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Project acronym: ENGIMMONIA

Project title: Sustainable technologies for future long distance shipping towards complete decarbonisation

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Thematic Priority: LC-MG-1-13-2020 - Decarbonising long distance shipping

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Confidential Deliverables

Confidential Deliverables

List of Confidential Deliverables

WP No	Del Rel. No	Title	Lead Beneficiary	Nature
WP1	**D1.1**	Executive Action Plan	RINA-C	Report
WP1	**D1.2**	Data Management Plan	RINA-C	Report
WP1	**D1.3**	ENGIMMONIA risk matrix and project objectives/impacts KPI Panel for project reporting/tracking	RINA-C	Report
WP3	**D3.1**	Exhaust gas emission mapping for 4-stroke ammonia engine operations	DTU	Other
WP3	**D3.2**	Exhaust gas emission mapping for 2-stroke ammonia engine operations	MAN	Other
WP3	**D3.3**	Lessons learnt from emission measurements for ammonia engine operations	MAN	Report
WP4	**D4.1**	Simulation software setup for the modelling of catalytic processes in the flue gas of the ammonia dual-fuel engine	AUTH	Report
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WP6	**D6.3**	HSE and regulatory aspects of ENGIMMONIA solutions to be installed on board	RINA-C	Report
WP7	**D7.1**	Integrated numerical platform for techno-economic modeling	NTUA	Report
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WP9	**D9.6**	First Exploitation Report and KERs identification	RINA-C	Report
WP10	**D10.1**	H-Requirements No.1	RINA-C	Report
WP10	**D10.2**	POPD-Requirements No.2	RINA-C	Report

Confidential Deliverables

D1.1 – "Executive Action Plan"
(RINA-C)

Executive Summary

D1.1 provides a more detailed description of the tasks and activities in the project than what is contained within the Grant Agreement, and joins this with the Governance Structure as set out in the Consortium Agreement (CA) and the procedures to be followed for collaboration and management of the project, presented by RINA-C during the KOM and agreed by all partners.
In details the following deliverable contains the description of the Work Packages, including tasks descriptions and relative involvement of the beneficiaries and estimated man effort. An overview of the related deliverables and milestones will also be included.
Special attention was paid to the synchronization of the activities as presented in the Grant Agreement after the recent Kick-Off of WP activities, in order to understand if there needed to be any changes.
Furthermore D1.1 will constitute, together with D1.2 and D1.3, a "project management package" where all partners will be able to find all the guidelines and tools related to proper project Management, Monitoring And Assessment. Such Package will be a sort of "Manual" about "how to run/participate to the project".
Report describes furthermore consortium agreed procedures related to how to manage the project and consortium partners' role and responsibilities.
It should be noted that as part of the outcome from the review and synchronisation of activities, there are some deviations to the Grant Agreement in terms of task, milestone and deliverable start and end dates. These are considered as relatively minor as they don't affect the overall completion of project objectives and have only a small impact on other parts of the project.

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D1.2 – "Data Management Plan"
(RINA-C)

Executive Summary

D1.2 represents the ENGIMMONIA Data Management Plan at month 11 (delayed from original M6 deadline mostly to understand which type of data would have been generated during the first RP1 and give consistency to the report). The scope of this deliverable is to describe the data management life cycle for the data to be collected, processed and/or created in the framework of the ENGIMMONIA project.
In particular, this document specifies how the ENGIMMONIA research data will be handled in the framework of the project as well as after its completion.

More in detail, the report indicated:

- what data will be collected, processed and/or created and from whom
- which data will be shared and which one will be maintained confidential
- how and where the data will be stored during the project
- which backup strategy will be applied for safely maintaining the data
- how the data will be preserved after the end of the project

Moreover, the deliverable presents a preliminary strategy for the ethic and correct management of some data generated in the framework of ENGIMMONIA project activities to be further presented in WP10 deliverables.
The present Data Management Plan has to be considered as a living document, and any future update or change in the ENGIMMONIA data management policy will be included in the periodic reports or will be specified in the deliverables related to the specific tasks.

Confidential Deliverables

D1.3 – "ENGIMMONIA risk matrix and project objectives/impacts KPI Panel for project reporting/tracking"
(RINA-C)

Executive Summary

D1.3 provides a more detailed description of how project coordinator (RINA-C), Scientific Coordinator (NTUA) and Steering Committee will monitor and supervise project activities to guarantee a high-quality R&D and adherence to project objectives.
In details the deliverable introduces Key Performance Indicators and metrics/specs relevant to be monitored to follow the status of i) project advancement, ii) project results relevance for EU R&D, iii) adherence to project objectives and Grant Agreement initial targets.
An overview of the KPIs to track project advancement and technical performances both at project and WP per WP level is therefore presented.
The project KPI panel for the evaluation of ENGIMMONIA technologies benefits to be used in simulation, pilot testing and replication activities is defined. The KPIs were defined including respective quantification methods to be considered to be integrated in WP2-4-7 models and to be used to post-process testing data from WP3-5-6.
Further than KPIs already presented in the Grant Agreement (and recapped in this report also to facilitate project advancement tracking and project reporting) other "More general" project KPIs were identified and classified into the following four categories: technical, economic, environmental, and mixed.
In summary, this document has provided a detailed description of project KPIs to be used to track all WP activities in the project, and has updated the Grant Agreement project Risk Matrix, also to identify per each WP specific KPIs that would be helpful to track risks occurrence and milestones achievement. This is a relevant aspect particularly considering that the project started in a complex historical period (Pandemic era) bringing force majeure reasons that could hinder risks for project smooth progress.

All of this will allow for a smoother, more collaborative and successful project, as well as to a proper tracking of both activities, facilitating project reporting activities and benchmarking of ENGIMMONIA innovation with other technologies.

The KPIs defined and presented in this deliverable lay the groundwork for all project development and this document will therefore act as a living document to be further updated along project lifetime.

Confidential Deliverables

D3.1 – "Exhaust gas emission mapping for 4-stroke ammonia engine operations" (DTU)

Executive Summary

D3.1 corresponds to task 3.1 (T3.1) in which an "Exhaust gas emission mapping for 4-stroke ammonia engine operations" is performed at and by DTU.
The most obvious requirements for ammonia to become a successful green alternative to traditional marine fuels are that:

- the energy efficiency of an ammonia marine engine should match the high efficiency of marine engines burning other green fuels. Otherwise, it may be hard to compete on cost per ton saved CO_2 basis.
- the saving of CO_2 emission by using carbon free NH_3 is not sacrificed by emission of another stronger greenhouse gas, such as N_2O.
- harmful emission of NOx and NH_3 is below regulation limits.

Previous studies have shown that NH_3 is difficult to ignite, which however also means that knocking resistance is large. The planning of task 3.1 was based on previous experience with NH_3/H2 combustion made on the same engine as intended for the emission mapping. Several safety measures should be implemented in order to resume NH_3 experiments for ENGIMMONIA and other projects. A long row of modifications also had to be made in order to use spark ignition developed in another project and enable wider parameter variations of the experiments with high accuracy of measurements needed for the ENGIMMONIA project.
The extensive improvements to the test engine has proven successful in terms of energy efficient engine operation on NH_3 to promote ignition and combustion. Measured emission levels have also been promising. However, the engine out NH_3 level and NOx level should preferably match each other on molar basis in order to obtain complete reduction in after treatment systems. The engine out N_2O level should preferably also be reduced.

Confidential Deliverables

D3.2 – "Exhaust gas emission mapping for 2-stroke ammonia engine operations" (MAN)

Executive Summary

D3.2 corresponds to task 3.2 (T3.2) in which "Exhaust gas emission mapping for ammonia 2-stroke marine engine" is performed by MAN. This deliverable describes details of the experimental methods and setup.
Tests of ammonia as fuel in a large marine 2-stroke engine using the MAN-ES dual fuel platform have successfully been carried out on a single cylinder of a multi cylinder engine. This deliverable concerns the means of measuring and quantifying the emissions from the ammonia cylinder across a wide range of parameter variations. The methods for isolating the emissions from the ammonia cylinder have been described in detail.

- Ammonia and nitrous oxide have been quantified from the total exhaust gas from the engine, as these species are exclusive to the ammonia cylinder.
- NOx emissions have been quantified by sampling directly from the exhaust bend of the ammonia cylinder, synchronous with the exhaust valve opening.
- Hydrogen was measured from both the total and single cylinder.
- Other species of interest such as hydrogen cyanide and iso-cyanic acid were not detected in significant amounts.

The test results include the range of the various emissions that were measured during the parameter variations.

Confidential Deliverables

D3.3 – "Lessons learned from engine testing campaign"
(MAN)

Executive Summary

D3.3 corresponds to task 3.3 (T3.3) in which the lessons learned from the test campaign on ammonia combustion in a large marine 2-stroke engine are discussed. A large facility has been built/installed at the Research center in Copenhagen, designed to facilitate testing of ammonia as fuel for a large 2-stroke marine engine. The lessons learned from these tests are as follows:

- Ammonia is compatible with the dual fuel combustion process
- The stability of the process respect to other commercial engines was defined
- Nitrous oxide emissions were quantified
- Ammonia and NOx emissions were quantified
- Hydrogen emissions were quantified
- Hydrogen cyanide emissions were quantified
- Isocyanic acid emissions were quantified.

Confidential Deliverables

D4.1 – "Simulation software setup for the modelling of catalytic processes in the flue gas of the ammonia dual-fuel engine"
(AUTH)

Executive Summary

The objective of D4.1 is to present the simulation platform that will be used for setting up the models, which will be then implemented to support the development and optimisation of the EATS of the ammonia engine. The emission abatement system will comprise a deNOx (SCR) catalyst and a deN2O catalyst, the latter depending on the N_2O emission levels at the ammonia engine outlet. In this context, the simulation models will support the improvement of existing SCR systems when these are operating with the flue gas of the ammonia engine (Task 4.2), while they will be also used for the design and evaluation of the deN2O system that will be developed in Tasks 4.3 to 4.6. The accurate development of the models for both systems will be supported by the appropriate experimental activities conducted within WP4, with appropriate input received from WP3.

The first step is to develop a model for the SCR catalyst. To that aim, a template model was set up, incorporating all the necessary features of the software. In order to test its functionalities, some indicative model runs were performed, using test data sourced in the literature. It is clarified here that this was done solely for demonstration purposes and did not intend to reproduce the experimental data of the literature, for which not all the relevant information was known.

Initially, the model was calibrated with the literature test data, aiming at demonstrating the procedure and illustrating an indicative comparison between simulation and experimental results. The target was not to fully reproduce the tests, but rather present the procedure and the functionalities of the software.

Using this template SCR model, a mini parametric analysis was performed aiming at presenting the functionalities of the model and evaluating qualitatively the impact of some parameters on NO_x conversion efficiency.

Confidential Deliverables

D4.4 – "Active powder catalyst for N2O abatement"
(DTU)

Executive Summary

The first version of D4.4, with the main findings achieved until M36 of the project, concluded to the principal material that can be effectively used in the EATS of the ammonia engine. This provides already the basis for the development of the relevant technology up to TRL 5 in the following tasks of WP4. Nevertheless, further investigation will be conducted towards optimizing the exact formulation of the catalyst, building on top of the findings achieved until M36 and setting the basis for developing the relevant technology to higher TRL. In this direction, an updated version of D4.4 will be provided in M45. It is underlined that this schedule does not affect the activities of the following tasks of WP4. The overall objective of this deliverable is to develop a catalyst for N_2O abatement from the flue gas of ammonia-fuelled ship engines. A wash coating slurry based on the main catalytic material concluded in this task will be formulated in Task 4.4 and will be applied on a monolith substrate to yield a catalytic monolith. The coated monolith will be further characterized and evaluated in Task 4.5, providing deeper insights into the technologies that can be integrated in the EATS of the ammonia-fuelled engine.
In D4.4 detailed literature study was carried out to screen different active materials for the removal of N2O by either direct decomposition or reduction using ammonia (NH_3). Based on the literature review and the knowledge gaps identified therein, a variety of different catalysts were synthesized and tested for N_2O abatement. The catalysts were synthesized by different techniques and were tested for either direct N_2O decomposition or NH_3-assisted N_2O reduction in a reactor in a wide temperature range. The effect of presence of water in the feed gas on the catalytic activity of synthesized materials was also evaluated. The catalysts were also characterized to determine the phase composition, elemental composition, and BET surface area of the materials.

Confidential Deliverables

D5.3 – "Design/material identification for adsorption chiller for use in long distance vessels" (FAHR)

Executive Summary

Adsorption chillers and heat pumps utilize heat, for example renewable heat from solar plants, or waste heat, from engines, generators or combined heat and power plants (CHP), district or process heat, to generate cooling without the use of mechanical compression. The thermodynamic cycles of the adsorption chillers / heat pumps are sometimes called "thermal compression" and are based on the periodic heating and cooling of an adsorbent (highly hygroscopic substance) within a reactor also called a sorption generator or simply an adsorption bed.

The vessels are a very attractive application case for the adsorption cooling because:

a) Availability of waste heat in large quantities and good quality (suitable temperature level and heat transfer medium).
b) Large cooling demand, especially on passenger vessels such as ferries and cruise ships.
c) Availability of a heat sink with high heat capacity at beneficial temperature levels (sea water).
d) Benefits for the vessel operator and the environment are significant. The lower the electrical energy consumption of the HVAC system, the lower the fuel consumption and the longer range of the ship. In addition, the reduced fuel consumption directly leads to lower emissions of CO_2, sulphur, and nitrogen oxides.

The integration of the adsorption chiller on board of a vessel means planning of three hydraulic circuits, the drive circuit (HT), the re-cooling circuit (MT), and the cold-water circuit (LT)

The activity presented D5.3 has been carried out jointly by CNR and Fahrenheit and represents the first steps needed for the design of the sorption systems for the application in vessels. To this aim, a first screening was carried out on several sorption working pairs using data from experimental measurements carried out at CNR, in terms of sorption capacity and specific heat. Results from the measurements were used within a thermodynamic model developed by CNR to estimate the Coefficient of Performance (COP) and Specific Cooling Effect (SCE) for the various materials.
Finally, starting from design parameters from Fahrenheit and previous models available at CNR, dynamic evaluation was carried out at CNR. Also cooling capacity was investigated.
Results of the dynamic simulations obtained will be validated with the measurements that will start at M14 at CNR and possible other configurations will be evaluated.

Confidential Deliverables

D5.5 – "Design and Material identification for composite PV modules use in long distance vessels"
(TECNALIA)

Executive Summary

D5.5 describes the activity carried out under the Task 5.3 - Design and Development of lightweight PV Composite surfaces for vessels within WP5 - Development of clean energy solutions for marine application. The content of this deliverable refers to the selection of the materials involved in the manufacture of the PV modules, and the preliminary design layout of the structure and modules that will be installed in the project pilot vessels. In this task, the main work has been developed with the objective to select the best solution in terms of coating of the composite according to the marine application and the features of the PV module.
The study was focussed on two applications: (1) a general PV module application in the vessels deck and a (2) walkable area. For that, specific tests were carried out to select the more adequate coatings for the modules in those applications and environmental conditions.
For the PV module, two compatible coatings were tested, and different thickness were compared in terms of PV performance and durability. For this purpose, 15 single-cell modules were manufactured in composite and coated accordingly. To evaluate the coated modules performance, standard characterization techniques were employed, and the results of the measurements were analysed. Successively, specific ageing tests such as the damp-heat according to the PV international standard were carried out.
Finally, the selected coatings were exposed to outdoor conditions for 6 months and subjected to visual inspection in order to select the best option for the final prototype.
For the walkable PV module, 7 different coatings and 2 different anti-sliding additives were selected following the criteria of offering good anti-sliding properties and also suitable properties to guarantee the IEC 61215 standard. Additionally, a preliminary design of the shape and size of the modules with the suitable structure to fix it to the vessels deck was done. In addition, a mechanical check of these modules has been carried out for a certain wind load of in their most unfavourable orientation possible.

Confidential Deliverables

D6.1 – "ENGIMMONIA KPI Panel for demonstration"
(RINA-C)

Executive Summary

D6.1 reports the results of the activities carried on under task T6.1: Demo vessels baseline assessment of the ENGIMMONIA project. RINA-C and NTUA, in close collaboration with ANEK, FAMOUS, DANAOS, have defined a panel of Key Performance Indicators (KPIs) to provide a proper, quantitative and monitorable way for the continuous assessment of the impact of the ENGIMMONIA solutions.
The KPIs have been defined considering different parameters such as the size, type and routes of the vessels, their installed power capacity, cruise schedule, location and taking into account future projections of their energy demand and fuel type use.
The KPIs are supposed to encompass diverse aspects related to energy efficiency (fuel consumption, energy savings), economic viability (CAPEX, OPEX, ROI conditions), environmental impact (emissions, life cycle impact, RES share), practical feasibility (spatial efficiency, compactness, robustness, autonomy and reliability, invasiveness to ships' infrastructure and electric grid/thermal network and disruption of crew/passengers routine) and societal aspects.
The list of KPIs is taken and fully elaborated from D1.3 – "ENGIMMONIA risk matrix and project objectives/impacts KPI Panel for project reporting/tracking".
To these KPIs, few more have been added, specifically tailored on the technologies that are being integrated on the pilot ships, i.e. the Organic Rankine Cycle system (ORC), the Adsorption chiller and the photovoltaic panels.

Confidential Deliverables

D6.2 – "Engineering design of demo-vessels and integration of solutions to be demonstrated" (NTUA)

Executive Summary

D6.2 reports the results of the activities carried on under Task 6.2: "Engineering of demo-vessels and integration of solutions to be demonstrated" of the ENGIMMONIA project.
At the same time, with the help of RINA-C, general guidelines that can be used for the implementation of the above technologies, in various types of vessels, have been identified.
A general introduction of the demo vessels and the respective technologies is being made respectively, drawing data from the corresponding deliverables. Following, the general plan for action, is explained, including all the necessary steps, such as the basic and detailed engineering. Afterwards the final designs as well as the difficulties faced and the necessary amendments, are being discussed per ship. Stages of each technology module preparation and integration are deeply described.
A complete list of drawings is provided in an ANNEX, supporting the purpose of the Deliverable.

As an assistance to this deliverable and all necessary approvals, IMO guidance on treatment o innovative energy efficiency technologies is mentioned at the ned of this deliverable.

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D6.3 – "HSE and regulatory aspects of ENGIMMONIA solutions to be installed on board" (RINA-C)

Executive Summary

D6.3 describes the activity carried out during the Task 6.3 - HSE and regulatory aspects of ENGIMMONIA solutions to be installed on board within WP6 - Integration and testing of solutions on-board and full-scale evaluation.
The document is intended to provide a preliminary risk assessment for the installation of three technologies, i.e. an adsorption chiller system, PV panels and ORC cycle, in the ships involved in the project.
The risk assessment was performed by RINA-C together with the producers of the technologies, employing a HAZard IDentification (HAZID) analysis. This methodology allowed to preliminarily identify all the possible hazards posed by the implementation of the packages and to associate a risk ranking to them. In particular, the followed procedure was supported by the use of a hazard checklist, tailored for marine application. The checklist helped to identify hazards for each aspect of the design, implementation, operation and maintenance of the packages. Subsequently, a Risk Matrix was employed to qualitatively assess the risk associated to each hazard as a combination of the severity of consequences and the likelihood of the hazardous events; in particular, three risk areas were considered: low risk, medium risk and high risk.
In conclusion, the implementation of the three packages within the ships can be considered preliminary safe, even though HAZID represents a general qualitative analysis.

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D7.1 – "Integrated numerical platform for techno-economic modelling" (NTUA)

Executive Summary

D7.1 was prepared within the framework of Work Package 7 and it reports the results of the activities carried on under Task 7.1: "Numerical platform for assessing the integration of all solutions" of the ENGIMMONIA project. NTUA, in close collaboration with UNIGE and all the technology providers (ORCAN, FAHRENHEIT, TECNALIA, METIS), has prepared a numerical tool to predict the individual or combined performance of the ENGIMMONIA technologies on-board under real operating conditions.
An introduction to the already existing tools provided by UNIGE, is made, focusing on the needed input, provided outputs and means of calculation of the results.
The individual testing rigs created for mapping the performance of the ENGIMMONIA technologies are being presented. Unfortunately, by the time of this deliverable, there are still no data from the final testing campaigns of the respective modules. For both the 100kWel and 200 kWel ORC modules, a first model has been provided by ORCAN's in house testing campaigns.
For the adsorption chiller and the PV modules, there are still no available data for their performance, so data provided from TECNALIA and FAHR for already existing modules have been used.
Engine modelling and waste heat potential are also examined. Trip related data, including vessel's working load, engine's RPM, route, exhaust gas temperatures, as well as analysis of the ship's state (port time, anchorage, full speed sailing), can be provided by METIS to evaluate the waste heat potential of each provided vessel.

Confidential Deliverables

D9.3 – "Communication and Dissemination Plan"
(RINA-C)

Executive Summary

D9.3 gives an introduction of the steps of the communication and dissemination activities (to be performed in the framework of Work Package 9) in terms of strategy, tools' development, website design, social media and it serves as a blueprint as well as internal practical guide for the members of the consortium for engaging with the dissemination activities in the framework of the ENGIMMONIA project.
The definition of a dissemination and communication (D&C) plan for the suitable promotion of the project, such as identification of agreed dissemination measures/procedures/channels, dissemination events, stakeholder's engagement, definition of a target audience and events, is one of the key activities to guarantee a proper project promotion and the achievement of the expected impacts.
However, a communication and dissemination plan, to be effective, should be flexible and living. Therefore, the planning will be regularly monitored and updated during the course of the project. In order to monitor if D&C activities will reach the targeted impacts, the measures presented in this report will be verified at M24 (via D9.4 and D9.5) and at the end of the project (via D9.7).

Confidential Deliverables

D9.6 – "First Exploitation Report and KERs identification"
(RINA-C)

Executive Summary

The first main outcome of T9.4 "Exploitation and IPR Management" is the D9.6, which was created within the context of WP9 activities.
This deliverable represents a first exploitation plan and the definition of the project's Key Exploitable Results for the ENGIMMONIA project consortium. It aims to define an effective exploitation strategy supported by a lean approach to market outreach and trustworthy routes to market to ensure that ENGIMMONIA outcomes are real and long-lasting after the project and funding are finished.
In this framework, this first version provides a preliminary overview of the main Key Exploitable Results (KERs) under a technological and innovation aspects, market perspective as well as an analysis of the ENGIMMONIA partners responsible for their development, focusing on the related IPR management. In this way, the document clarifies the main roles and responsibilities of project partners towards personal and/or joint exploitation of project results, giving a first overview of possible future exploitation strategy that will be further analysed, together with each responsible partner, during the project.
D9.6 will be updated in D9.8 "Final Exploitation Report and IPR Management guidelines" at the end of the project.

Confidential Deliverables

D10.1 – "H-Requirements No.1"
(RINA-C)

Executive Summary

D10.1 was prepared in the framework of WP10 "Ethics requirements" under the responsibility of RINA-C and it is complementary with respect to D10.2 related to the protection of personal data gathered in the project (mostly in the stakeholders' engagement activities – nothing related to demonstration).

The purpose of the deliverable is to outline a preliminary strategy for the ethic and correct management of some data generated in the framework of ENGIMMONIA project activities that incidentally can come from the participation of humans in the activities and may therefore involve the processing of related Personal Data.

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D10.2 – "POPD-Requirements No.2"
(RINA-C)

Executive Summary

D10.2 was prepared in the framework of WP10 "Ethics requirements", concerning the ethical issues raised by ENGIMMONIA project, with particular reference to the protection of sensible data gathered during the stakeholders activities to be performed by the Consortium.
First, international and European requirements related to the protection and treatment of sensible data are analysed.
Secondly, the type of activities and data gathered that could be affected by ethical issues within ENGIMMONIA project are identified and investigated, according to the ethical issue checklist provided by the European Commission for ethical self-assessment.
Finally, a preliminary assessment of the procedures to be implemented during the project for data treatment was performed.