Retrofitting towards climate neutrality

D4.1 First report: End System Requirements & KPI's

Programme: HORIZON EUROPE

Grant agreement number: 101096522

Project acronym: Green Marine

Project title: Retrofitting towards climate neutrality

Prepared by: CMMI

Date: 28/02/2023

Report version: v1.0

Funding acknowledgement

Funded by the European Union; funding from the European Union's Horizon Europe research and innovation program under grant agreement No. 101096522

UK participation in Green Marine project is co-funded by Innovate UK funding scheme

HISTORY OF CHANGES		
Version	Publication Date	Changes
1.0	[02/02/2023]	First draft
1.0	[17/02/2023]	Incorporation of feedback from Kick-Off meeting + subsequent meetings
1.0	[28/02/2023]	Submission to EC portal

DETAILS	
Grant Agreement No.	101096522
Project acronym	Green Marine
Project full title	Retrofitting towards climate neutrality
Dissemination level	Public
Due date of deliverable	M1
Actual submission date	M1
Deliverable name	First report: End System Requirements & KPI's
Type	Report
Status	Initial version
WP contributing to the deliverable	WP4
Author(s)	George Mallouppas (CMMI), Angelos Ktoris (CMMI), Andreas Paradeisiotis (CMMI), Constantina Ioannou (CMMI)
Other Contributor(s)	Gregor Luthe (WPS/SMP), Marius Sandrus (SINTEF), Lance A. Scott (CCM), Luis Miguel Campos (PDM), Louis De Wolf (CalMac), Ruth Rise (CalMac)
Reviewer(s)	Elias Yfantis (CMMI)
Keywords	Green Marine, KPIs, CO_2 capture, membrane, chemical adsorption, syngas, genset retrofits, end system requirements

1. INTRODUCTION

The main objective of **Green Marine** is to significantly accelerate climate neutrality of water borne transport through retrofitting existing fleets with cost and emission control solutions. To support decision makers retrofitting protocols and a software tool catalogue that gathers knowledge will be developed and validated. We will demonstrate these tools and the innovative solutions aimed at carbon capture mineralization, which also aids in deacidifying our seas; energy savings for HVAC systems through air-reuse; carbon and water capture with membranes, and the use of excess engine heat to produce a syngas to save on fuel consumption. An ultra-sound technology will be tailored to suit vessels allowing air-reuse saving energy for HVAC systems and operated as pre-treatment enhancing a membrane carbon capture process. The Ca/Mg – alkali solvent capture process is capable of removing 75% of the CO_2 from flue gases. All solutions will be demonstrated first on a land-based engine followed by the selection of the most suitable solution for a demonstration on a waterborne vessel. The (land-based) demonstrations will represent the operation of a majority of vessel engines. By developing retrofitting protocols, simulations of the solutions, data generated at the demonstrations a software catalogue tool will be developed. Through engagement activities this tool will gain more users and more knowledge, its value and effectiveness will increase for all users. The project aims to bring the different solutions to TRL 8. The demonstrations, the software tool catalogue, and the dissemination and exploitation activities ensure that project results will be replicated globally. The consortium consists of 10 partners from 7 countries with 4 research institute, 1 ship company, which will host a demo as end user and 5 SMEs.

The objectives of WP4 – KPIs, Integration, TEA, SEA, LCA, Risk, Safety, & Legal Evaluations are to evaluate the Demos, aid in cross-cutting activities and prepare for software tool integration of data:

- Provide a set of requirements for CCUS and relevant KPIs in terms of materials, end user design and quality monitoring, regulatory compliance, in order to help guide the Green Marine project and conduct evaluations.
- Quality, Safety, Environmental & Health (QSEH) control: ensure project goals in terms of QSEH can be achieved; making use of quality document & standards (align with Project Handbook).
- Risk (and Safety): conduct a Safety assessment for all demonstration activities
- Perform evaluations on: Techno-economic evaluations (TEA) of at least 2 solutions based on preliminary land based results and at least 2 assessments for vessels. Conduct Life Cycle Assessment (LCA), social economic assessment (SEA) for the technical solutions.
- Benchmark against alternative capture technologies and investigate compatibility of 3rd party data to our platform
- Internal exploitation: to determine the business case for end-users

Task 4.1 is about the definition of End System Requirements & KPIs. This report will be delivered at M1 but it is scheduled to be updated on M6, M18, M36 (interim reports) and M48 (final report). Therefore, this is a "live" document which will be monitored and updated as needed throughout project activities. Note, the first version of this report includes feedback and preliminary requirements of the technologies to be tested. These have been obtained from partners at the Green Marine Kick-Off Meeting (15th-16th February 2023, Larnaca, Cyprus; physical and online participation) and subsequent meetings.

In particular, Task 4.1 entails:

- Identification of technology requirements for the proposed retrofitting solutions
- Definition KPIs per locale for the demonstrations. Towards the demonstrations and commercial application, the documented requirements will be updated regularly based on progressive insight throughout project execution.
- Definition of requirements and KPIs for the software tool, which will include for e.g., GUI, API interface. These KPIs will be used as evaluation method for future use, validation and application.

Feedback from this version of this report and its revisions will be fed into the following work packages:

- WP1 – Demonstrate retrofitting of existing fleets (led by UoS)
- WP2 – Land based testing and integration of solutions (led by CMMI)
- WP3 – Solutions development and scale-up (led by SINTEF)
- WP5 – Software tool catalogue for GHG-emission reduction solutions (led by PDM)

Note that at this early stage of the report, some KPIs and End System Requirements are qualitive and quantitative.

2. LAND BASED ENGINE TESTS LINKED TO WP2

WP2 activities entail the retrofitting of a land-based engine with the carbon and capture technologies (that includes SINTEF's membranes, CCM's technology and the SepaRaptor and Thermoelectric Element; TEE by SMP). The genset will be first identified, retrofitted and tested with emissions measuring equipment provided by CMMI and the electric energy gain by the TEE. Land based testing activities require the operation, retrofitting and testing of a marine genset. The subcontracting activities require the following:

- Provision of a genset (including O&M services) to accommodate emissions and other measurements by CMMI
- Engine to be tested for approximately for up to 250 hrs (exact duration to be determined in following reports)
- Support the installation of the carbon capture machine by CCM, CO_2 capture membranes by SINTEF and SepaRaptor by SMP/WPS (including transportation and logistics)

- Verification and compatibility of genset with technology providers (CCM, SINTEF, WPS & SMP)
- Appointment of a health and safety manager

2.1 Duties of Health & Safety manager for land based testing

As per Task 7.4, a health & safety manager is needed to oversee the land-based testing activities including the retrofitting and emissions measurement activities.

2.2 Land based testing of developed solutions

2.2.1. Genset engine specifications & operation

Preliminary the genset specifications, and as discussed at the Kick-Off Meeting, are provided in the Table 1 below. Note that the final genset will be determined in following reports, after the appointment of the relevant organisation.

Table 1. Preliminary genset engine specs (as described and presented in the Grant Agreement) at the Port of Limassol.

Engine Model	Deutz A12L 714—Diesel Engine
Model year	1966
Displacement (cm^3)	19,000
Compression Ratio	19.2
Bore X Stroke (mm)	120 × 140
Configuration	Naturally aspirated, air-cooled, 12-cylinder, No EGR available
Rating power (kWe/rev. min^{-1})	112/1800
Injection timing	24° BTDC
Injection nozzle	Opens at 126.66 bar
Approximate flue gas flow rate	50-150 Nm^3/hr (to be verified). Flue gas flow rate (Nm^3/h) to be determined when genset selection is finalised
Nominal fuel consumption @80% power	To be determined from engine owner/manufacturer
Power	146kW

As per Mallouppas et. al. [1] the genset has the following performance at diesel only conditions (see Table 2).

Table 2. Genset performance at diesel only conditions

Parameter	Diesel only operation
Exhaust gas temperature (°C)	237
O_2 (%)	14.8
CO_2 (%)	3.3

Parameter	Diesel only operation
UHC (ppm)	54.7
NO (ppm)	271
Smoke (opacity)	4.5
Knock phenomena	No

2.2.2. Specifications of measuring equipment

2.2.2.1 Gas analyzer

The flue gas analyzer is Lancom 4 from Land Ametek. Lancom 4 is a portable analyzer designed to measure flue gas emissions [2]. Up to nine flue gases, flue gas temperature and pressure can be measured.

- Temperature units: °C, K
- Gas concentration units: mg/Nm^3, ppm
- Pressure units: inH_2O, hPa
- Hydrocarbon concentration units: %, ppm

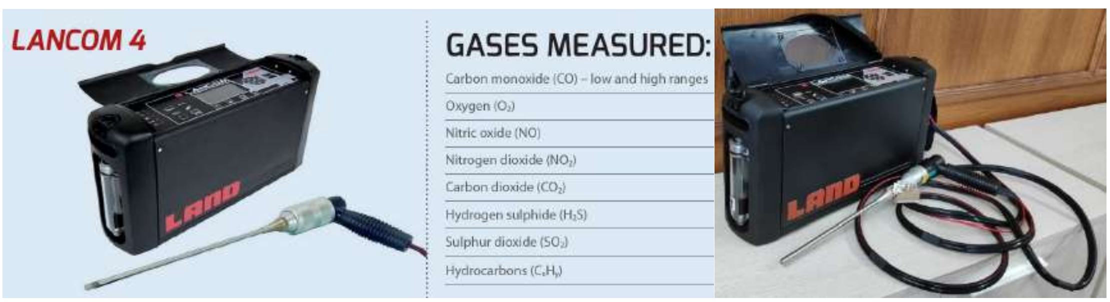

Figure 1. Lancom 4 Gas analyzer

2.2.2.2. Smoke detector

Smoke detector connected to Lancom 4 Gas Analyzer to measure smoke emissions for exhaust gas analysis.

Figure 2. Smoke detector connected to Lancom 4 Gas Analyzer

2.2.2.3. Thermocouples

The Type T45 thermocouples of Sika are DNV approved for marine use (see Figure 3). The temperature sensor is a robust sensor designed to measure exhaust gas temperatures for large diesel engines (include marine engines). The following specifications are listed below:

- Thermocouple class 1
- Interchangeable measuring insert
- 4.5mm diameter
- IP54 degree of protection
- 800ºC maximum measuring exhaust temperature
- Fitting SW5, 3-4mm stainless steel 1.4571 process connection

Figure 3. DNV approved thermocouples

2.2.2.4. Fuel/oil flow meter

Contoil fuel oil meters for measurement of fuel and oil flow rates (4-200 litres/hr); see Figure 4. Areas of application:

- to measure heating fuel consumption by oil burners (for example, in heating boilers, industrial furnaces, tar processing plants)
- consumption monitoring and optimisation

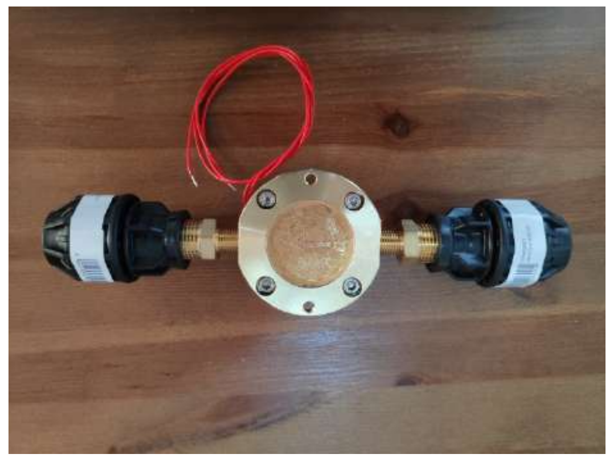

Figure 4. Fuel/oil flow meter

2.2.2.5. Air (thermal mass) flow meter

The S401 is a flow sensor which is designed to measure the consumption of compressed air and gases within the permissible

Figure 5. Air (thermal mass) flow meter

operating parameters (see Figure 5). The S401 can measure the following values:

- Volumetric flow of the compressed air or gas.
- Total consumption of the compressed air or gas

2.2.2.6. In cylinder pressure sensor analyser

PREMET® diesel indicators compatible with low-, medium- and high-speed engines (see Figure 6). This device provides the opportunity to fine tune an engine to a higher efficiency resulting in lower costs.

Figure 6. In-cylinder pressure sensor analyser.

2.2.2.7. Vibration monitoring and analysis equipment

VA5 Pro A4404 – SAB Virtual Unit is a portable vibration analyzer which is based on unique Digital Signal Processing (DSP) board developed by Adash [3]; see Figure 7. Adash's A4500-VA5 Pro is a vibration analysis instrument, amongst many others in the market, including several additional features for machine diagnosis, such as thermal imaging, ultrasound detection and provides direct measurement processing. In addition, DDS software, the company's appurtenant software, allows for a more detailed analysis via built-in packages to facilitate the measurements. The methodology of VA5 incorporates monitoring phenomena related to degeneration or tracking the behaviour of a failure, by collecting and processing data. Such processes fall under the spectrum of non-destructive control systems and more precisely "Vibration Spectrum Analysis".

Figure 7. VA5 Pro A4404 vibration analyzer

2.2.3 Specifications of GHG-reduction technologies

Technical requirements of technologies by technology providers:

2.2.3.1. Carbon Capture Machine (CCM)

Due to the low TRL5 of CCM, definition of KPIs and end system requirements will mature in later versions of the report. Preliminary, KPIs and End System Requirements of Carbon Capture Machine, however, these will be revised in later version of the report:

- Size: to fit 20ft container; but to be designed in a modular framework to use available space at land based testing and sea based demonstrations
- Storage requirements of chemicals
    - NaOH, will need a room for storage tank that depends on test duration (250 hours)
- High exhaust temperatures (ideally room temperature) so may need a heat exchanger to cool down

   - Can reclaim waste heat if not in competition with the Thermoelectric elemement (TEE)
- CCM energy consumption similar to 2x a Reverse Osmosis (RO) water separation unit (producing necessary brine) 2x 4 kW/m^3
- 60-120 kg CO_2/ton alkaline (preliminary, to be determined once genset is known)
- Low CAPEX and OPEX / at cost parity with direct competition
- Minimum electricity consumption
- Product quality meeting customer demands: amount of CO2 converted to PCC, fineness material, price of product

2.2.3.2. SepaRaptor (SPM/WPS)

The main benefit of the SepaRaptor is the agglomeration of nano-particles (5-300 nm) to micro-particles (2-6 µm) which will enable their eventual removal from the system. Appendix A: SepaRaptor Technology provides additional explanations on how the SepaRaptor technology works. HEPA (high efficiency performance filters) have a filter gap at nano-size range. As per Appendix A, the following KPIs regarding SepaRaptor:

- Typical HVAC filters have an MPPS around 200–300 nm, whereas the MPPS of high efficiency (HEPA and ULPA) filters is smaller, according to ISO 29463 mostly in the range from 120 nm to 250 nm. This is exactly the size of the SARS CoV-2 where the HEPA and ULPA filter exhibit the lowest filter efficiency.
- Efficiency removal: nanoparticles >90% and >95% aerosols, viruses
- Use low cost and durable equipment, electric consumption piezos: 20 – 40% OPEX improvement on membranes
- 50% HVAC energy savings (air resuse increase);
- 99.9% removal of viruses for air ventilation systems
- The maximum efficiency found in this study was approximately 35% for F7 HEPA Filter systems**.**

In terms of measurements, a SMPS (scanning mobility particle sizing) device is needed to measure the size of the particles before and after the SepaRaptor for effective monitoring.

Properties that affect toxicity: To be quantified at later versions/updates of this report

- Size is a key factor in determining the potential toxicity of a particle,
- Chemical composition,
- Shape,
- Surface structure,
- Surface charge,
- Aggregation and solubility, and
- Presence or absence of functional groups of other chemicals.

The large number of variables influencing toxicity means that it is difficult to generalise about health risks associated with exposure to nanomaterials – **each new nanomaterial must be assessed individually and all material properties must be taken into account**.

2.2.3.3. *Thermoelectric Element - TEE (SPM/WPS)*

Genset could be water-cooled or air-cooled, preferably water-cooled system to avoid a different setup from the demonstrations of WP1. In the event of an air-cooled engine, the TEE heat exchanger will be modified accordingly by designing, building and testing new system.

The additional benefit of water-cooled engines is that we closed loop there is no potential pollution of the environment by leaking chemicals like oils.

The KPI of the electricity energy gain to be determined in following reports after the complete definition of the overall system requirements.

In addition, as per the Grant Agreement, the following KPIs and end system requirements for the Thermocouple-System are expected (or defined if not yet known):

- High efficiency
- Minimum amount of space required
- Operational temperature range
- Electricity produced per thermal Watt heat
- Working fluid selection, depending on temperature range (as per Subtask 3.3.2):
    - Water: 170 – 600 K
    - Ammonia: 150 -170 K
    - Mercury: 400 – 800 K
    - Lithium or silver: >1000 K
- Protection of piping from thermal, mechanical and chemical effects with coating.
- Electrolyser selection (as per Subtask 3.3.2): a Polymer Electrolyte Membrane (PEM) to be selected. Note since TEE output is always the same (DC current), it cannot be optimised

2.2.3.4. *Catalyst requirements - (SMP/WPS/BX)*

The following KPIs and end system requirements are expected (or defined if not yet known):

- Definition and selection of suitable catalysts non-precious metals: as per Subtask 3.3.1, such as Ni or Cu-based materials
    - Exposure of catalyst materials to flue gas environments and heat to determine the efficiency ratios; aim is 50 or 80% from original value
    - 10-20 grams are foreseen for each catalyst type
- Catalyst regeneration – MechoChemistry: maintain purity of catalyst
- Removal of contaminants of catalyst
- Processing time
- CAPEX and OPEX of MechanoChemistry unit

2.2.3.5. *CO_2 Membranes - (SINTEF)*

The following KPIs and end system requirements are expected (or defined if not yet known):

- Base case for the current capture technology assessment is capture from a flue gas for a ship engine running at 66% load producing 50-150 Nm^3/h flue gas with a CO_2 content of up to ~5.0 vol% (wet) with Diesel as fuel

- we aim at CO_2 recovery of >35%
- Membrane KPIs: selectivity 50-100, CO_2 permeability up to 1000 Barrer. Maintain or increase permeability & selectivity ≥100
- Membrane area:1.5 – 20 m^2 per module on land, 2x 10 m^2 semi-commercial module on vessel
- Water by-product: possibility to recover water vapour to be determined to avoid membrane flooding. Drain may be needed to remove the condensed water vapour
- High water purity
- Ability to operate with SepaRaptor
- Hold initial performance and increase lifetime = x2

The KPIs and end system requirements are derived from SINTEF research activities [4, 5, 6, 7].

Note these requirements are aligned with SINTEF's modelling membrane tools (SimpleSIM [8], a Python-based flexible simulator framework for feasibility assessments developed at SINTEF).

2.3.4 Syngas in genset

Mapping of the engine and relevant ship compartments, to consider the different operational modes which will enable the optimal spec design of the solution. The KPIs are:

- Weight (to be defined in future versions/updates of this report),
- Energy density (to be defined in future versions/updates of this report),
- Safety – safe re-injection in engine without syngas slipping with consideration of relevant IMO regulations – in terms of CO, H_2, CH_4 slipping; preliminary:
    - E.g. fumigation/ventilation requirements (to be defined in future versions/updates of this report),
    - Sensors to monitor CO, H_2, CH_4
- vol% of syngas composition (to be defined in future versions/updates of this report),
- Temperature and pressure of syngas before re-injection (to be defined in future versions/updates of this report)
- Definition of type of injection (to be defined in future versions/updates of this report)

3. SOFTWARE TOOL CATALOGUE LINKED TO WP5

As per the Grant Agreement, general KPIs regarding the software tool are:

- Number of software tool users = 100
- User engagement survey feedback = satisfactory engagement of 500 users

Figure 8 illustrates the Green Marine software catalogue tool with different "software modules" or "Service Provider Layers". Figure 8 provides the high-level visual understanding of data flow to be used within the Green Marine software platform.

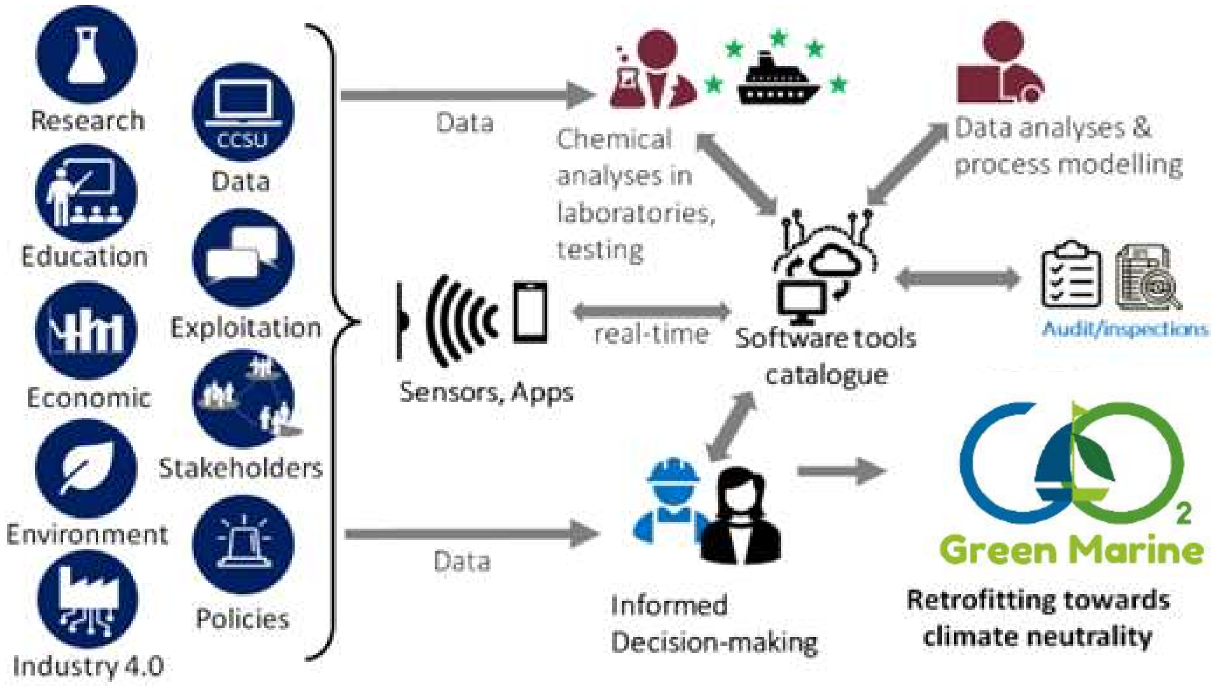

Figure 8. As per the Grant Agreement; the envisioned Green Marine software decision tool catalogue

3.1 APIs AND INDIVIDUAL SOFTWARE MODULES

The following KPIs and end system requirements for Task 5.1 are expected (or defined if not yet known). As per the Grant Agreement these are:

- Exact definition of API interfaces to allow 3rd parties to connect to the platform with their tools or software apps
- GUI definition (see §3.2.2)
- Data security
- User engagement (see §3)
- Quality and validation of data for benchmarking/model development
- Stakeholder acceptance and engagement

3.2 SOFTWARE PLATFORM

The software platform will integrate independent physical models of the different technological solutions and addresses the lack of integrated environment for complex distributed simulations and lack of data validation (see §3.2.1) that are needed to feed the models to be developed. Thus, the requirement of the software platform is to provide a fully integrated CCUS platform by using the state of the art tools.

3.2.1 Tailor existing AI technologies

AI technologies to facilitate predictive performance of the technologies and retrofits. The AI algorithms will "learn" from the land-based test data (WP2) and demonstration data (WP1). Thus predictions and recommendations for GHG avoidance measures based on ship operations, engine type etc.

Thus, preliminary KPIs and end system requirements regarding the AI technologies are:

- Large data samples to train the deep neural networks (DNN)
  - This requires the duration of the tests to be long enough for a statistical acceptable sample
  - If this is not achievable, closure models will be needed
- Creation of repository data / models that can be used by researchers in a privacy-preserving way ensuring collaboration without sharing of proprietary data (using federated learning techniques by not sharing raw data)
- Reliable algorithms that do not lead to Floating Point Exceptions or any other issue; quality assurance to filter out bugs
- Optimised algorithms in terms of performance depending on techniques for digital mimic (up to x10 speed-up of current GPU architectures with usual federated learning techniques of the current state of the art)
- Accurate algorithms; up to 10% variation with land-based and demonstration data

3.2.2 Software framework

As per the Grant Agreement, for easy processing of all results can be visually presented, including different circularity scenario options – computers do not make decisions on a set of parameters, people do so, based on their understanding. Therefore, also "gamification" of the tool is envisaged, where the user interacts with the platform to try a circular scenario.

Thus, preliminary KPIs and end system requirements regarding the software framework are:

- Opensource user friendly GUI with multiple visual interfaces (for example Graphana)
- Development of a high-quality technical documentation that is openly available
- Advanced navigation and visualisation interface to simplify information access and usage (effective information management)
- Organisation management configuration & administration features
- APIs for data visualization
- Independent reference modules for calculation decisions
- Facilitate gamification user experience
- Facilitate logistics process
- Seamless interaction and coordination of modules

3.3 Computational Fluid Dynamics (CFD) simulations

CFD simulations will provide physical models which will iterate to be part of the software framework. However, CFD activities are planned in WP3, WP4 and WP5.

3.3.1 Activities related to Task 3.1 "Tailor (Develop) aerosol control solutions"

CFD simulations by SINTEF will optimise the flow streams passing through the membranes of the SepaRaptor and UV system. The following requirements are needed for successful CFD simulations:

- Selection of a CFD software package & estimation of computational power and estimated CPU time
- Definition of boundary and initial conditions (definition of inlet velocities, temperatures, species composition, pressure etc)
- Definition of physical models, such as membrane porosity and appropriate numerical schemes to be used
- Provision of CAD model (SepaRaptor + UV system)
- Generation of a suitable mesh

KPIs of CFD simulations for Task 3.1 "Tailor (Develop) aerosol control solutions" are:

- Verification/validation with available experimental data as generated by WP2 activities and open access literature, and any deviation of results to be within 10% of experimental data.
- Optimisation of system, once verified, through various simulations to mitigate back-pressures and improve overall efficiencies of the system
- Scale up of overall system via optimised flow streams

3.3.2 Activities related to Subtask 4.4.1 "Process modelling"

As needed in Subtask 4.4.1 "Process modelling", to determine the back-pressures of the overall system (genset + CCM + membranes as set by the WP2 setup), the following requirements are needed for successful CFD simulations:

- Selection of a CFD software package & estimation of computational power and estimated CPU time
- Definition of boundary and initial conditions (definition of inlet velocities, temperatures, species composition, pressure etc)
- Definition of physical models and appropriate numerical schemes to be used
- Provision of CAD model of genset + CCM + membranes
- Generation of a suitable mesh

KPIs of CFD simulations for Subtask 4.4.1 "Process modelling" are:

- Verification/validation with available experimental data as generated by WP2 activities, and any deviation of results to be within 10% of experimental data.
- Optimisation of system, once verified, through various simulations to mitigate back-pressures and improve overall efficiencies of the system (eg reduction of fuel consumption)

3.3.3 Activities related to Task 5.2 "Air circulation"

As needed in Task 5.2 "Air circulation", the HVAC system will be modelled via CFD calculations to determine with the air circulation using the SepaRaptor with UV technologies. The following requirements are needed for successful CFD simulations:

- Selection of a CFD software package & estimation of computational power and estimated CPU time

- Definition of boundary and initial conditions (definition of inlet velocities, temperatures, species composition, pressure, passive scalar etc)
- Definition of physical models and appropriate numerical schemes to be used
- Provision of CAD model of a cabin
- Generation of a suitable mesh

KPIs of CFD simulations for Task 5.2 "Air circulation" are:

- Verification/validation with available experimental data and any deviation of results to be within 10% of experimental data.
- Optimisation of system, once verified, through various simulations to mitigate back-pressures and improve overall efficiencies of the system

3.4 DIGITAL MIMIC OF CRITICAL PARTS/TECHNOLOGIES OF VESSEL

Under Task 5.3, the KPIs and end system requirements will be defined in future versions/updates of this report.

- Three validated retrofitting approaches
- Create models (digital mimicking of models) of the three technologies to be retrofitted
- Technology providers will need to develop/provide the model
- Option 1: Will need the physical model in order to create its digital mimic
- Option 2: Use neural networks to re-create the model from a large pool of inputs/outputs

3.5 RETROFIT DESIGN CATALOGUE TOOLS

Under Task 5.5, the KPIs and end system requirements will be defined in future versions/updates of this report.

4. DEMONSTRATIONS LINKED TO WP1

4.1 DUTIES OF HEALTH AND SAFETY ADVISOR DURING DEMONSTRATIONS

Procedures will be documented, especially in regard to risk & eventual approval (under Lloyds Register) by the Health & Safety Advisor. The specific role to be allocated to CalMac to deliver obligations, through CalMac's internal "HSQE department". The department has the relevant competencies and skills to ensure Health and Safety during the WP1 demonstrations.

Briefly these roles and scope of work in relation to Green Marine:

- Head of Safety and Security; responsible for providing professional support to vessel and shore-based operations for all relevant safety and security matters.
- Environmental Manager; responsible for providing professional support to vessel and shore-based operations for all relevant environmental matters.
- Health and Safety Manager; responsible for providing professional support to shore-based operations for all relevant safety and security matters.

- Marine Safety Advisors; responsible for providing professional support to vessel operations for all relevant safety and security matters.

In Appendix B: Safety protocols expected from CalMac's contractors – Managing contractors process, the safety protocols expected from CalMac's contractors, also known as Managing Contractors Process, is presented. This document will form the basis of the safety protocols in the WP1 demonstrations.

4.2 PERMITS AND ACTION PLANS FOR ALL DEMOS

For the effective vessel demonstrations, the relevant sites and permits will be required. Demonstrations will possibly occur where CalMac ferries operate, as shown in Figure 9. A demonstration route will be and defined at later versions of this report.

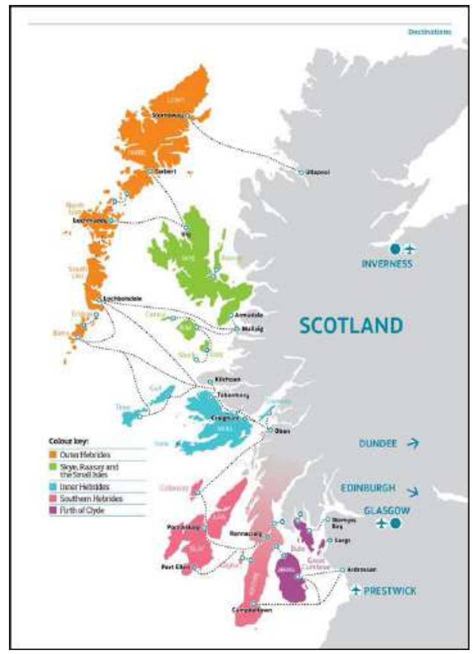

Figure 9. Region of operation of CalMac ferries, as discussed at the Green Marine Kick-Off Meeting

The necessary action plans as per the Grant Agreement are:

- GHG emission reduction goals;
- responsible contact person;
- quality reviewer;
- safety and environmental issues;
- test campaigns;
- planning;
- quality monitoring,
- Classification Society/regulatory authority compliance (under an appropriate classification society – the majority of CalMac ferries are registered with Lloyds Register),
- onboard technologies evaluation, certification procedures

As per the Grant Agreement, the final action plan and test campaign will be authorized by the end users responsible site's Environmental, Health & Safety manager (as defined in §4.1).

As discussed at the Kick-Off meeting, during the General Assembly, all partners have agreed that the discharge of de-acidification minerals into the sea requires interaction from the start of the project with the relevant authorities (Subtask 4.4.3) will require compliance with MARPOL strict regulations (environmental rules). Hence, the proposition is to produce lab-scale testing with sea samples in a controlled environment to investigate the impact of de-acidification of minerals from CCM's products. Thus, this will be a simulation of the discharge of de-acidification minerals into the sea.

4.3 VESSELS TO BE USED FOR DEMONSTRATIONS

As discussed at the Green Marine Kick-Off meeting, Figure 10 depicts the possible CalMac vessels to be used in WP1 demonstrations. Note that, final selection will be determined by vessel owners and requirements of the overall system requirements. In addition, demonstrations will occur at the auxiliary engine of the vessels.

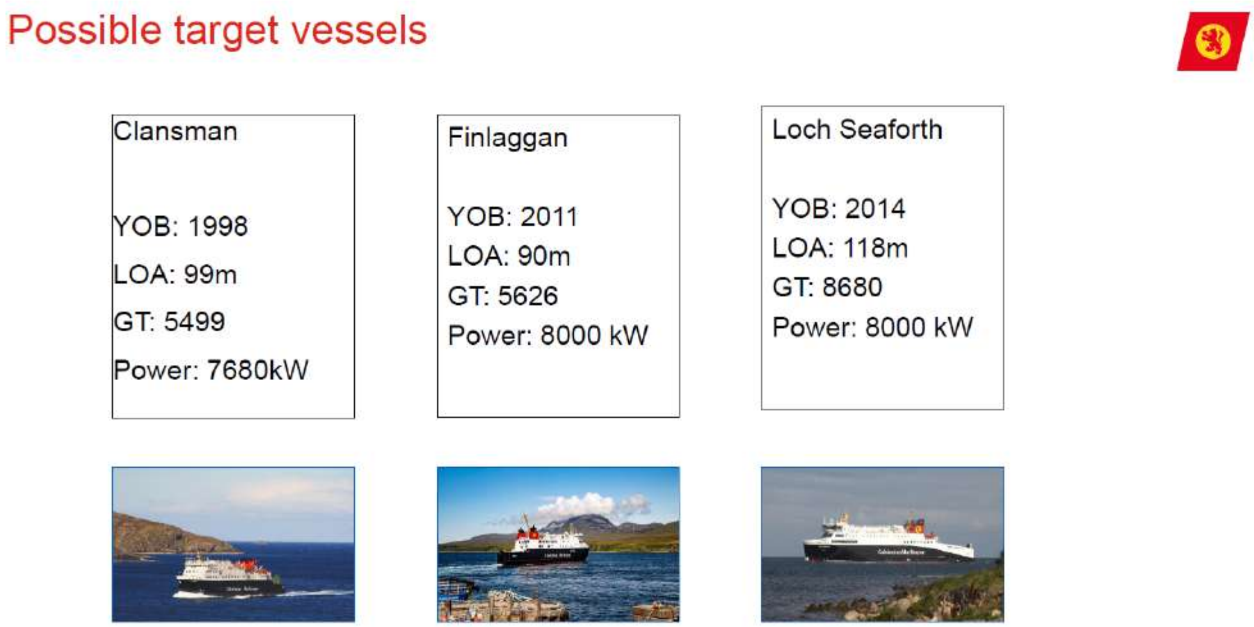

Figure 10. Possible vessels to be used for demonstrations.

As per IHS Markit [9] the auxiliary engine specifications of the possible vessels mentioned in Figure 10:

<u>Clansman:</u> Design: Cummins, Engine Builder: Cummins 4 x KTA-19-M, 4 Stroke 6Cy. 159 x 159, Mcr: **441 kW**

<u>Finlaggan:</u> Design: Mitsubishi, Engine Builder: Mitsubishi 3 x S6R2-MPTA, 4 Stroke 6Cy. 170 x 220, Mcr: **530 kW**

<u>Loch Seaforth:</u> Design: Mitsubishi, Engine Builder: Mitsubishi 1 x S6R-MPTK, 4 Stroke 6Cy. 170 x 180, Mcr: **640 kW** Design: Mitsubishi, Engine Builder: Mitsubishi 1 x S6R2-MPTA, 4 Stroke 6Cy. 170 x 220, Mcr: **595 kW** Design: Wartsila, Engine Builder: Wartsila 3 x 8L20, 4 Stroke 8Cy. 200 x 280, Mcr: **1600 kW**

4.3.1 Carbon Capture Machine (CCM) on-board vessels

Due to the low TRL5 of CCM, definition of KPIs and end system requirements will mature in later versions of the report. Preliminary, KPIs and End System Requirements of Carbon Capture Machine, however, these will be revised in later version of the report:

- Based on land-based engine power (preliminary 146kW), the CCM system will be designed to absorb the corresponding proportion of CO_2 emissions
- Size: to fit 20ft container; but to be designed in a modular framework to use available space at land based testing and sea based demonstrations
    - Design in a modular fashion that can be positioned throughout the vessel

  - Optimisation of piping for minimum drop in efficiencies and less interruption on vessel operation
- Storage requirements of chemicals
  - NaOH, will need a room for storage tank that depends on test duration (several months at sea)
- High exhaust temperatures (ideally room temperature) so may need a heat exchanger to cool down
  - Can reclaim waste heat if not in competition with the TEE
- Access to sea water on-board (KPIs and end system requirements to be determined)

CCM to work with Scottish Association for Marine Sciences (SAMS ENTERPRISES LTD) as per the Grant Agreement.

4.4 ENGINEERING AND PREPARATIONS FOR RETROFITTING

KPIs and end system requirements will be defined in future versions/updates of this report.

4.5 RETROFITTING SHIPS

KPIs and end system requirements will be defined in future versions/updates of this report.

4.6 DEMONSTRATE GHG EMISSION REDUCTION BY >35%

KPIs and end system requirements will be defined in future versions/updates of this report.

4.7 COMMERCIALISATION APPLICATIONS

KPIs and end system requirements will be defined in future versions/updates of this report.

5. CONCLUSIONS

The first version of this report is to document the necessary End System Requirements and KPIs under deliverable D4.1 of WP4 due on M1. This document has recorded the initial requirements needed for:

- WP1 – Demonstrate retrofitting of existing fleets (led by UoS)
- WP2 – Land based testing and integration of solutions (led by CMMI)
- WP3 – Solutions development and scale-up (led by SINTEF)
- WP5 – Software tool catalogue for GHG-emission reduction solutions (led by PDM)

This is reports is scheduled to be updated on M6, M18, M36 (interim reports) and M48 (final report). Therefore, this is a "live" document which will be monitored and updated as needed throughout project activities. Note, the first version of this report includes feedback and preliminary requirements of the technologies to be tested. These have been obtained from partners at the Green Marine Kick-Off Meeting (15th-16th February 2023, Larnaca, Cyprus; physical and online participation) and subsequent meetings.

Note that at this early stage of the report, some KPIs and End System Requirements are qualitive and quantitative.

REFERENCES

[1] G. Mallouppas, E. A. Yfantis, C. Frantzis, T. Zannis and P. G. Savva, "The Effect of Hydrogen Addition on the Pollutant Emissions of a Marine Internal Combustion Engine Genset," *Energies,* vol. 15, no. 19, pp. 1-13, 2022.

[2] AMETEK Land , "Lancom 4 User Guide," AMETEK Land , Dronfield, UK.

[3] Adash, *User Manual: VA5 Pro A4404 – SAB Virtual Unit,* Adash, 2022.

[4] M. Sandru, E. M. Sandru, W. F. Ingram, J. Deng, P. M. Stenstad, L. Deng and R. J. Spontak, "An integrated materials approach to ultrapermeable and ultraselective CO2 polymer membranes," *Science,* vol. 376, pp. 90-94, 2022.

[5] T.-J. Kim, M. W. Uddin, M. Sandru and M.-B. Hägg, "The effect of contaminants on the composite membranes for CO2 separation and challenges in up-scaling of the membranes," *Energy Procedia,* vol. 4, pp. 737-744, 2011.

[6] M. Hagg, A. Lindbrathen, S. Nodeland and T. Cantero, "Pilot demonstration - reporting on CO2 capture from a cement plant using hollow fiber process," *Energy Procedia,* vol. 114, pp. 6150-6165, 2017.

[7] M. Sandru, T.-J. Kim, W. Capala, M. Huijbers and M.-B. Hagg, "Pilot scale testing of polymeric membranes for CO2 capture from coal fired power plants," *Energy Procedia,* vol. 37, pp. 6473 - 6480, 2013.

[8] A. Einbu, T. Pettersen, J. Morud, A. Tobiesen, C. Jayarathna, R. Skagestad and G. Nysæther, "Energy assessments of onboard CO2 capture from ship engines by MEA-based post combustion capture system with flue gas heat integration," *International Journal of Greenhouse Gas Control,* vol. 113, no. 103526, pp. 1 - 12, 2022.

[9] IHS Markit Global Sarl, "SeaWeb; S&P Global Maritime & Trade," IHS Markit Global Sarl, 2023. [Online]. Available: https://maritime.ihs.com/Account2/Index . [Accessed 2023].

APPENDIX A: SEPARAPTOR TECHNOLOGY

Electricity is used to power the piezos that generate high frequency sound waves. A standing wave is formed between the piezos (distance 6-8 cm), this is an open structure allowing air to flow through without any restriction. Where the nodes meet, the pressure is zero and agglomeration of nanoparticles occurs. Nanoparticles act like a gas, and not as a particle, and under these circumstances they will remain situated in this node (pressure is zero). They will bound to each other and to larger particles to form even more larger particles. This agglomeration occurs for nanoparticles sizes 1 to 5000 nm (or higher) for: particles, bacteria, metal salts, organics, acidic compounds, aerosols and *viruses*. The agglomeration of nanoparticles is well known. This has been identified by the US EPA in roadside measurements which classified four modes i.e. nucleation (average particle diameter: 6 nm), aitken (20 nm), accumulation (350 nm) and coarse mode (6,7 µm)[1]. These agglomerated particles do not breakdown in smaller particles after assimilation. So once assimilated the size can be larger than 2 µm. The following figure shows the working principle. The formed particles can be removed with a filter or a 2nd layer of piezos as shown in the figure, that guide the particles to the side of the pipe wall exiting the gas flow (or entering an open filter). For the viro-blocker the aim is to apply UV-light.

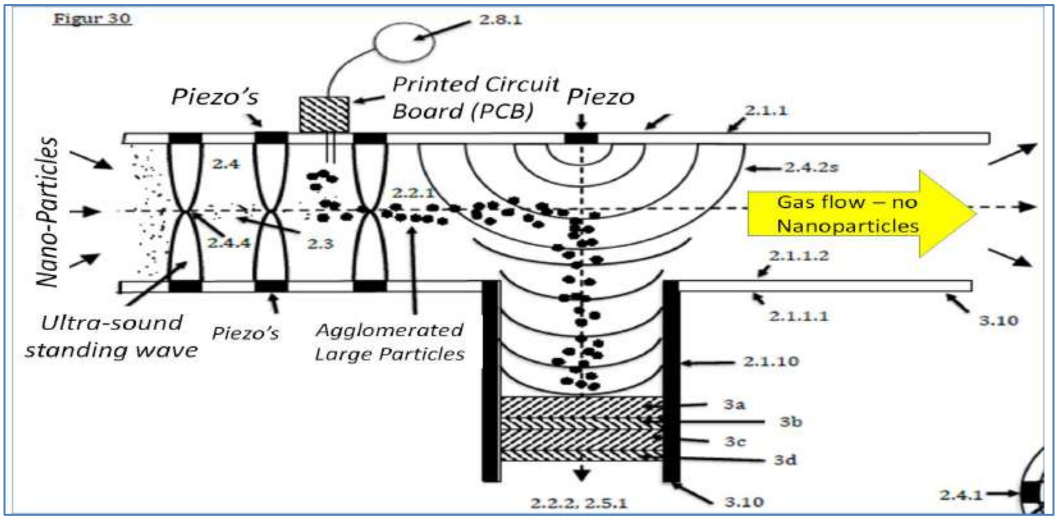

Figure 1A. Schematic of agglomeration of nanoparticles (viruses, aerosols etc.) using ultra-sound

Typical HVAC filters have an MPPS around 200–300 nm, whereas the MPPS of high efficiency (HEPA and ULPA) filters is smaller, according to ISO 29463 mostly in the range from 120 nm to 250 nm. This is exactly the size of the SARS CoV-2 where the HEPA and ULPA filter exhibit the lowest filter efficiency.

[1] https://openi.nlm.nih.gov/detailedresult.php?img=PMC2761850_1743-8977-6-24-1&req=4

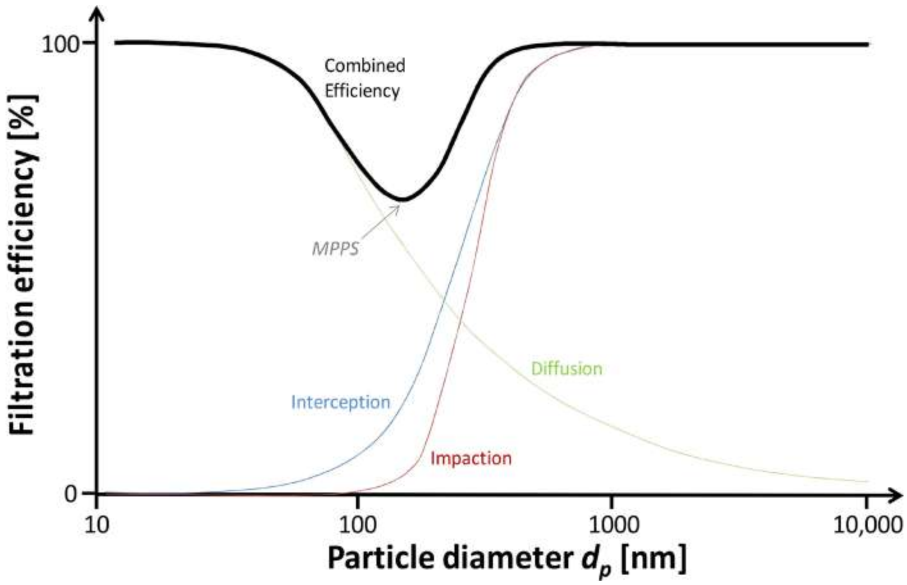

Figure 2A: Filter gap demonstrated as exemplary fractional filtration efficiency of filters. Adapted from Hinds, W. Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles; Wiley: New York, NY, USA, 1999.

As can be seen from Figure 2A, the filtration efficiency for small nanoparticles is very high, but decreases with increasing particle size until it reaches a minimum, before interception and impaction become dominant. Fractional filtration efficiency curves have been experimentally determined down to the nanometer size range for flat sheet media samples, wire screens, and respirators. Recently, a method has been developed to determine the fractional filtration efficiency of flat sheet media in a particle size range from 3 nm to 500 nm and successfully undergone an inter-laboratory validation. Experimental studies were also used to verify numerical data.

According to EN 779, the classes of full-scale HVAC filter cassettes (≤F9) are only rated based on the fractional filtration efficiency at a particle size of 0.4 µm. It is determined for a polydisperse DEHS test aerosol using an optical aerosol spectrometer. As of now, an established method to determine the fractional filtration efficiency of full-scale HVAC filters down to the nanometer size range is lacking. Published data on the filtration efficiency of HVAC filter cassettes for nanoparticles are therefore scarce. Hecker and Hofacre investigated for the US Environmental Protection Agency (EPA), how the filtration efficiency of HVAC filters with different MERV classes (according to ASHRAE 52.2) changes with filter aging for a wide particle size range from 30 nm to 10 µm. In their study they used a potassium chloride (KCl) aerosol, but do not specify how it was generated. Their data were later used by Azimi et al. to estimate the filtration efficiency of HVAC filters for ambient fine and ultrafine particles. Stephens and Siegel determined the fractional filtration efficiency for particle sizes ranging from 7 nm to 100 nm in situ in HVAC systems with MERV4 to MERV16 filters, using ambient aerosol. According to EN 1822 only the measurement of the deposition efficiency in MPPS, as well as a leak test, is carried out for full-scale filters.

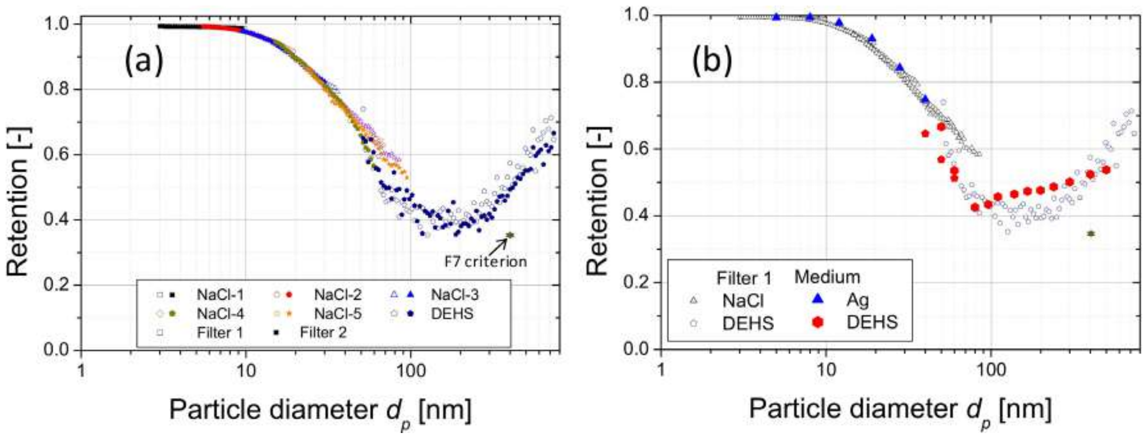

Figure 3A: Exemplary results for (a) two identical full-scale F7 filter cassettes, flow rate 4250 m3/h, tested with different NaCl and DEHS aerosols (see Table 3); open symbols: filter 1, closed symbols: filter 2; (b) comparison of results from filter cassette 1 with data obtained from media sample. Source: Atmosphere 2020, 11(11), 1191; https://doi.org/10.3390/atmos11111191.

The maximum efficiency found in this study was approximately 35% for F7 HEPA Filter systems.

Under normal working conditions there would be two PCBs with piezo's and UV light diodes across opposite other. A standing wave is formed between the piezos (distance 6-8 cm), shown in Figure 3A. This is an open structure allowing air to flow through without any restriction. Where the nodes meet, the pressure is ideally zero and agglomeration of nanoparticles occurs. However, there is allways motion. They will bound to each other and to larger particles to form even more larger particles. This agglomeration occurs for nanoparticles sizes 1 to 5000 nm (or higher) for: particles, bacteria, metal salts, organics, acidic compounds, aerosols and *viruses*. The agglomeration of nanoparticles is well known. This has been identified by the US EPA in roadside measurements which classified four modes i.e. nucleation (average particle diameter: 6 nm), aitken (20 nm), accumulation (350 nm) and coarse mode (6,7 µm). These agglomerated particles do not breakdown in smaller particles after assimilation. So once assimilated the size can be larger than 2 µm.

The particle number size-distribution (PSD) and even more distinct the surface- and the volume size-distribution of the particle size typically exhibit one or several modes which result from different source and sink mechanisms. These modes overlap in the size spectrum, because the particles sizes continuously change due to condensation, coagulation, fragmentation and evaporation. In Figure 4A schematic view of a multi-modal particle size distribution illustrates the different growth- and shrink processes: The smallest particles form by Gas-to-particle conversion (nucleation mode) and grow through condensation of gases and water vapour, initially relatively fast (Aitken mode) and from size of 50-100 nm diameter (accumulation mode) slower in size by coagulation and coalescence. Beyond particle sizes of several 100 nm the efficiency of thermodynamic (evaporation, sublimation) and mechanical sink mechanisms (e.g. sedimentation, deposition/impaction) strongly increases. Simultaneously, fragmentation/grinding- and evaporation processes act against a growth of particle sizes.

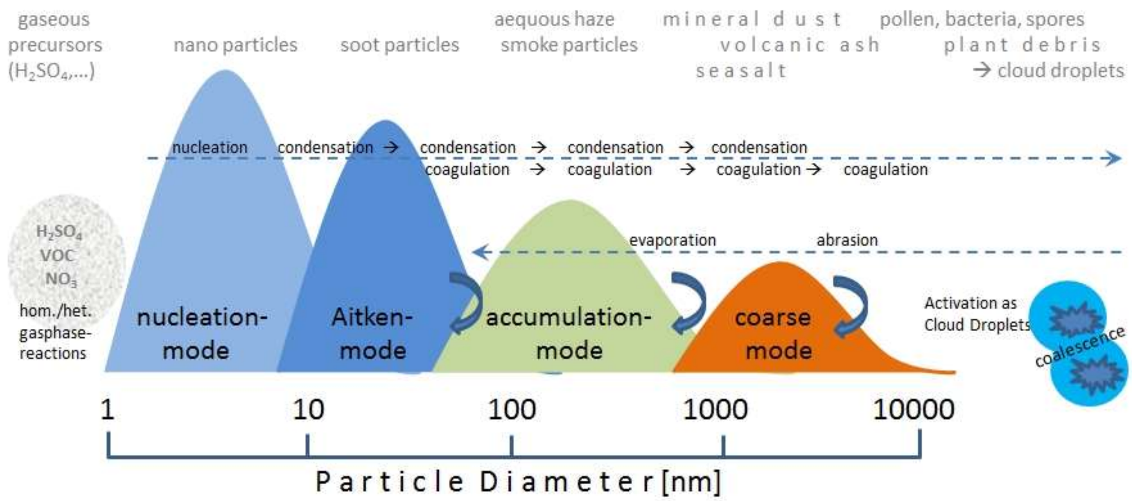

Figure 4A: Schematic multi-modal particle size distribution with typical transformations and example particle types within each mode. Source:
https://www.dwd.de/EN/research/observing_atmosphere/composition_atmosphere/aerosol/cont_nav/particle_size_distribution_node.html

Directly emitted (primary) particles are distinguished from secondary particles which are formed by transformations. In the atmosphere each particle mode has its specific sources. Nucleation particles form by condensation of super-saturated gases, Aitken particles from the nucleation mode or incomplete combustion (e.g. soot), accumulation mode particles from Aitken particles or intensive mechanical processes and coarse particles from accumulation mode particles and moderate mechanical processes (e.g. abrasion of mineral dust, volcanic ash, sea spray). In most cases the modes are not monodisperse (of a single size) but polydisperse and the size distribution can be described mathematically in good approximation by one or more logarithmic normal distributions of the particle number concentration dN/dlogr or dN/Dlnr respective the particle surface- and volume-concentration:

$$\frac{dN}{d\ln r_P} = \frac{N_g}{\sqrt{2\pi}\ln\sigma_g}\exp\left[-\frac{(\ln r_P - \ln r_g)^2}{2(\ln\sigma_g)^2}\right]$$

with the geometric mode radius r_g and the mode width σ_g ($\sigma_g \approx 1.2 – 2$). In the troposphere the envelope of the modal PSD often can be approximated by a power law number size-distribution $N(r) \sim r^{-2...4}$ (Junge-distribution), but near sources and sinks it will in general be quite different. Often, volume- or mass size-distributions are used to highlight specific details of the size spectrum ($dVdlogr = dN/dlogr * 4\pi r^3/3$ or $dMdlogr = dN/dlogr * 4\rho\pi r^3/3$, with density ρ).

The nanoparticles aggregate due to dangling bonds. In chemistry, a dangling bond is an unsatisfied valence on an immobilized atom. An atom with a dangling bond is also referred to as an immobilized free radical or an immobilized radical, a reference to its structural and chemical similarity to a free radical. In order to gain enough electrons to fill their valence shells (see also octet rule), many atoms will form covalent bonds with other atoms. In the simplest case, that of a single bond, two atoms each contribute one unpaired electron, and the resulting pair of electrons is shared between them. Atoms which possess too few bonding partners to satisfy their valences and which possess unpaired electrons are termed "free radicals"; so, often, are molecules containing such atoms. When a free radical exists in an immobilized environment (for example, a solid), it is referred to as an "immobilized free radical" or a "dangling bond".

Both free and immobilized radicals display very different chemical characteristics from atoms and molecules containing only complete bonds. Generally, they are extremely reactive. Immobilized free radicals, like their mobile counterparts, are highly unstable, but they gain some kinetic stability because of limited mobility and steric hindrance. While free radicals are usually short lived, immobilized free radicals often exhibit a longer lifetime because of this reduction in reactivity.

A1. Toxicity of Nanoparticles

Nanomaterials appear to have toxicity effects that are unusual and not seen with larger particles, and these smaller particles can pose more of a threat to the human body due to their ability to move with a much higher level of freedom while the body is designed to attack larger particles rather than those of the nanoscale. For example, even inert elements like gold become highly active at nanometer dimensions. Nanotoxicological studies are intended to determine whether and to what extent these properties may pose a threat to the environment and to human beings. Nanoparticles have much larger surface area to unit mass ratios which in some cases may lead to greater pro-inflammatory effects in, for example, lung tissue. In addition, some nanoparticles seem to be able to translocate from their site of deposition to distant sites such as the blood and the brain.

Nanoparticles can be inhaled, swallowed, absorbed through skin and deliberately or accidentally injected during medical procedures. They might be accidentally or inadvertently released from materials implanted into living tissue. One study considers release of airborne engineered nanoparticles at workplaces, and associated worker exposure from various production and handling activities, to be very probable.

Appendix B: Safety protocols expected from CalMac's contractors – Managing contractors process

CalMac safety protocol internal document follows overleaf.

Management of Contractors on CFL Operated Shore Locations

Process

Rev No. and Date	Description of Revision	Approved by	Authorised by
Rev 0 28/10/20	Final draft – for release	HSQE Manager	HSQE Director
Rev 1 November 2021	Review and amend for inclusion in HSE Manual	HSQE Manager	HSQE Director

1. Introduction

CalMac Ferries Ltd. (the Company) recognises its moral responsibility and legal duty under the Health and Safety at Work Act 1974 to ensure the health, safety and welfare of all employees and any other person involved in and affected by its shore operations. This includes contractors and sub-contractors ("Contractors").

As part of this general commitment and specifically in relation to Contractors, in compliance with The Management of Health and Safety at Work Regulations 1999 (the Management Regulations) the company will ensure consideration is given to Contractors when undertaking:

- Risk assessments;
- Setting up emergency procedures;
- Co-operating with others, including other employers, on health and safety matters;
- Providing health and safety information.

To ensure compliance with the relevant legal and contractual obligations the Company will:

- Ensure a structured approach to health, safety and welfare for duties and activities which are undertaken by Contractors at CFL operated ports, including any other shoreside locations at which CFL retain responsibility for certain or specific operations.
- Ensure that adequate information is provided to all Contractors.
- Ensure that all hazards that could affect Contractor's personnel are clearly defined and controlled.
- Ensure that the interests of company operations, staff, customers, site users, visitors and the environment are protected before and during any work carried out by Contractors.

This process sets out the arrangements in place for the safe management of Contractor activity and provides guidance on the preparation for site visits and undertaking Contractor Induction.

To ensure that all work undertaken by outside contractors is carried out safely, with the minimum interference to the company's operations, having regard to relevant statutory requirements and company standards, and with the minimum impact on the environment.

This process defines Responsible Managers as any person with managerial or supervisory responsibility for a department, location, site, activity or number of colleagues.

For work on shore the term Responsible Manager includes but is not exclusive to Line Manager, Harbour Manager, Port Manager, Harbour Supervisor and Port Supervisor as appropriate.

Guidance in support of this process are available from the HSE Manual on the Company Management System.

2. Scope

This process applies to all contractors engaged by any party to carry out work at all CFL operated ports, including any other shoreside locations at which CFL retain responsibility for certain or specific operations.

This process is also applicable for any planned work being undertaken by any 3rd Party when the work being undertaken may have an impact upon CFL operations.

This process is applicable from the planning stage through to completion of all work.

2.1 Exceptions

This process is applicable for Contractors working on vessels – but only specifically to any direct interaction with shoreside and/or harbour operations. Work onboard vessels that has no direct impact on or places any risk upon the shoreside and/or harbour operations is not in scope. See further detail in section 3.1.2.

Specific arrangements for the management of commercial diving contractors can be found within the Diving section of the HSE Manual. Detailed within are all relevant information, guidance and necessary forms.

3. Responsibility

3.1 All persons responsible for engaging contractors (the Client)

Must ensure that the designated contractor is competent to carry out the required works safely and in compliance with relevant statutory requirements and company standards.

The person engaging the contractor (the Client) must liaise with and involve the Responsible Manager in the planning of any contractor works or activities that may directly affect the operation of the port, shore or harbour areas and shall provide the Responsible Manager with copies of the Contractor RAMS a minimum of **four** days in advance of the proposed work.

The Responsible Manager will require additional advance notice for significant works and works with the potential to seriously disrupt operations.

In certain cases, primarily with critical or emergency works it may not be possible to produce RAMS within the required time period. In this case prior agreement must be reached with the Responsible Manager and RAMS must be provided regardless, prior to any works commencing on site, with the Responsible Manager afforded necessary time to review and comment as applicable.

Where the Client is CMAL, RAMS shall be submitted by CMAL and the Port Diary updated by CMAL (noting the date and timescale of works and the relevant RAMS reference) using the CMAL IT reporting system (SharePoint).

Where the Client is CFL, support and guidance in relation to the appointment of contractors may be sought from the CFL Procurement Dept.

3.1.1 Contractor RAMS

In this context, 'Contractor RAMS' shall include appropriate Risk Assessment & Method Statements but may also include other appropriate documentation such as: Contractors programme, scope of works, insurances, drawings, contact details, Construction Phase Health & Safety Plan and so on.

3.1.2 Work onboard Vessels

The process as defined in *Section 1 – Vessel Safe Working Practices* of the HSE Manual, in the CMS, will apply for the management of contractors onboard CFL Ferries.

However, in all circumstances the Port Manager must be provided with sufficient details in order to evaluate the interaction with shoreside and/or harbour operations and ensure necessary controls are implemented. In this case the Port Manager will undertake the relevant responsibilities as defined for The Responsible Manager in Section 3.2.

Contractors intending to work on board a vessel at berth in a CFL Operated Harbour, must report to the Responsible Manager at the Port in the first instance.

The Responsible Manager at the Port will:

- Contact the vessel to confirm that they are expecting the contractor;
- Finalise and confirm the proposed work;
- Confirm all shore side safety, environmental, security and operational factors are suitably managed, where appropriate;
- Issue the contractor identification badge, where appropriate;
- Confirm site opening times and availability of parking and storage;
- Collect identity badges at the end of each working day, as appropriate.

The vessel Master/Skipper is responsible for managing all contractors aboard the vessel and will delegate a responsible person to manage the contractor, whilst onboard, as appropriate.

3.1.3 Work being undertaken at locations not directly within CFL responsibility but where CFL may be impacted in some way

The Port Manager must be made aware of the planned works and provided with sufficient details in order to evaluate the interaction with shoreside operations and ensure necessary controls are implemented. In this case the Port Manager will undertake the responsibilities as detailed in step 3.2.

3.2 The Responsible Manager

Has overall responsibility for the management of Contractor operations to ensure the work is carried out safely, with the minimum interference to the company's operations, having regard to relevant statutory requirements and company standards, and with the minimum impact on the environment.

The Responsible Manager will review the provided information, and shall provide the following response to the Client and/or Contractor (dependant on the specific circumstances):

1. Advise where the planned works will or may affect ferry, port or harbour operations and raise any issues and concerns.
2. Provide information on known operational hazards and risks with the potential to affect the contractor works.

The Responsible Manager shall provide such review/comments to the contractor direct or via the Client, as appropriate.

The Responsible Manager shall NOT comment on the methods of work proposed by the Contractor, unless they have specific concerns that the proposed method of work is clearly unsafe and/or will have direct impact on the shore, port or harbour operations.

Specifically, for work at harbours or within operated facilities which are operated by CFL on behalf of CMAL the HOM – Contractor RAMS Process should be referenced by the Responsible Manager for detailed instruction relating to:

1. Review of RAMS provided by CMAL;
2. Review and Upload of RAMS provided by any other Client than CMAL;
3. The update of the CMAL SharePoint Port Diary by the Responsible Manager.

4. Process

4.1 The process starts with a decision to carry out work which is defined in Scope above.

4.2 Initial discussion must be undertaken between the person engaging the contractor (the Client) and the Responsible Manager to ensure clarity and understanding of on-site requirements. In relation to Vessel work this will also include the Port Manager.

4.3 Contractor RAMS will be provided for review, with all relevant feedback given by the Responsible Manager (as per the requirements detailed in Section 3 Responsibilities).

4.4 Start date and time for commencement of work must be agreed in advance.

4.5 All contractors arriving at site must report to the Responsible Manager prior to the commencement of any works and **every day** thereafter, or at an agreed interval. Agreed interval to be documented within the formal **Contractor Site Induction**.

4.6 Using the Contractor Port Induction Form 2.348 the responsible manager will conduct a Site Induction with the contractor to;

a) Finalise and confirm the proposed work;
b) Confirm all safety, environmental, security and operational factors are suitably managed;
c) Issue the contractor identification badge;
d) Issue the **Rules and Conditions for Contractors on Site**;
e) Confirm any additional site information on operational hazards and risks with the potential to affect the contractor works;
f) Provide details of emergency contact and arrangements; including local first aid provision;
g) Provide details of available site services and welfare facilities;
h) Confirm site opening times and availability of parking and storage;
i) Complete the relevant **Permits to Work**;
j) Provide details on collection of identity badges at the end of each working day.

4.7 Where face to face site meetings are not possible owing to logistics, operational constraints and/or any restrictions in force the Client, Contractor and Responsible Manager shall agree methods for ensuring that necessary Site Inductions and Permits to Work (as described in 4.6 above) are still completed in line with contingencies in place. The contractors work shall not proceed until the necessary elements are undertaken with completed records in place.

4.8 The Responsible Managers will only allow contractor employees on site on the successful completion of all aspects of the Site Induction.

4.9 The Responsible Manager will monitor the contractor at regular intervals, as deemed appropriate by the manager, to ensure the contractor follows the agreed working methods.

4.10 The Responsible Manager retains the right to stop work and/or remove contractors from site, where in their opinion, an act or omission by the contractor has the potential to cause injury, damage to property, environmental impact or unplanned disruption to operations.

4.11 In the event of unacceptable performance or behaviour, the contractor or individual employees may be removed from site.

4.12 Such events of stopping work or removal of a contractor from site must be reported by the Responsible Manager to the Client, in addition to any such incident or near miss PURE reporting.

4.13 The Responsible Manager has access to support, guidance and information on all aspects of managing contractors at ports or within shore facilities from;

- CMS HSE Manual;
- HSQE;
- Harbour Operations Department.