11,000 teu container vessel

MAN Energy Solutions
Future in the making

An ME-GI powered vessel fitted with fuel gas supply system and boil-off gas handling

Future in the making

Contents

The new fuels, regulations and the challenging and dynamic environment that has been formed in the marine business over the past years have created a complicated equation in terms of optimising the design of a future vessel.

In order to address the increasing needs from vessel operators, MAN Energy Solutions has gathered data and operating experience and created a default setup including potential options.

For a global transporter such as an 11,000 teu container vessel, it is always a challenge to identify the optimum operating profile for the expected 25 years of vessel operation.

MAN Energy Solutions has gathered information and integrated data from similar vessels operating according to different patterns. The design characteristics of such a vessel are presented in Table 1.

With a service speed of 22 knots, the endurance of the vessel is approximately 18,000 nautical miles. The vessel is expected to sail for 40 days between bunkering, which is considered to be one round trip.

The average port stay duration of the vessel for this calculation is set at 28 hours and six port stays in a period of 40 days (one round trip).

The operation area consists of non-NECA zones, meaning that 100% of the operation is in Tier II NO_X emission areas.

Fuel oil is a compliant fuel of the VLSFO type (<0.5% S), and gas operation time for the main engine is 100%.

This study does not take manoeuvring time into account.

Main engine characteristics

Specification	Parameter
Ship type	11,000 teu CV
Service speed	22 knots at 80% load (NCR)
Main engine	MAN B&W 8G95ME-C10.5-GI
SMCR	42.31 MW at 76.9 rpm

Table 1: Main engine characteristics

An 8-cylinder G95 Mk. 10.5 engine is considered for this project, including the GI Mk. 2 gas version. The updated technology design for both the G95 and GI Mk. 2 gives obvious benefits such as lower engine weight, improved consumption values (1% pilot oil consumption*), and zero methane slip thanks to the direct diesel injection technology.

The main engine's operating time is estimated at 6,000 hours, corresponding to approximately 7.5 round trips.

* expected by Q3 2019

Operating profile

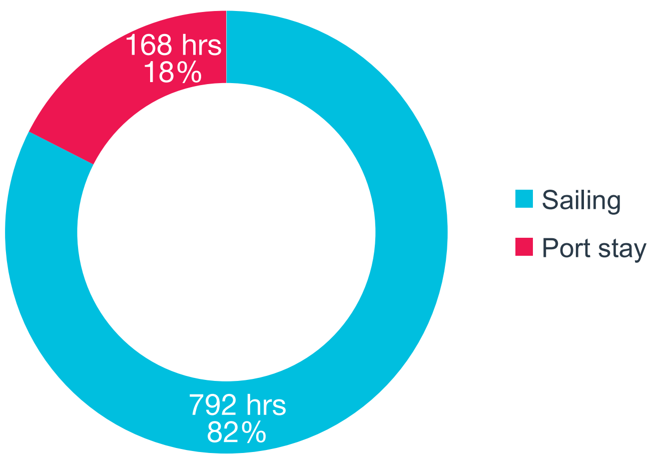


Fig. 1: Operating profile of the vessel for one round trip (40 days)

Main engine

The MAN Energy Solutions online application CEAS (computerized engine application system) http://marine.man.eu/two-stroke/ceas has been used to calculate the specific gas consumption for each engine load as shown in Fig. 2.

The main engine gas consumption can be calculated for each given engine load using Equation 1.

$$ME\_consumption_{gas}\,[ton] = (Power)_{load}\,[MW] \cdot SGC\,[g/kWh] \cdot 10^{-3}$$

Equation 1 – Gas consumption calculation

The main engine pilot oil consumption can be calculated for each given engine load using Equation 2.

$$ME\_consumption_{oil}\,[ton] = (Power)_{load}\,[MW] \cdot SPOC\,[g/kWh] \cdot 10^{-3}$$

Equation 2 – Pilot oil consumption calculation

ME load profile

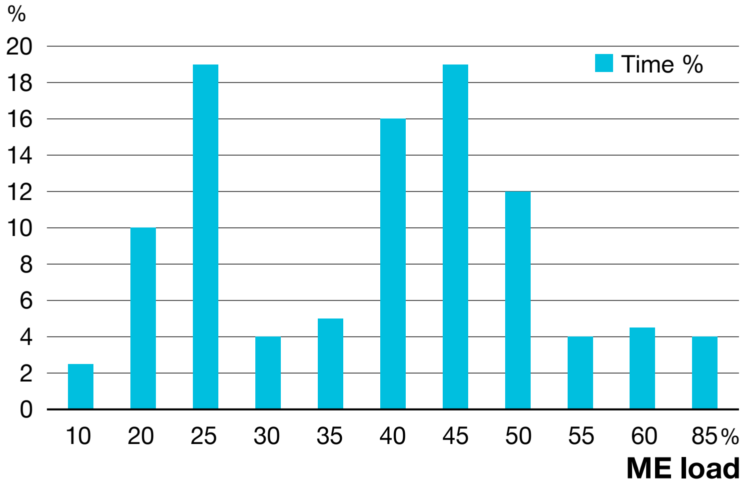


Fig. 2: Main engine load profile for a period of one round trip

ISO ambient conditions (ambient air temperature: 25 ˚C, scavenge air coolant temperature: 25 ˚C)

Load % SMCR	Power (kW)	Speed (r/min)	SPOC (g/kWh)	SGC (g/kWh)	Exh. gas (kg/s)	Exh. gas temp. (˚C)	Steam (kg/h)
100	42,310	76.9	2.0	131.5	89.5	230	6,000
95	40,195	75.6	2.1	130.2	86.5	223	4,870
90	38,079	74.2	2.2	129	83.3	217	3,990
85	35,964	72.8	2.3	128	80.1	213	3,330
80	33,848	71.4	2.3	127.6	76.7	211	2,880
75	31,733	69.9	2.5	125.7	73.2	210	2,600
70	29,617	68.3	2.6	125.1	69.4	210	2,490
65	27,502	66.6	2.7	125.3	65.5	211	2,520
60	25,386	64.9	2.8	125.8	61.4	214	2,650
55	23,271	63	3.0	126.3	57.1	219	2,860
50	21,155	61	3.2	126.9	52.6	225	3,110
45	19,040	58.9	3.4	128	47.8	233	3,130
40	16,924	56.7	3.7	129	42.9	242	3,720
35	14,809	54.2	4.1	130.1	37.9	251	3,780
30	12,693	51.5	4.5	130.6	39	209	1,320
25	10,578	48.4	5.1	131.8	33	215	1,430
20	8,462	45	5.9	132.8	20	211	1,040
15	6,347	40.9	7.2	135.1	23.5	195	280
10	4,231	35.7	9.4	141.8	20.1	157	0

Table 2: CEAS data for the selected engine

Auxiliary engine

This type of vessel is typically equipped with auxiliary engine power in the range of 12 MW, which means four units of 3×4 MW.

Table 3 lists sailing and port electrical load operation of the vessel.

Mean values used for this study may fluctuate according to the number of refrigerated containers on board, though the overall result is not expected to change significantly.

The average gas consumption of the auxiliary engines is estimated at 190 g/kWh (gas consumption).

The electrical efficiency of the generator is calculated at 90%.

The port load will correspond to the minimum gas consumption.

Tank size

By using Table 2, Equation 1, Equation 2 and Equation 3, the average weighted consumption of gas consumers can be calculated to tonnes of gas per hour of operation.

$$\sum(\text{consumption}_{\text{gas}} \cdot \text{time}\%)$$

Equation 3 – Sum of gas consumption calculated for each time share

In order to cover the endurance required (40 operating days), the vessel should carry approximately 2,575 tonnes of LNG, and with an average density of 440 kg/m³, the volume of

Estimated sailing and port load of auxiliary engines

Specification	Parameter
Sailing load	4 MW
Port load	1.8 MW

Table 3: Estimated sailing and port load of auxiliary engines

LNG tank size

Specification	Parameter
LNG bunkered volume	6,150 m³
Tank size	6,300 m³

Table 4: Summary of LNG tank size

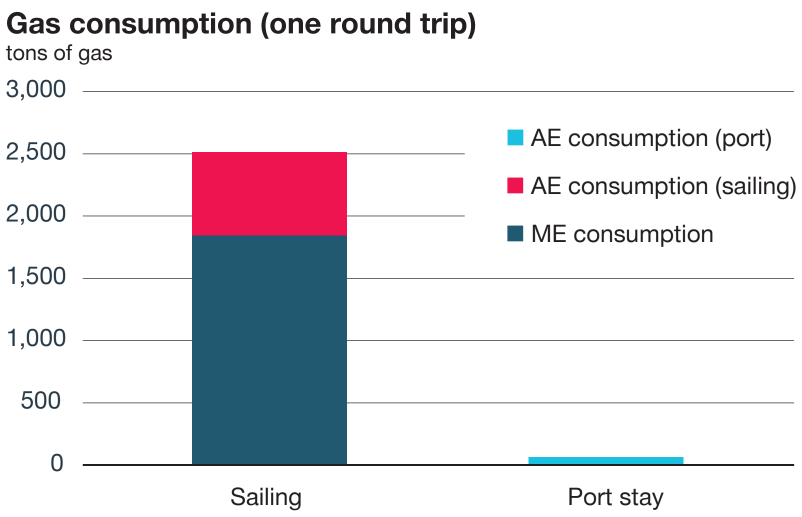


Fig. 3: Weighted average gas consumption

LNG containment system comparison

Category	Integrated tanks	Independent self-supporting tanks		
Classification	Membranes	Type A	Type B	Type C
Design criteria	Full secondary barrier	Full secondary barrier	Partial secondary barrier “drip tray”	No secondary barrier
Design pressure	≤0.25 barg (max. 0.7 barg)	≤0.7 barg	≤0.7 barg	> 0.7 barg

Table 5: LNG tank comparison as defined by IMO

commercial LNG consumed corresponds to 5,900 m³. The typical filling rate of LNG tanks is 98%, and if a 5% tank heel is included, the total volume of the tank should be approximately 6,300 m³.

Given the volume calculated, the optimal solution would be a choice between a membrane and a type A tank.

A Type-C tank cannot be excluded, but due to its size, it is not deemed as being a cost effective solution.

Boil-off gas

The boil-off gas rate for a typical membrane tank is in the range of 0.25% to 0.32%/day. Given the bunkered LNG volume in the tank, the boiled gas corresponding to the boil-off gas rate is calculated and shown in Fig. 4.

The red line would represent the typical boil-off gas rates of membrane tanks, while the "Port load" mark represents the port load minimum gas consumption. With this rate, the vessel's daily operation can consume the boil-off gas generated.

In this specific operating case scenario, where the minimum consumption is expected to be 380 kg/h (port load mark), the boil-off gas rate for the tank would correspond to approximately 0.36% per day.

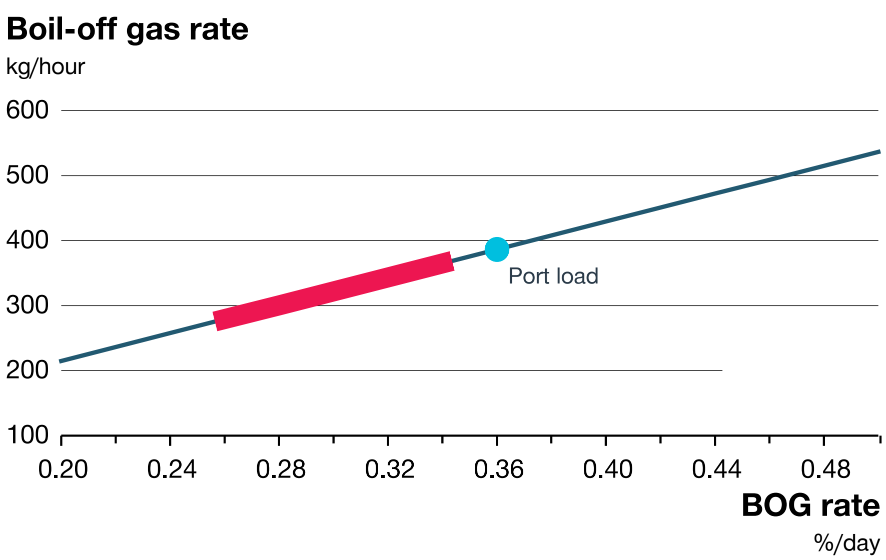


Fig. 4: Boil-off gas rate calculation for a given tank

Fuel gas supply system

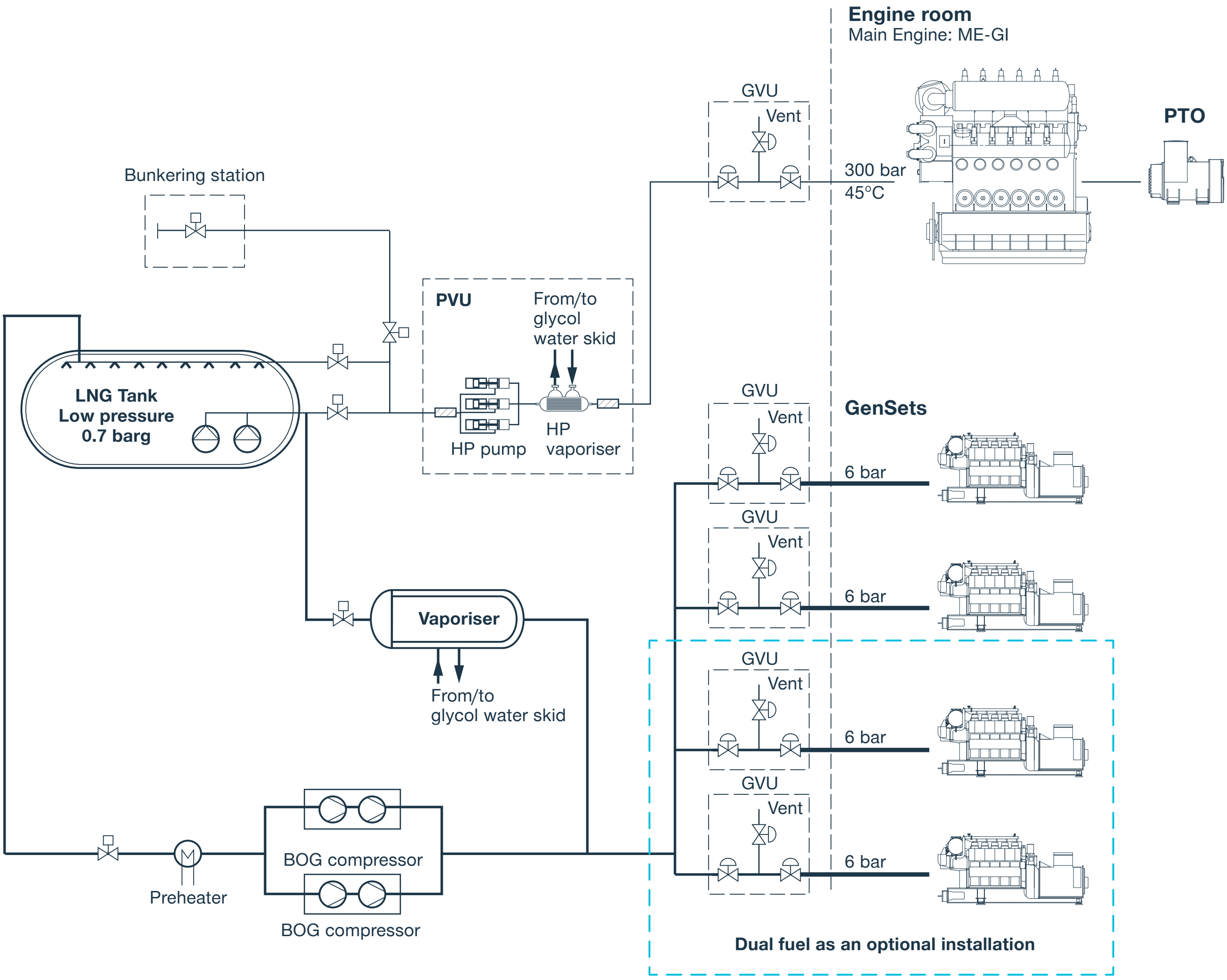


Fig. 5: Schematic presentation of proposed installation

Fig. 5 presents a schematic of the proposed installation.

The main components of the fuel gas supply system are:

- 2 x submerged pumps (2 x 100%)
- 1 x PVU (pump vaporiser unit)
- 1 x glycol water heating loop (typically 2 x 100% glycol water pumps)
- 2 x BOG compressors (2 x 100%)

Submerged low-pressure pump

Submerged low-pressure pumps are installed inside the tank. They have a double purpose:

1. Feed the PVU with LNG at specified conditions
2. Pump gas to the low-pressure vaporiser at the required pressure level for the auxiliary engines.

Pump vaporiser unit (PVU)

The PVU developed by MAN Energy Solutions combines the cryogenic pump and the vaporiser in one compact unit, thereby simplifying the entire fuel gas supply system (FGSS). The PVU consists of three cryogenic booster pumps, a compact vaporiser, LNG, glycol and 10 μm natural gas filters. The cost optimisation has been achieved by optimising the overall layout of the system and by reducing the number of valves, safety valves, and blow-off lines. The PVU is controlled by means of the in-house developed multipurpose controllers (MPCs). This simplifies the interface with the ME-GI engine, which uses the same controllers.

Actuation of the pumps is done by high-pressure hydraulic oil. The hydraulic oil can be provided from a stand-alone hydraulic unit, or be supplied from the main engine.

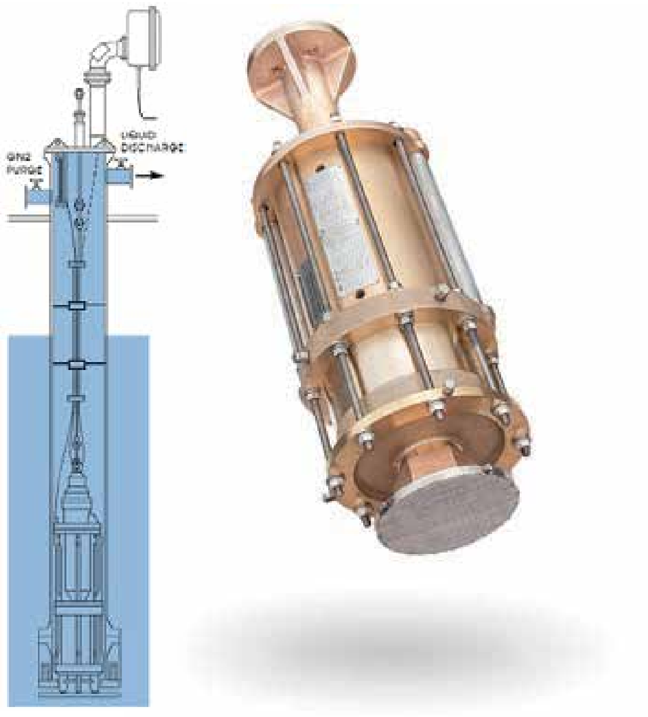


Fig. 6: Schematic of submerged cryogenic pump

Fig. 7: MAN PVU high-pressure cryogenic pump

Glycol water heating loop

Waste heat from the main engine jacket cooling water can be used as an energy source to heat up a heating media – typically a glycol/water mix – which warms up the gas, to the specified conditions of +45°C ±10°C at engine inlet.

BOG compressor

The fuel gas supply system relies on two low-pressure compressors to feed auxiliary engines with excess boil-off gas.

Gas compressors can typically deliver 8 barg gas and are non-cryogenic types. Therefore, a preheater unit on the suction side of the compressor is required.

Gas compressor operation provides a double benefit for the system. Tank pressure management can be achieved without the use of the gas combustion unit while at the same time boil-off gas is utilized in the auxiliary power engines to cover the electrical demand on board the vessel.

Electrical energy consumption

Table 6 presents the rated electrical power from the main equipment of the fuel gas supply system.

LNG tank sizing

Electrical consumers	Rated power
Low pressure pump	30 kW
PVU	220 kW
Glycol water pump	20 kW
Low pressure compressor	300 kW

Table 6: Summary of LNG tank

For the given operating profile, the fuel gas supply's electrical consumption is calculated and shown in Fig. 10.

Fig. 8: Glycol water heating skid

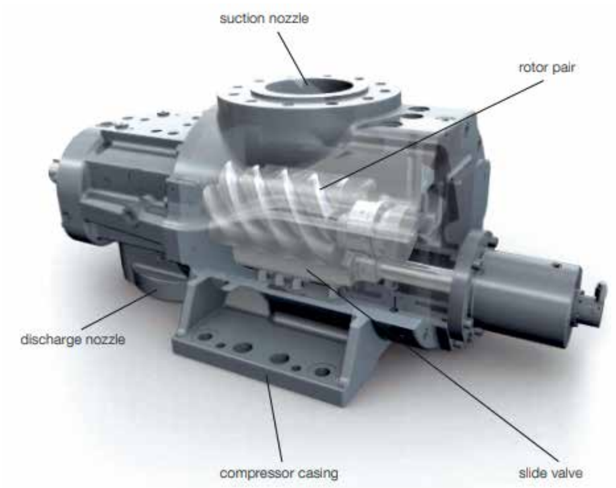


Fig. 9: MAN oil injected screw compressor

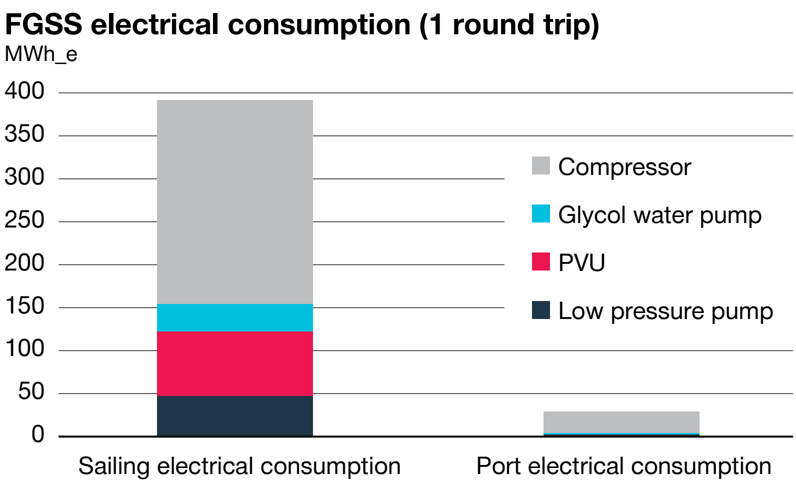


Fig. 10: Fuel gas supply system electrical consumption per 1 round trip

Installation of PTO

Installation of a PTO on the main engine for electricity production during sailing would result in further optimisation of the energy consumption on board.

Electricity would be produced by the main engine, thus benefiting from the superior efficiency of the ME-GI versus the auxiliary engines.

The PTO size would normally be approximately in the range of 5% of the main engine's power, and for this case a 2.4 MW PTO is considered.

The total efficiency of the PTO is estimated to be 90%, including both mechanical and electrical losses.

Installation of a PTO offers a number of major benefits:

1 The electrical load required while sailing can, depending on the actual load, be fully or partly produced by the main engine

2 Electricity will now be produced also by the main engine by consequent increase (2.4 MW) of main engine load

3 Two-stroke superior efficiency is used to cover electrical needs, which leads to a better overall fuel efficiency

4 Initial investment costs can be reduced if only two out of the four auxiliary engines are dual fuel engines, while the other two remain normal diesel oil generators

5 EEDI index will be lowered

6 By optimising the energy consumption on board, the risk of excessive vessel operating costs due to increasing future fuel prices is reduced.

The installation of a PTO would result in subsequent change (with the same SMCR) of the main engine load profile.

The new main engine load profile has been calculated and shown in Fig. 11. It can be seen that approximately 6% more main engine load is now required

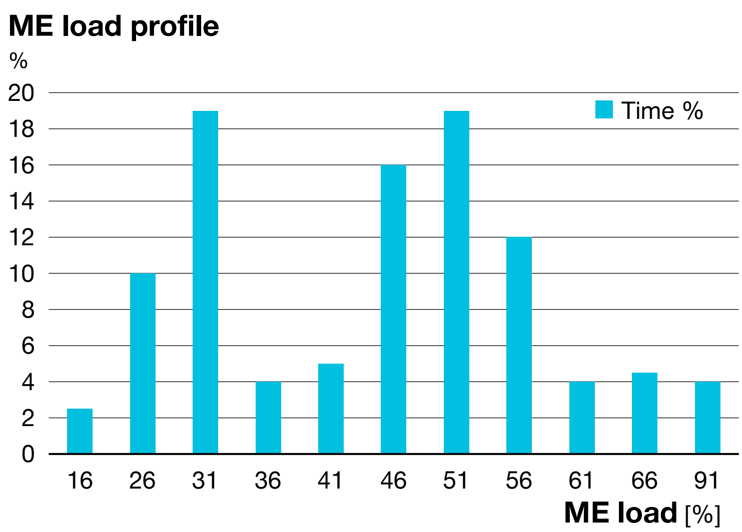


Fig. 11: Main engine load profile with PTO for a period of one operating year

to cover the new operation point (propulsion and production of electric load).

A PTO gives a better fuel efficiency with a consumption decrease of 165 tonnes of gas per round trip.

With 7.5 round trips per year, the PTO fuel savings would correspond to maximum 1,238 tonnes of gas annually.

Installation of a PTO could result in up to 6.4% better fuel efficiency.

The potential gains of a PTO installation (better fuel efficiency) can be translated into:

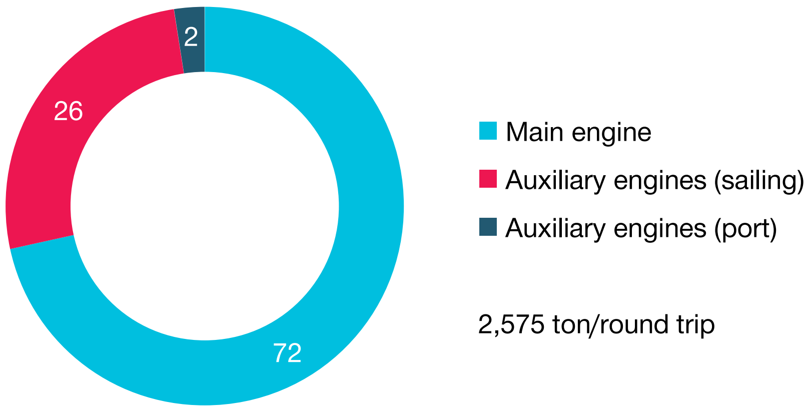
1. By maintaining the same sea endurance, the LNG tank can now be sized to 5,950 m^2, see table 7.

   That would result in a 350 m^3 smaller tank offering potential space and cost benefits. Moreover, the smaller tank size would mean a reduction in the boil-off gas rate [kg/hour], and less boil-off gas handling on board.

2. By maintaining the size of the tank, the time between LNG bunkering is increased.

   The tank's space and size is often decided on the basis of the hull structure and, therefore, the impact of a smaller tank cannot be directly translated to cost savings. Though having a PTO onboard would result in longer sailing endurance, so apart from the obvious fuel savings, other operating savings will occur, as for example shorter bunkering times or need for less gas onboard, etc.

Gas consumption in percentages (without PTO)



Gas consumption in percentages (with PTO)

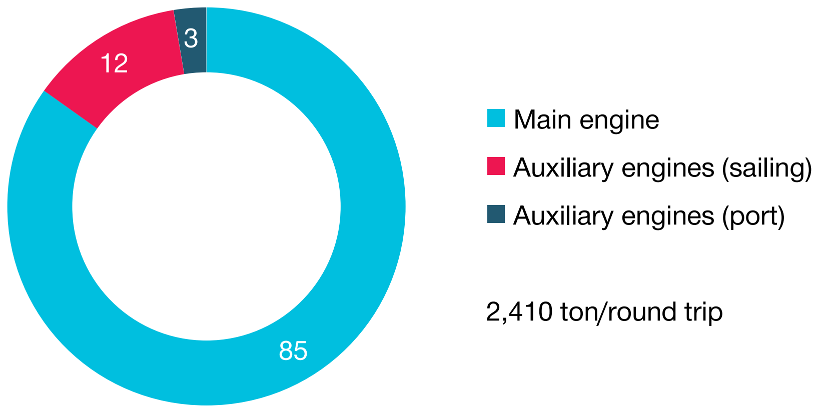


Fig. 12: Summary of gas consumption per day (installation with PTO)

Summary of LNG tank size

Specification	Parameter
LNG bunkered volume	5,800 m^3
Tank size	5,950 m^3

Table 7: Summary of LNG tank size

Conclusion

This study has taken a step into describing a “standard” container vessel in terms of main engine selection, tank sizing, and other major machinery equipment utilised with a gasfuelled ME-GI engine. Fig. 13 presents a decision-making schematic on how to approach the case of designing a gas-fueled container vessel.

MAN Energy Solutions’ state-of-the-art dual fuel two-stroke ME-GI main engines, the dual fuel four-stroke engines, and the recent developments on the fuel gas supply system – the MAN PVU – have all demonstrated our commitment to support the gas-fueled vessels of the future.

Installation of a PTO is an option to cover the electrical demand during sailing.

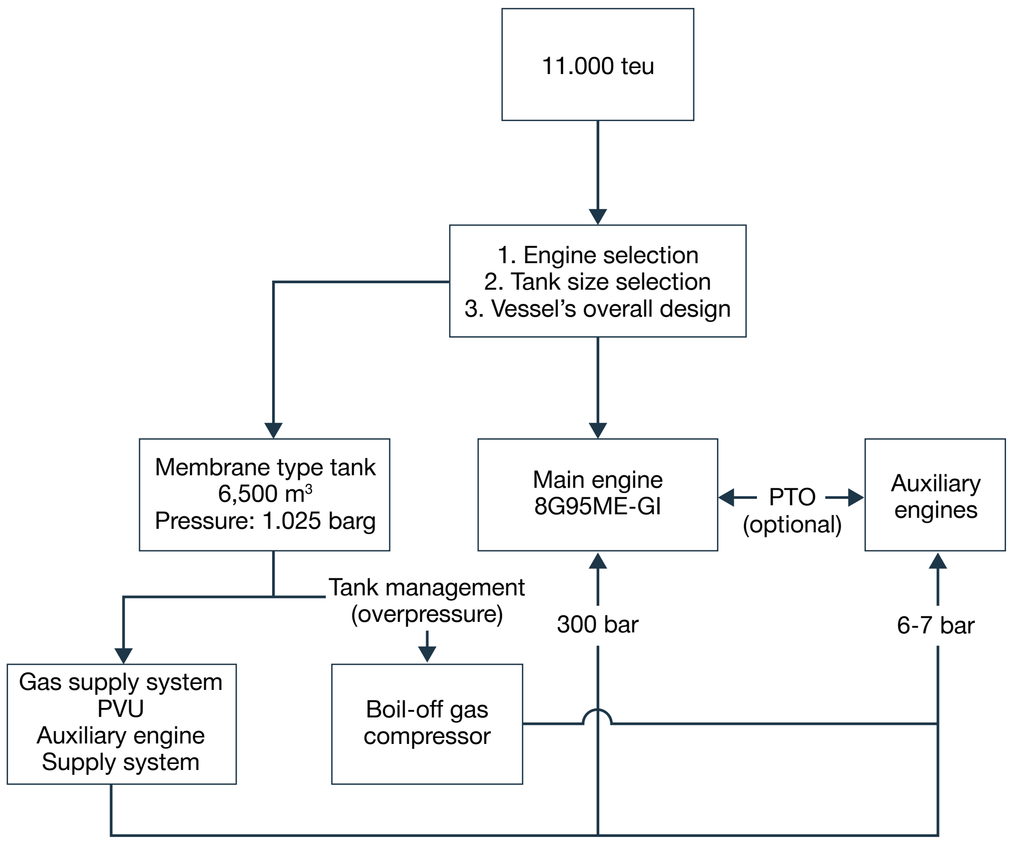


Fig. 13: Decision making schematic

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5510-0212-00ppr Dec 2018 Printed in Denmark