Interreg
EUROPEAN UNION
Danube Transnational Programme
GRENDEL

WP4 – Preparatory actions
WP4.1 – Individual advanced vessel concepts & energy efficient navigation

Development of innovative and greening inland vessel concepts

SHIP DESIGN GROUP (SDG) and NAVROM involvement

GRENDEL 4th Consortium meetings
29th of October 2020

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Project co-funded by European Union Funds (ERDF, IPA)

Carbon neutral pathways and the transition

Public opinion of ship owners and operators in regards to new technologies changes once these become:

- **Safe**
- **Proven**
- **Economically viable**

There are three probable pathways towards zero-carbon transportation

	Light gas	Delicate storage Dedicated infrastructure	Heavy gas	Less demanding storage	Bio/Synthetic	Renewable sources
Current deployment	LNG	Cryogenic Mature technology	LPG, MeOH	Significant reduction in CO2	Bio-/Renewable Diesel	Infrastructure is there Engines already use it
Transition stage	Bio-/Electro -Methane	Carbon-neutral	Bio-/Electro -Fuels	Carbon-neutral	Gas-to-Liquid Fuels	Carbon capture Electrolysis
Zero-carbon stage	Hydrogen	Needs research	Ammonia	Needs research Needs regulation	Next generation biodiesel	Currently hypothetical

European regulation for the transition stage

Emission limits for non-road mobile machinery have been put forth to aid the process of transition. Inland waterway vessels have been included in the regulations.

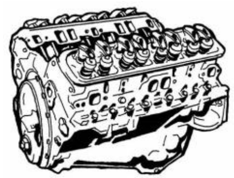
Engine Category	Power ranges (kW)	Sub-category (1)	Reference Power(2)	Placing of engines on the market	Emission durability period(3)	CO g/kWh	HC g/kWh (4)	NOx g/kWh (4)	PM mass g/kWh	PN #/kWh
IWP Inland waterway propulsion engines	19<P<75	IWP-1	Maximum/ Rated power	1st of January 2019	10000 hours	5.00	Total < 4.70		0.30	-
	75<P<130	IWP-2				5.00	Total < 5.40		0.14	-
	130<P<300	IWP-3				3.50	1.00	2.00	0.10	-
	P>300	IWP-4		1st of January 2020		3.50	0.19	1.80	0.015	1×10^{12}
IWA Inland waterway auxiliary engines	19<P<75	IWA-1		1st of January 2019		5.00	Total < 4.70		0.30	-
	75<P<130	IWA-2				5.00	Total < 5.40		0.14	-
	130<P<300	IWA-3				3.50	1.00	2.00	0.10	-
	P>300	IWA-4		1st of January 2020		3.50	0.19	1.80	0.015	1×10^{12}

Vessels already in operation

For existing vessels, one means of achieving emission reduction during the transition stage is by retrofitting with exhaust after-treatment systems or equivalent compliant systems.

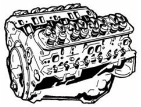
- **Replace the engine**
- **Replace the engine and the gearbox**
- **Replace the engine, gearbox and propeller**

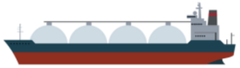
Add an after-treatment system → **Perform modifications to structure, piping, electrical systems and related trials**



The GRENDEL project is an attempt to modernize the inland Danube fleet and increase competitiveness of inland transportation. For GRENDEL, SHIP DESIGN GROUP and NAVROM have studied two propositions.

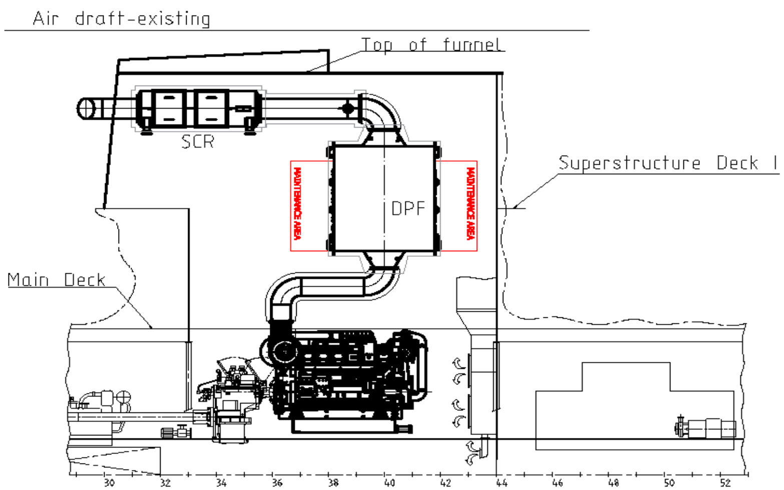
- **Retrofit technologies**
- **LNG for newbuilds**



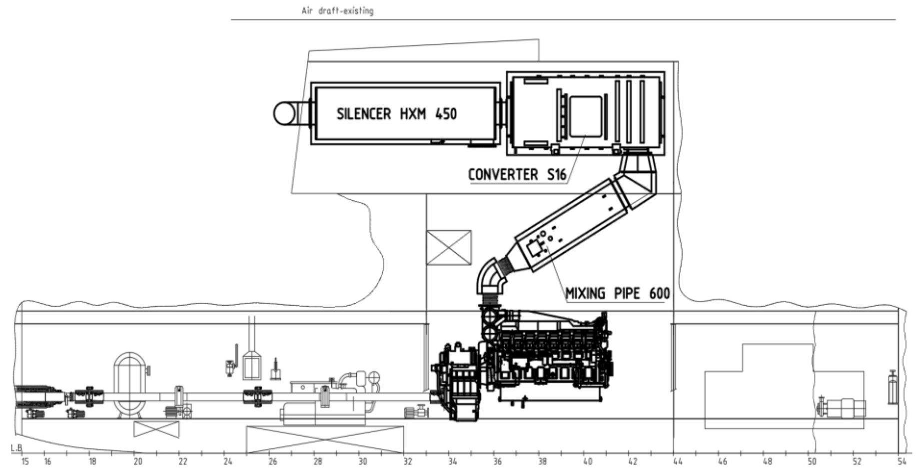


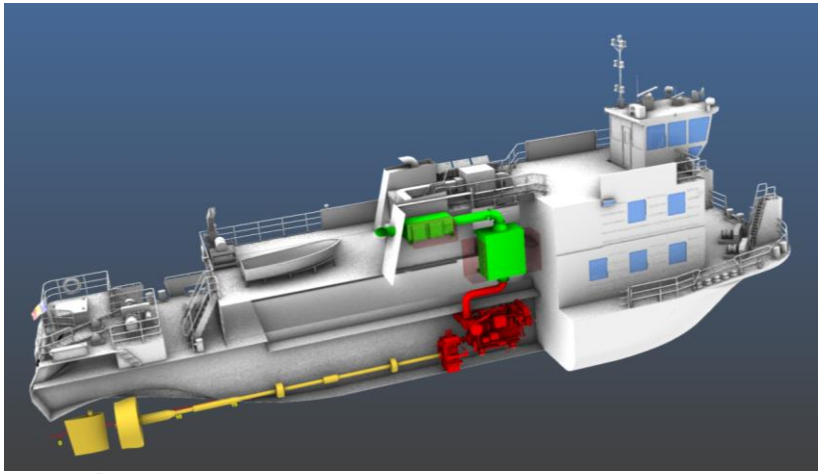
Retrofit solutions – Type 1 NAVROM pusher

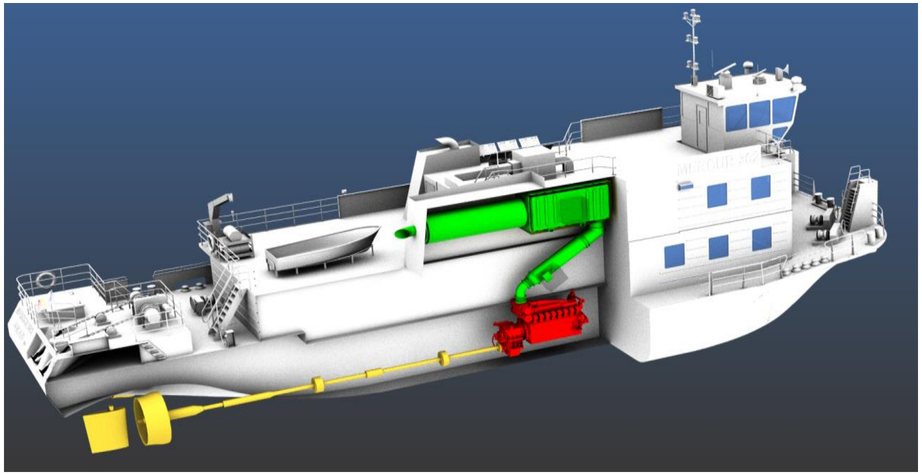
CATERPILLAR solution



MITSUBISHI solution







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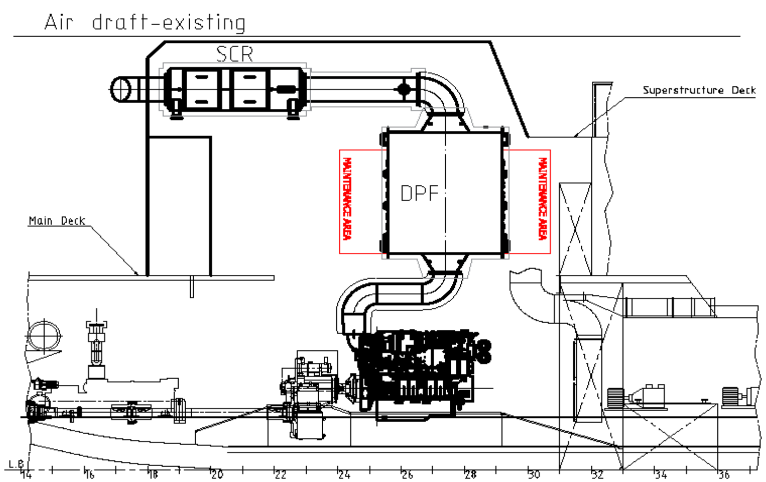
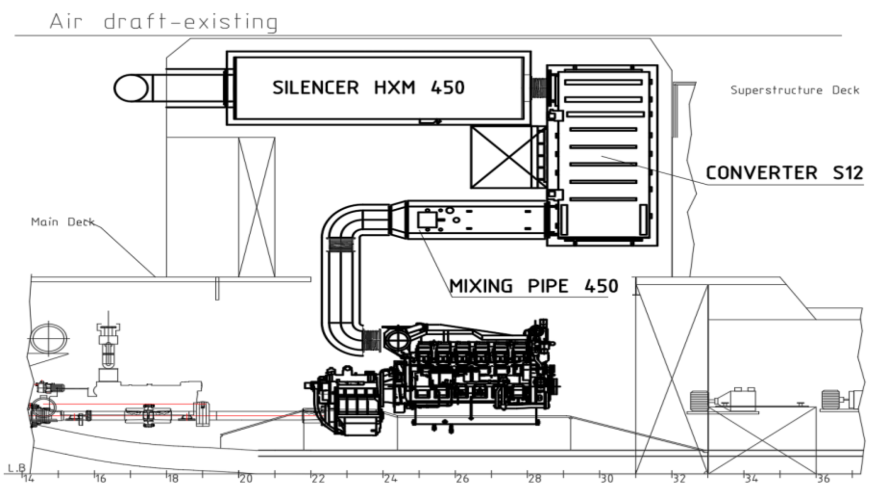
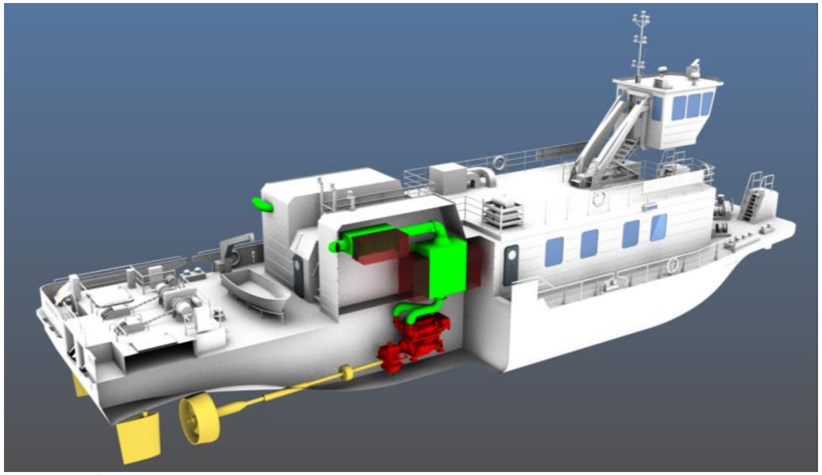
Retrofit solutions – Type 2 NAVROM pusher

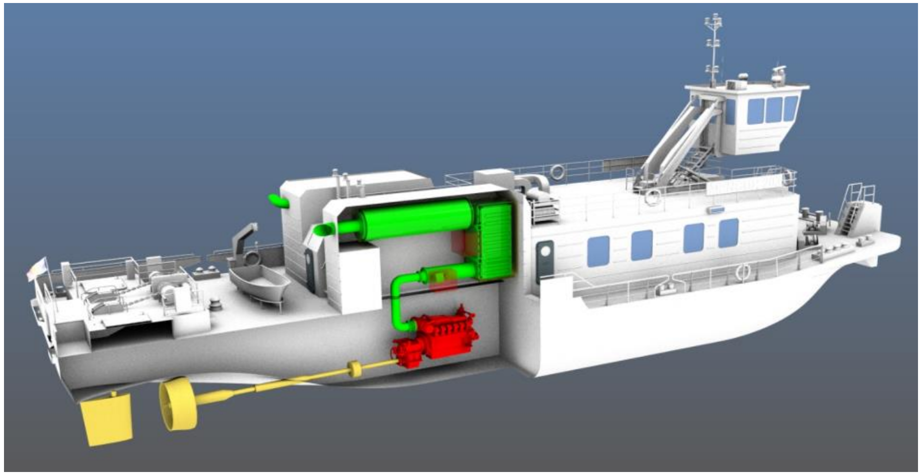
CATERPILLAR solution



MITSUBISHI solution



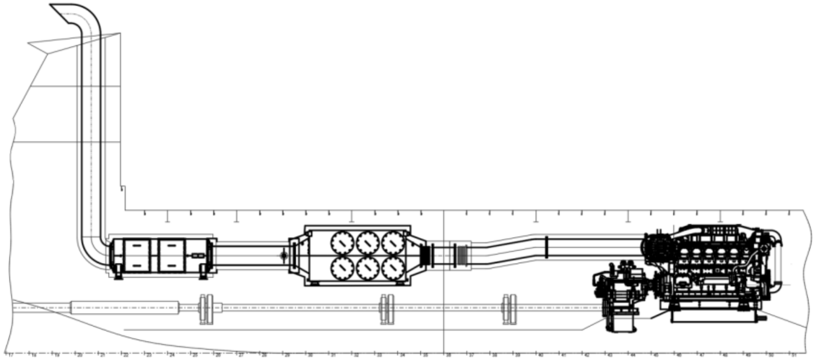


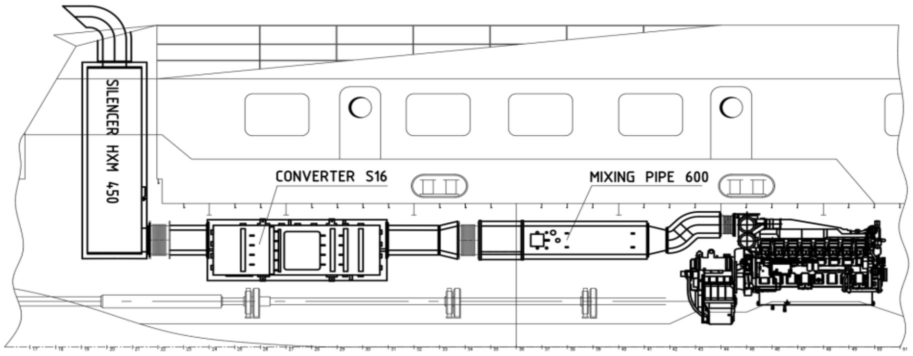


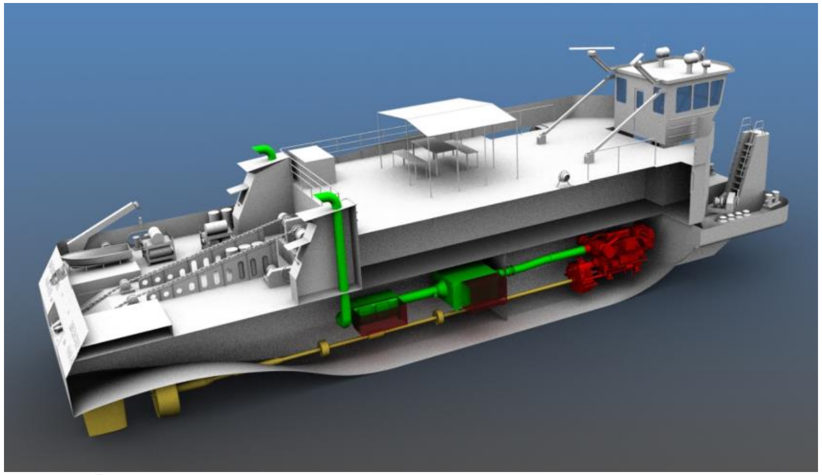
Retrofit solutions – Type 3 NAVROM pusher

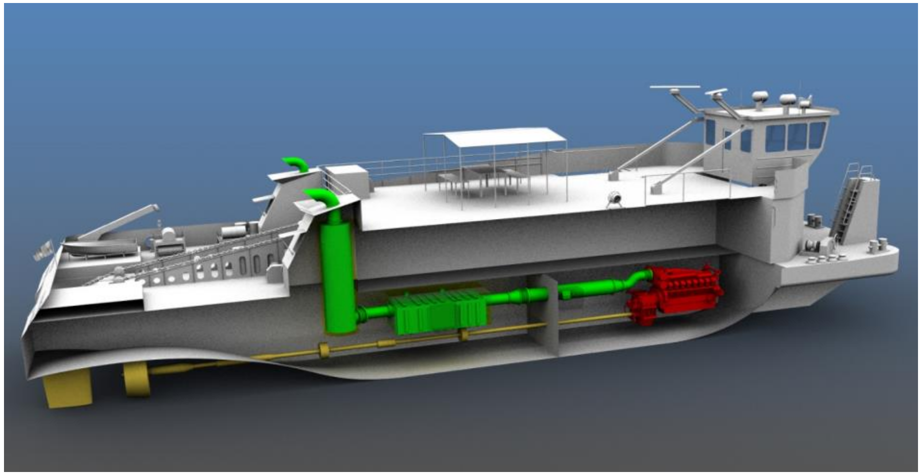
CATERPILLAR solution

MITSUBISHI solution



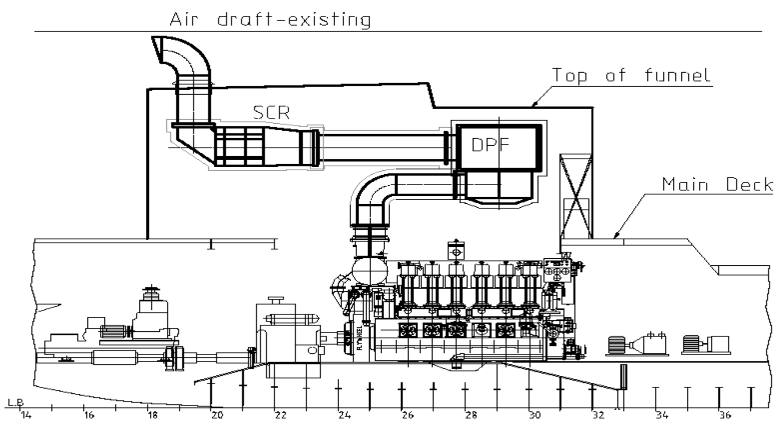






Retrofit solutions – Type 4 NAVROM pusher

ABC solution



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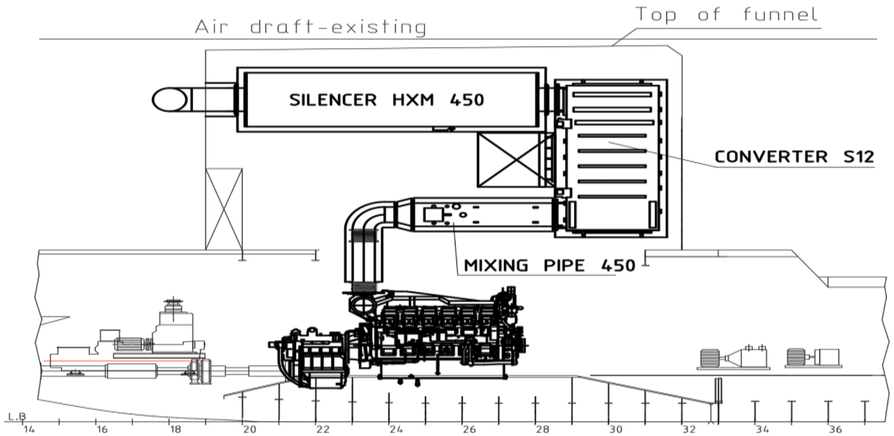

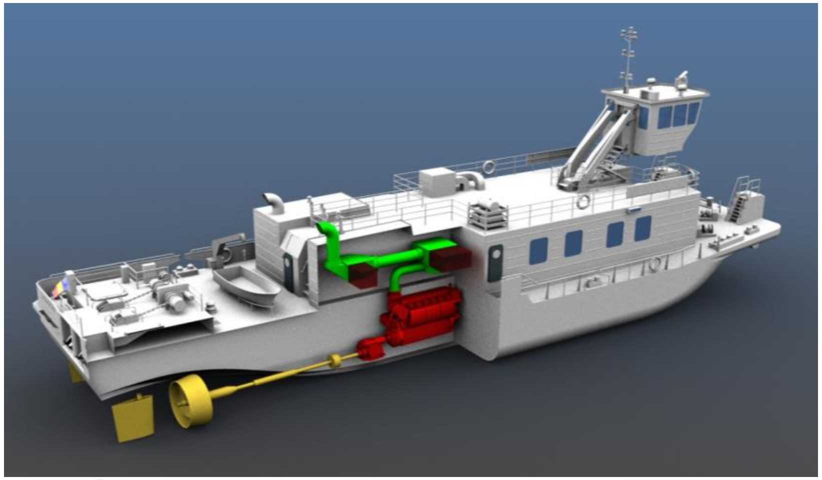

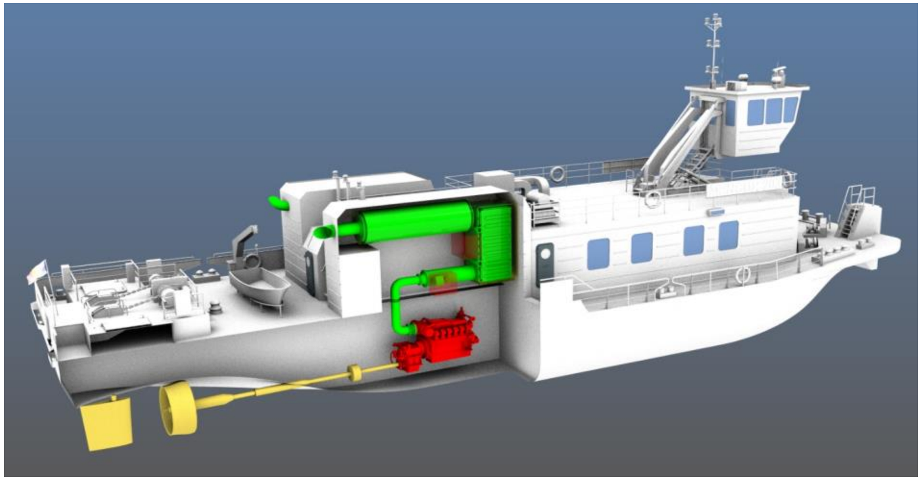

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What have we learned, what can we achieve

Structural modifications

- New main engine foundation
- New supports for the EATS
- Funnel modifications
- New urea tank
- Miscellaneous structural modifications

Piping modifications

- New exhaust after-treatment system
- Modifications of engine-related piping
- New urea system
- New compressed air system
- Miscellaneous piping modifications

Electrical system modifications

- Main switchboard modifications
- Replacement of monitoring equipment
- Replacement of control equipment
- New cabling systems
- Miscellaneous electrical modifications

Results of modifications

Ship type	Number of ships	Total reduction HC	Total reduction NOx	Total reduction PM
Type 1	2	0.90	102.02	11.96
Type 2	4	0.20	144.12	17.96
Type 3	3	23.67	157.83	17.79
Type 4	2	12.32	82.14	9.28
	Total for all vessels (tons)	37.09	486.11	56.99

The LNG pusher – pathway towards zero-carbon

LNG technology

Economically feasible

Community perspective improving

Supply chains improving

Technology is mature

NAVROM requirements

Ship type	Pusher
Ship fuel	LNG
Power	> 4000 HP
Range	> 1000 km upstream
Navigation area	Danube river, up to Passau
Length	< 42 m, due to Danube locks
Breadth	< 23 m, due to Danube locks
Draught	< 2 m, due to Danube depth
Air draught	< 7.7 m, Passau bridge

SDG input

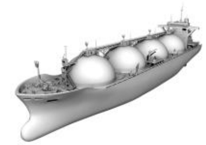
The design process

The concept vessel

"One of the most powerful and modern pushers on the Danube River"

Why is LNG challenging

Engine manufacturers have been focusing on maritime applications



The materials used need to be certified for cryogenic temperatures

LNG related systems need to have carefully controlled pressure reliefs

The LNG tanks and the processing units need careful placement

The ventilation system is critical

The gas piping and tank storage need to be protected and separated from safe spaces

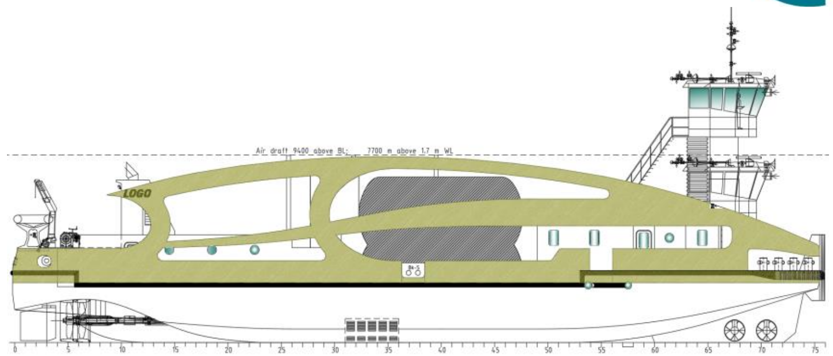
Conventional vessel systems are impacted by the LNG addition

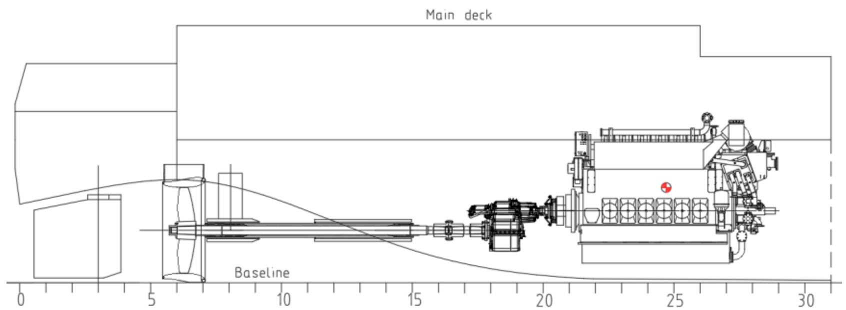
Leaks have to be controlled and accounted for during the design process

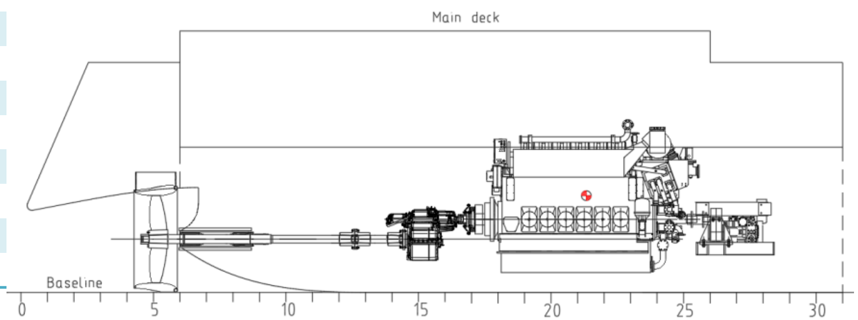
The general arrangement of the vessel is critical

Particular data

Main dimensions		
Length overall	42.00	m
Length hull	41.5	m
Breadth	13.5	m
Depth	3.0	m
Design draught	1.85	m
Scantling draught	2.0	m
Air draft above B.L.	9.40	m
Capacities		
Ballast	83	m^3
Fresh water	30	m^3
Sewage at 85% fill	26	m^3
Lubrication oil	8	m^3
LNG (total/net)	220/190	m^3
Crew	8	
Equipment		
Propulsion engines	3x1460 kW @ 900 RPM	
Gearbox	1:2.548 gearbox ratio	
Shaft generator	100 ekW	
Gas generator	100 ekW	
Side thrusters	42", 2x250 kW	
Propellers	2 x FPP, 1 x CPP, 1.8 m	
Hydraulic unit	600 kW	
LNG Pack	2 Bilobe tanks @ 110 m3	

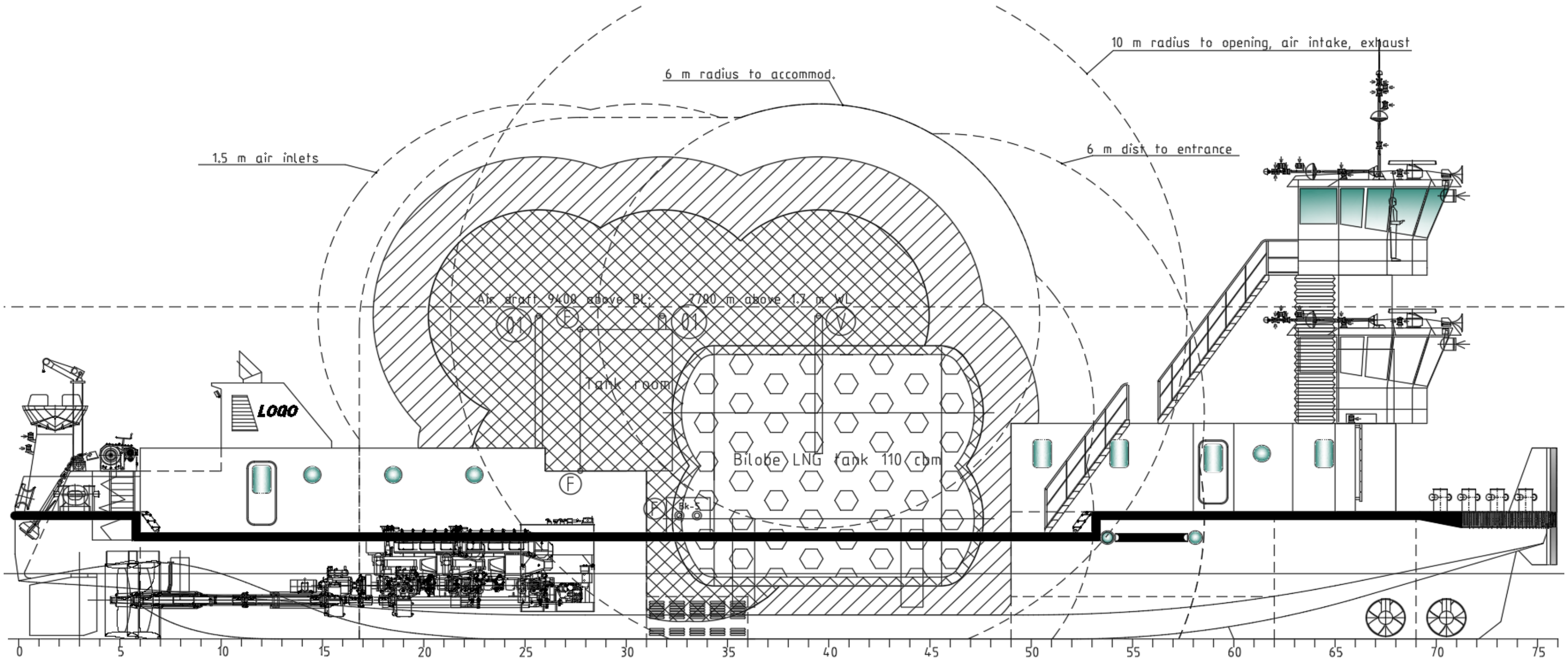




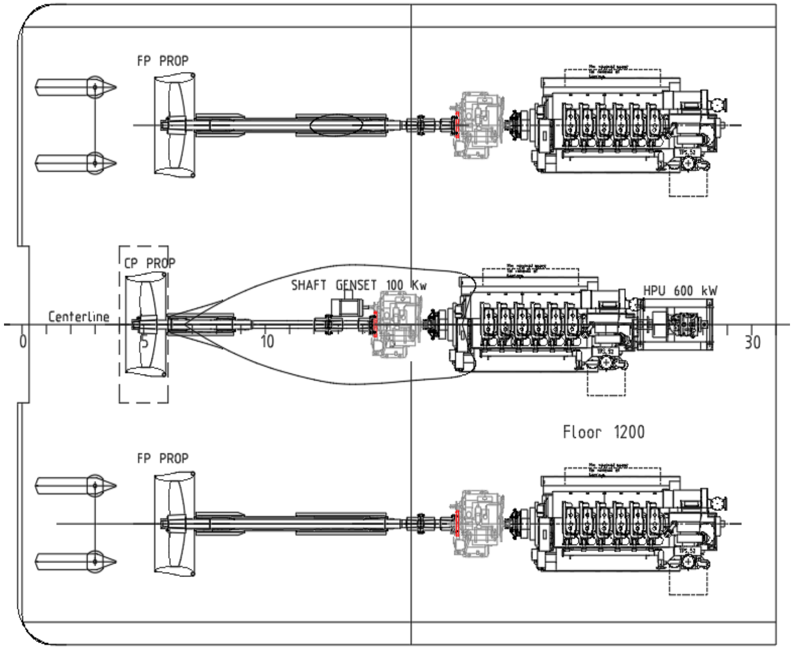


The hazardous areas plan

Critical for the design stage, the Hazardous Areas plan is done according to regulation and it dictates the layout of the vessel, the routing of piping systems and placement of equipment. The LNG concept has an engine compartment rated as 'Gas safe', due to employing double-walled piping and safety mechanisms.



Performances



With an average flow speed of 4 km/h, the convoy speed relative to the land is at least:

- **8 km/h upstream**
- **14 km/h downstream**

Presumed range of the vessel:

- **Upstream: 1200 km**
- **Downstream: 3150 km**

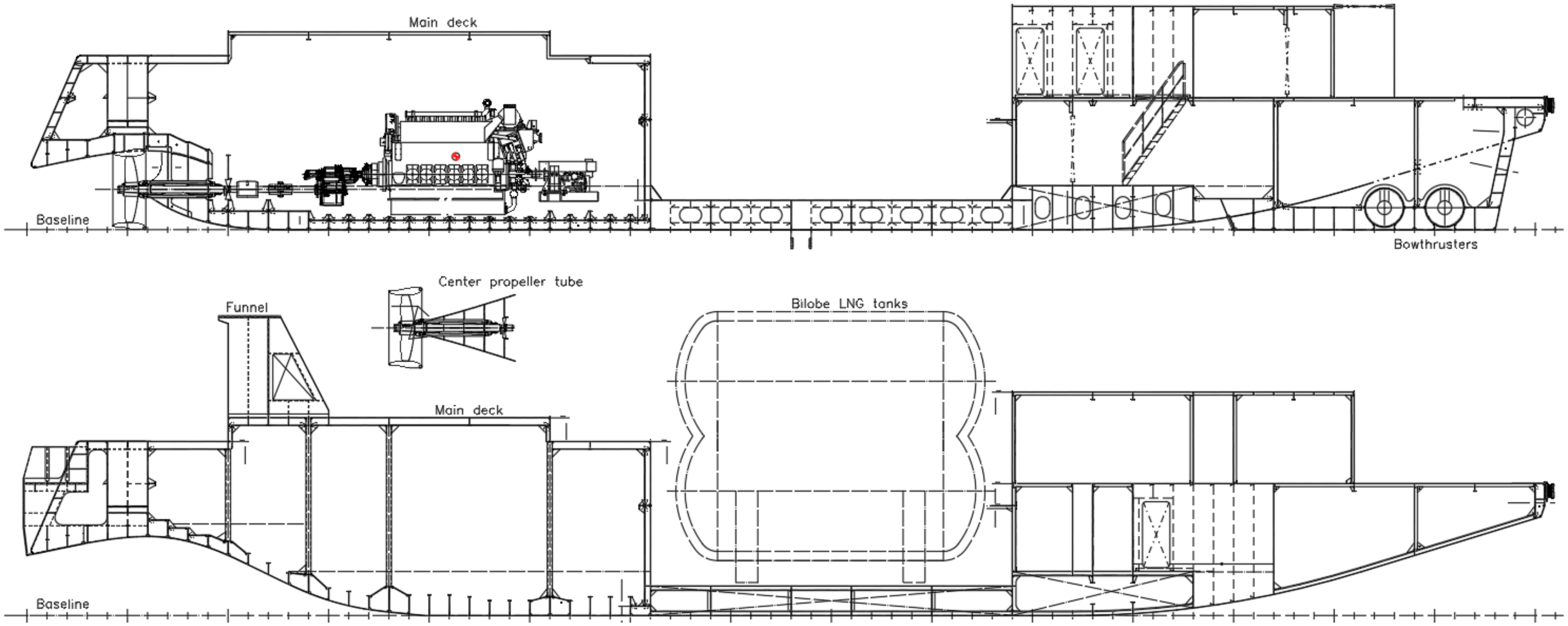
One year of operation results in approximately 3150 m³ of LNG consumption.

Scenario	kW	HP	Thrust [kN]	Speed [km/h]
Maximum thrust	4050	5500	408	13
Using side thrusters and shaft generator	3400	4600	355	12
Side engines only	2700	3650	270	11

The hull basic design

The hull technical concept involves the assessment of relevant strength criteria and resulting structure scantlings.

- Steel hull, grade A or equivalent
- Vessel specific solutions
- Designed for efficiency



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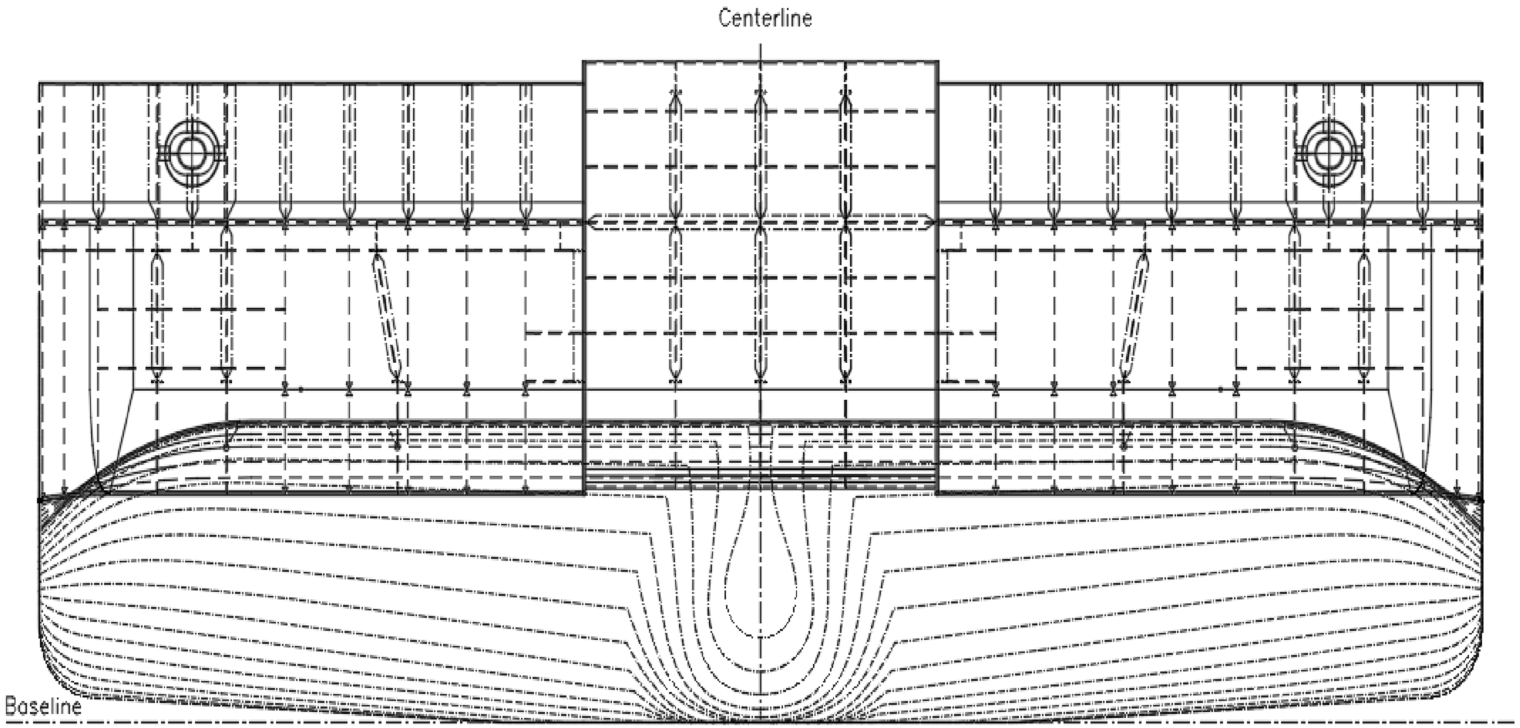

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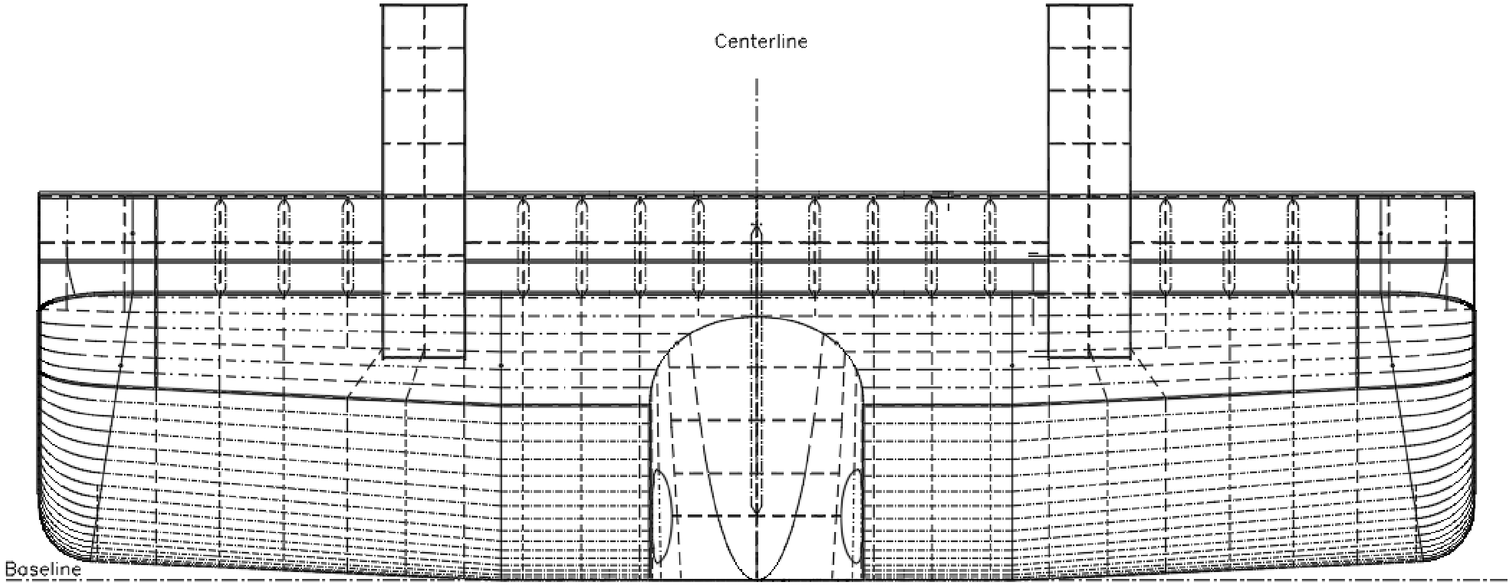

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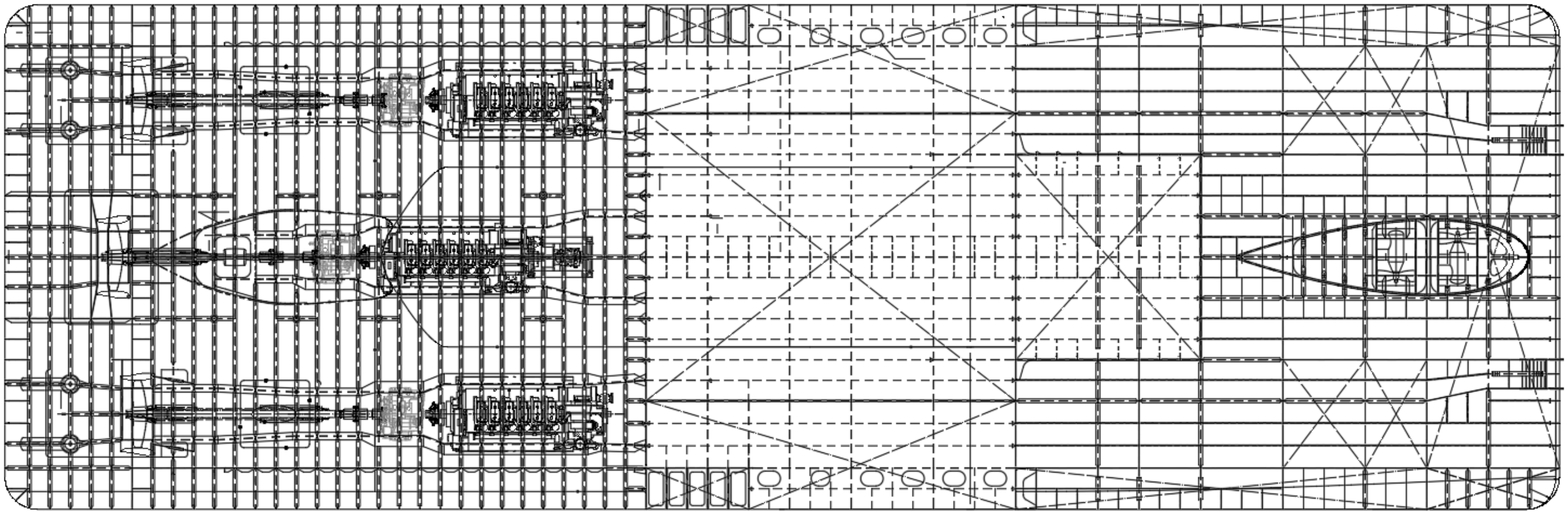

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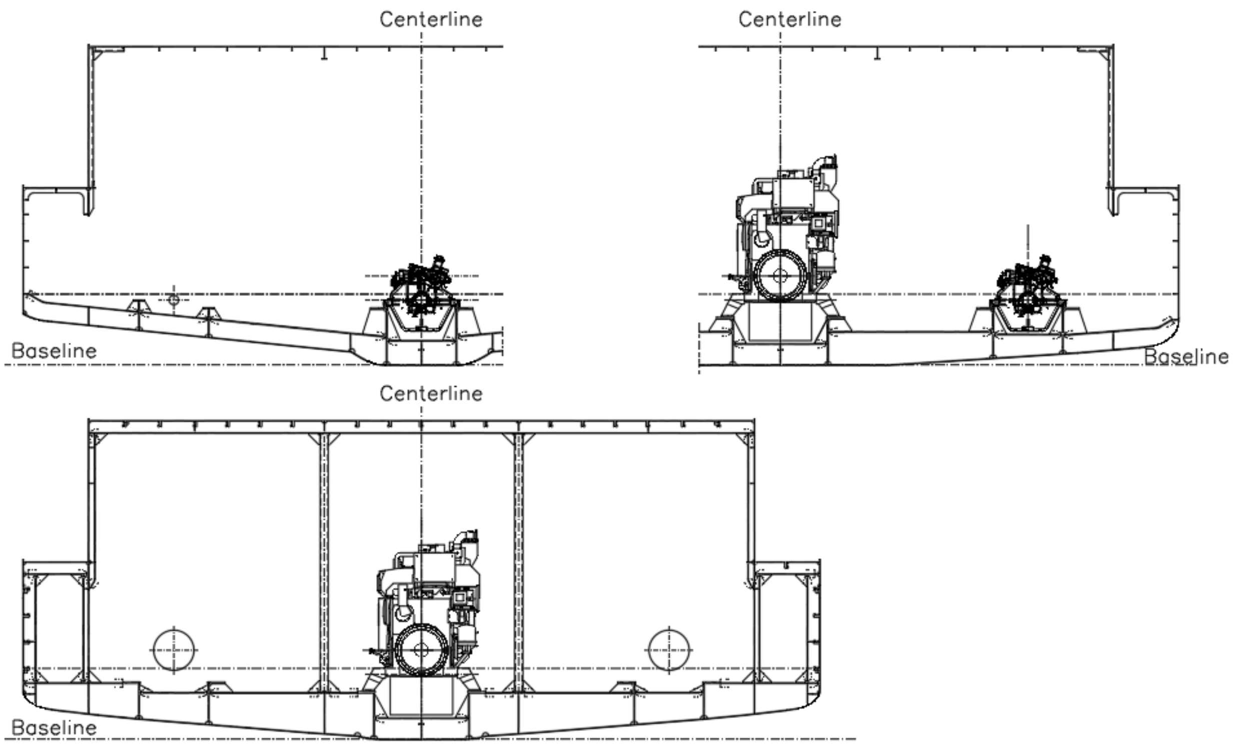


The piping basic design

Special care is needed when designing systems that can interfere with the LNG system or auxiliary ones.

The tank sounding system → **Sounding pipes connect spaces and need careful consideration**

The piping basic design

Special care is needed when designing systems that can interfere with the LNG system or auxiliary ones.

- **The tank sounding system**
- **The ventilation system** → **Can connect safe spaces with hazardous areas and the other way around.**

The piping basic design

Special care is needed when designing systems that can interfere with the LNG system or auxiliary ones.

- The tank sounding system
- The ventilation system
- The bilge system

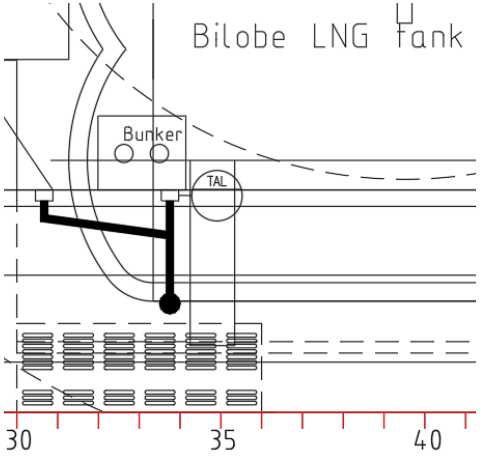
Leakages underneath the LNG tanks need to be collected. The material used must be cryogenic. The piping used for LNG discharge must be separated from the rest of the system.

The piping basic design

Special care is needed when designing systems that can interfere with the LNG system or auxiliary ones.

- **The tank sounding system**
- **The ventilation system**
- **The bilge system**
- **The external drainage system**

The bunker station drainage needs to lead overboard and beneath the waterline. Draining it on the hull plate exposes the steel to cryogenic temperatures.



The piping basic design

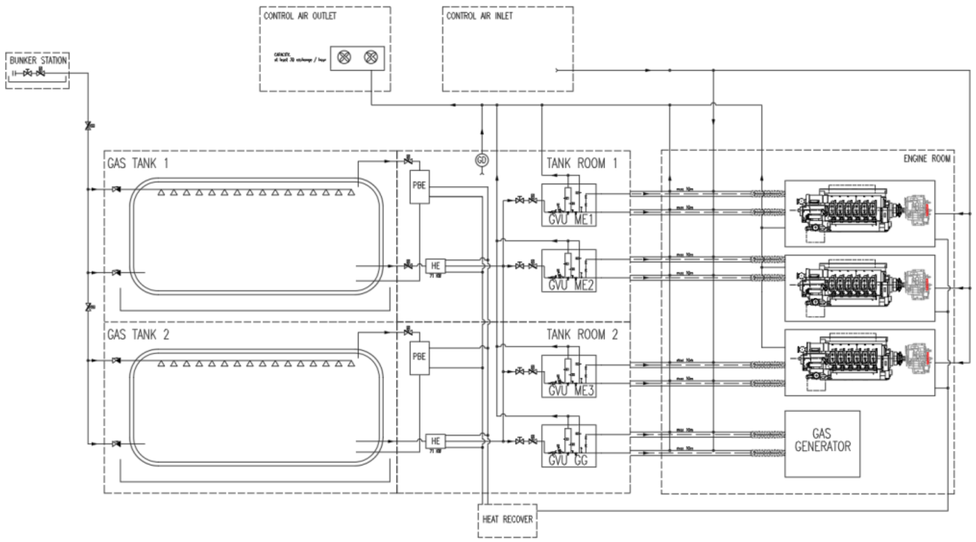
Special care is needed when designing systems that can interfere with the LNG system or auxiliary ones.

- **The tank sounding system**
- **The ventilation system**
- **The bilge system**
- **The external drainage system**
- **The water spray system** → **The system uses fresh water to cool the area around the LNG tanks in case of leakages, which prevents rapid evaporation of the gas.**

The piping basic design

Special care is needed when designing systems that can interfere with the LNG system or auxiliary ones.

- The tank sounding system
- The ventilation system
- The bilge system
- The external drainage system
- The water spray system
- The fuel gas system

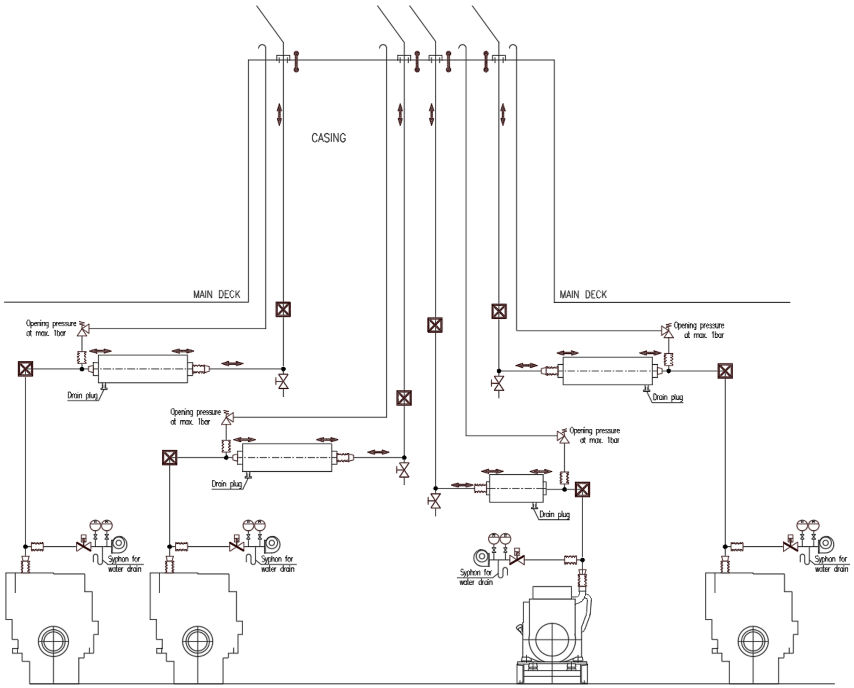


A critical system, piping is double walled, the gap between the pipes is constantly ventilated. A three way valve allows discharge to the atmosphere in case of emergency

The piping basic design

Special care is needed when designing systems that can interfere with the LNG system or auxiliary ones.

- **The tank sounding system**
- **The ventilation system**
- **The bilge system**
- **The external drainage system**
- **The water spray system**
- **The fuel gas system**
- **The exhaust gas system**

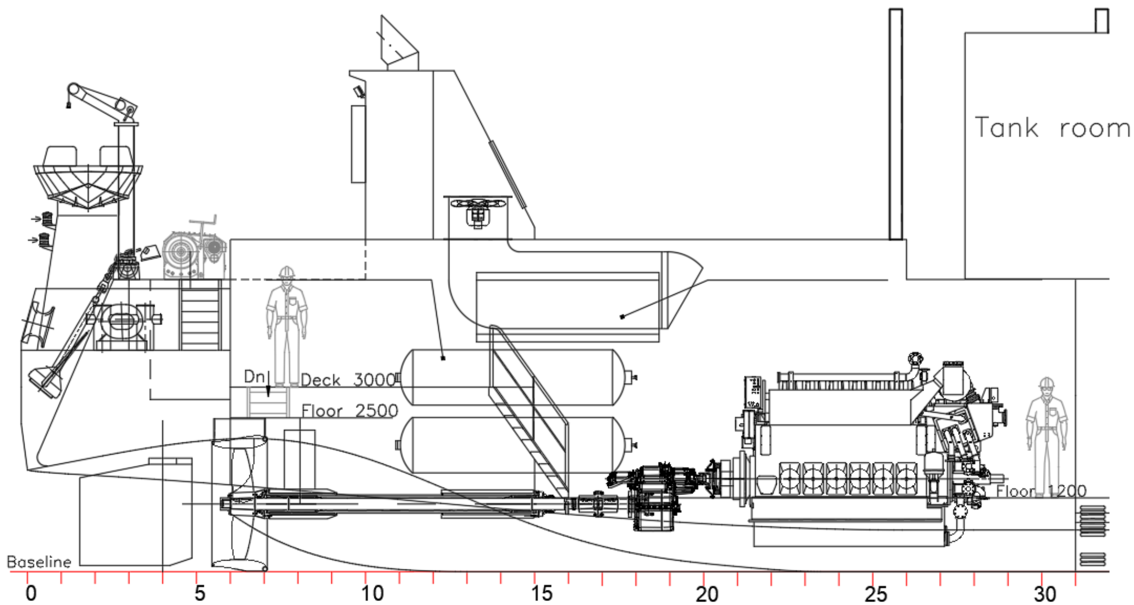


Pipes need to be ventilated to prevent accumulation of gas from methane slips. The system should be able to withstand over-pressure from LNG explosions. The pipelines create a hazardous area around the funnel.

The piping basic design

Special care is needed when designing systems that can interfere with the LNG system or auxiliary ones.

- The tank sounding system
- The ventilation system
- The bilge system
- The external drainage system
- The water spray system
- The fuel gas system
- The exhaust gas system
- The compressed air system



The air bottles of the starting system are large due to the nature of the fuel, the large capacity of the engine cylinders and the minimum startups required by Regulations.

Is Stage V achievable?

By retrofitting

- **Type 1** – 2 x 1600 HP → **Yes**: Caterpillar technology, Mitsubishi technology
- **Type 2** – 2 x 1200 HP → **Yes**: Caterpillar technology, Mitsubishi technology
- **Type 3** – 2 x 1600 HP → **Yes**: Caterpillar technology, Mitsubishi technology
- **Type 4** – 2 x 1260 HP → **Yes**: ABC technology, Mitsubishi technology

85% reduction of HC, 80% reduction of NOx, 98% reduction of PM, per ship

By new-builds

- **Yes**: LNG technology, BIO/Synthetic LNG

25% reduction of CO2, 90% reduction of NOx, 100% reduction of PM

The LNG concept, towards zero-carbon

SHIP DESIGN GROUP

A modern concept, flexible both in operation and in design variations. A step ahead Stage V regulations and a future-proof vessel, ready to accommodate implementations of hydrogen as fuel. The design process was delicate, but has brought to limelight particularities of the technology. Once perspective of the inland shipping operators changes, the first-movers will be able to benefit from the insight provided by Ship Design Group and NAVROM via the GRENDEL project.