



Retrofitting towards climate neutrality

Report of retrofitting ships

Programme: HORIZON EUROPE

Grant agreement number: 101096522

Project acronym: Green Marine

Project title: Retrofitting towards climate neutrality

Prepared by: Calmac/UoS

Date: 17/07/2026



Funded by the
European Union

Funding acknowledgement

Green Marine is funded by the European Union funding from the European Union's Horizon Europe research and innovation program under grant agreement No. 101096522. UK participants in Horizon Europe Project Green Marine are supported by UKRI grant numbers 10064539 (University of Strathclyde), 10068477 (CalMac Ltd) and 10064666 (CCM).

Disclaimer: The views expressed in this deliverable are those of the authors and are disclosed in a non-reliance basis and for information purposes only. The authors, the **Green Marine** consortium and partner employees and directors do not express or implied representation and/or warranty as to the accuracy and completion of the information set out in this report (including in any opinion, estimate, forecast and/or projection disclosed herein) and shall have no liability to the readers for any reliance placed on this report. The readers will rely solely upon their own independent investigation and evaluation of the information provided herein. Finally, this deliverable is based in information, legislation and data available as at the date of its creation and the authors shall have no responsibility for updating the information contained in this report and for correcting any inaccuracies in it, which may become apparent. The content of this deliverable does not reflect the official opinion of the European Union.

TABLE OF CONTENTS

ABBREVIATION TABLE.....	7
EXECUTIVE SUMMARY	9
1. INTRODUCTION.....	10
1.1 DOCUMENT STRUCTURE.....	11
2. SELECTION OF GMIS.....	11
2.1 DESCRIPTION OF GMIS	12
2.2 PROCESS FLOW DIAGRAM (PFD).....	13
3. REGULATORY AND CERTIFICATION REQUIREMENTS.....	16
3.1 LR REQUIRMENTS	16
3.1.1 METHODOLOGY FOR THE RBC PROCESS ACCORDING TO LR	16
3.2 LR DOCUMENTATION AND HAZID REQUIREMENTS	18
3.3 CALMAC REQUIREMENTS.....	19
3.4 UK MARITIME & COASTGUARD AGENCY	21
3.5 COMMON REQUIREMENTS	22
4. RBC-1 for the Demonstration Ship.....	23
4.1 3D DRAWING FOR THE INTEGRATED SYSTEM.....	23
5. RBC-2 FOR THE DEMONSTRATOR SHIP.....	26
5.1 OURCOMES OF IN-HOUSE HAZID WORKSHOP	28
5.2 OPERATIONAL HAZID WORKSHOP WITH LR INVOLVEMENT	31
5.2.1 SUMMARY OF LR'S 41 RECOMMENDATIONS	31
5.2.2 INTEGRATION OF THE LR SAFEGUARD LIST	34
5.2.3 ACTION REGISTER	34
6. CARBON CAPTURE MACHINE (CCM) TECHNOLOGY.....	35
6.1 WORKING PRINCIPLE	35
6.2 OUTCOMES OF IN-HOUSE HAZID WORKSHOP – CCM TECHNOLOGY	36
7. SHIPYARD (LIST COMPONENTS, JOBS).....	40
7.1 SCOPE OF SHIPYARD RESPONSIBILITIES	40
7.2 MECHANICAL AND STRUCTURAL INTEGRATION	41
Equipment Mounting and Foundations.....	41
Pipework Fabrication and Installation	41
7.3 ELECTRICAL AND CONTROL SYSTEM INTEGRATION.....	42
7.4 INTEGRATION WITH EXISTING VESSEL SYSTEMS.....	42

7.5	TESTING, COMMISSIONING, AND VERIFICATION.....	43
7.6	DOCUMENTATION AND HANDOVER	43
7.7	A CONTINGENCY PLAN	43
8.	ONBOARD-BASED TEST MATRIX	44
8.1	TEST PHILOSOPHY AND OBJECTIVES	44
8.2	OPERATING CONDITIONS AND LOAD STEPS	45
8.3	MEASUREMENT STRATEGY	45
8.4	TEST EXECUTION AND DURATION.....	46
8.5	DATA HANDLING AND POST-PROCESSING	47
9.	PROJECT PROGRAM AND GANTT CHART	47
9.1	PHASE 1 — LR WORKSHOP AND DESIGN MODIFICATIONS	48
9.2	PHASE 2 — LAND-BASED TESTING AND VALIDATION	48
9.3	PHASE 3 — ENGINEERING VERIFICATION AND CLASS APPROVAL.....	48
9.4	PHASE 4 — SHIPYARD PREPARATION AND SUB-ASSEMBLY	49
9.5	PHASE 5 — ONBOARD INSTALLATION.....	49
9.6	PHASE 6 — COMMISSIONING AND ONBOARD TESTING	49
9.7	PROGRAMME SUMMARY	50
10.	CONCLUSIONS AND FUTURE WORKS.....	50
10.1	CONCLUSIONS.....	50
10.2	FUTURE WORK.....	51
	REFERENECES	52
11.	52	
	APPENDIX A: INSTRUMENTS, EQUIPMENT AND INTERFACES LIST	
	ASSOCIATED WITH THE PFD FOR GMIS.....	54
	APPEMDIX B: HAZID TABLE FOR GMIS	57
	APPENDIX C: LIST OF HAZID RECOMMENDATIONS AND SAFEGURADS FROM	
	LR-HAZID WORKSHOP.....	70
	APPENDIX D: HAZID TABLE FOR CCM TECHNOLOGY	82
	APPENDIX E: SHIPYARD JOB LISTS.....	86
	APPENDIX F: ONBOARD TEST MATRIX.....	89
	APPENDIX G: GANTT CHART FOR THE ON-BOARD DEMOSTARTION.....	90

ABBREVIATION TABLE

Abbreviation	Full Form
ALARP	As Low As Reasonably Practicable
AiP	Approval in Principle
CCS	Carbon Capture System
CCM	Carbon Capture Machine
CO ₂	Carbon Dioxide
DSS	Design and Safety Statement
EU	European Union
FMECA	Failure Mode, Effects and Criticality Analysis
GA	General Arrangement
GMIS	Green Marine Integrated System
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
IoT	Internet of Things
LR	Lloyd's Register
MCA	Maritime and Coastguard Agency
P&ID	Piping and Instrumentation Diagram
PAR	Preliminary Appraisal of Rules
PFD	Process Flow Diagram
RBC	Risk Based Certification
RAMS	Reliability, Availability, Maintainability and Safety
SMS	Safety Management System
SWIFT	Structured What-If Technique
TEE	Thermoelectric Element

ToR	Terms of Reference
UoS	University of Strathclyde
UPS	Uninterruptible Power Supply
WP	Work Package
WTR	Water Treatment/Testing Related Equipment (context-specific in report)

EXECUTIVE SUMMARY

This deliverable presents the consolidated engineering, regulatory, and risk-based preparations required for the planned retrofitting of the Green Marine Integrated System (GMIS), a membrane based carbon capture system supported by auxiliary technologies, onboard the MV *Coruisk*. It brings together the extensive work completed under WP1 to date, including early engagement with Lloyd's Register (LR) and the UK Maritime & Coastguard Agency (MCA), the development of updated system designs, and the completion of both internal and formal HAZID processes. These activities have resulted in a refined Process Flow Diagram (PFD), updated 3D spatial arrangements, and a consolidated set of 41 LR/MCA recommendations, all of which will be incorporated into the maturing design. The deliverable also documents CalMac's 12-, 6-, and 3-month requirements, updated installation options, and the shipyard components and tasks necessary to support a safe and compliant retrofit. This work reflects the significant coordination effort undertaken by the University of Strathclyde (UoS), CalMac, technology providers, and regulatory authorities to ensure that all preparatory steps are aligned with LR's Risk Based Certification (RBC) framework [2, 3] and the operational realities of a live passenger ferry, MV *Coruisk*.

A comprehensive HAZID has been completed, combining internal assessments and LR/MCA workshops. The analysis covers the cooling system, bypass system, membrane module, condensate handling, and associated control and safety functions. In addition, a dedicated HAZID assessment was conducted for the separate Carbon Capture Module (CCM) technology, identifying hazards, evaluating potential consequences, and confirming that risks are addressed through existing safeguards and mitigation measures. The CCM technology is expected to operate independently and connects with the bypass system to capture CO₂ from the flue gases. Risks were evaluated using LR's likelihood-severity matrix, and mitigation measures were defined to ensure that they are demonstrably As Low As Reasonably Practicable (ALARP). In parallel, shipyard preparation requirements have been defined in alignment with CalMac's operational planning timelines, and a detailed list of components and installation tasks has been produced. Updated spatial assessments confirmed that Option 1 is infeasible, while Options 2, 3, and 4 remain viable, subject to further engineering refinement.

An updated onboard test matrix has been developed to mirror the land-based testing sequence and ensure a consistent verification pathway for the integrated system. This includes functional, safety, performance, and integration tests to be conducted during dock trials and sea trials. Overall, this deliverable confirms that the preparatory engineering, regulatory alignment, risk assessment, and shipyard planning activities required for retrofitting have been completed to the extent possible at this stage. It does not include installation results, operational performance, or GHG reduction outcomes, which will be addressed in D1.3 (M48). The work presented here provides the necessary foundation for safe, compliant, and technically robust integration of the GMIS onboard the MV *Coruisk*.