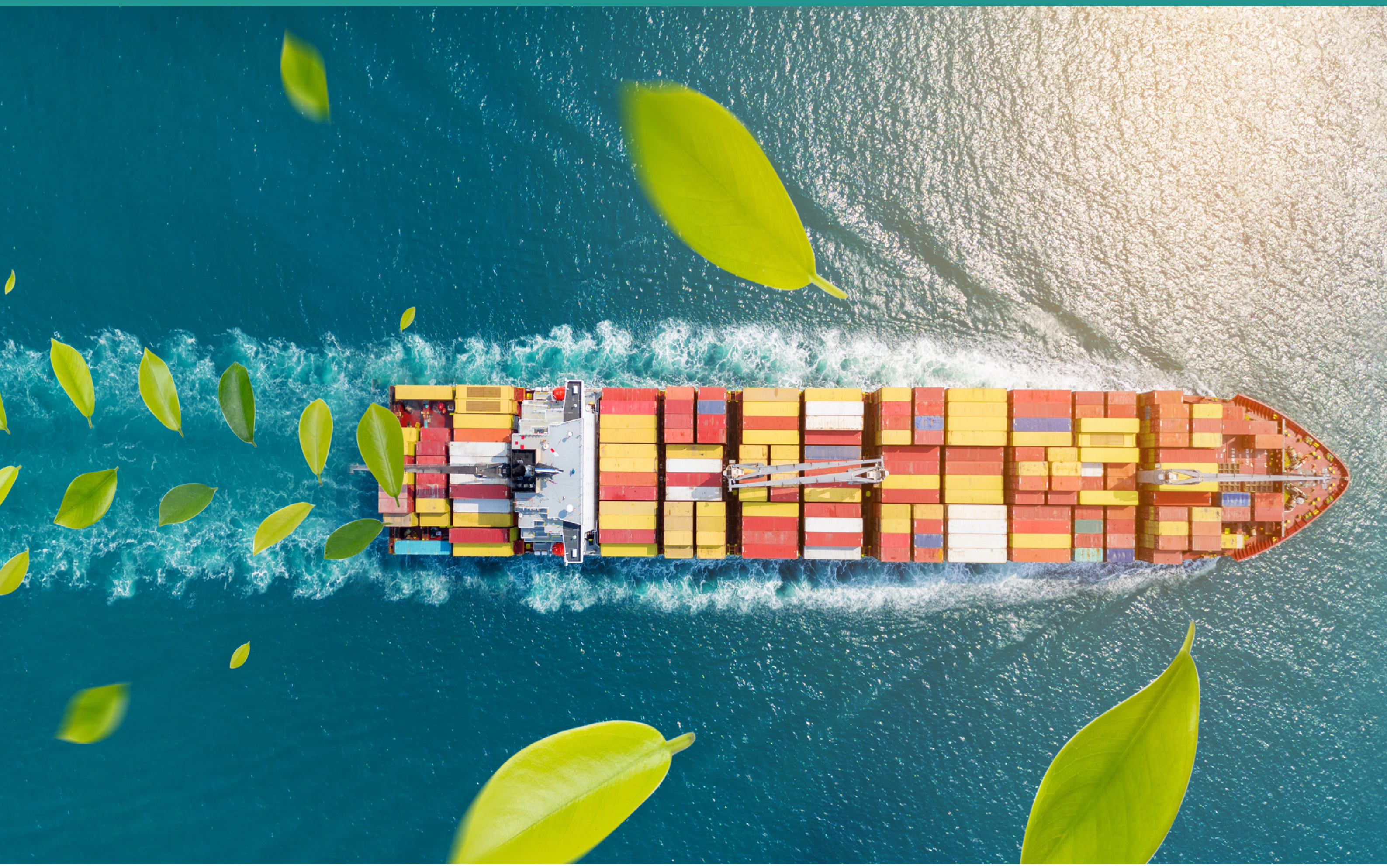
Green Shipping in the Dutch State Fleet

Deliverable 3: Concept Designs

2 Vessel Concept Designs, one for Hydrogen and one for Metha-nol

Technical Support Instrument

Supporting reforms in 27 Member States



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LIST OF ABBREVIATIONS

ACD	Accelerated Concept Design
AIP	Approval in Principle
BV	Bureau Veritas (project partner)
CAD	Computer Aided Design
CAPEX	Capital Expenses
DP	Dynamic Positioning
EC	European Commission
ER	Engine Room
FC	Fuel cell
GA	General Arrangement
ICE	Internal Combustion Engine
MARIN	Maritime Research Institute Netherlands
MBSE	Model Based Systems Engineering
MEPC	Marine Environment Protection Committee
MSN	Marine Service Noord (project partner)
NMT(F)	Netherlands Maritime Technology (Foundation) (project partner)
PPE	Power, Propulsion and Energy

1 INTRODUCTION

On 25 June 2019, the Dutch government and the maritime industry signed a Green Deal on Maritime and Inland Shipping and Ports. The agreement aims, among other things, for a 70% reduction of CO_2 in shipping by 2050 (compared to 2008) and for the launch of at least one zero-emission seagoing vessel by 2030. The climate objectives of the government fleet are: '20% reduction in carbon emissions by 2020, carbon neutral by 2030 and fully climate-neutral and climate-resilient by 2050'. To verify the feasibility of these objectives, the Dutch State Government Shipping Company promised to study alternative means of propulsion technology, like the use of methanol and hydrogen. The current project fits in with these promises and its results will prove the feasibility of these technologies, leading to timely introduction on the first new builds.

More information about the background of this project and the European program can be found in Deliverable 1; Inception Report [1] and Deliverable 2: Basic Customer Requirements [2].

This report is Deliverable 3, the concept design report capturing the results of the concept design phase.

The report will initially be published in English. A Dutch translation will be made. In case of differences in content or interpretation the English version prevails.

2 REFERENCE DOCUMENTS

Ref nr	Title	Written by	Date
[1]	Deliverable 1 Inception Report REFORM/SC2021/119	Green Shipping in the Dutch State Fleet	May 2022
[2]	Deliverable 2 Basic customer requirements V1.0	Marin	September 2022
[3]	21.092-000-032-ACD STUDY	C-Job	August 2022

3 DESIGN PHILOSPHY

3.1 Goal work package 3

To validate whether the concepts are feasible and to provide a further assessment showcasing how these two concepts differ on main layouts and principle dimensions.

Chapters 4 and 5 of this document contain the concept design report for both vessel configurations, methanol and hydrogen. In these chapters, designs for the Methanol and Hydrogen fueled vessels are presented and supported with checks and calculations on the general layout and requirements. This is to ensure that the main particulars and vessel layout meet the requirements and are sufficiently validated to perform the next engineering phase upon.

3.2 Methodology for WP3

The goal of WP 3 is to develop a vessel design based on the PPE system requirements and Vessel and hull requirements as per WP2 report. The steps performed during WP 3 are illustrated by the project methodology as presented in the inception report [1]. The current phase is illustrated by the following figure.

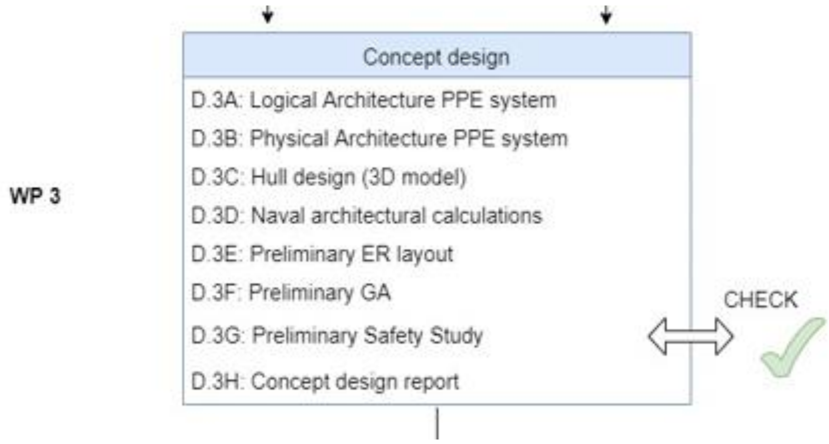


Figure 1 WP3 main activities, ref [1]

A first study with regard to the feasible vessel main particulars is done utilising the C-Job ACD framework. Based on the gross properties of the developed logical architecture for the PPE systems and vessel requirements, the main particulars are determined. This process and results are reported in the ACD study report, [3].

During the design process the logical and physical architecture of the PPE system will be implemented in the (naval architectural) design.

The resulting naval architecture design will be reviewed and verified by performing preliminary calculations on critical items regarding the design requirement, weight, stability and scantlings in order to verify the feasibility of the designs.

The next chapters of this report consist of the two concept design reports, one for the methanol design and one for the hydrogen design.

Initially the design requirements were set equal for both concept designs. During the design process slight alteration to the design requirements were made based on physical limitations of the design and/or additional wishes from RR. The design requirements are therefore presented and evaluated in the applicable chapters.

4 METHANOL CONCEPT DESIGN REPORT

4.1 Design requirements

Requirements are derived from WP2 document. For each requirement is indicated whether this is met in the presented design, and where applicable remarks regarding the requirements are noted.

Table 1 Rijksrederij requirements methanol design

Requirement title	Specification	Remarks	Complies?
Hull length	Maximum 65 m. (Initial requirement was 60m. The change to 65 has been agreed on 23/8/2022)	60.0m considered as maximum for Methanol Design	Yes
Draught	Preferred vessel draught: 3,5 m. Maximum draught 3,80m	Maximum draught 3.2m	Yes
Freeboard	Freeboard above the working deck as low as possible. Minimum 1,00 meter, maximum 1,30 meter.		Yes
Elevated platform	To be determined. (Measuring equipment needs to be at least 2.5 m above sea level.)	Platform can be added for specific operations	Yes
Ice class	Ice-strengthening bow asked. Use Young-Ice 2 class rules for determining steel weight. Roughly increase of bow plating with about 5-6mm.	Additional steel at bow considered for LSW	Yes
Ship speed	10 knots @ sea state 3 4 knots @ sea state 5	Estimated resistance is slightly lower compared to the WP2 results	Yes
Endurance	11 days at sea	Tank capacity determined for 11 days autonomy	Yes
Propulsion type	Preferably thrusters or pods. No conventional propulsion with shafts, propellers and rudders.	2 steerable thrusters applied	Yes
Additional propulsion power to operate the ground planning system	Low, not decisive for propulsion power or energy storage	See WP2 report [2] for resistance estimate	Yes
DP performance	DP2: The vessel should remain in position with a tolerance of 1 m under the following conditions:	Not addressed to detail at this stage	T.B.D

Requirement title	Specification	Remarks	Complies?
	· Tidal flow 2 knots perpendicular to the vessel. · wind 10 m/s +/- 30 degrees from the bow. · Significant wave height of 1,88 m +/- 30 degrees from the bow. · Wind and waves may come from different directions. The vessel should be able to follow a straight course over a distance of 1000 m, with a maximum deviation of half the width of the ship, under the following conditions: · Speed over ground: 2 knots · No tidal flow · Wind: 5,5 m/s perpendicular to the vessel · Significant wave height 0,88 m from all directions. · No use of tunnel thrusters for sideways propulsion.		
Power consumption of DP operation	To be determined.	An average Power of 180kW is estimated in WP2. This was not included in the design starting points for the total energy capacity. See remarks in WP2 report.	T.B.D
Energy storage margin	20%	Included in fuel consumption estimates	Yes
Energy storage rest volume	For methanol: 2%	Min. Tank filling Methanol 2%	Yes
Flat working deck around the moonpool	A flat working deck and free space of at least 1,5 m needs to be available around the moonpool. Behind the moonpool the flat deck and free space must be at least 6m. This is necessary for operations with the drilling system for seabed quality survey.		Yes

Requirement title	Specification	Remarks	Complies?
Payload deck capacity	1) Deck area 200-240m2 2) Fuel tank of 40m3 on deck 3) Storage of 4x 20' containers not impacting free deck area under 1. 4) Deck load capacity in weight and vertical center of gravity 5) Specific storage capacity/weights not part of the main ship systems below deck. -125 ton deck load (centre of gravity 2 meter above the work deck) - Work deck strength > 8 ton/m2.. - Storage capacity for 35 ton heavy equipment with a footprint of 30m2	5) Cargo hold footprint is 31.2 m^2 as per current GA	Yes
Moonpool	LxW= 4000 x 4000 mm		Yes
Crew accommodation	24 total: 14 single, 5 double		
Accommodation comfort level	1) clear deck heights in cabins, public spaces etc.. 2) Amount and size of the following additional accommodation spaces: Office workplaces, Conference rooms, Recreation rooms, fitness, smoking room, luggage room and any other required. 3) Specific requirements for certain cabin types and sizes? Crew, Officer, passengers? 4) Stair inclination	2) Smoking room and luggage room are absent as per current GA based on discussions with the Rijksrederij	Yes
Hotel load	200 kW		Yes
Fresh water supply	Preferable tanks, no fresh water maker	2 fresh water tanks are included in the design	Yes
Crane	- 10 ton @ 10 m outboard - 15 ton @ 4 m outboard	Palfinger PTM1800 (12-18 m outboard) is present as per current GA	Yes
Crane for railing shipwrecks	Outreach 5 ton @ 1 m		Yes
Anti-heeling system for crane	Not required		Yes
A frame	width 5000 mm		Yes
Refrigerated container power interface	3 kW reefer connection.	Onboard power considered, connection to be designed.	T.B.D

Requirement title	Specification	Remarks	Complies?
Firefighting pumps and monitors	Ships preferably equipped with firefighting pumps and monitors. Required specification for one monitor: · Flow 1200 m3/hr · Reach 100/120 m	Fire monitor shown in front of bridge. Pump allocated in engine room	Yes
Multi-beam sounder location	MBS must be located on the Centre Line, on a point with minimal turbulence, thus in front of the moonpool, minimum 3,5 m below the waterline and 0,5 – 2 m below the BL.	Included in GA	Yes

4.2 Elementary design principles

- Methanol in double bottom tanks.
- Work deck for buoy handling as clear as possible.
- Double aft bridge consoles visibility with preferably all around visibility, with good visibility on open bulwarks and shark jaws.
- Deckhouse in front
- Moonpool close to LCB
- No Diesel pilot or emergency fuel on board. Battery based emergency power system.

4.3 Rules and regulations

Class Notation: I ✠ Hull ✠ Mach Special service unrestricted navigation

Flag: Netherlands

Future fuels: Methanol

Applicable rules:

- NR 600 for construction (Starboat)
- NR467 for systems (machinery, safety, electrical, stability)
- NR 670 for methanol

4.4 Design Risks

The technical risks with potential to impact the overall project as perceived by the design team is listed and will be maintained throughout the project execution.

The following main technical risks and challenges are identified during the initial design phases.

Table 2 In WP3 identified design risks

Risk	Consequence	Mitigation action
Insufficient space for PPE systems	Vessel size increases	Assess volume requirements and place items from physical architecture
Accessibility and layout of cofferdams around methanol tanks	Inaccessible voids and difficult to produce construction	Assess accessibility in early main construction drawing sketches.
Increase of energy demand	Unable to complete missions	Asses expected vessel resistance in each design stage
Impact of hazardous zone on vessel operation	(Temporary) limitations on deck operations.	Initial place holders foreseen for venting and ventilation purposes.

4.5 Design evaluation

A conceptual design for a methanol powered multipurpose vessel is presented with the following main characteristics.

Table 3 Main particulars design methanol design

Main Particulars	
Length O.A.	52.7 m
Rule length	50.6 m
Breadth	13.1 m
Depth (maindeck)	4.4 m
Design draught	3.2 m
Accommodation	24 persons

Main dimensions

These initial main dimensions are determined by means of an ACD parameter study where the gross properties and requirements of the vessel were utilized as input for the parametric model where the most optimum result regarding expected LSW and resistance performance was selected.

The main drivers for the dimensions are:

- Length -> To accommodate sufficient deck area an internal space volume
- Breadth -> Minimum while retaining sufficient initial stability to perform lifting operations
- Depth -> Minimum to comply with the requirement that the distance to the W.L. during operations is < 1.3m.

Lightweight

Based on the vessel design the lightweight is determined, the main weight group results are presented in the table below:

Table 4 Lightship weight methanol design

SFI	Description	Weight (gross) [t]	LCG [m]	TCG (PS+) [m]	VCG [m]
LSW	**Total LSW**	**1317.14**	**27.74**	**0.10**	**4.58**
W2	HULL	786.89	28.18	0.00	4.45
W3	EQUIPMENT FOR CARGO	73.79	10.24	1.55	8.49
W4	SHIP EQUIPMENT	47.23	46.25	0.00	5.97
W5	EQUIPMENT FOR CREW AND PASSENGERS	262.60	33.06	0.01	4.62
W6	MACHINERY MAIN COMPONENTS	45.76	7.24	0.00	1.60
W7	SYSTEMS FOR MACHINERY MAIN COMPONENTS	21.67	28.31	-0.28	2.61
W8	SHIP COMMON SYSTEMS	79.20	22.73	0.31	3.54

Deadweight items

The following table of design deadweight items are considered in the design and reflected in the loading conditions.

Table 5 Design deadweight methanol design

Item	Weight [t]
Deckload	125.0
Cargo hold	35.0
Stores, spares and provisions	4.7
Other deadweight items	13.6
Methanol fuel	74.2

Fresh water	30.4
Lube & hydraulic oil	1.4
Hydraulic oil	2.3
Total deadweight capacity	286.6

Hull design

A hull shape for the vessel is developed matching the requirements with respect to the main particulars and required buoyancy. The rough 3D hull shape form the parametric ACD study is used as starting point. This rough shape is adapted to have a smooth and faired shape with the desired hydrostatic particulars and stern and bow shape features to enhance sailing and DP capability performance. Especially by means of having a pram shaped stern providing sufficient space for large azimuth thrusters. Figure 2 gives an impression of the developed 3D hull shape.

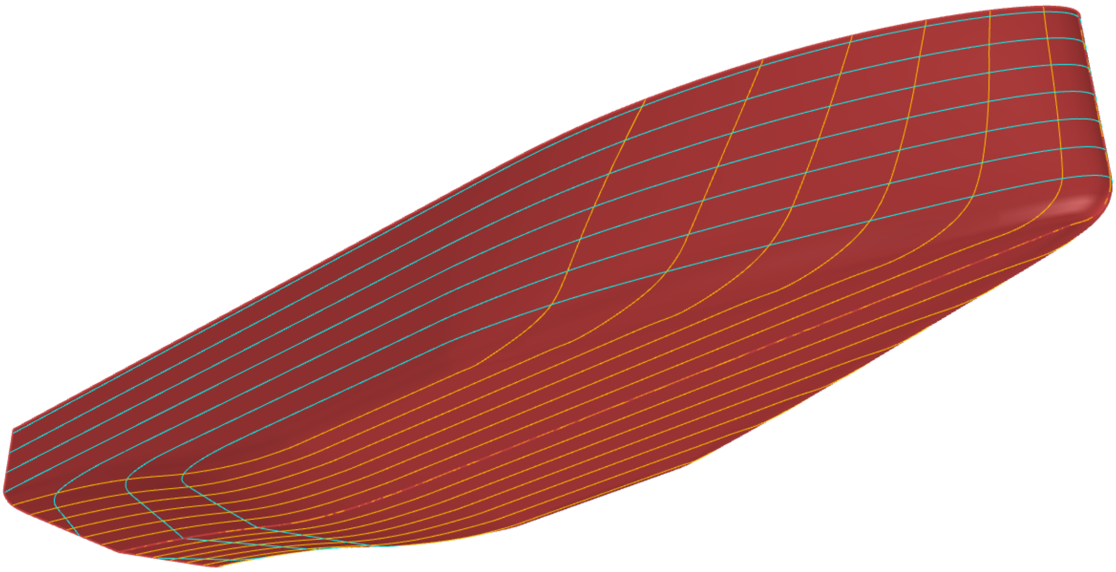


Figure 2 Preliminary hull shape overview

The characteristics of the hull are summarized in the following table:

Table 6 Hydrostatic particulars methanol design

Description	Qty.	Unit
Displacement Bare Hull @ design draught @ rho=1.025 t/m^3	1509	t
Length on the waterline	52.65	m
Width on the waterline	13.10	m
Design draught	3.20	m
Longitudinal Centre of Buoyancy forward of Transom	27.26	m
Longitudinal Centre of Flotation forward of Transom	23.52	m
Wetted Surface Area	820	m^2

*The design draught is slightly exceeded in the loading conditions and might need a minor adjustment in the next engineering phase. Impact is expected to be limited.

Tank capacities

The table below present the tanks an capacities considered for the initial design. These tanks will be reviewed during the development of the corresponding equipment during further engineering in Work Package 4, based on the in this report presented preliminary stability results

Table 7 Design tank capacities methanol design

Name	ID	Volume	Weight [t]
Methanol tank center	M1	32.8	26.0
Methanol tank PS*	M2	29.4	23.3
Methanol tank SB*	M3	29.4	23.3
Freshwater tank 1	FW1	16.0	16.0
Freshwater tank 2	FW2	16.0	16.0
Grey/Black water tank	GW	36.0	36.0
Lube oil	LO	0.7	0.6
Hydraulic oil	HO	2.5	2.3
Dirty oil	DO	3.5	3.0
Bilge water tank	BW	11.0	11.0
Water ballast AFT	WB	48.0	49.2
Water ballast FWD	WB	20.0	20.5

* These tanks expected to be adjusted in WP4 to include day and overflow tanks in the same vessel area.

Fuel capacity evaluation

The required fuel capacity showed some development throughout the WP3 design phase. The table below presents the development of the fuel capacity requirement and the attained capacity.

Table 8 Summary fuel capacity requirements

Reference:	Fuel capacity in ton
Design starting point as per WP2 report [2]	68.9
Corrected WP2 requirement for DP power estimate	80.6
Update capacity requirement with speed power prediction WP3	72.9
Attained fuel capacity in concept design WP3	**74.2**

From the table above is concluded that the methanol has sufficient fuel storage capacity to complete all specified mission profiles as prescribed by the Rijksrederij.

Stability

For the initial design primary attention is paid to the design displacement and center of buoyancy with

regard to the floating position. The preliminary loadcase overview below presents the range of drafts throughout the operations. In general is noted that the stability of the range of operations meet the relevant intact stability criteria from BV.

Table 9 Initial stability summary

Description	Draft [m]	Trim [m]	List [deg] + to PS	GM' [m]	Complies (BV RULES)
LC00 - Lightship	2.878	0.470	2.4	2.048	Complies
LC01A - Light sailing arrival	2.984	0.028	0.8	2.044	Complies
LC01B - Light sailing departure	3.072	0.498	2.3	2.033	Complies
LC02A - Fully loaded arrival	3.242	-0.305	-0.1	1.922	Complies
LC02B - Fully loaded departure	3.268	-0.237	1.1	2.112	Complies
LC10 - Lifting at min. draft	3.018	0.249	-3.1	1.987	Complies
LC20 - Lifting at max. draft	3.393	-0.051	-2.7	1.983	Complies

The crane operations have been assessed for minimum and maximum draft conditions considering a maximum lift of 15 ton at 4m outboard measured from the ship's side. The resulting heeling angle is 2.7 degrees at conditions at the design draft without using any active ballasting. For lighter loaded conditions the heeling angle is to be reduced by means of ballasting the vessel.

LC02B reflect the vessel at the maximum draft. During the next engineering phase the tank and LSW arrangement will be reviewed in more detail to attain zero list in all operational conditions focusing on minimizing the need for water ballast in the fully loaded conditions.

Speed power prediction

The speed power prediction assumes the use of a fixed pitch propeller inside a nozzle. The calculation has been performed with 2 propellers with each a diameter of 1.7 m. Further selection of the thrusters will be performed in the next engineering phase.

Based on the design parameters of the Methanol design in WP3, Marin recalculated the resistance and power prediction. The results are summarized in the tables below.

Table 10 Resistance prediction methanol design

Speed [kts]	Resistance ideal trial condition [kN]	Resistance sea state 3 [kN]
4	8	20
5	12	24
6	18	31

7	24	38
8	32	46
9	43	58
10	57	72
11	77	93

Table 11 Powering prediction methanol design

Speed [kts]	Power ideal trial condition [kW]	Power sea state 3 [kW]
4	33	104
5	63	144
6	106	217
7	168	301
8	260	408
9	398	579
10	599	**799**
10.7	**799**	
11	909	1155

The C-Job Methanol version of the MPV 50 requires 799 kW power to reach 10 knots in sea state 3.

In ideal trial condition the expected speed at 799 kW is 10.7 knots.

Comparing these results with the predictions as presented in the WP2 report [2], the required powering reduced from 953kW to 799kW.

Structural design

Prelim main cross section

Due to the way the methanol tanks are included in the design, a preliminary main cross section is set-up to determine the initial scantlings, structural grid and its impact on the spaces below deck.

These scantlings are used as basis for the steelweight estimation.

Special attention is paid to the construction below tanktop, where a double bottom tank for methanol is constructed with a void on top. To verify the feasibility of this design the typical Web frame as shown in Figure 3 is developed.

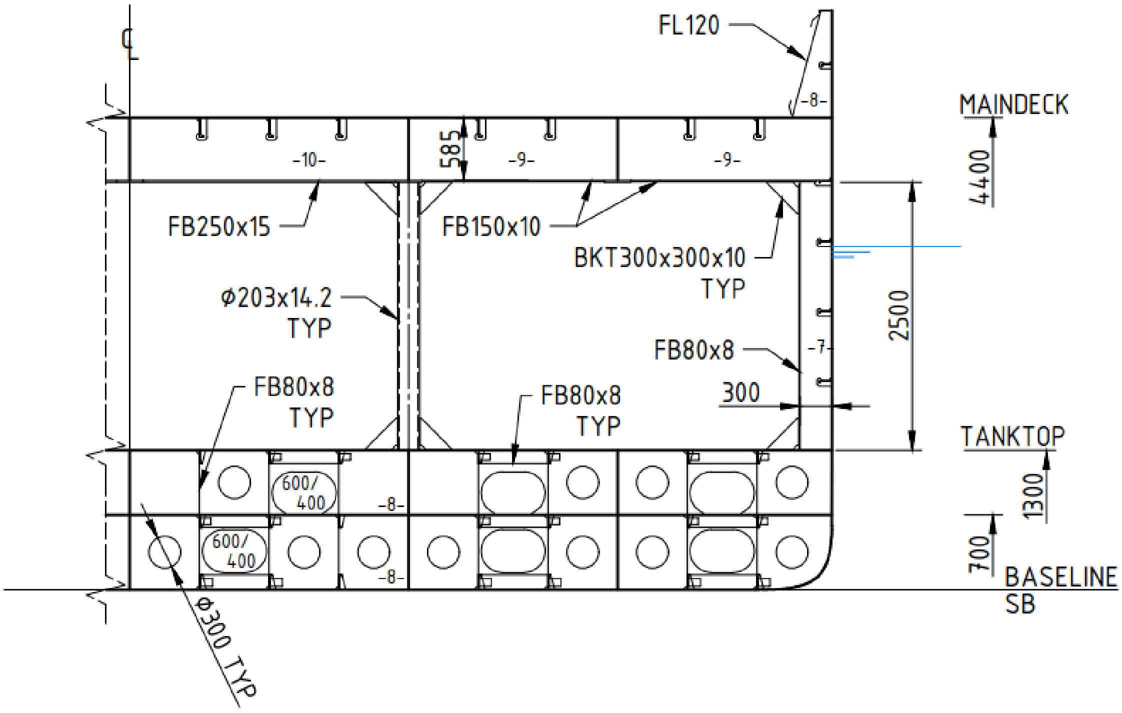


Figure 3 Typical Midship section showing the double bottom constructions with cofferdam on top.

Steelweight

A preliminary steelweight was estimated in the parametric studies based on volumetric properties of the vessel. The section differs from standard vessel designs by the way the double bottom is constructed with an additional tanktop plate and webs forming the cofferdam on top of the methanol tanks.

To take this into account a design based weight estimate is made utilizing the sectional properties of the main cross-section. This results in the following steelweight estimate.

Table 12 Steelweight estimate summary

Item	Material	Nett calculated weight [t]
HULL	GR-A	530
SUPERSTRUCTURE	GR-A	74
TOTAL		604

The total weight is the net calculated mass. The additional weight for the ice strengthening requirement are included in this estimate. This estimate is used for the lightweight estimation of the hull structure, where additions are added for design contingency, corrosion, welding and plate rolling allowances.

Material selection

The hull scantling design is based on GR-A steel.

Methanol is corrosive, and tank protection solutions are under development. As a design principle, a GR-A steel tank with a protective coating is chosen. Since sharp corners and stiffeners cannot be avoided in the double bottom design, the performance of the coating might fail. Therefore, a corrosion addition of 0.5mm is considered.

For the current design it is assumed that the tank is made of GR-A, has a coating and has a corrosion addition of 0.5mm.

Propulsion, power & energy system design

A simplified logical architecture of the power and propulsion system has been defined in WP2 and is described in the report Basic Customer Requirements. It was initially used to develop space claim and weight requirements for the design. It featured a diesel powered emergency generator system. After evaluation the design team has decided that the emergency backup function would be sufficiently covered if the ship could stabilize its situation and wait for assistance in case of power failure. For this requirement an emergency power battery system is sufficient, and a diesel generator becomes unnecessary. Because the methanol ICE is spark ignited and not dual fuel there is also no need for a diesel tank. The resulting Logical Architecture is shown below.

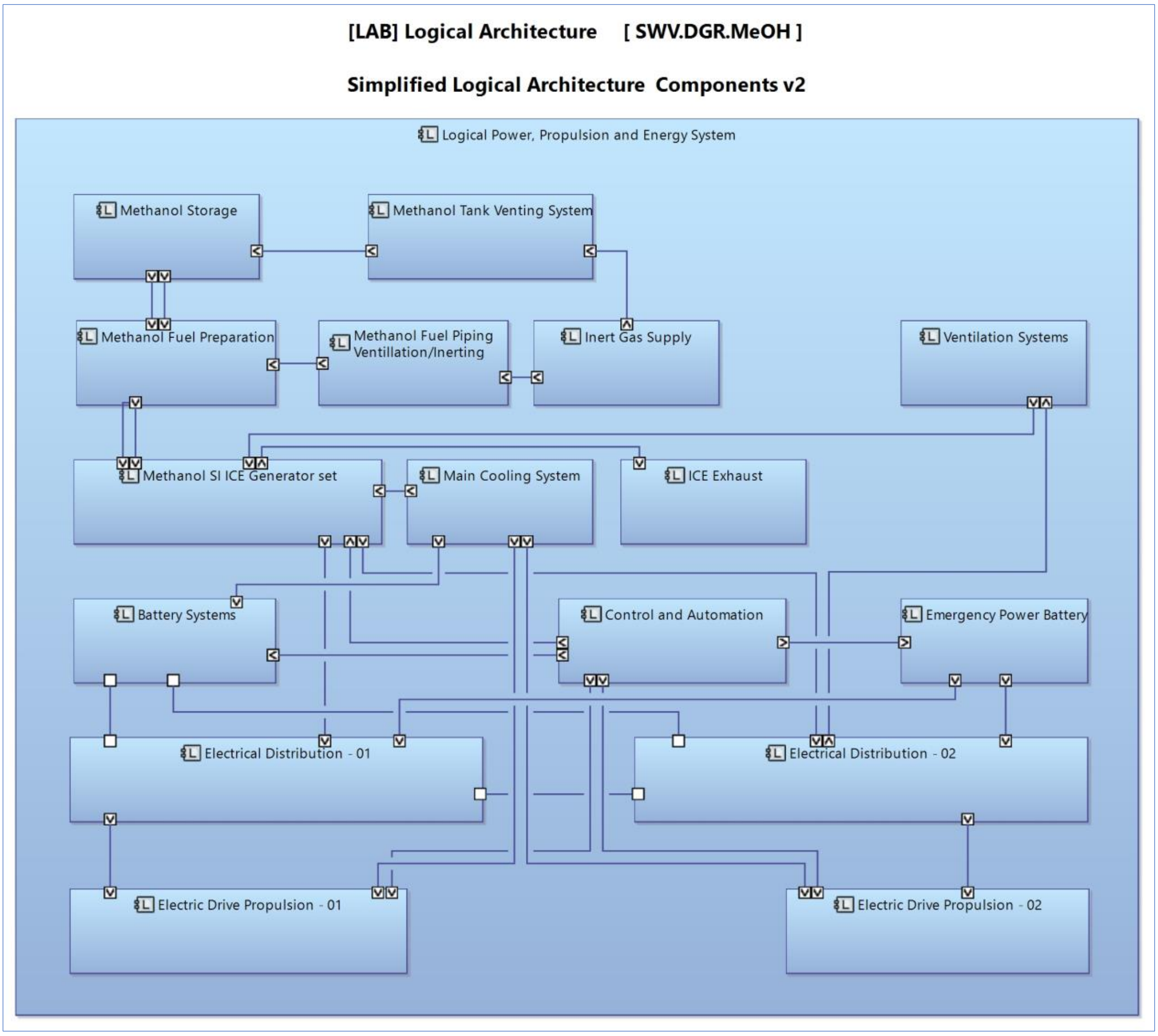


Figure 4 Logical architecture Methanol Power, Propulsion and Energy system (Marin)

During WP3 Conceptual design the team has developed this further into the physical architecture included in the design. During the initial design, primary attention is paid to the arrangement of methanol related systems. Marin delivered the physical architecture outcome of the MBSE analysis for inclusion in the concept design. The building blocks of the main systems are shown in the diagram below.

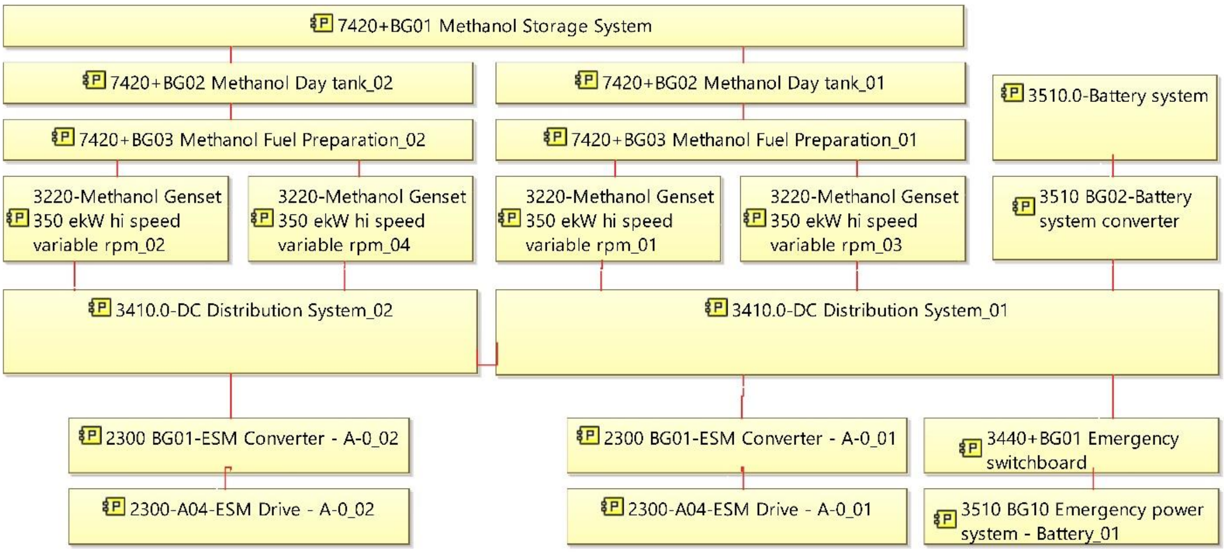


Figure 5 Physical Architecture of the methanol PPE system, showing the main elements.

From this overview it is clear that four methanol generator sets are placed. These are configured as such to allow efficient loading of the generators, ensuring higher efficiency. In case of a power failure in DP operations, this can also offer additional redundancy.

A small battery system (not shown here) is positioned for peak-shaving and spinning reserve of the main engines.

Table 13 gives the complete list of equipment forming part of the Methanol PPE system. The columns "In Dwg." indicate that the equipment was included in the arrangement plans and the 3D model (Figure 7). In addition, a list of interfacing Building Groups is provided: this shows what is connected to a certain building groups and with what means (interface type). For example, the ESM (electric shaft machine) converter is connected to the ESM drive, DC distribution System and Cooling System (MT). The latter is a cooling water pipe providing coolant, as the converter is water-cooled. The AC/DC cabling interfaces indicate that the converter converts DC power from the DC Distribution system to AC power for the ESM drive. In the interfacing building group also "Physical Actors" are mentioned: these are the external systems that interface with the PPE system, in this case the bunker provider and the power consumers (payload and propulsion).

Table 13 PPE system equipment included in machinery arrangement methanol design

	Building group	**In Dwg.**	**Incl. Fig. 5**		**Interfacing Building Group**	**Interface type**
2300 BG01	ESM Converter	X	X	2300-A04	ESM Drive	AC cable
				3410	DC Distribution System	DC cable
				7320	Cooling System (MT)	MT coolant pipe
2300-A04	ESM Drive	X	X	2300 BG01	ESM Converter	AC cable
				7320	Cooling System (MT)	MT coolant pipe
					Propulsor (Physical Actor)	mechanical shaft

Building group		In Dwg.	Incl. Fig. 5	Interfacing Building Group		Interface type
3220	Methanol Genset	X	X	7420-A02	Methanol Block and Bleed	SW Methanol pipe
				7610+BG01	Engine exhaust /silencer system	exhaust pipe
				7350	Cooling System (RW)	RW coolant pipe
3410	DC Distribution System	X	X	3510-BG02	Battery system converter	DC cable
				3430	Grid Converter	DC cable
				3220	Methanol Genset	DC cable
				2300 BG01	ESM Converter	DC cable
3430	Grid Converter	X		3450	AC Distribution	AC cable
				3410	DC Distribution System	DC cable
3450	AC Distribution	X		3430	Grid Converter	AC cable
				4100	C&A Cabinets	AC cable
				7320	Cooling System (MT)	AC cable
				7330	Cooling System (LT)	AC cable
				7350	Cooling System (RW)	AC cable
				7700 BG01	Ventilation ICE space	AC cable
				7710 BG01	Ventilation Hazardous area	AC cable
				Payload consumers (Physical Actor)		AC cable
3510-BG02	Battery system converter	X	X	3510	Battery system	DC cable
				3410	DC Distribution System	DC cable
				7320	Cooling System (MT)	MT coolant pipe
3510-BG10	Emergency power system - Battery	X		3440+BG01	Emergency switchboard	AC cable
3510	Battery system	X		3510-BG02	Battery system converter	DC cable
				7320	Cooling System (LT)	LT coolant pipe
4100	C&A Cabinets	X		3450	AC Distribution	AC cable
7320	Cooling System (MT)	X		7420+BG03-A20	Methanol Fuel Preparation	MT coolant pipe
				3510-BG02	Battery system converter	MT coolant pipe

Building group		In Dwg.	Incl. Fig. 5	Interfacing Building Group		Interface type
				2300 BG01	ESM Converter	MT coolant pipe
				2300-A04	ESM Drive	MT coolant pipe
				3430	Grid Converter	MT coolant pipe
				3450	AC Distribution	AC cable
7330	Cooling System (LT)	X		3510	Battery system	LT coolant pipe
				3450	AC Distribution	AC cable
7350	Cooling System (RW)	X		3220	Methanol Genset	RW coolant pipe
				3450	AC Distribution	AC cable
7420+BG05	Methanol Bunker Station	X		7420+BG01-A01	Methanol tanks	DW methanol pipe
				External Bunker Station (Physical Actor)		methanol bunker pipe
7420+BG01-A01	Methanol tanks	X		7420+BG05	Methanol Bunker Station	DW methanol pipe
				7550	Nitrogen generation	inert gas
7420+BG03-A20	Methanol Fuel Preparation	X		7550	Nitrogen generation	inert gas
				7420-BG02-A20-T11	Methanol Day Tank	DW methanol pipe
				7320	Cooling System (MT)	MT coolant pipe
				7420-A02	Methanol Block and Bleed	DW methanol pipe
7420+BG01-A03-T01	Methanol Drain Tank / Overflow	X				
7420-BG02-A20-T11	Methanol Day Tank	X		7420+BG01-A01	Methanol tanks	DW methanol pipe
				7550	Nitrogen generation	inert gas
				7420-A02	Methanol Block and Bleed	DW methanol pipe
				7550	Nitrogen generation	inert gas

Building group		In Dwg.	Incl. Fig. 5	Interfacing Building Group		Interface type
7550	Nitrogen generation	X		7420-BG02-A20-T11	Methanol Day Tank	inert gas
				7420+BG01-A01	Methanol tanks	inert gas
				7420+BG03-A20	Methanol Fuel Preparation	inert gas
				7420-A02	Methanol Block and Bleed	DW methanol pipe
7610+BG01	Engine exhaust /silencer system	X		3220	Methanol Genset	exhaust pipe
7720+BG01	Methanol tank venting system					
3440+BG01	Emergency switchboard	X		3510-BG10	Emergency power system - Battery	AC cable
7700 BG01	Ventilation ICE space	X		3450	AC Distribution	AC cable
7710 BG01	Ventilation Hazardous area	X		3450	AC Distribution	AC cable
7420-A02	Methanol Block and Bleed			7550	Nitrogen generation	inert gas
				3220	Methanol Genset	SW Methanol pipe
				7420-BG02-A20-T11	Methanol Day Tank	DW methanol pipe

A geometric representation of the building blocks of the methanol system and fuel storage is shown in the diagram below.

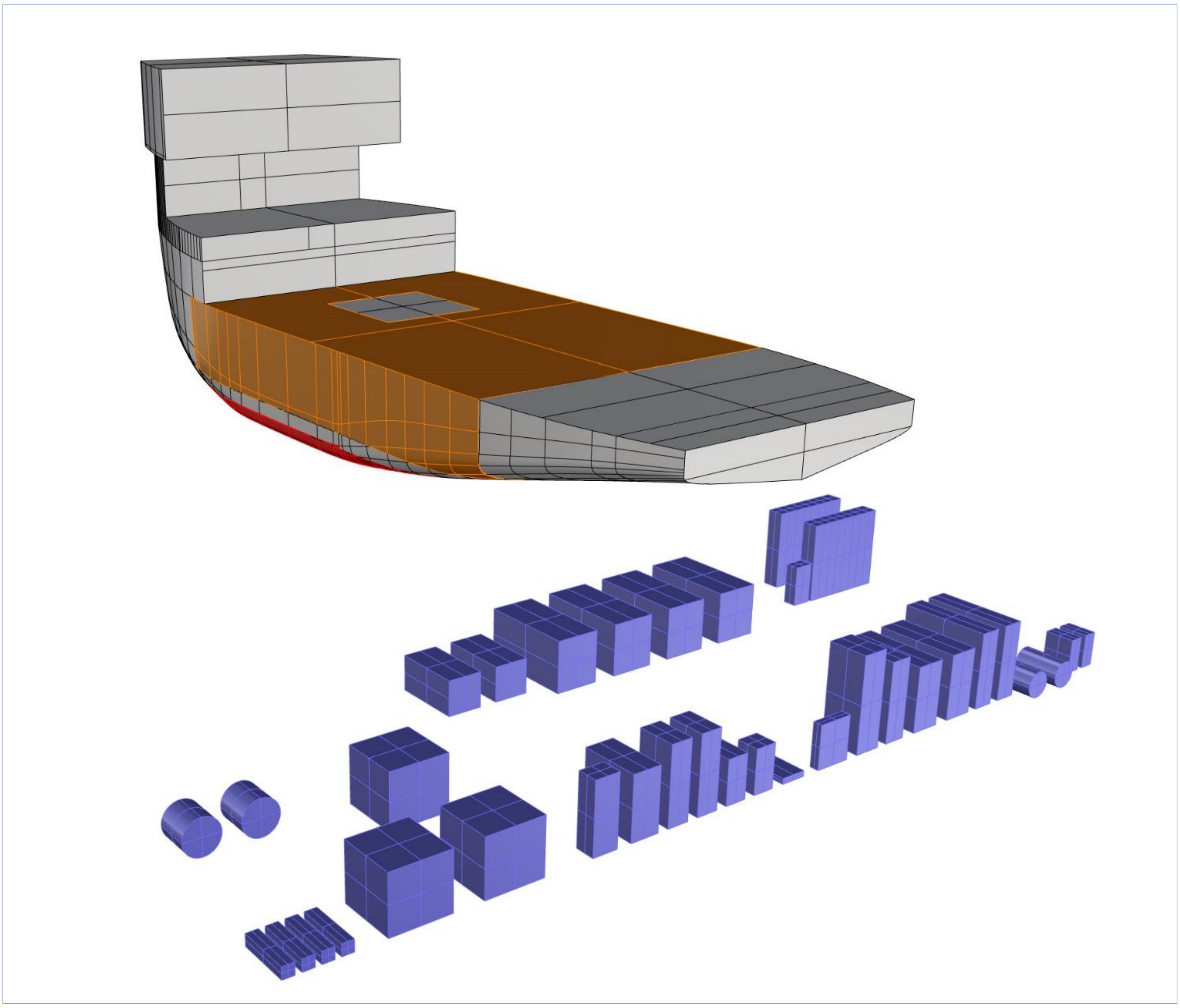


Figure 6 Global overview of geometric building blocks for the methanol system (initial hull shape shown to demonstrate proportions between systems and ship, later modified to accommodate all the systems)

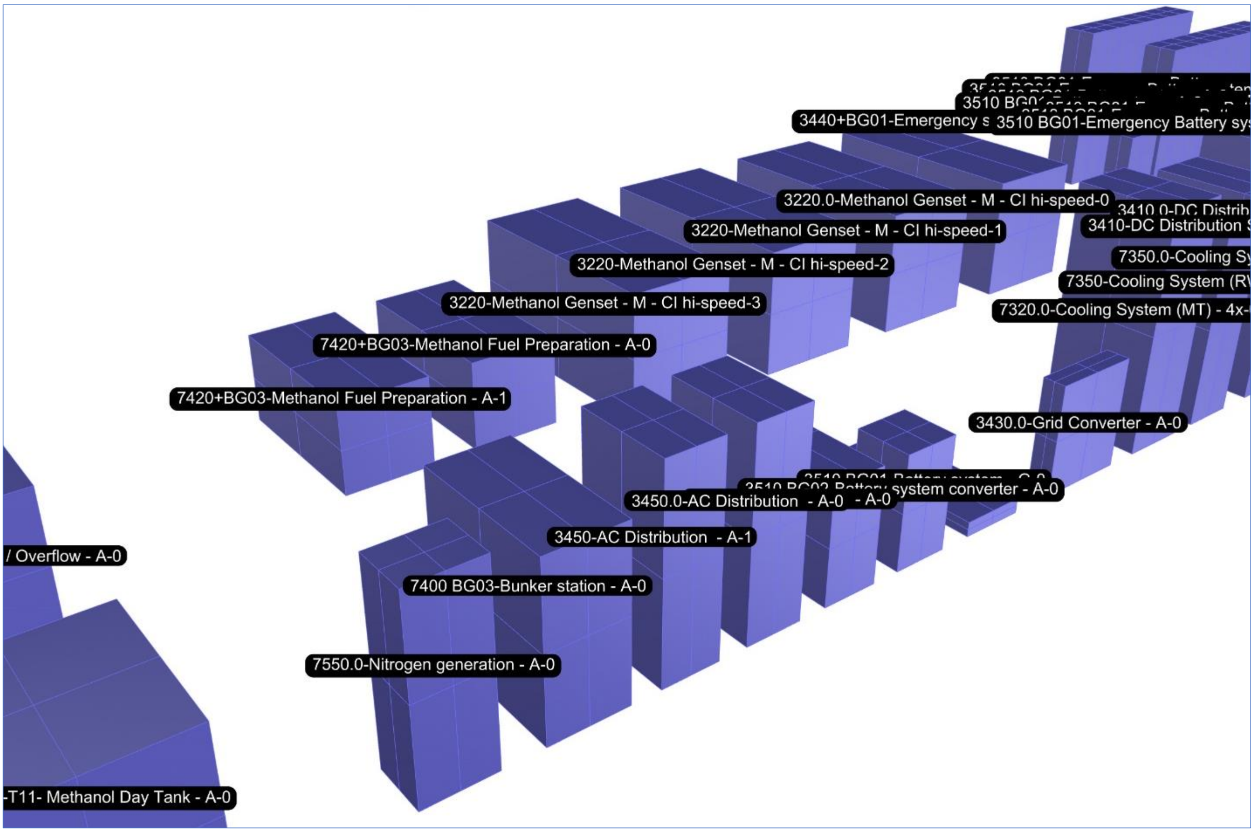


Figure 7 Example of building blocks used for layout of the general arrangement.

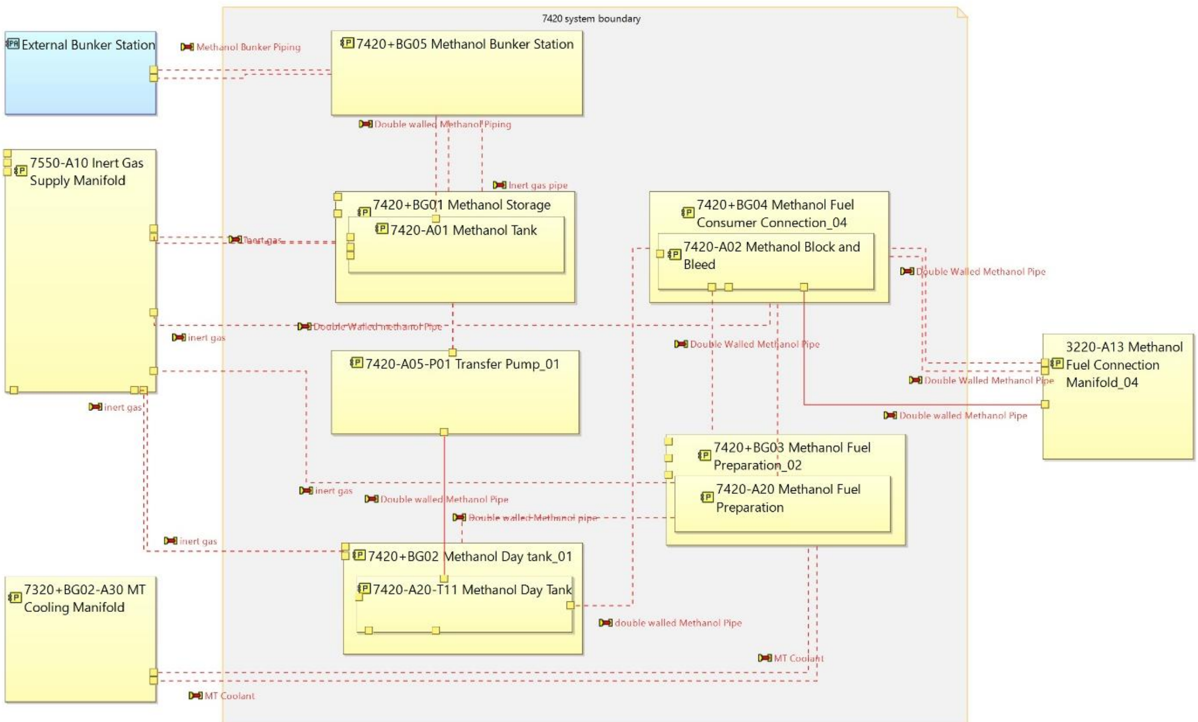


Figure 8 Methanol supply system showing the interfacing building groups

Based on Figure 8, a preliminary methanol system P&ID is produced. This is shown in Appendix A.

The methanol fuel treatment space is also separated into two systems, as also required by classification. In this conceptual design the day-tank is positioned in the machinery space, but due to the cofferdam arrangement not practical. In further design/basic engineering it can be moved to the double bottom, possibly requiring an additional fuel transfer pump.

The methanol fuel treatment equipment is not placed in a dedicated compartment but features a cover which is placed over the specific equipment, within the machinery space. The equipment is ventilated separately. The emergency power supply, as required by SOLAS, is realized via a dedicated battery system above main deck level. As such, no diesel is on-board.

4.6 Conclusion Methanol design

Based on the presented initial design, feasibility of the proposed vessel concept based on Methanol fuel is confirmed. The main particulars and overall layout is herewith concluded. The presented design is taken as starting point for the next engineering phase where the main systems and vessel structure will be analyzed into more detail on room/system level of detail

The following recommendations are made to the design to be taken care of in the next design phase:

- Design shows a list in all conditions. Placement of consumable tanks to be optimized to reduce heel and trim, focusing on minimizing the use of water ballast in the loaded conditions.
- Lifting at shallow draft shows large heeling angles. Provisions for water ballast in the design to be investigated to allow for lifting over the complete draft range without the active use of the ballast system during operations.
- Methanol day tanks might be moved in the double bottom, avoiding additional cofferdam structures around the tanks currently placed in the ER.

4.7 WP 3 Documents for Methanol based vessel

The deliverables part of work package 3 are listed in the table below.

Table 14 Deliverable summary methanol design

Deliverable	Document name	Owner	Type	Remarks
General arrangement	21.092-M-000-001-General arrangement	C-Job	Drawing	
Machinery room arrangement	21.092-M-052-100-Engine room arrangement	C-Job	Drawing	
Preliminary 3D hull design	21.092-M-000-011-Hullshape	C-Job	3D model	
Light weight assessment	-	C-Job	Report	Part of this report
Stability assessment	-	C-Job	Report	Part of this report
Preliminary PPE concept & Speed power prediction	-	C-Job	Report	Part of this report
Preliminary Safety Study		Marin	Report	Part of this report

5 HYDROGEN CONCEPT DESIGN REPORT

5.1 Design requirements

Requirements are derived from WP2 document. For each requirement is indicated whether this is met in the presented design, and where applicable remarks regarding the requirement are noted.

Table 15 Requirement table hydrogen design

Requirement title	Specification	Remarks	Complies?
Hull length	Maximum 65 m. (Initial requirement was 60m. The change to 65 has been agreed on 23/8/2022)	60m considered as maximum for Methanol Design	Yes
Draught	Preferred maximum vessel draught: 3,5 m. Maximum draught 3,80m		Yes
Freeboard	Freeboard above the working deck as low as possible. Minimum 1.00 meter, maximum 1.30 meter.		Yes
Elevated platform	To be determined. (Measuring equipment needs to be at least 2.5 m above sea level.)	Platform can be added for specific operations	Yes
Ice class	Ice-strengthening bow asked. Use Young-Ice 2 class rules for determining steel weight. Roughly increase of bow plating with about 5-6mm.	Additional steel at bow considered for LSW	Yes
Ship speed	10 knots @ sea state 3 4 knots @ sea state 5	Estimated resistance is slightly lower compared to the WP2 results	Yes
Endurance	11 days at sea	Tank capacity lacking ~25 % considering maximum feasible tank size and update powering predictions, see also section ‘fuel capacity evaluation’ in this report.	No
Propulsion type	Preferably thrusters or pods. No conventional propulsion with shafts, propellers and rudders.	2 steerable thrusters applied	Yes
Additional propulsion power to operate the ground planning system	Low, not decisive for propulsion power or energy storage	See WP2 report [2] for resistance estimate	Yes

Requirement title	Specification	Remarks	Complies?
DP performance	DP2: The vessel should remain in position with a tolerance of 1 m under the following conditions: · Tidal flow 2 knots perpendicular to the vessel. · wind 10 m/s +/- 30 degrees from the bow. · Significant wave height of 1,88 m +/- 30 degrees from the bow. · Wind and waves may come from different directions. The vessel should be able to follow a straight course over a distance of 1000 m, with a maximum deviation of half the width of the ship, under the following conditions: · Speed over ground: 2 knots · No tidal flow · Wind: 5,5 m/s perpendicular to the vessel · Significant wave height 0,88 m from all directions. · No use of tunnel thrusters for sideways propulsion.	No use of tunnel thrusters for sideways propulsion is unrealistic for DP operations since transverse thrust at the bow is required. Alternative is a much more expensive retractable thruster at the bow.	T.B.D
Power consumption of DP operation	To be determined.	An average Power of 180kW is estimated in WP2. This was not included in the design starting points for the total energy capacity. See remarks in WP2 report.	T.B.D
Energy storage margin	20%	Included in the calculation of the required tank storage capacity. See section fuel capacity evaluation for further explanation.	Yes
Energy storage rest volume	For liquid hydrogen: 20%	No, reassessment of tank type resulted in a tank design with a utilisation range from 5% to 70%	No
Flat working deck around the moonpool	A flat working deck and free space of at least 1,5 m needs to be available around the moonpool. Behind the moonpool the flat deck and free space must be at least 6m.		Yes

Requirement title	Specification	Remarks	Complies?
	This is necessary for operations with the drilling system for seabed quality survey.		
Payload deck capacity	1) Deck area 200-240m2 2) Fuel tank of 40m3 on deck 3) Storage of 4x 20' containers not impacting free deck area under 1. 4) Deck load capacity in weight and vertical center of gravity 5) Specific storage capacity/weights not part of the main ship systems below deck. 6) 125 ton deck load (centre of gravity 2 meter above the work deck) 7) Work deck strength > 8 ton/m2.. 8) Storage capacity for 35 ton heavy equipment with a footprint of 30m2		Yes
Moonpool	LxW= 4000 x 4000 mm		Yes
Crew accommodation	24 total: 14 single, 5 double		Yes
Accommodation comfort level	1) Clear deck heights in cabins, public spaces etc.. 2) Amount and size of the following additional accommodation spaces: Office workplaces, Conference rooms, Recreation rooms, fitness, smoking room, luggage room and any other required. 3) Specific requirements for certain cabin types and sizes? Crew, Officer, passengers? 4) Stair inclination	2) Smoking room and luggage room are absent as per current GA based on discussions with the Rijksrederij.	Yes
Hotel load	200 kW		Yes
Fresh water supply	Preferable tanks, no fresh water maker	2 fresh water tanks are included in the design	Yes
Crane	- 10 ton @ 10 m outboard - 15 ton @ 4 m outboard	Palfinger PTM1800 (12-18 m outboard) is present as per current GA	Yes
Crane for railing shipwrecks	Outreach 5 ton @ 1 m		Yes
Anti-heeling system for crane	Not required		Yes
A-frame	Width 5000 mm		Yes

Requirement title	Specification	Remarks	Complies?
Refrigerated container power interface	3 kW reefer connection.	Onboard power considered, connection to be designed.	T.B.D
Firefighting pumps and monitors	Ships preferably equipped with firefighting pumps and monitors. Required specification for one monitor: · Flow 1200 m3/hr · Reach 100/120 m		Yes
Multi-beam sounder location	MBS must be located on the Centre Line, on a point with minimal turbulence, thus in front of the moonpool, minimum 3,5 m below the waterline and 0,5 – 2 m below the BL.		Yes

5.2 Elementary design principles

- Liquid hydrogen stored in vacuum insulated tanks in main hull.
- Fuel cells as primary source of power
- Work deck for buoy handling as unobstructed as possible.
- Double aft bridge consoles visibility with preferably all around visibility, with good visibility on open bulwarks and shark jaws.
- Deckhouse in front
- Moonpool as close to LCB as practically possible
- Battery based emergency power system

5.3 Rules and regulations

Class Notation: I ✠ Hull ✠ Mach Special service unrestricted navigation

Flag: Netherlands

Future fuels: Hydrogen

Applicable rules

- NR 600 for construction (Starboat)
- NR467 for systems (machinery, safety, electrical, stability)
- NR 547 for ships using fuel cells
- NR 529 for gas fueled ships

5.4 Design Risks

The technical risks with potential to impact the overall project as perceived by the design team is listed and will be maintained throughout the project execution.

Table 16 In WP3 identified design risks

Risk	Consequence	Mitigation action
Insufficient space for PPE systems	Vessel size increases	Asses volume requirements
Tight integration of LH2 fuel tank	Difficult to build, midship section sensitive to design changes	Review of tanks space reservations and integration.
Routing of hazardous ventilation ducts to outlet location	Ventilation mast might impact deck operations. Routing of large ducts might clash with other functions	Included rough duct sizing estimates from PPE analysis in early design stages.

5.5 Design evaluation

A conceptual design for a hydrogen powered multipurpose vessel is presented with the following main characteristics.

Table 17 Main particulars hydrogen design

Main Particulars	
Length O.A.	65.0 m
Rule length	62.4 m
Breadth	12.9 m
Depth (maindeck)	4.3 m
design draught	3.0 m
Accommodation	24 persons

Main dimensions

These initial main dimensions are determined by means of an ACD parameter study where the gross properties and requirements of the vessel were utilised as input for the parametric model where the most optimum result regarding expected LSW and resistance performance was selected.

The main drivers for the dimensions are:

- Length -> To accommodate sufficient deck area an internal space volume
- Breadth -> Minimum while retaining sufficient initial stability to perform lifting operations
- Depth -> Minimum to comply with the requirement that the distance to the W.L. during operations is < 1.3m. Secondly the depth was limiting for the Hydrogen tank sizing. In order to accommodate a larger diameter tank, the depth of the hull was increased from 4.0 m as presented in de parameter study to 4.3m following the physical architecture of the Hydrogen system.

Lightweight

Based on the vessel design the lightweight is estimated an presented in the table below:

Table 18 Lightshipweight summary hydrogen design

SFI	Description	Weight (gross) [t]	LCG [m]	TCG (PS+) [m]	VCG [m]
LSW	**Total LSW**	**1495.45**	**33.73**	**0.09**	**4.75**
W2	HULL	868.46	33.39	0.00	4.31
W3	EQUIPMENT FOR CARGO	74.71	12.19	2.58	8.33
W4	SHIP EQUIPMENT	55.60	56.95	0.00	6.12
W5	EQUIPMENT FOR CREW AND PASSENGERS	286.58	40.16	-0.14	6.21
W6	MACHINERY MAIN COMPONENTS	31.15	7.07	0.00	1.21
W7	SYSTEMS FOR MACHINERY MAIN COMPONENTS	91.51	32.78	0.04	2.59
W8	SHIP COMMON SYSTEMS	87.44	30.11	-0.19	3.88

Deadweight items

The following table of design deadweight items are considered in the design and reflected in the loading conditions.

Table 19 Design deadweight capacity hydrogen design

Item	Weight [t]
Deckload	125
Cargo hold	35
Stores, spares and provisions	4.7
Other deadweight items	13.6
Liquid hydrogen capacity	11.8
Fresh water	32
Lube oil	0.6
Hydraulic oil	2.3
Total deadweight capacity	230

Hull Design

A hull shape for the vessel is developed matching the requirements with respect to the main particulars and required buoyancy. The rough 3D hull shape form the parametric ACD study is used as starting point. This rough shape is adapted to have a smooth and faired shape with the desired hydrostatic particulars and stern and bow shape features to enhance sailing and DP capability performance. Especially by means of having a pram shaped stern providing sufficient space for large azimuth thrusters. Figure 9 gives an impression of the developed 3D hull shape.

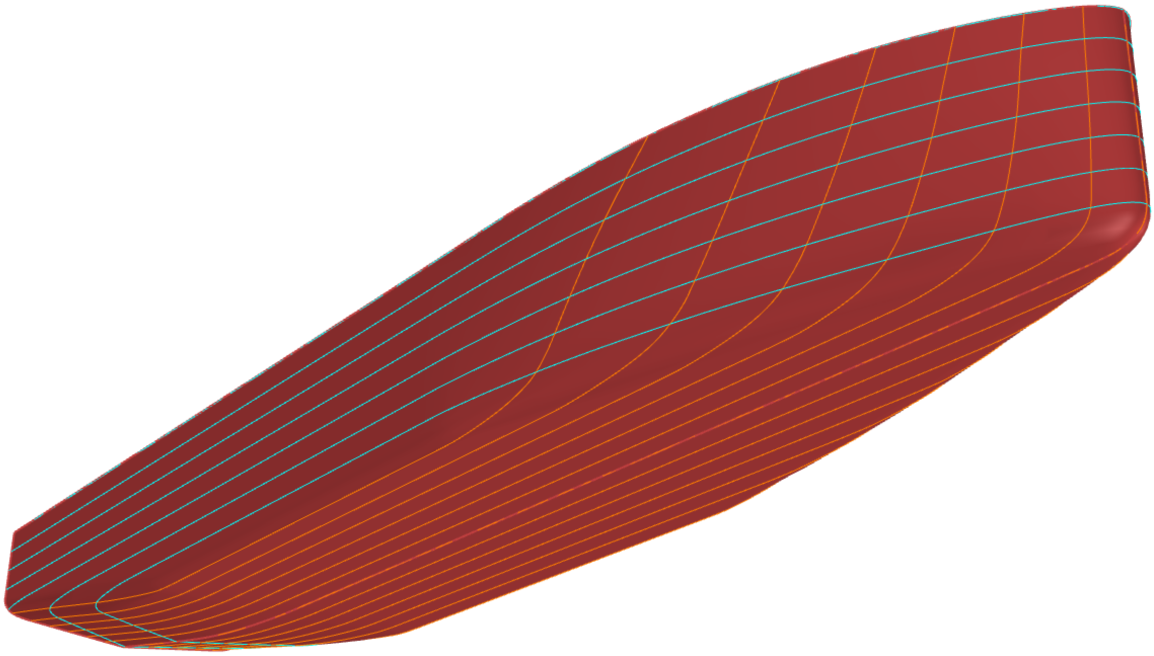


Figure 9 Preliminary hull shape hydrogen design

The characteristics of the hull have been summarized in the following table:

Table 20 Hydrostatics hydrogen design hull shape

Description		Unit
Displacement Bare Hull @ design draught @ rho=1.025 t/m^3	2004.7	t
Length on the waterline	65.00	m
Width on the waterline	12.90	m
Design draught	3.0	m
Longitudinal Centre of Buoyancy forward of Transom	31.7	m
Longitudinal Centre of Flotation forward of Transom	29.5	m
Wetted Surface Area	1044.14	m^2

Tank capacities

The table below present the tanks an capacities considered for the initial design. These tanks will be reviewed during the development of the corresponding equipment during further engineering in work package 4.

Table 21 Tank capacities hydrogen design

Name	ID	Volume [m^3]	Weight [t]
Hydrogen tank*	H1	170	**
Freshwater tank 1	FW1	14.5	14.5

Freshwater tank 2	FW2	13.5	13.5
Grey/Black water	GW	25.2	25.2
Lube oil*	LO	0.7	0.63
Hydraulic oil*	HO	2.5	2.25
Dirty oil	DO	3.5	3.045
Bilge water	BW	13	13
Water ballast	WB	450	462

* Tanks to be included as non-structural tanks in the design

** Available capacity is depending on the hydrogen system design. For further details please refer to section 'Propulsion, power & energy system design'.

Hydrogen tank & fuel capacity evaluation

Figure 10 indicated the placement of the hydrogen tanks within the vessel main cross-section, where the tanks diameter is maximized within the available space. An IMO Type C tank is selected as is most common for liquefied fuels. Indicated in Figure 10 are the primary, secondary barriers of the tank, additionally the space reservation made for external insulation is shown. External insulation was considered necessary after consulting a supplier of LH_2 tanks. This is included when placing the tank inside the ship's hull, to protect it from embrittlement due to potential fuel leakages (safety aspect). Previous arrangements with two smaller diameter tanks did not attain a high capacity as maximizing the diameter (due to the insulation space reservation) is key to obtaining tank volume. The tanks must also be placed inboard ⅕ of the ship's beam (NR 529 for Gas fueled ships).

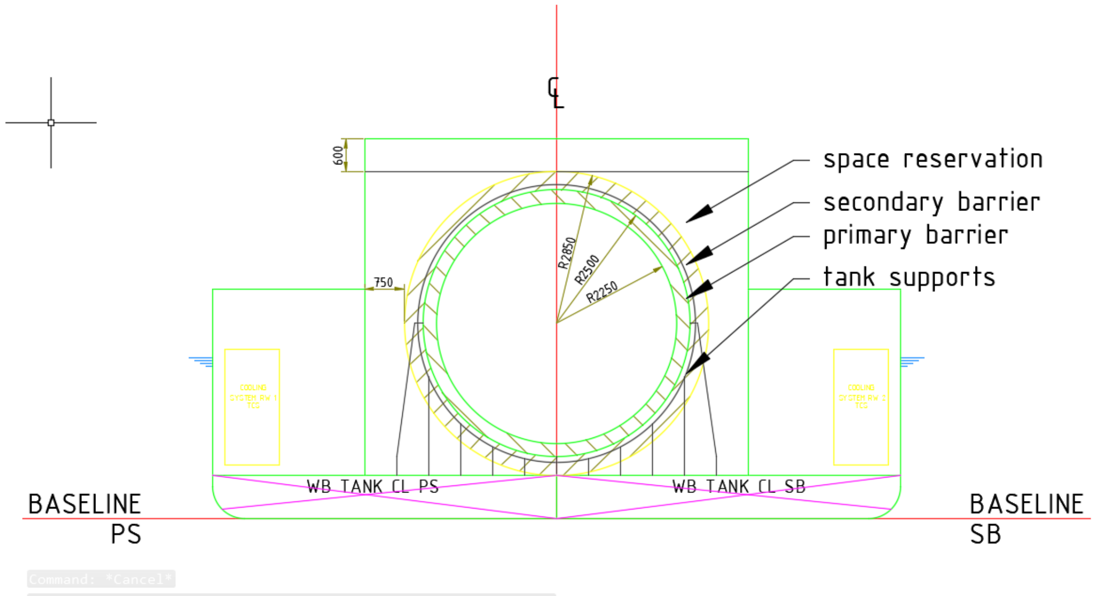


Figure 10 Section view of hydrogen tank placement and sizing.

The required fuel capacity showed some development throughout the WP3 design phase. The table below presents the development of the fuel capacity requirement and the attained capacity.

Table 22 Fuel capacity summary hydrogen design

Reference	Fuel capacity in ton
Design starting point as per WP2 report [2]	11.8
Corrected WP2 requirement for DP operations	13.7
Update capacity requirement with speed power prediction WP3	12.6
Attained fuel capacity in concept design WP3	**6.9 t**
Potential tank capacity in design without moonpool	**11.2**

Concluded is that the current Hydrogen vessel design is lacking about 45% of fuel capacity and is therefore not capable of completing the missions required by the Rijksrederij. The tank capacity can be increased significantly if the insulation of the tank can be reduced or the external insulation can be omitted, however it will still be less than the required capacities stated in Table 22.

Stability

Below preliminary loadcase overview presents the range of drafts throughout the operations. In general is noted that the stability of the range of operations meet the relevant intact stability criteria. Compared to the methanol design two more loadcases, LC03A, LC03B are added to confirm the capability to operate with a freeboard of 1.3m to support buoy handling operations.

Table 23 Initial intact stability summary hydrogen design

Description	Draft [m]	Trim [m]	List [deg] + to PS	GM' [m]	Complies (BV RULES)
LC00 - Lightship	2,355	0,597	2,1 (PS)	2,559	Complies
LC01A - Light sailing arrival	2,613	-0,028	-0,6 (SB)	2,391	Complies
LC01B - Light sailing departure	2,729	0,006	0,7 (PS)	2,295	Complies
LC02A - Fully loaded arrival	2,971	0,008	-0,7 (SB)	1,762	Complies
LC02B - Fully loaded departure	3,031	-0,041	0,8 (PS)	1,817	Complies
LC010 - Lifting at min. draft	2,579	-0,039	-2,2 (SB)	2,316	Complies
LC020 - Lifting at max. draft	3,003	-0.025	-2,0 (SB)	1,918	Complies
LC30A - de-Ballasted arrival	2.545	0.096	-0.1 (SB)	2.393	Complies
LC30B - de-Ballasted departure	2.677	0.065	0.0 (PS)	2.084	Complies

The crane operations have been assessed for both conditions considering a maximum lift of 15 ton at 4.0 m outboard measured from the ship’s side. The resulting heeling angle is less then 2.0 degrees at conditions at the design draft. For lighter loaded conditions the heeling angle is to be reduced by means of ballasting the vessel.

The vessel is capable of reducing the draft in transit by means of de-ballasting. This is reflected by loading conditions LC30A and LC30B. A draft of 2.7m is used for the propulsion and powering calculations.

During next engineering phase the ballast tank arrangement will be optimized to further reduce the trim and heel in all operational conditions.

Speed power prediction

The speed power predictions are based on a draft of 2.7m since this design is capable of de-ballasting before going into transit, which is reflected by loading conditions LC30A and LC30B.

The speed power prediction assumes the use of a fixed pitch propeller inside a nozzle. The calculation has been performed with 2 propellers with each a diameter of 1.7 m. Further selection of the thrusters will be performed in the next engineering phase.

Based on the design parameters of the Methanol design in WP3, Marin recalculated the resistance and power prediction. The results are summarized in the tables below.

Table 24 Resistance prediction hydrogen design

Speed [kts]	Resistance ideal trial condition [kN]	Resistance sea state 3 [kN]
4	9	20
5	14	25
6	20	32
7	27	40
8	36	49
9	47	61
10	62	76
11	81	96

Table 25 Powering prediction hydrogen design

Speed [kts]	Power ideal trial condition [kW]	Power sea state 3 [kW]
4	39	105
5	75	153
6	127	227
7	199	323
8	300	444
9	446	619
10	660	**860**
10.7	**860**	
11	970	1209

The C-Job Hydrogen version of the design requires 860 kW power to reach 10 knots in sea state

3. In ideal trial condition the expected speed at 860 kW is 10.7 knots

Comparing these results with the predictions as presented in the WP2 report [2], the required powering reduced from 953kW to 860kW.

Structural design

Steelweight

Preliminary scantling calculations have been performed to derive initial sectional properties for the vessel main cross-section. A design based weight estimate is made utilising the sectional properties of the main cross-section. This results in the following steelweight estimate.

Table 26 Steelweight estimate hydrogen design

Item	Material	Nett calculated weight [t]
HULL	GR-A	575
SUPERSTRUCTURE	GR-A	90
TOTAL		655

The total weight is the net calculated mass. The additional weight for the ice strengthening requirement are included in this estimate. This estimate is used for the lightweight estimation of the hull structure, where additions are added for design contingency, corrosion, welding and plate rolling allowances.

Material selection

The hull scantling design is based on GR-A steel.

Special attention need to be paid to areas surrounding systems containing (liquid) hydrogen. As design basis the following initial assumptions are made with regard to the material of the hydrogen tank hold.:

- Tank supports made of SS316L to connect to the tank interfaces
- Tanktop & supporting structures below and in direct vicinity of the cargo tanks to be made of DH or higher grade steel based on outer tank temperature analysis of the tank supplier.

Propulsion, power & energy system design

A simplified logical architecture of the power and propulsion system has been defined in WP2 and is described in the report Basic Customer Requirements. It was initially used to develop the space claims and weight requirements for the design. It featured a diesel powered emergency generator system. After evaluation the design team has decided that the emergency backup function would be sufficiently covered if the ship could stabilize its situation and wait for assistance in case of power failure. For this requirement an emergency power battery system is sufficient, and the diesel generator and storage system become superfluous.

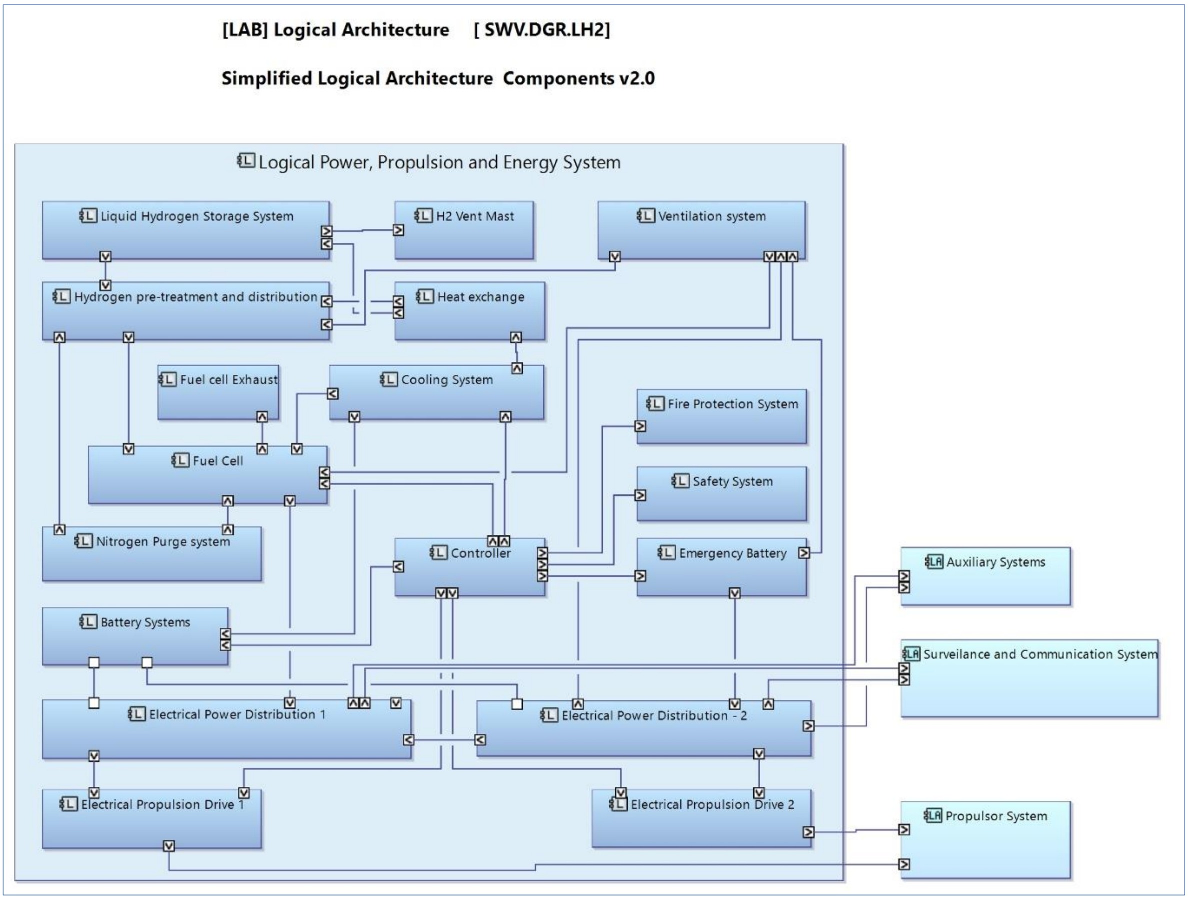


Figure 11 Logical architecture LH2 Power, Propulsion and Energy system (Marin)

During the initial design, primary attention is paid to the arrangement of hydrogen related systems to be located within the safety boundaries. Especially the requirement having al systems containing hydrogen within the B/5 limits are challenging.

During the design process, Marin delivered the physical architecture outcome of the MBSE analysis for inclusion in the concept design. The building blocks of the main systems are shown in the diagram below.

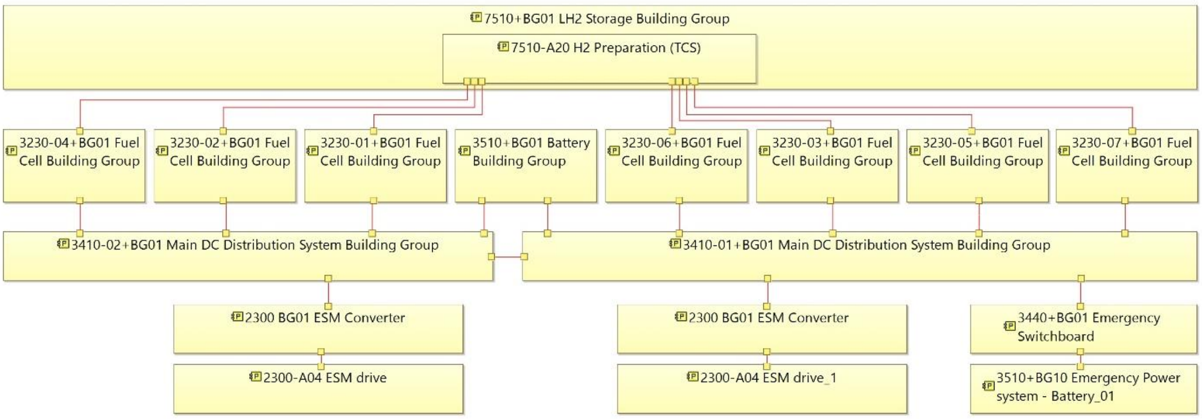


Figure 12 Physical Architecture of the methanol PPE system, showing the main elements.

Table 27, gives the complete list of equipment forming part of the Hydrogen PPE system. The columns "In Dwg." indicate that the equipment was included in the arrangement plans and the 3D model (Figure 7). In addition, a list of interfacing Building Groups is provided: this shows what is connected to a certain building groups and with what means (interface type).

Table 27 Machinery space equipment hydrogen design

Building group		In Dwg.	Incl. Fig. 11	Interfacing Building Group		Interface type
2300 BG01	ESM Converter	X	X	2300-A04	ESM Drive	AC cable
				3410	DC Distribution System	DC cable
				7320	Cooling System (MT)	MT coolant pipe
2300-A04	ESM Drive	X	X	2300 BG01	ESM Converter	AC cable
				7320	Cooling System (MT)	MT coolant pipe
				Propulsor (Physical Actor)		mechanical shaft
3230	PEMFC	X	X	7700+BG01	Ventilation System	air ducting
				7710+BG01	Ventilation Hazardous area	air ducting
				7350	Cooling System (RW)	RW coolant pipe
				3230 BG02	PEMFC Converter	DC cable
3230 BG02	PEMFC Converter	X		3230	PEMFC	DC cable
				3410	DC Distribution System	DC cable
				7320	Cooling System (MT)	MT coolant pipe

Building group		In Dwg.	Incl. Fig. 11	Interfacing Building Group		Interface type
3410	DC Distribution System	X	X	3510-BG02	Battery system converter	DC cable
				3430	Grid Converter	DC cable
				3230 BG02	PEMFC Converter	DC cable
				2300 BG01	ESM Converter	DC cable
3430	Grid Converter	X		3450	AC Distribution	AC cable
				3410	DC Distribution System	DC cable
3450	AC Distribution	X		3430	Grid Converter	AC cable
				4100	C&A Cabinets	AC cable
				7320	Cooling System (MT)	AC cable
				7330	Cooling System (LT)	AC cable
				7350	Cooling System (RW)	AC cable
				7700 BG01	Ventilation System	AC cable
				7710 BG01	Ventilation Hazardous area	AC cable
				Payload consumers (Physical Actor)		AC cable
3510-BG02	Battery system converter	X	X	3510	Battery system	DC cable
				3410	DC Distribution System	DC cable
				7320	Cooling System (MT)	MT coolant pipe
3510-BG10	Emergency power system - Battery	X		3440+BG01	Emergency switchboard	AC cable
3510	Battery system	X		3510-BG02	Battery system converter	DC cable
				7320	Cooling System (LT)	LT coolant pipe
4100	C&A Cabinets	X		3450	AC Distribution	AC cable
7320	Cooling System (MT)	X		3230	PEMFC	MT coolant pipe
				3510-BG02	Battery system converter	MT coolant pipe
				2300 BG01	ESM Converter	MT coolant pipe
				2300-A04	ESM Drive	MT coolant pipe
				3430	Grid Converter	MT coolant pipe
				3450	AC Distribution	AC cable

Building group		In Dwg.	Incl. Fig. 11	Interfacing Building Group		Interface type
7330	Cooling System (LT)	X		3510	Battery system	LT coolant pipe
				3450	AC Distribution	AC cable
7350	Cooling System (RW)	X		3230	PEMFC	RW coolant pipe
				3450	AC Distribution	AC cable
7400+BG03	Bunker Station	X		7510+BG01	LH_2 Storage	LH_2 piping
				External Bunker Station (Physical Actor)		LH_2 bunker hose
7510+BG01	LH_2 Storage (incl. TCS)	X		7550	Nitrogen generation	inert gas
				7400+BG03	Bunker Station	LH_2 piping
				7320	Cooling System (MT)	MT coolant pipe
				3230	PEMFC	H_2 piping
7550	Nitrogen generation	X		7510+BG01	LH_2 Storage	inert gas
				7700+BG01	Ventilation System	air ducting
3440+BG01	Emergency switchboard	X		3510-BG10	Emergency power system - Battery	AC cable
7700+BG01	Ventilation System	X		3450	AC Distribution	AC cable
				3230	PEMFC	air duct
				7550	Nitrogen generation	air duct
7710 BG01	Ventilation Hazardous area	X		3450	AC Distribution	AC cable
				3230	PEMFC	air duct
				7510+BG01	LH_2 Storage	air duct

A geometric representation of the building blocks of the hydrogen system and fuel storage is shown in the diagram below.

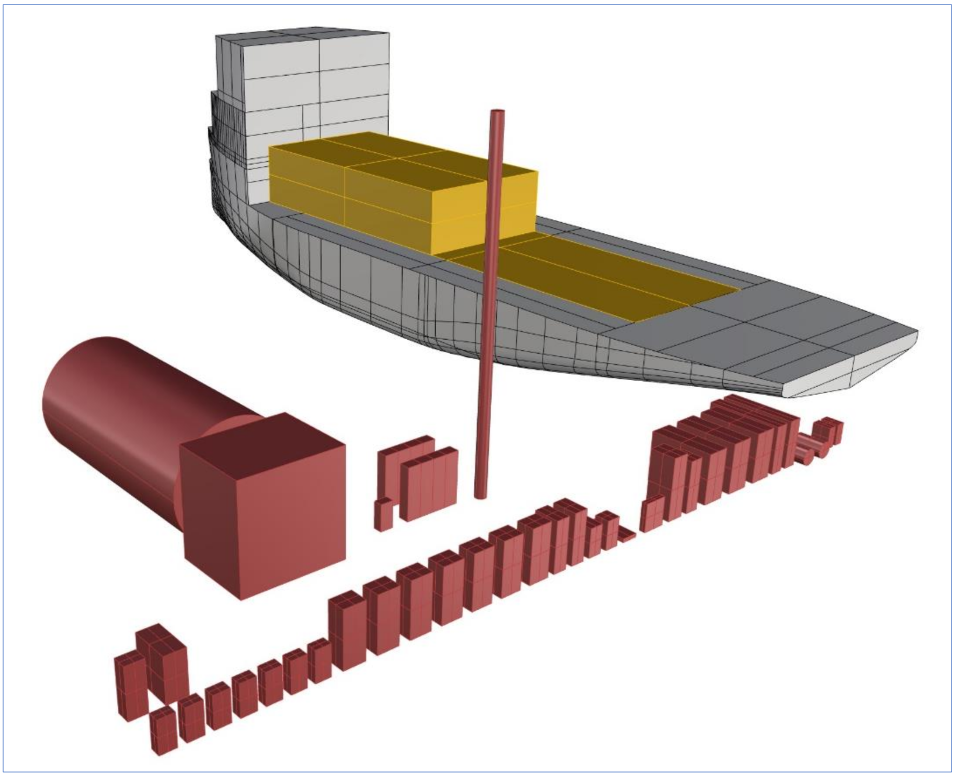


Figure 13. Overview of the geometric building blocks for the hydrogen power system and energy storage.

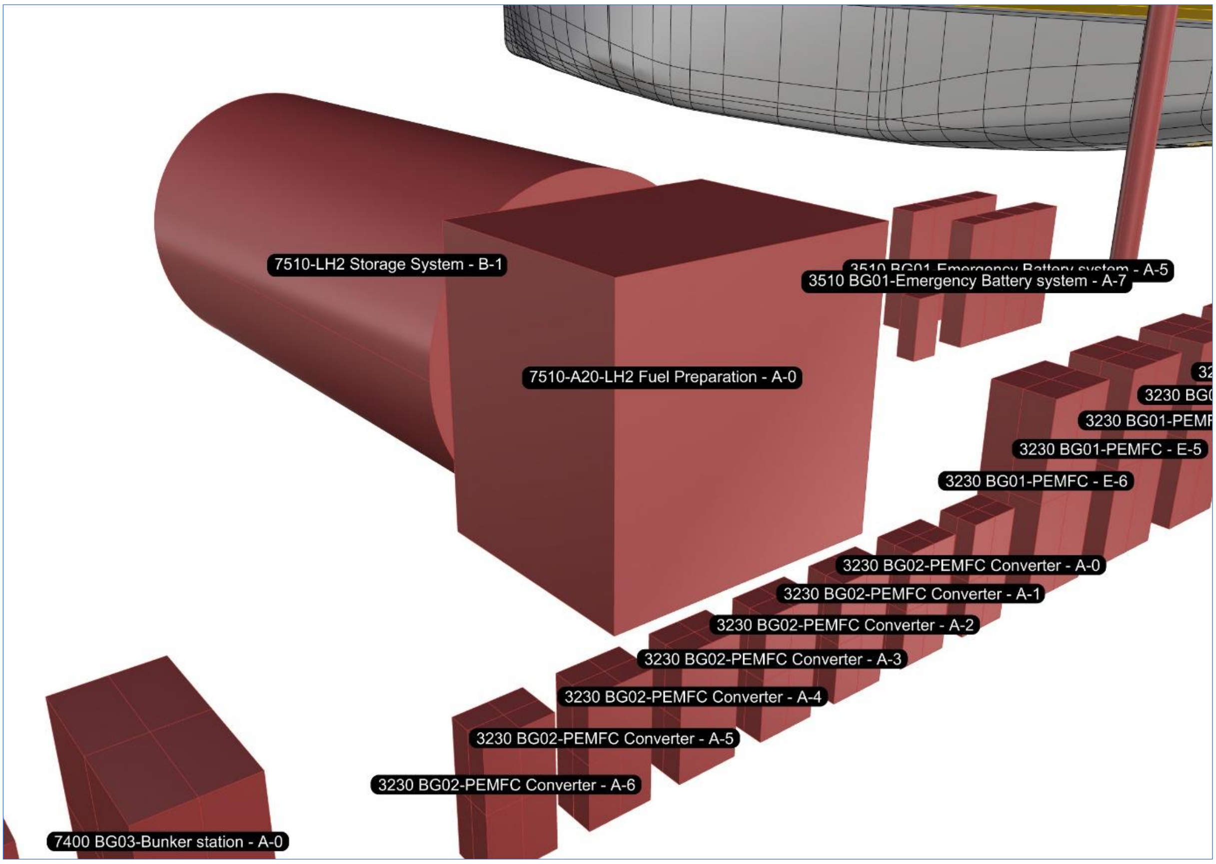


Figure 14. Examples of geometric building blocks for the hydrogen system used for layout of the general arrangement.

A preliminary LH_2 system overview is presented in Appendix B.

In this overview it is clear that the LH_2 supply system and the fuel cell system is redundant and also placed in physically separated compartments. Because the fuel tank is a Type C tank it does not have to be redundant (i.e. one tank is sufficient). In case of a failure in the fuel cell system the available power will be reduced (still sufficient for 7-8 knots of speed). The provided redundancy is related directly to the regulations: NR 529 for Gas fueled ships.

In addition, as the main source of electrical power is required for propulsion of the vessel, the main busbar is divided into two parts, as required by NR467.

5.6 Conclusion hydrogen design

From the fuel capacity evaluation is concluded that the design has a reduced fuel capacity of roughly 45% of the energy storage capacity required and is therefore not capable of completing all specified missions and therewith cannot fully comply with set requirement by the Rijksrederij without exceeding the design length of 65m or extending the vessel significantly in other ways. The situation where the requirement to have a moonpool is omitted has been investigated and the resulting capacity in such design the capacity is 95% of the required capacity which might be gained by some other minor alteration to the design.

The results have been discussed with the Rijksrederij and it was concluded that the required fuel capacity cannot be met without altering the design to such extent that other design requirements would be violated.

Taking the above into account, the main particulars and overall layout is herewith concluded. The presented design is taken as starting point for the next engineering phase where the main systems and vessel structure will be analyzed into more detail on room/system level of detail.

The combination of having Hydrogen systems and a moonpool in the vessel put a large strain on the design. Both systems need to be allocated approximately at the middle in the vessel. The LH2 systems due to safety regulations and the moonpool due to operational limitations. Recommended to the Rijksrederij is to reconsider this combination of requirements for further designs. The following recommendations are made to the design to be taken care of in the next design phase:

- Design shows a list to all stability loading conditions. Placement of consumable tanks to be optimized to reduce heel for the complete operating range.
- Significant amount of water ballast is required to attain sufficient draft to meet the freeboard between 1.0m - 1.3m criteria. Current design shows sufficient overall capacity, but the actual tank arrangement need to be further refined.

5.7 WP 3 Documents for hydrogen based vessel

The deliverables for the hydrogen based vessel, part of work package 3 are listed in the table below.

Table 28 Deliverable summary hydrogen design

Deliverable	Document name	Owner	Type	Remarks
General arrangement	21.092-H-000-001 -General arrangement	C-Job	Drawing	

Machinery room arrangement	21.092-H-052-100 -Engine room arrangement	C-Job	Drawing	
Preliminary 3D hull design	21.092-H-000-011 -Hullshape	C-Job	3D model	
Light weight assessment	-	C-Job	Report	Part of this report
Stability assessment	-	C-Job	Report	Part of this report
Preliminary PPE concept & Speed power prediction	-	C-Job	Report	Part of this report
Preliminary Safety Study		Marin	Report	Part of this report

6 PRELIMINARY SAFETY ASSESSMENT

6.1 Introduction

Based on the conceptual layout of the engine/machinery room, energy storage space and bunker area a preliminary safety study has been conducted. The following aspects were considered:

- Verify compliance with existing IMO/classification guidelines applicable to the chosen energy- and power system;
- Consider whether the requirements for redundancy are being met;
- Identify the hazardous zones;
- Consult safety experts on specific rule interpretations;
- Conclude with a list of "attention areas" which need to be considered in basic engineering/HAZID study;

6.2 Applicable rules

- For both ship types:
    - NR467 for Systems (machinery, safety, electrical, stability) https://marine-offshore.bureauveritas.com/nr467-rules-classification-steel-ships
    - NR 600 for construction https://marine-offshore.bureauveritas.com/nr600-hull-structure-and-arrangement-classification-cargo-ships-less-65-m-and-non-cargo-ships-less
    - Statutory: the usual: SOLAS/MARPOL/LL/FSS/LSA/IS etc.

- Methanol/ICE powered ship:
    - NR 670 for methanol https://marine-offshore.bureauveritas.com/nr670-methylethyl-alcohol-fuelled-ships
    - Statutory: specific for methanol: MSC 1621

- Hydrogen/FC powered ship:
    - NR 547 for fuel cells https://marine-offshore.bureauveritas.com/nr547-ships-using-fuel-cells
    - NR 529 for hydrogen (gas fuelled ships, a dedicated rules note for Hydrogen is under construction, expected second half 2022. If available the new rules note it will be used for review of the AiP documentation, but as long as it is not available the ship design does not include it.). https://marine-offshore.bureauveritas.com/nr529-gas-fuelled-ships
    - Statutory: specific for hydrogen: IGF and CCC 4 /WP.3 - "Amendments to the IGF code and development of guidelines for low-flashpoint fuels".

6.3 Required documents

For the safety study BV has specified the following documents to be reviewed. In the table below is indicated which documents are at which stage available.:

Table 29 Documents required for safety study

	Methanol Design	Hydrogen Design	Remark
General arrangement plan	WP 3	WP 3	

Main cross-section	WP 4		
Fuel system diagram	WP 3	WP 3	Preliminary version as part of the Physical system architecture.
Single line diagram	WP 4	WP 4	
Hazardous zone plan	WP 4	WP 4	
Preliminary safety plan, high level - Fire control & Escapes - Life saving appliances - Structural fire integrity	WP 4	WP 4	
Preliminary safety report	WP 4	WP 4	
Tank arrangement	WP 4	WP 4	(preliminary visible in General arrangement WP3)
Inert gas system diagram	WP 4	WP 4	
Drain and bilge diagram	WP 4	WP 4	
Bunker diagram.	WP 4	WP 4	

Currently, at the end of WP3 Concept Design, most of these documents are not yet available. They will be at the end of WP4 Basic Engineering, when the HAZID study will be conducted.

6.4 Preliminary assessment

A preliminary safety assessment has been made based on the current GA's of both ships. Participating were BV, C-Job, NMT and MARIN. A summary of the results and attention points is reported below.

- Methanol ship
  - Fuel preparation space.
    This is a double walled box, vented, approximately 1 m^3, placed in the engine room. The requirement of accessibility by stairs is not applicable.
    Suggested approach: HAZID and suitable mitigation measures.
  - Cofferdam above the methanol tank, 600mm height, gas detection, vented.
    Access to open deck seems problematic. Access for maintenance through man holes with bolted hatches, not during operations at sea.
    Suggested approach: HAZID and suitable mitigation measures.
  - Engine room escape routes: through switchboard room by stairs, or two hatches give direct access to open deck. Is this sufficient?
  - Battery system, LiIon, 30 kWh in the switchboard room. This probably results in specific requirements.
    Check NR 467 chapter 14.1.

- Hydrogen ship
  - Hydrogen tank
    A double walled cylinder with vacuum insulation space between the walls. Inside wall has cryogenic temperature, outside normally more moderate. But when leaks should appear the outside wall also reaches cryogenic temperatures, causing risk for brittleness. Material choice

    of outer wall and frame need to be accordingly.
  - Air lock
    Gives access to the hydrogen tank space. The location of the airlock effects the size of the tank space, thus influencing the ventilation capacity.
  - Exhaust and venting systems
    Below deck they are separated, but can they be combined once above deck?
    To be checked.
  - Fuel cell space
    There are multiple fuel cells, now placed in one space. Is this ok, or do they need to be in separate spaces?
    To be checked.

- General
  - Redundancy, DP2.
    Power generation architecture is redundant on both ships, but is this sufficient to cover DP 2 requirements? Specific attention required for failure of the electrical systems and control systems.

7 DESIGN AND PROJECT LOG:

Throughout the project, minutes of meetings, action lists and design and/or requirement changes haven been documented.

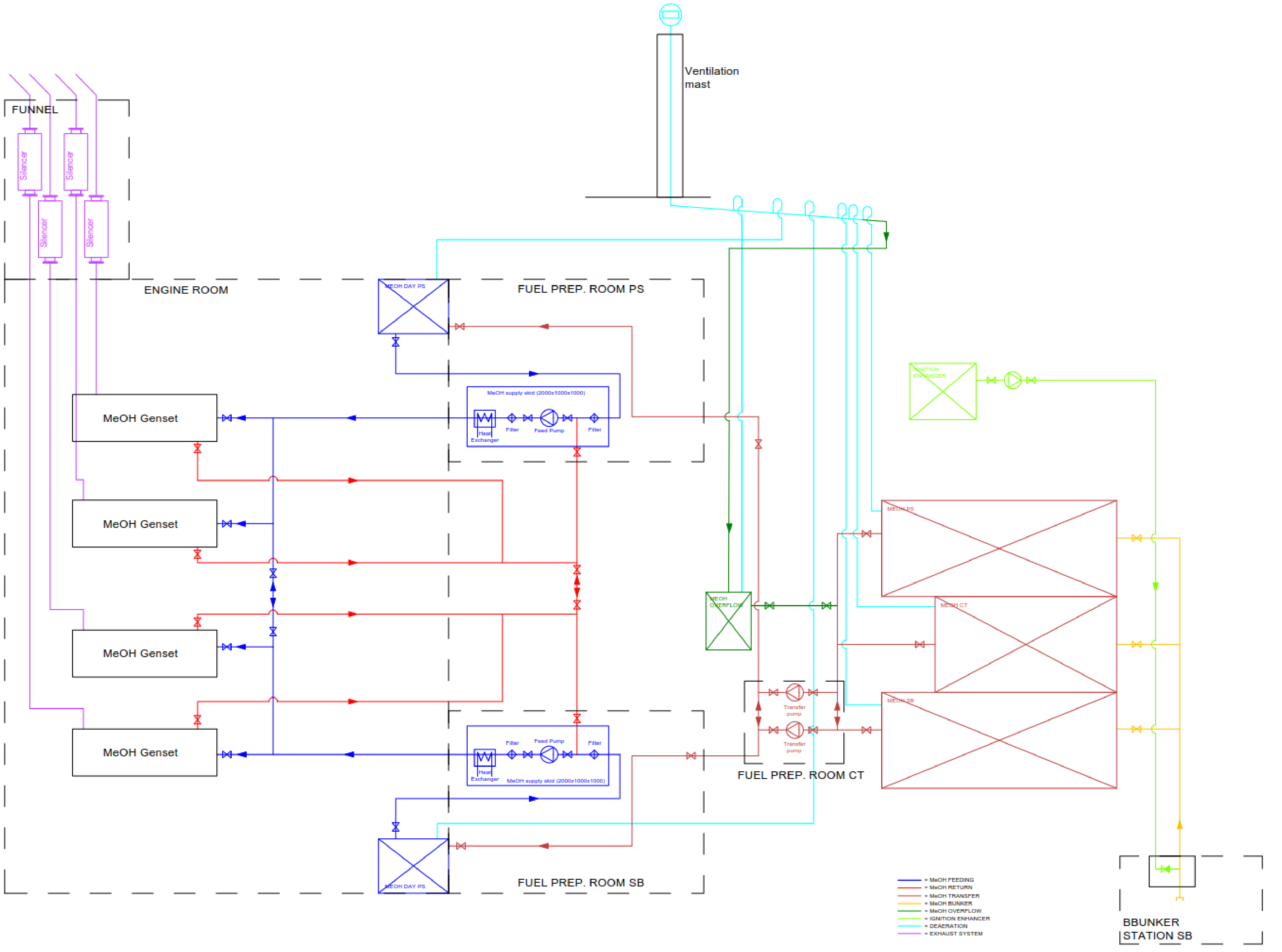
These documents are delivered as part of work package 3 in the following document:

Project_log_WP3.zip

Selection of main design changes made affecting the presented concept design:

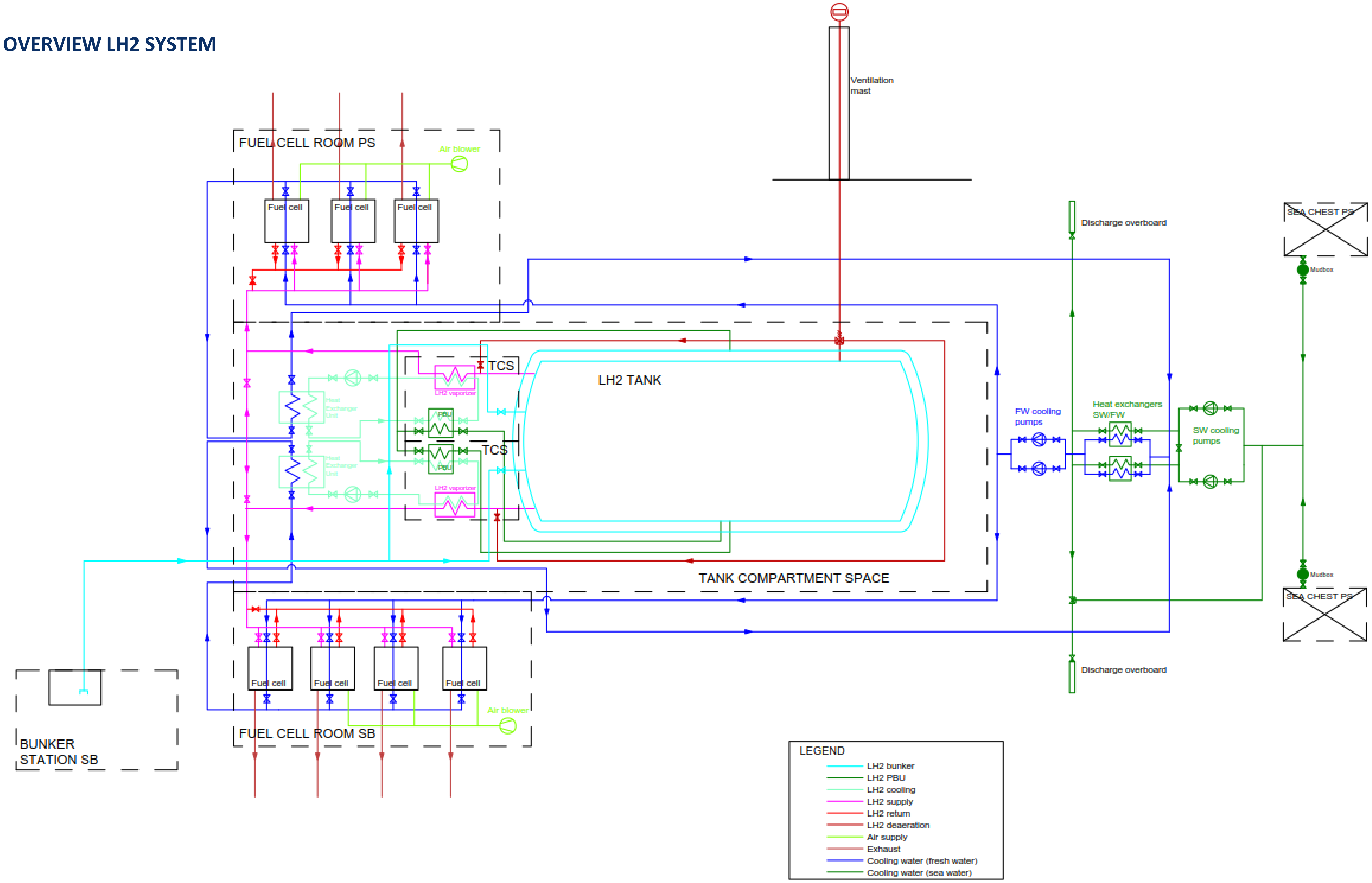
- Aim is to achieve 100% Methanol operations. So preferably no dual fuel solutions.
- Requirement to have laboratory with direct access to work deck removed.
- Reduction deck workshops from 40m^2 to 20m^2
- Wish to have visibility all around from bridge deck.
- Update on the WP2 report resulted in additional tank capacity requirements, exceeding the design parameters as used as basis for WP3.
- Decided to proceed with hydrogen design with lacking tank capacity. Agreed is to include the following items in the design report:
    - Impact on mission profile of the lack of capacity
    - Influence of removing the moon pool from the design to the available tank capacity.

A. PRELIMINAIRY OVERVIEW MEOH SYSTEM



DG REFORM: PRELIMINARY CONCEPTUAL MEOH SYSTEM (Version 1.0)

B. SCHEMATIC OVERVIEW LH2 SYSTEM



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