FLAGSHIPS

Clean waterborne transport in Europe

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Abstract

Deliverable abstract	
The aim of the FLAGSHIPS project is to raise the readiness of zero-emission waterborne transport to an entirely new level by demonstrating two commercially operated hydrogen fuel cell vessels. The demo vessels include two vessels: the Lyon demo is a push-boat operating as a utility vessel on the river Rhône, while the Stavanger demo is a passenger and car ferry operating as part of the local public transport network. Total of 1.0 MW of fuel cell power will be installed on board the vessels which will then run on hydrogen produced with electrolyzers powered by renewable electricity. Gaseous hydrogen will be used in the vessels' on-board hydrogen storage. Both vessels will be approved for safety. The ship owners expect to maintain the ships in normal commercial operation after the 18-month demonstration period of the project and to this end, a solid support from local end-users and community has been gathered. The project will reduce the capital cost of marine fuel cell power systems significantly by leveraging knowhow from existing on-shore and marine system integration activities. European supply chains for H2 fuel and FC system technologies are strengthened by networking through the project. This report will cover the activities and main results of the FLAGSHIPS project during the 1st reporting period, 1.1.2019-30.4.2020.	

Contents

1 Objectives

The objective of the FLAGSHIPS project is to raise the technical, business and regulatory readiness of fuel cells and hydrogen as a means to zero-emission waterborne transport of freight and passengers to a new level. To reach this target, two demonstration vessels will be built and operated during the project with following objectives:

1) Demonstrate for at least 18 months the operation of a hydrogen-fueled 600 kW power class passenger and car ferry in the Stavanger area, Norway.
2) Demonstrate for at least 18 months the operation of a hydrogen-fueled 400 kW power class pusher boat in the Lyon area, France.
3) Develop the necessary safety measures of said vessels to enable their class approval.
4) Develop marine capable PEM fuel cell systems, which meet both technical (lifetime, availability) and business (cost) requirements.
5) Develop and demonstrate bunkering technology for gaseous hydrogen fuel
6) Foster new European supply chains around zero-emission solutions for the marine and waterborne transport sector

More detailed technical and economical project objectives are:

7) A PEMFC system meeting safety and operational requirements with lifetime of at least 25 000 hours
8) A complete FC & H2 system cost of below 4000 EUR/kW (for ship with gaseous H2 storage).
9) Strengthen the European supply chain and competence network for hydrogen fuel and PEMFC system technologies for maritime applications

1.1 COVID-19

Towards the end of the 1st period of the project, COVID-19 situation has caused some difficulties in the scheduling. Many partners have had to work only remotely which has caused some issues in the work. Also, COVID-19 situation affected the suppliers as well. For this reporting period, delays caused by this pandemic are still rather mild but further delays might be cause in the next period. It is still too early to assess the full effect of the COVID-19 though.

2 Activities in the project

2.1 Design of H2&FC power system

In the project, considerations for marine hydrogen propulsion systems are given a careful thought and the final goal is to collect this knowledge and make it available for future consortiums approaching the same task.

During the first part of the project, the pre-analysis phase, the two different demo vessels teams have been very much focused in identifying the correct ways to approach this new challenge.

General Design Considerations

In the early stages of the project, workshops were arranged in order to identify and discuss the main design challenges, interdependencies, constraints and opportunities within each partner´s scope. These inputs are collected and main learnings will be reported later in the project in public deliverable *Fast start guide for new hydrogen ship design.*

One main issue identified was that fuel cells used as power sources require special considerations for control, monitoring and protection of the propulsion system. The following design considerations were identified:

- Accurate and robust fuel cell current control must be performed to optimize fuel cell lifetime and reliability.
- Energy storage devices should be parallel operated with fuel cells to provide enough power dynamic response for the shipboard power system. The energy storage devices are also needed to ensure that an adequate minimum load power (as required by fuel cells) can be maintained, even when propulsion is not used.
- Propulsion power rates should be controlled to accommodate fuel cell power dynamics.
- Fuel cell and power system safety circuit should be designed so that following failure (in any of the power sources) can be quickly detected and isolated.
- Safe operation (e.g., instalment, commissioning, and maintenance) of equipment must always be ensured.

Fuel cell design for maritime applications

The analysis of the fuel cell design for maritime applications was also in the scope of the activities, where Ballard's team focused the biggest part of their efforts and work.

During the reporting period, BPSE have gotten to the precise definition of the requirements needed for a maritime-specific Fuel Cell module. This was achieved by:

- A close collaboration and communication with all the partners, as end-users, integrators, and ship owners of the vessel, to collect knowledge and requirements from the marine world.
- Iterative workshops with Classification Societies and meetings with National Authorities, whose expectations´ fulfilment is a basic requirement for the practical achievement of a maritime-specific Fuel Cell module.
- An intense research and development work, carried out in the newly established BPSE´s marine centre of excellence offices, which combined the inputs collected and the Fuel Cells know-how, to design and specify the most suitable solution for marine applications. Also, extra effort has been made to ensure that the designed system includes the safety measures to enable a classification approval

Figure 1 and **Error! Reference source not found.** below show, respectively, the external and internal design of Ballard´s 200kW Marine Fuel Cell module, which will be used in both project demos.

Figure 1. Ballard Power Systems FCwaveTM : External View.

2.2 Stavanger Demo

The work in Stavanger demo case has been focusing on design of the hydrogen system and related systems. This includes detailed design of the hydrogen process from fueling to use in fuel cells, all auxiliary systems and safety related issues and systems. Also, dimensioning of the associated battery package is included, as well as the control system. The structural parts have also been analyzed to make a robust frame for the whole system.

During the first period, ferry concept and specification was completed. It was noted that the engineering period for the hydrogen system on board has taken longer than expected and that safety matters are far from business-as-usual. This is an iterative, time-consuming process with several involved parties, but the progress is well under way.

After the first period, the design was ready, but not detailed enough to be issued for construction.

- P&IDs documents of the design are ready for a first issue, but there are still some issues that need more work before the final version can be issued. These issues, still being work at, are related to the filling and containing of hydrogen.
- The storage concept design and the fuel cell arrangement are ready.
- Stability analysis has been performed and the structure changes have been analyzed.
- The layout and placement of the equipment onboard the vessel is complete.
- Hydrogen system and sub-systems diagrams, structural analysis and design are mature and near completion.
- The final input for the electrical propulsion system will be ready within short time, then the details for this system too will be ready.

The whole process of designing a hydrogen fuel cell for use in a ferry is new. Thus, there is not much experience to lean on. Also, without a formal set of rules and regulations all parts of the system must be analyzed in a risk-based approach. This means that the process is time consuming and leads to iterative steps where corrections are made as the process goes forward.

Route study and ship specification

General arrangement of the vessel showing the location of all main hydrogen related equipment, including fuel cells, storage bottles, bunkering station, batteries etc. were done. Then a preliminary lightship weight estimate was developed. Many other parameters such as the car deck layout, passenger ways, quay interfaces, propulsion arrangement were considered in the hull design. A hull model was then built and tested at a towing tank facility. The results from the towing and propulsion tests were analyzed and post-processed to calculate an accurate power consumption of the propulsion system. This power consumption could hence be used in a detailed route study that gave input to an electrical load analysis providing input and verification to development of the power/energy systems.

Also, several arrangement drawings process and instrumentation (P&ID) diagrams were developed:

- arrangement of the hydrogen equipment room (HER=fuel cell room)
- arrangement of the CH2 storage and processing area
- arrangement of the nitrogen room
- diagram of the H2 gas detection system
- CH2 system P&ID
- Nitrogen system P&ID
- Fresh-water cooling system P&ID
- Instrument air system P&ID
- Fuel cell exhaust system P&ID
- Ventilation of hydrogen equipment room system P&ID

Finally, an outline specification for the ship build work was developed, where all systems that shall be utilized on-board the ferry are specified, thus collecting input from the development work in the other tasks.

Electrical hybrid power system and propulsion integration design

Also, power topology, showing how power from fuel cells and batteries is managed through the drivetrain, for the Flagships Stavanger demonstrator vessel **Error! Reference source not found.**were designed, Furthermore, based on the route-study for the project and vessel characteristics, considerations on energy and power capacity were given attention.

Further, system design of a complete control system handling all ship systems, including operational and safety protocols were developed. This architecture of automation is the backbone of processing all relevant information and commands in the optimization activities during operation. The optimization facilities provided by this automation system will have interfaces with drives, switchboards, batteries, fuel cells, shore chargers and H2 storage tanks.

In addition, the integration of safety systems for the hydrogen plant with the operational systems, both power and automation was outlined. Further work is still needed as when selection of H2 storage system (tanks and processing equipment) and bunkering principles is done.

The principles for Emergency Shut Down (ESD) of the H2 plant, how it will be managed in conjunction with the ship automation system have been created. The functional safety topics that need attention such as definitions of state, functional descriptions and interfaces to be handled were also listed.

Hydrogen bunkering system

The operational profile for the ferry has been analyzed to find the daily consumption for H2, and this will be in the range of 500 kg/h, depending on where in the life cycle the fuel cells are and conditions that will vary such as weather, sea margin, loading condition. The system on board is detailed out, and the bunkering connection will be at car deck height at starboard mid/aft.

The supplier of hydrogen has not yet been chosen but negotiations are ongoing. The ferry will need to bunker once every day, and Norled is currently working to find if this can be done in a 40 min's slot in the evening, or if it needs to be conducted at night time after finishing the route. It will be beneficial if the evening slot can be used as the night time bunkering would mean that there would be need to hire more crew members. The preferred location to bunker is at Judaberg quay, which is one of two places for mooring at night, but there are details yet to be finalized, and it needs to get a safety approval from DSB (The Norwegian Directorate for Civil Protection).

Supply of systems and componentry

Preparation work for acquaintance for subsystems and components is going well forward. The system design is almost finished for all systems on board, and when finished the drawings for construction can be produced.

The fuel cells themselves will be produced at Ballard's facilities, and this can be done as soon as all testing is finished. Westcon will deliver switchboards etc. from their facilities, and also the control system.

The yard which will install all equipment has not been chosen yet. A detailed plan for procurement and installation will be made in the coming period.

Task 3.11 – Vessel safety assessment and approval

The approval process with Norwegian Maritime Authority (NMA) started with first two: providing the preliminary design documents for the authority and conducting the first safety analysis, i.e. pre-Hazid for the preliminary design. The aim of the pre-Hazid was to identify critical areas of the design and point out the critical issues and possible showstoppers. This pre-Hazid was specifically focused on the gaseous high-pressure hydrogen storage arrangements. The main issues identified considered the bunkering speed, fire/heat resistance of composite storage cylinders, hydrogen leakages, effects of periodical testing requirement of cylinders to the storage structure and dumping of hydrogen in the case of an emergency. The work will continue by preparation of Hazid, where the design will be analyzed more thoroughly emphasizing the first findings in the pre-Hazid.

Work will now continue with the finishing of the preliminary design. After that, actual HAZID meeting is held. Based on the input from there, design will be iterated while modelling work and FMEA analysis is done. After this, HAZID will be reviewed and updated and the residual risks will be handled accordingly. This process is illustrated in Figure 2.

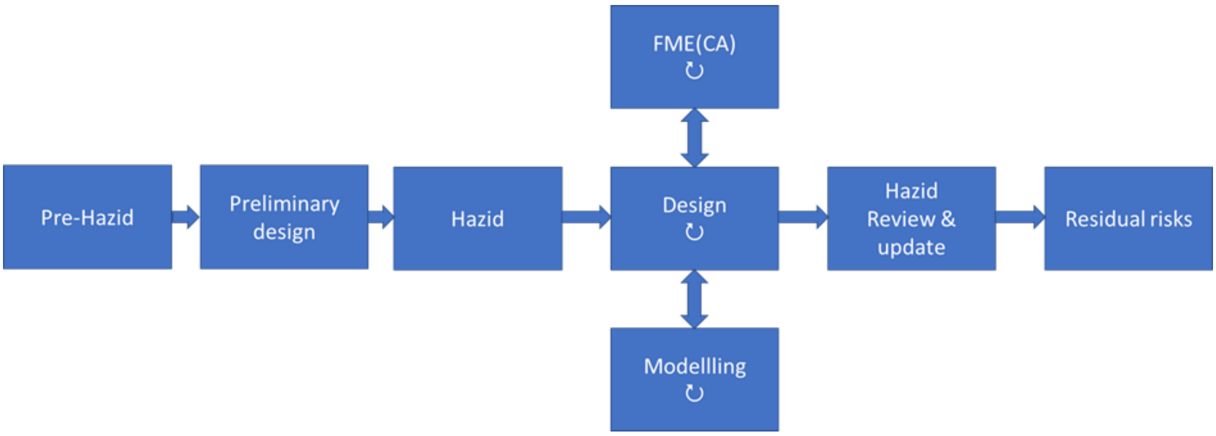


Figure 2. Safety assessment process flow.

2.3 Lyon demo

In the first reporting period work related to Lyon demo consisted design and safety aspects with objective of having a detailed design at the end of the period which would open the door for ship fabrication and hydrogen fuel cell integration.

Although closely related, two main design field were identified: power train design, which has been mostly done by ABB and pusher machinery space arrangement and system design that has been carried out by LMF.
CFT has acted as coordinator between these design areas by ensuring that both designs were consistent and compatible and also as designer to provide the overall arrangement of the ship. In addition, CFT, as ship operator, ensured that the proposed design was in line with its expectation and habits.

The work carried during in this period is detailed in the following and is divided in five main categories:

- Machinery space design
- Powertrain design
- Pusher overall design and hydrogen storage and bunkering
- System safety
- Shipbuilding

Machinery space design:

The first months of the project, between January to August 2019 were used to develop the pusher's design from an overall conceptual level to a first projection of arrangement (hull, outfitting and machinery area) and technical specification.

General Arrangement:
The general arrangement aims at giving a first representation of the vessel architecture, metering and overall disposition for main equipment. The development of the design was initiated using a representation of existing pusher from CFT. In parallel, and using these inputs, LMF worked on the integration of main powertrain equipment (Fuel cells, diesel generators, batteries, main switchboard, transformers etc.) in order to provide simple operability for the crew, and take into account initial safety consideration (based on LMF's previous experience for risk based designs) and balancing stability. Finally, CFT made sure that the offer was matching the need for river operations and complied with owner's preferences.

Weight initial estimation:
For ship equilibrium, weight balance is of outmost importance and it is essential to ensure a stable floating vessel. Based on initial inputs from equipment manufacturers (ABB, BPSE and some suppliers outside the consortium), LMF provided to CFT an estimation of machinery weight with center of gravity's position. In return, an estimation for the hull overall weight and accommodation weight was provided by CFT to obtain a general view on ship's balance in comparison with hull's characteristics.
Thanks to these elements, LMF developed a light ship calculation table to follow the load repartition in the ship along the design process.

Push-boat outline specification:
The outline specification aimed to draw a full picture of the equipment that will be installed onboard. It also defines the requirement with regards to material used, fabrication method, and control applied during the shipbuilding. Technical meetings between LMF and CFT were organized to account owner's preferences in design or systems and list down

requirements for vessel's function. The gathering of all information led to the edition of an initial vessel outline specification.

Hydrogen storage system:
In parallel to the machinery space design done by LMF, CFT has conducted a tender for hydrogen storage system. The main goal was to have a clear picture of what the system could look like and identify the potential supplier.
The storage system shall consist in swappable equipment as intended filling station is not located at the quay side.

This tender has permitted to set up the following properties:

- The system will be integrated into a 20" container shape in order to ease handling.
- It will consist of hydrogen cylinder, Number and capacity will depend on the selected supplier
- 300kg to 350kg will be stored onboard at a pressure of 300 to 350 bars

Figure 3 shows a typical hydrogen cylinder arrangement inside a 20 feet container.

Figure 3. Typical hydrogen storage arrangement

To summarize, the work carried out between January and August 2019 allowed to have a full "concept design" associated to a complete specification. This was the basis to develop the detail design of the pusher.

The following months from August 2019 to April 2020 have been used to push forward the development of technical documentation of the vessel. The technical documentation produced can be grouped into four (4) categories:

- General design and arrangement drawings
- Structure/foundation drawings
- System P&IDs
- Safety/fire plans

General design and arrangement
General design document present, in a general way, the design appearance and metering of the vessel as well as positioning, distribution or routing of main equipment. Past development performed during last quarter of 2019 allowed LMF to produce a first revision of general arrangement drawing. The design was kept to date and revised after modifications in equipment suppliers (such as Diesel engines), integration of systems (see subpart systems), revisions for safety considerations (see subpart safety). In addition, new designs were offered for vent mast (fuel cell exhaust lines, battery gas venting, diesel generators) as well as hydrogen dumping. Several technical coordination meetings

were also organized with external stakeholders such as shipyards and state representatives in order to review documentation and lead to revisions and modification of technical offers.

This work lead to the production of arrangement drawings:

- General arrangement revised
- Vent mast arrangement
- Fuel cells room arrangement

Structure

The structure documentation provides input for mechanical integration of equipment within ship's structure frame and ensure a sufficient resistance compared to stress induced by operations (vibrations, accelerations etc.).
Using inputs from consortium members (ABB and BPSE) and inputs from general design task (ship's structure framing) foundations were designed for hydrogen and power distribution related equipment. Revision documents were provided to shipyard and technical coordination shall be required in next months.

This work lead to the production of foundation drawings:

- Foundations for fuel cells
- Foundations for fuel cell control cabinets
- Foundations for Hydrogen storage container
- Foundations for Fuel Cell and Battery Power Unit (FBPU) converters
- Foundations for FBPU transformers
- Foundations for Propulsion frequency converters
- Foundations for Propulsion motor breakers

System

System documentation aims to provide functional and schematic description of equipment and their interconnections to serves the main functions of the vessels (propulsion, energy generation, equipment cooling) Such a documentation may integrate Process flow diagrams (PFDs), Process and instrumentations diagrams (P&IDs) or annexes technical notes as calculations, sizing considerations or description for systems operations.
As the vessel is to use hydrogen as main source of energy, which is an innovation for naval architecture, most of resources of this last quarter was used for development of a functional and reliable hydrogen system for the vessel. This task required both process engineering consideration (technical operability) but also sizing calculation for equipment (pipe diameters, pressure differential considerations, flow, hydrogen physics) and safety analysis (HAZID, failure modes and effects analysis). Several revisions with consortium members and external advisory expert (Air Liquide, Ariane Space, Linde etc.) were needed in order to iteratively have LMF's designs to approach an optimal solution. In addition, annex systems were designed, reviewed and submitted to CFT and shipyard to ensure auxiliary functions such as cooling, air instrumentation or ventilation.

This work lead to the production of following drawings:

- Hydrogen and fuel cell system P&ID
- Nitrogen purging system P&ID
- Instrument air system P&ID
- Fresh water-cooling system P&ID
- Ventilation system P&ID

Safety

The aim of safety documentation is to provide inputs for safety systems functional and schematic descriptions. This can include hydrogen related hazards, or fire detection and firefighting apparatus.

The HAZID workshop conclusion provided in last quarter of 2019 were developed into design revisions and additional system to be designed during the last months. Several meeting with hydrogen experts and discussion with river authorities of Lyon were concluded with questions to be addressed to comply with the "risk-based design" procedure. In particular, a research topic was identified for the control of gas rejection (prevention of inflammable gas cloud formation around the vessel) or a better analysis of mitigation procedures in the event of fire on board or major hydrogen leaks. Dedicated effort in that direction will allow the project to face the milestone of certification and approbation from the state authority. Therefore, collegial design methodology shall be organised with expert in this domain (hydrogen detection, hydrogen burner applications, gas dispersion analysis, explosion analysis) to provided updated design choices (hydrogen systems, hydrogen detection and nitrogen purging).

This work lead to the production of drawings:

- Gas hazardous area plan
- Ventilation arrangement
- Fire zone classification plan
- Fire control and safety plan
- Hydrogen detection plan

To conclude for the ship and system design part, the work done so far allowed the consortium to complete and produce sufficient drawings for technical coordination with shipyards and equipment providers. On the other hand, the development of systems and safety analysis showed blind spots that shall be addressed in the coming months. Further revisions and design development shall be needed to step-up the design level for classification and state approval (derogative zone approval based on French's legislation for innovative project).

Powertrain design:

A high-level design work for the shipboard powertrain was performed. The targets of the high-level design were optimization of total cost of ownership and operational performance of the fuel cell powered system. A special consideration, however, was put on risks related to hydrogen availability and local regulation related to hydrogen propulsion on the rivers near Lyon area. Following the initial high-level design work, a detailed powertrain design work was started as well. In the following, the electric powertrain related work performed in the first period of the project is described.

Following the design work, the power system illustrated in the single line of Figure 4 was found to be the most suitable for the pusher. The total propulsion power of the pusher is 2 x 300kW. The total fuel cell supply power capacity is 2 x 200kW. In order to be able to provide full 600kW propulsion power with zero emission, 2 x 100kW batteries are integrated for parallel operation with fuel cells. The fuel cell power sources and propulsion motors connected to each other through Insulated Gate Bipolar Transistor (IGBT) based power converter devices.

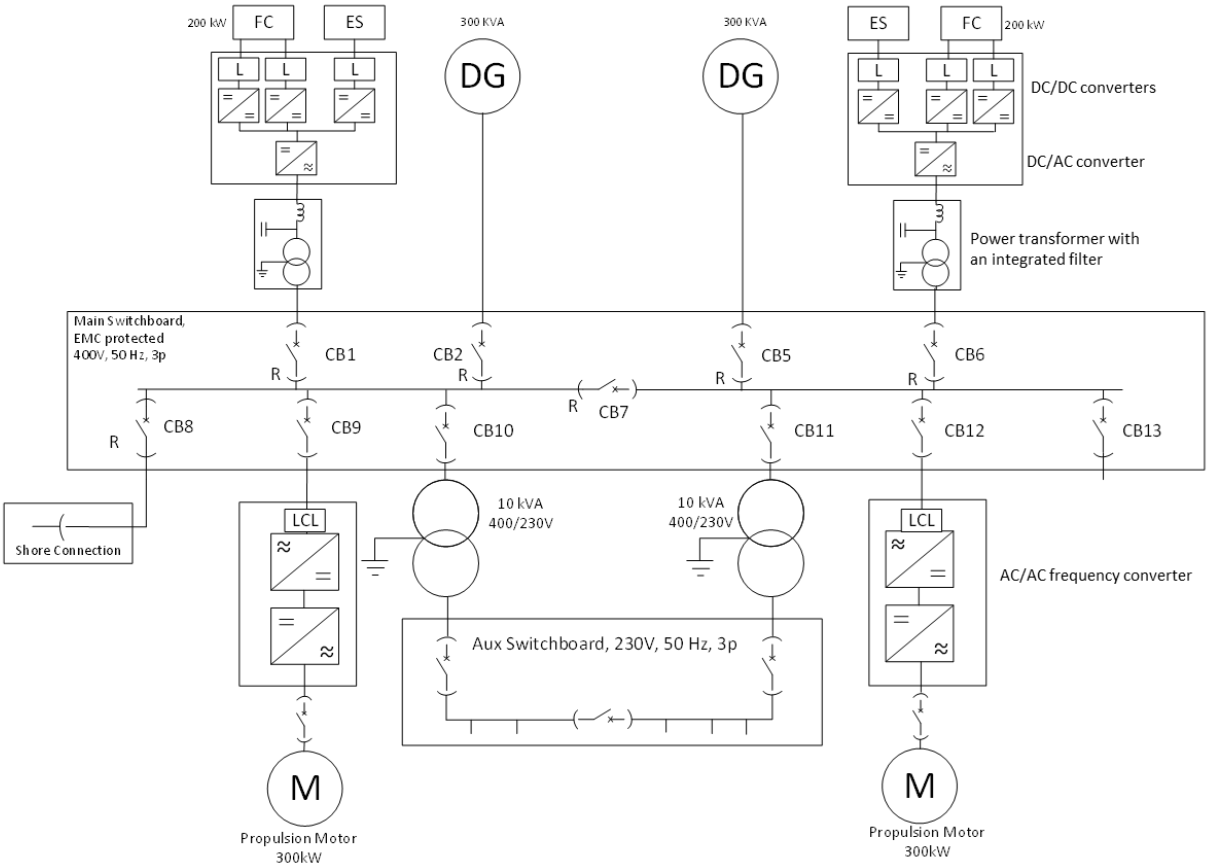


Figure 4: Lyon pusher power system single line diagram.

In general, the power and energy capacities of the fuel cells and the batteries are enough to supply cover all power and energy needs of the pusher. However, due to fuel cells not yet being fully mature and proven power sources in marine vessels, two diesel generators are added as back-up power sources. Moreover, during times when hydrogen refuelling might not be available or in areas where operation purely on hydrogen is not allowed, the availability of diesel engines ensures that the vessel is always available for operation. Therefore, due to the inclusion of diesel generators, the power system was chosen to be based on traditional alternating current (AC) based power distribution with AC breakers used as main electrical protection devices.

The fuel cells and batteries are both direct current (DC) based power sources with their voltages varying depending on delivered power. On the other hand, diesel generators are AC based power sources with their voltage depending on operational speed of diesel engine and settings of an automatic voltage regulator (AVR). In order to parallel operate fuel cells, batteries diesel generators, high speed power converters are used to regulate the output voltages of the power sources to a suitable type and level for common coupling. Since the power system is based on AC power distribution, the main switchboard (MSB) was selected as the main coupling point (i.e., point where all power sources interact with each other) for interaction (see Figure 4). Therefore, the output voltages of fuel cell and battery are transformed into AC through DC/DC converters and DC/AC converter. This converter topology is illustrated in Figure 5a. As shown in Figure 5a, the fuel cell and the battery are coupled at a common DC link between the DC/DC converters and the DC/AC converter. This enables use of a single DC/AC converter and transformer for AC power production. This allows for lower capital expenditure and higher energy efficiency compared to an identical system but with separate power conversion devices for both fuel cell and battery. However, the use of separate DC/DC converters allow full controllability of loading between the fuel cell and the battery. This way, proper current control as required by fuel cells (one of the design considerations) is managed as shown in Figure 5a. In Figure 5b, the load power illustrates the total output power of both fuel cell and battery (i.e., power produced by the DC/AC converter). It is shown that fuel cell power ramp rates are constantly controlled as required by the fuel cell supplier to enhance fuel cell lifetime and efficiency, which is expected to result into reduced total cost of ownership for the system.

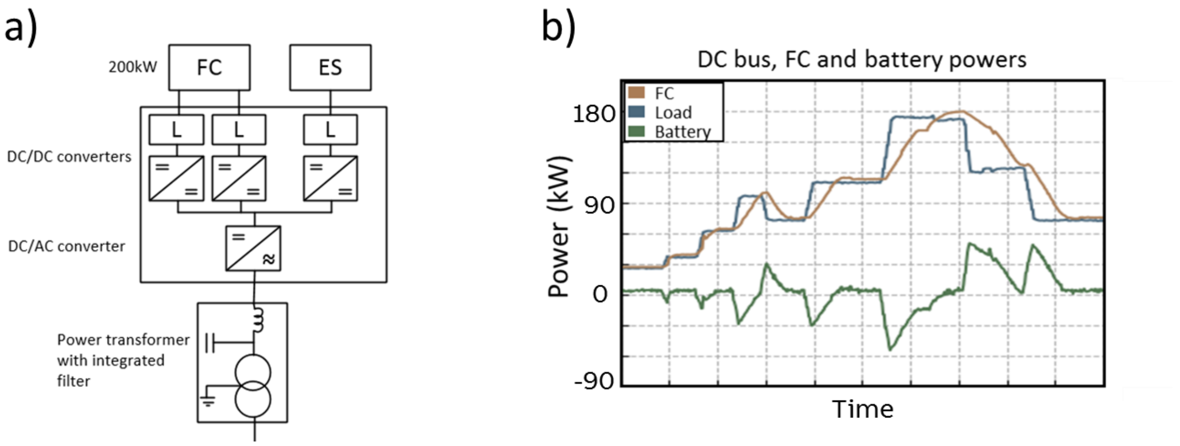


Figure 5: a) fuel cell and battery power unit (FBPU) and b) load sharing scheme between fuel cell and battery.

The monitoring and control of the fuel cell and battery power sources, DC/DC converters and DC/AC converter requires advanced control and monitoring software and hardware. For this, a dedicated fuel cell control system (FCCS) is specified and designed to, among other things, perform the following functionality:

- Automatic start/stop of fuel cell, battery and power converters
- Fuel cell and battery power control
- AC power control through the DC/AC converter
- Fuel cell, battery and converter alarm handling
- Communication with upper level power and energy management system (PEMS)

The fuel cell and battery powertrain together with FCCS control hardware are illustrated in Figure 6.

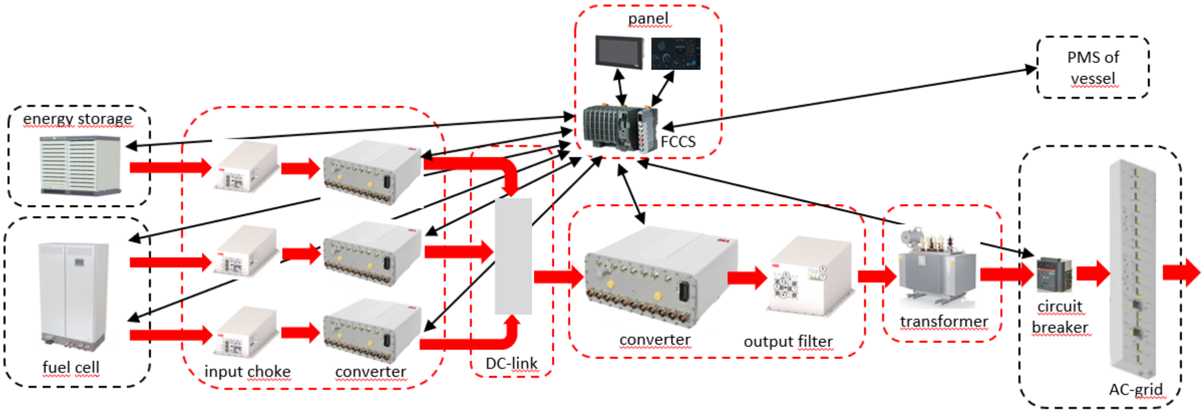


Figure 6: Fuel cell and battery power system including main FCCS controller and local power unit control panels.

Safety aspect:

Beyond these design aspects, the acceptance by Class and regulatory authority has to be granted and this requires a proper and in depth safety analysis. This analysis is done continuously along the design process.

Two major events can be identified in the safety analysis process:

- Pre-HAZID meeting: On June 12th 2019, a pre-HAZID meeting has been held in Aalborg with VTT, LMF, BPSE and CFT. The purpose of this meeting was to identify the major risk and engage the safety analysis process to mitigate all possible risk onboard the pusher.

- HAZID meeting: On November 13th – 14th, the safety assurance process continued with the Hazard Identification (HAZID) two-day workshop hosted by LMF in Toulouse, France. Experts from Bureau Veritas led and reported the workshop. The objective of the HAZID workshop was to ensure that all the risks linked to hydrogen gas installation and its use for propulsion and electrical power generation on-board the ship are eliminated or reduced to as low as reasonably practicable (ALARP). Representatives of FLAGSHIPS partners CFT, LMF, BPSE, PE and VTT were present and in addition, Bureau Veritas inland navigation expert and representatives of Umoe Advanced composites (a H2 storage system provider) also attended the workshop.

In the HAZID workshop risks of identified scenarios were assessed twice: first according to the current design solution and then after the planned mitigation actions have taken place. The most critical scenarios without planned mitigating actions were hydrogen leaks from the piping, fittings etc., operational hazards during hydrogen container swap, during maintenance or installation phase or due to bad quality of hydrogen gas, hazards due to extreme natural conditions and injuries of external visitors. The most critical scenarios after the planned actions were hydrogen leaks in fuel cells, coolant leak in fuel cells, emergency situation in adjacent area (e.g. fire onboard the ship), collision with another ship and dumping/venting of hydrogen while the pusher is in the lock.
A HAZID report has then been issued by Bureau Veritas Solution and includes a list of recommendation to be considered in the design process to ensure the safety of the ship.
Based on HAZID conclusion, the design has evolved in order to tackle most of the safety blind spots. Beside the follow up of HAZID recommendation, component level failure mode and effects analysis (FMEA) studies has been started by VTT for hydrogen and nitrogen systems to reveal the effects of single component failures on the system operation. The FMEAs have been conducted in close cooperation with LMF; if the design has changed, also the FMEA has been updated accordingly. When the design solution is freezed, the FMEA will be completed with criticality assessment to illustrate the residual risk of the design; i.e. FMEA becomes FMECA.
In addition, VTT is also conducting CFD-modelling on the low pressure pipeline venting scenario (see Figure 7) and the work will continue with emergency dumping modelling, where the high pressure hydrogen storage or a part of it is released into air to mitigate the effects of emergency situation onboard. Safe dumping of high pressure hydrogen is a challenge: the released hydrogen causes an explosion risk and the consequences of an explosion especially in urban areas might be severe.

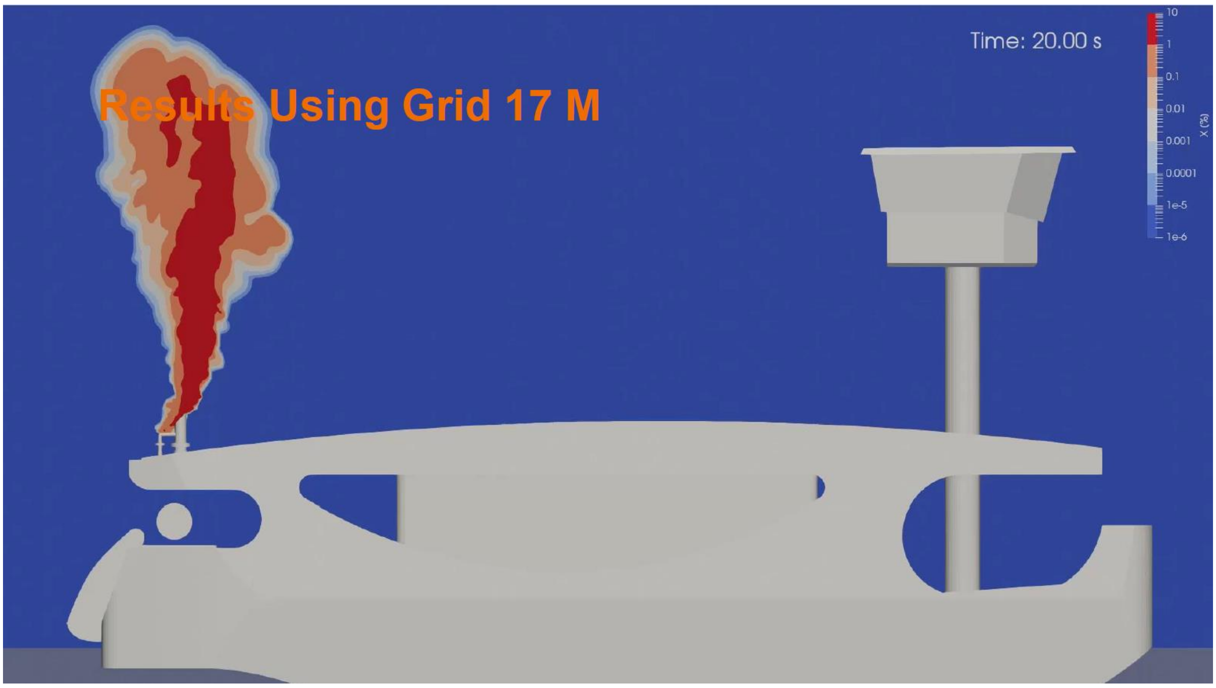


Figure 7 - Low pressure venting

2.3 Regulatory side

The overall objective of the work conducted so far consist in deepening the understanding of the national and international regulation framework regarding marine application of fuel cells and hydrogen by expanding it to inland waterway applications bound by European regulation framework.

National level

Towards the national level, with a focus on the approval process for the 2 vessels, close contact with approving authorities and class societies has been kept.

Lyon demo

The technical requirement for inland navigation are prescriptive, meaning that what is not written is forbidden. Hence, a derogation will be required for the pusher to be allowed to operate. In February 2019, a first meeting was conducted with French administration in order to present the project and discuss about the condition to get the derogation. This process requires the constitution of a technical committee that will assess the acceptance of the derogation request, mostly based on ship safety from operation point of view, but also considering safety to other ships sailing on the Rhône River.

The technical committee, initiated by CFT, was then formed and a kick off meeting has been done in July 2019. Further to this, other meetings have been conducted, first in January 2020 to present the HAZID report results and then in February 2020 to present the technical document prepared by LMG.

Next step is the formalisation of the safety analysis and emergency system in order to present it to the Technical Committee. Although not yet scheduled, the next meeting should take place around September 2020.

Members of the technical Committee are:

- DDT69 : Local authority in charge of vessel title and derogation – committee leader
- DGITM / PTF6 : National authority in charge of inland navigation transport
- SDIS69 : local firefighters
- DREAL: Local authority in charge of establishing policy for environment, territory development, and housing
- VNF: Public structure in charge of river operation
- CNR: Rhône river operator
- CFT: ship owner
- LMG Marin France: ship designer
- Bureau Veritas: Classification society

Stavanger demo

In Stavanger case, Norwegian Maritime Authority, NMA, is the approving national authority. The approval process of the vessel will be handled with NMA through the process described in Figure 8.

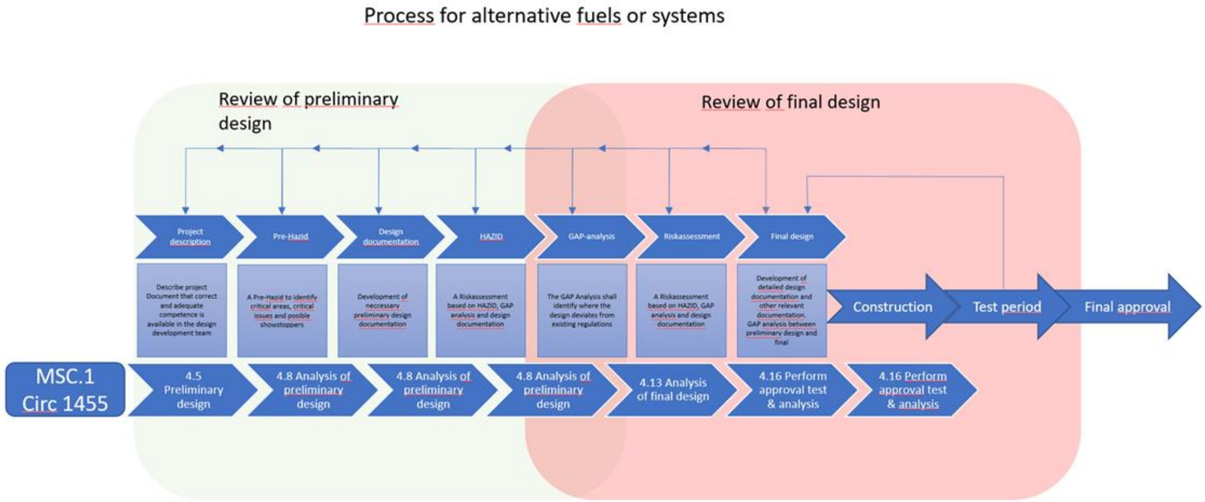


Figure 8. Approval process for alternative fuels or systems.

This work was started by contacting NMA and providing them a project description of the vessel building project. This was prepared and presented to NMA by NOR.

To follow that pre-HAZID meeting was held in April 2020 with all the relevant consortium members and also NMA and UMOE (potential hydrogen storage supplier). The process will continue with finalization of design documentation, after which actual HAZID meeting will be held. This will be again, done together with NMA and also plan is to invite DNV-GL, as a class society, to the actual HAZID meeting. DNV-GL will be engaged as a third party for approval, in addition to NMA.

A learning from the pre-HAZID workshops was that there is general lack of hydrogen safety rules and culture in the field and thus, some additional efforts are required to come up with solutions or mitigation actions (which could be established as rules or standards in future).

European and international level

Towards the European and international level, Persee performed an update of the regulations, codes and standards (RCS) review for marine applications performed within the MARANDA project with a specific emphasis on liquid hydrogen and inland waterways. This review considered the most recent updates from IMO on fuel cells, the progress made within SFEM on LH2 for the maritime sector, the actions under way within CESNI. Such updates were also gathered through dissemination actions in London at IMO and in Brussels at CEN/CENELEC SFEM gathering. This task was performed in collaboration with e4ships and HyseasIII in order to build the wider consensus.

The outcome was reported in the public deliverable D5.1 Common, applicable safety regulations and approaches submitted in November 2019.

This deliverable confirms the gaps highlighted by the equivalent deliverable from Maranda project 3 years before and the generalisation of these gaps for inland waterways. A targeted course of action towards IMO is recommended and should be conducted by an upcoming FCH JU project leveraging the experience acquired from all the FCH demo projects. If not successful an industry driven initiative should be envisaged in relation with a NGO having consultative status at IMO. Such results have been disseminated to the policy makers from the hydrogen network in Brussels, at the joint DOE-FCH JU H2@port workshop in San Francisco and at various H2 for maritime fairs.

2.4 Communication, Dissemination and Exploitation activities

In the first period focus has been given to information on project objectives and planned activities to ensure awareness of the project and its objectives among key stakeholder groups and to allow external parties and projects to cooperate. In a later stage, when validated results become available, information on results and knowledge will be spread to a wider academic, research, public and industrial community to foster exploitation, education and rule development.

Following Dissemination, Communication & Exploitation KPIs are set for the project:

Table 1. Dissemination, Communication & Exploitation KPIs

Tool	Indicator	Target value	Status M16
Website	Number of hits	10.000 hits from 20 countries	X hits, 36 countries
Social media	Number of posts, number of followers	200 posts, 1000 followers	26 posts, 178 followers
Press releases	Number of press releases	5	7
Premade stories	Number of premade stories sent to the press	At least 5	3
Participation in the media	Number of appearances	At least 300	351
Confirmed presentations at conferences	Number of presentations	At least 20 presentations	46
Journal papers/scientific media	Number of papers/articles published	6	1
Public workshops	Number workshops, number of participants, number of projects represented	3 workshops, 200 participants, 5 projects represented	0
Brochure	Number of brochures produced	1	1
Movies/Videos	Number of movies created, views	1 promotional video, 2 project videos, 2000 views	0
Project final event	Number of participants	At least 100 participants	NA

<u>The website</u>
The project website was launched as a central hub for external communication (http://www.flagships.eu). The website contains information about the project, news, the partners, events, contact information and publications.

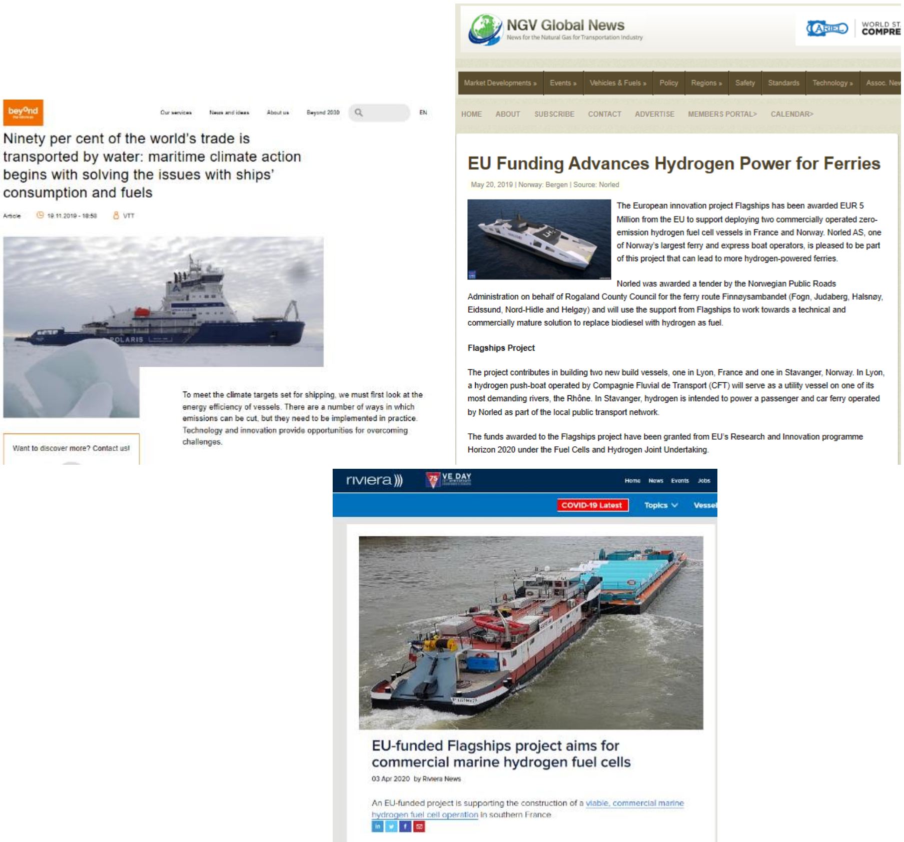
<u>Publications and articles</u>
In the project VTT is overseeing and administering the production of technical and scientific publications, as well as feature articles for maritime and systems engineering magazines and newspapers. As results from the project and

technical advancements are made available in the next reporting period VTT will ensure effective dissemination to the academic and technical
R&D audience. This will require utilizing such professional forums as well as maritime and systems engineering magazines and newspapers.

FLAGSHIPS was also accepted for at the Transport Research Arena conference -TRA 2020 (27-30 April 2020, https://traconference.eu/), which runs under the motto “Rethinking transport – towards clean and inclusive mobility”. This is entirely within the scope of the FLAGSHIPS project for cleaner and more competitive maritime transport and despite the early stage of the project some early project results were planned to be presented and discussed by the conference participants. As a result of the Corona virus outbreak TRA2020 was cancelled, however the project’s paper has been published in the TRA2020 portal and on the FLAGSHIPS website.

Premade stories

The project has had considerable activity within press relations in the first reporting period. Stakeholders and communication needs have been defined in the Communication & Exploitation Plan.
Three premade stories have been created tailored for the maritime media and distributed broadly: Two stories on hydrogen’s potential role in decarbonization of shipping; and one story on the Lyon case to international media.



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Ninety per cent of the world’s trade is transported by water: maritime climate action begins with solving the issues with ships’ consumption and fuels

Article | 19.11.2019 - 18:58 | VTT

To meet the climate targets set for shipping, we must first look at the energy efficiency of vessels. There are a number of ways in which emissions can be cut, but they need to be implemented in practice. Technology and innovation provide opportunities for overcoming challenges.

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EU Funding Advances Hydrogen Power for Ferries

May 20, 2019 | Norway: Bergen | Source: Norled

The European innovation project Flagships has been awarded EUR 5 Million from the EU to support deploying two commercially operated zero-emission hydrogen fuel cell vessels in France and Norway. Norled AS, one of Norway’s largest ferry and express boat operators, is pleased to be part of this project that can lead to more hydrogen-powered ferries.

Norled was awarded a tender by the Norwegian Public Roads Administration on behalf of Rogaland County Council for the ferry route Finnøysambandet (Fogn, Judaberg, Halsnøy, Eidssund, Nord-Hidle and Helgøy) and will use the support from Flagships to work towards a technical and commercially mature solution to replace biodiesel with hydrogen as fuel.

Flagships Project

The project contributes in building two new build vessels, one in Lyon, France and one in Stavanger, Norway. In Lyon, a hydrogen push-boat operated by Compagnie Fluvial de Transport (CFT) will serve as a utility vessel on one of its most demanding rivers, the Rhône. In Stavanger, hydrogen is intended to power a passenger and car ferry operated by Norled as part of the local public transport network.

The funds awarded to the Flagships project have been granted from EU’s Research and Innovation programme Horizon 2020 under the Fuel Cells and Hydrogen Joint Undertaking.

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EU-funded Flagships project aims for commercial marine hydrogen fuel cells

03 Apr 2020 by Riviera News

An EU-funded project is supporting the construction of a viable, commercial marine hydrogen fuel cell operation in southern France

Figure 9. Example of media coverage as a result of premade stories.

In addition, six articles about project activities have been published on the project website.

Social media management

Project accounts were created on Facebook and LinkedIn in M10 to reach a large share of the different stakeholder groups and promote the project visibility. In total 25 social media posts have been published during the first reporting period. In total the projects channels have 178 followers.

Figure 10. Example of LinkedIn post.

In the next reporting period focus will be put on increasing the number of followers in social media by increasing the number of posts. A decision will also be taken whether to change platform from Facebook to Twitter.

Press releases

To launch the project to the public, a press release was developed and distributed when the funding from the European Commission was announced. Individual partner press releases to announce the project were also distributed from ABB, Ballard, Norled and VTT. The press releases resulted in comprehensive media coverage; 141 articles in 108 different medias:

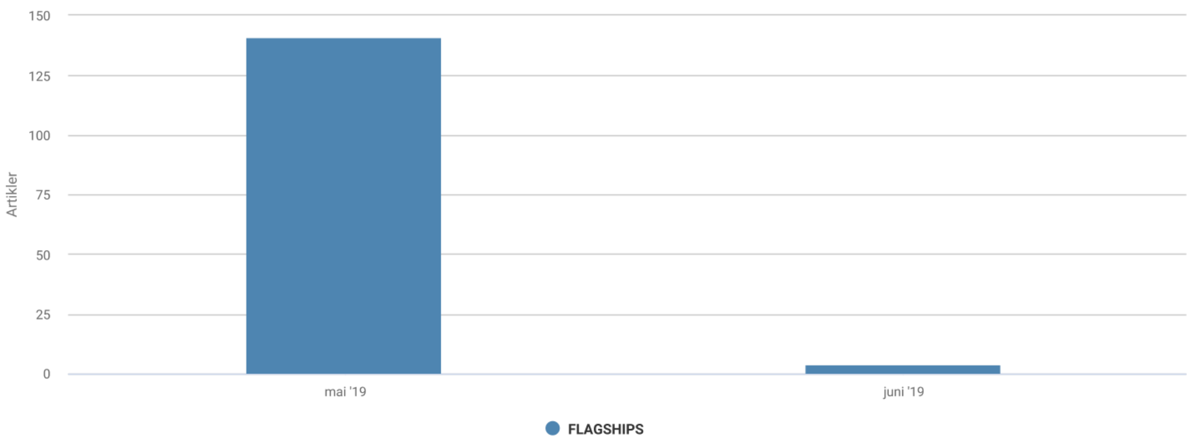

Figure 11. Media coverage from the launch, source: Retriever media tracker.

A press release was also distributed by Norled in M12 to announce the design contract between Norled and LMG Marin. Another press release was distributed in M13 when the project was awarded the Hydrogénies award for its innovative work within the field of hydrogen in the maritime sector.

Brochure

A brochure presenting the project has been created and made available for the project partners and the public.

Task 7.3 Workshops, events and conference

The project plans to organise several project events about the process, activities and results throughout the project. During the first reporting period the planning of two public workshops was initiated for the next reporting period; one hydrogen safety workshop in relation with the Hydrogen Safety Europe Conference 2020 in Frankfurt, Germany on October 20-21, 2020, and one workshop with invited political representatives from the European Commission on technologies for zero emission shipping in Brussels during spring 2021.

The project recognizes the importance of sharing knowledge with other relevant projects and initiatives and has during the first reporting period participated in workshops arranged by other parties such as an IMO workshop on alternative fuels and a H2@Ports workshop arranged by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) in collaboration with the U.S. Department of Energy Fuel Cell Technologies Office and the U.S. Maritime Administration in San Francisco. Furthermore, the project arranged a meeting with the EU funded ELECTRA project in M5 to exchange information and experiences on the safety aspect of hydrogen applications. FLAGSHIPS is also in in close contact with the EU funded MARANDA project and will have ongoing discussion with them during the whole project duration.

Examples of articles in the media

http://www.gulfprojects.me/DetailsTA/366110/EU-project-working-to-create-hydrogen-fuel-cell-marine-solutions

http://www.handyshippingguide.com/shipping-news/hydrogen-power-for-experimental-vessel-generated-by-the-water-she-sails-on_12794

https://www.rivieramm.com/news-content-hub/eursquos-flagships-project-aims-to-create-a-viable-hydrogen-fuel-cell-operation-58791

https://fuelcellsworks.com/news/flagships-project-wins-hydrogenies-trophy/

http://www.dailyfinland.fi/business/10803/VTT-to-coordinate-deployment-of-2-hydrogen-vessels

https://www.rivieramm.com/news-content-hub/norled-spearheads-hydrogen-use-with-two-new-ferries-55133

https://www.shipandoffshore.net/news/shipbuilding/detail/news/order-placed-for-environment-friendly-norwegian-ferry-project.html

http://www.hydrogenfuelnews.com/hfc-ships-to-be-deployed-in-france-and-norway/8537521/

https://shipandbunker.com/news/emea/909350-france-set-for-worlds-first-hydrogen-powered-river-vessel

https://www.offshore-energy.biz/flagships-project-gets-usd-5-6-mn-for-two-hydrogen-fueled-ships/

https://www.infomarine.net/maritime-news/137-green4sea/135176-eu-grants-usd-56-million-for-two-hydrogen-fueled-ships.html

https://www.maritime-executive.com/article/hydrogen-fuel-cell-vessels-destined-for-france-and-norway

http://www.biofuelsdigest.com/bdigest/2019/05/13/eu-project-to-partly-fund-norwegian-ferry-operators-trial-switch-to-hydrogen-from-biodiesel/

https://watch.maritime-network.com/2019/05/14/eu-awards-eur-5-million-to-flagships-project-for-deploying-two-hydrogen-vessels/

www.stockwatch.com/News/Item.aspx?bid=Z-C%3aBLDP-2762079&symbol=BLDP&region=C

https://gcaptain.com/abb-to-enable-worlds-first-hydrogen-powered-river-vessel/

http://www.ngvglobal.com/blog/eu-funding-advances-hydrogen-power-for-ferries-0520

http://www.ngvjournal.com/s1-news/c7-lng-h2-blends/flagships-project-eu-funds-construction-of-two-hydrogen-powered-vessels/

https://www.freightweek.org/index.php/en/more-news-2/4131-5-million-in-eu-backing-for-zero-emission-vessels

https://steelguru.com/logistic/flagships-project-to-deploy-two-hydrogen-vessels/540286#tag

http://www.hydrogenfuelnews.com/hfc-ships-to-be-deployed-in-france-and-norway/8537521/

https://www.ship-technology.com/news/eu-funds-project-flagships/

http://www.transportweekly.com/pages/en/news/articles/157373/

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