements can also be exceeded in this area.

With regard to NO_x emissions, the MARPOL regulation specifies bandwidths that apply in ECAs or outside the ECAs and accordingly reflect the Tier II or Tier III classification of engines. The limit value to be applied in the specific case within the Tier III bandwidth refers to the number of revolutions of the motor under consideration at about 80-90 % machine utilization. The Tier III classification specifies certain ranges for NO_x emissions. It is expected that the installation of the SCR will achieve Tier III status with respect to the NO_x emission value.

Contribution to increasing demand for LNG and to the development of LNG supply

Due to the large amounts of LNG bunkers (approx. 4,786 mt LNG per round trip on route FE9), the bunker temperature of approx. -158°C, the heat input and the duration, the bunkering of a container ship such as the 23kTEU_LNG_Schiff cannot be carried out by truck from the shore side, but must be carried out by bunker ship on the sea side. Since additional layover times for bunkering would only lead to a "catch-up of the timetable" and immense additional fuel costs, only a so-called "simultaneous operation", i.e. bunkering during the regular loading-unloading process of the containers, is an economically viable option. In order to be able to keep to the timetable, bunkering must therefore take place on the sea side in a container hub (land-side container). However, the start-up time of the bunker ship must not be too long, otherwise there is a risk of LNG heating and boil off gas (BOG) formation. With regard to the BOG, a return of the BOG is required at the same time as the supply of liquefied petroleum gas in order to be able to control the potion pressures.

Although there is already a clear positive development with regard to the expansion of LNG infrastructure in Germany, Europe and worldwide,[10] the planned project could positively reinforce this development. By equipping a very large container ship for LNG operation, as intended in this project by Hapag-Lloyd, a significant increase in demand can be achieved. This applies in particular to a holistic view of the project in the context of further intended investment measures by Hapag-Lloyd in the development of its LNG fleet.

An increase in demand for LNG in Germany for the important and large market of container shipping provides a strong incentive for the further expansion of the LNG supply structure .

This will strengthen the role of LNG in the targeted diversification of fuel sources (as a further objective of the Directive on which this call for funding is based), as well as in reducing air pollutant emissions and increasing the environmental performance of shipping logistics.

Currently, there are also alternative courses of action that are cheaper in the short term and pay for themselves more quickly (such as the possibility of installing a scrubber or the use of low-sulfur MGO). With the expansion of its LNG fleet, Hapag is setting an example here and can influence the industry through its pioneering role (i.e. provide an incentive to further increase demand).

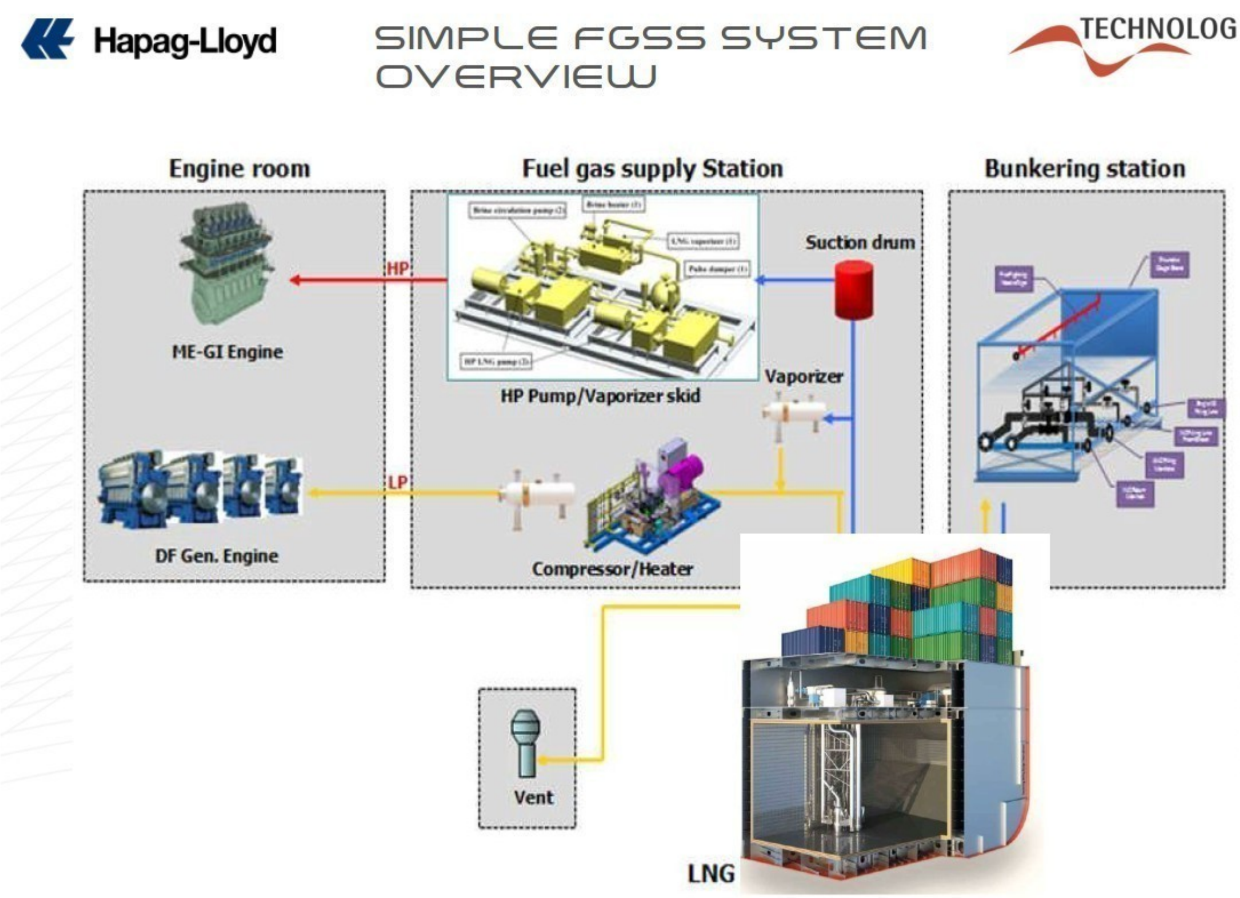
Influence on the further development of regulations for use in ports and European waters

The 23kTEU_LNG ship new LNG construction would help to develop an even deeper understanding of LNG as a marine fuel and its specific requirements, in particular with regard to monitoring by crew members as well as maintenance and bunkering processes. A corresponding incentive effect for the further development of the regulation is to be expected, in particular with regard to a sharpening of the requirements in the classification satellites and associated maintenance and certification processes as well as in the bunkering process. With regard to new construction and subsequent maintenance processes, it is also to be expected that the project will help to strengthen the supplier market for necessary components in new LNG construction and thus establish better availability of corresponding components for subsequent new construction projects. Hapag-Lloyd would thus play a pioneering role and contribute to the essential development of experience in the LNG market, from which other players can also benefit. A regulated regulatory environment, a more extensive LNG supply in ports world wide, an established supplier market for necessary components and experience in operating ships with LNG would serve as a strong incentive for other shipping companies to build LNG ships accordingly, as it is expected that the market and regulatory risk will decrease. Along with this, a certain "market maturity" of LNG as a marine fuel is to be expected, which is in line with the goal of the Mobility and Fuel Strategy of the Federal Government (MKS). [12]

In addition, Hapag-Lloyd's 23kTEU_LNG_Schiff is one of a total of twelve ships potentially to be equipped with LNG. The planned LNG equipment of other sister ships of the 23kTEU_LNG_Schiff with a container volume of 23,660 TEU would significantly increase the environmental protection effect described in this application. This increase in demand to a significantly higher level would provide a strong economic incentive to significantly increase LNG bunkering opportunities world wide. Looking ahead, this will pertain to the intended usage of synthetic LNG as well.

Technical Specification

Description of the technical concept



Schematic overview of the LNG Ship

23,660 TEU container ship

Hapag-Lloyd has already ordered 6 ships of the class 23,000 TEU in December 2020 and intends to order another newbuild within this class, which belongs to the ULCS (Ultra Large Container Ship) group, as part of this application. With a capacity of 23,660 TEU and a maximum speed of 22.0 knots (approx. 41 km/h), the new container ships will operate in regular service between Europe and East Asia. With a length of around 400 metres, a width of 61 metres and the MAN B&W 11G95ME-C10.5-GI eleven-cylinder two-stroke diesel engine, this series is expected to be manufactured at the Daewoo Shipbuilding & Marine Engineering shipyard in South Korea.

With the 23kTEU_LNG_Schiff1, an LNG vessel with a capacity of 23,660 TEU is also planned. In the following, the LNG-specific systems of the 23kTEU_LNG_Schiff are technically described.

LNG-specific equipment

For LNG operation, a dual-fuel-capable main engine and dual-fuel-capable auxiliary machines are to be installed. In addition, the installation of a special LNG tank and the installation of a gas treatment system (FGSS) with the aggregates and pipelines for the gas supply of the main engine for ship propulsion and the generator sets for electrical power supply is necessary. The main engine will be equipped with High Pressure Direct Injection technology. The required LNG-specific structures also include the gas tank connection room (TCS), the gas treatment room (FPR), the bunker stations on both sides, an ethylene glycol system and blow-off masts (vent mast).

Main engine, auxiliary machines and auxiliary boilers: The main engine, the auxiliary machines and the auxiliary boiler should be suitable for dual-fuel operation. Compared to conventional operation, LNG operation also requires the installation of special components certified for LNG operation, some of which are more expensive than non-LNG-certified components. These include suitable cylinder heads, cylinders, pistons, bushings, stuffing boxes, valves and systems for injecting the gases. In addition, special gas lines that are resistant to movement and vibration must be used for the cylinders in order to prevent cracks caused by voltages and high pressure.

It is planned to equip the ship with a MAN B&W 11G95ME-C10.5-GI Motor, which works in a very fuel efficient mode in a Diesel Combustion Cycle.

Operating in LNG Mode there is almost no Methane Slip as observed in older 2 stroke engines. The 4 stroke auxiliary engines are working in the Otto Cycle and do show a higher fuel consumption as well as methane slip. While the low pressure Win-GD Motors when running in LNG Mode are reaching IMO Tier III automatically , the MAN High pressure motor will require also in LNG mode an EGR or SCR, in order to reach Tier III-Status.

In order to use LNG in the main engine a high compression of 300 bar is required.

For comparison, the auxiliary engines running in the Otto cycle, a pressure of 6 bar is sufficient.

LNG will be used to run the main engine, the auxiliary engines, as well as the auxiliary boiler, which all could be used with compliant fuel in the dual fuel mode. The auxiliary engines do require boil off compressors. Boil off gas (BOG) is appearing in the tank due heat transfer, note the boiling point of LNG is at minus 162 Centigrade. The evaporation of LNG with the production of BOG is a continuous process.

If the BOG is not used , the pressure in the tank will increase continuously. The BOG pressure of 1,5 bar is higher than the regular ambient atmospheric pressure of 1 bar. The maximum permissible pressure of the tank has been designed for 1,7 bar, hence the BOG has to be consumed continuously from the tank to avoid blow-off via the safety valves. In order to use the BOG in the auxiliary engines the pressure will have to be compressed to 6 bar.

There is a lower steam consumption in LNG operation in comparison to HFO operated vessels, because it is not necessary to heat and liquefy HFO. An economic way to use BOG in all modes of operation (Sea, Coastal , Manoeuvring and in port) is to consume it in the auxiliary engines for electric power generation.

The special LNG tank must have the capability to store LNG und cryogene conditions. This is a significant difference to conventional HFO tanks.

The liquid gas preparation at a temperature of minus 160 Centigrade necessitates a controlled warming to plus 45 to 60 Centigrade prior burning it in the motor. The tank must be compact and have a good insulation. When the Brussels Express was converted to LNG operation a membrane tank by French maker GTT was used, for the 23k TEU newbuidlings a Type B High Mangan Steel Tank will be used. This is a new development by the DSME shipyard. A Type B Tank is a self-sustained Tank with a prismatic shape.

The primary barrier is in direct contact tot he LNG and is made of high Mangan Steel, this kind of steel will absorb thermal deformations caused by the cryogene temperatures of the fuel. The barrier is enclosed by an insulation panel made of polyurethane foam. The support structure is made of timber.

Drip trays will collect any LNG in case of a leakage and can evaporate in a controlled way.

Option E-Fuel:

The LNG Tank as well as the connected systems can also be operated with e-fuels, or synthetic fuels which will result in reaching the goal of net zero GHG emissions.

The main engine is fed by the HP FGSS (High Pressure Fuel Gas Supply System) . A LNG pump conveys LNG at a temperature of minus 158 Centigrade from the tank into the Fuel Preparation Room via a PVU (Pump and Vaporizer Unit). It evaporates and is passed via the GVT (Gas Valve Train) at a temperature of 45 to 60 centigrade to the engine.

There are bunker stations at the port and starboard side of the ship, these are located in the lowest tier of the 40ft container stacks on deck. The upper tiers can still be used for cargo on top of the station. There are two connections for LNG and a connection for BOG Vapour Return Gas while bunkering. There is a fire controlled control room for supervision of bunkering.

The bunker system enables a bunker rate of 1400 m^3/h) whiich will result in filling the complete tank within 5 hours. Once the bunker ship has completed the transfer and has departed, cargo operations with containers will be permitted.

The safety infrastructure for usage of the cryogene fuel is being reached by a ventilation rate of 30 air changes per hour. Gas detectors are installed and supply lines have double shelves. Fresh air suction is on port side while exhaust vents are on the starboard side.

Regular maintenance is necessary during operation , if the ship is going to drydock every five years , the tank and sytems must be purged completely. This is a process which is similar to commissioning the tank system and will take some time. Residual fuel gas in the tank is burned in the engine and the tank atmosphere will be replaced with Nitrogen. Once residual fuel is burned in the boiler, a normal safe working atmosphere can be safeguarded.

Expected reduction of emissions

The calculations of emission data for CO_2, NO_x und PM are derived from the LNG consumption data of the main engine based on indications by engine maker MAN.

Please see also annex consumption and emission data.

With reference to methane slip (CH_4) the values during MGO operation are considered as zero

For LNG-operation the maker is providing emission values for high engine loads, , whereas lower loads had been extrapolated as an estimate. Calculations of SO_x-Emissions are based on the molar mass, since the sulfur contents is not dependent on the maker.

In order to comply with NECA compliance Tier III status the SCR will be used when operating in the NECA.Once the ship is steaming out of the NECA the SCR will run without urea injection, hence, any NOx emissions will occur outside of the NECA.

Below estimates are based on a current deployment of the vessel in the Europe / Far East Trade via the Suez Canal.

	NO_x	CO_2	CH_4	PM	SO_x
LNG	2.718.807	49.863.533	35.956	6.806	1.399
MGO	2.718.807	66.543.421	0	25.862	203.992

In addition to the consumption of the main engine, the consumption of the auxiliary engines hast o be accounted for as well. The table shows the emissions of the auxiliary engines in kg per hour.

	NO_x	CO_2	CH_4	PM
LNG – At sea	4,6	1.474,8	12,4	0,5
LNG – At berth	3,9	954,5	22,3	0,4
MGO – At sea	3,1	1.965,2	0	0,8
MGO – At berth	2,0	1267,7	0	0,5