Scaling up and demonstration of a multi-MW Fuel Cell system for shipping

The scope of this topic is to adapt, scale up and demonstrate a fuel cell (FC) system for shipping with a total minimum nominal power output of 2 MW, capable of reducing GHG emissions by at least 70 % (both local and on a well-to-wake basis) and NOX, SOX and particulate matter by at least 80% compared to conventional diesel-based systems for the selected mode(s) of operation. A pathway towards zero-emission operation should also be outlined to ensure compatibility with longer-term IMO objectives. The topic is open to all types of FC technologies and all types of fuels, as long as the new system can meet the expected emissions reduction. The FC system may be used for propulsion and/or auxiliary loads or for port and pilotage operations on ships (e.g. a ferry, freight carrier, cruise ship, passenger boat etc.). Retrofit of a vessel, where the FC system replaces conventional fossil-fuelled engines is also allowed. The ship should be used for commercial services to gain relevant operational experience. The FC system can be built of smaller units (modules) but no lower than 500 kW with a total on board installed power within each vessel of at least 2MW.

The project should address the following key issues:

- Fuel cell system issues:

- Adapt and validate the FC module/system for reliable operation under maritime conditions for the selected fuel in line with prevailing technical (i.e. durability, power density) and regulatory (RCS, redundancy etc.) requirements;
- Assess how the FC module/system may be further up scaled to 20 MW power systems for larger ships;
- Particularly, if other fuels than hydrogen are chosen, maximise system efficiency to achieve a substantial improvement over current maritime combustion engine technology.

- Fuel storage and supply chain:

- For the selected fuel, identify the required refuelling facility for the FC-powered ship and the fuel supply arrangements required to meet the stated CO2 emission reduction targets. Consideration should be given to system weight, volume, required time for and operation time between bunkering, energy penalties and implications for larger ship designs (with regards to safety and potential loss of useful space);
- Define the fuel supply chain in volumes sufficient for short-range vessels and for long-range ocean-going vessels;
- For hydrogen as fuel:
    - an interim refuelling solution (e.g. containers) in relevant scale for the demonstrations is foreseen and
    - a study on a bunkering concept with the potential for scaling up (for compatibility with a 20 MW FC system) is required, ensuring minimization of hydrogen loss/leakages/boil-off (if relevant);
- For other fuels:
    - the bunkering solution is considered an integral part of the project.

- System integration and operation:

- Define vessel integration requirements and develop adequate maintenance procedures, in line with approval requirements;
- Adapt/design the multi-MW fuel cell system/power generating unit to vessel application;
- Physical integration of the fuel cell, the fuel system and power management system into the vessel and vessel systems;
- Define any additional battery storage systems that may be needed for load levelling.

- Regulatory, economic and societal issues:

- Contribute to the establishment and further development of maritime rules and guidelines for selected FC powered vessel design(s) and the alternative fuel to be utilized (i.e. explosion safety levels) in line with class/flag/port approval requirements;
- Assess and propose suitable business models, to foster further commercialisation of technical FCH solutions both on board the vessel and bunkering/refuelling;
- Quantify the potential for cost reductions as the FC and alternative fuel technologies mature and define the roadmap to get there;
- Assess the advantages of using FC systems in combination with the selected alternative fuel option in terms of emission reduction during operation, noise reduction, availability and reliability;
- Discuss /share experiences with the shipping industry to contribute to raise awareness of the potential of FC propulsion technology;
- Define training requirements for operator and crews.

With regard to the regulatory, economic and societal issues, it is expected that the project will contribute towards the objectives and activities of the Hydrogen Innovation Challenge (as detailed under section 3.2.G.International cooperation).

Promoting international collaboration beyond EU Member States and H2020 Associated Countries is therefore strongly encouraged.

The project should closely follow the developments in the IGF Code Correspondence Group at the IMO, works of the European Sustainable Shipping Forum (Sub-group on alternative fuels) and relevant work of the certification bodies. The project should moreover take into account and seek synergies with other ongoing activities such as research projects arising from the 2019 Horizon 2020 topic LC-MG-1-8-2019: Retrofit Solutions and Next Generation Propulsion for Waterborne Transport addressing high power FC passenger ship concept.

The project should include an operational period of at least 12 months (including both winter and summer season) and a minimum of 3,000 operational hours demonstrating the TRL of the FC system and vessel. The ship should be used on a regular basis in order to gain relevant operational experience. Bunkering to sustain the normal operational profile of the vessel(s) is considered within the scope of this topic. Exploitation of synergies with refuelling infrastructure for other applications is considered advantageous. Excess fuel expenses during the demonstration compared to diesel is considered eligible costs.
If the selected fuel is hydrogen, “CertifHy Green H2“ guarantees of origin should be used through the CertifHy platform to ensure that the hydrogen consumption is of renewable nature.

The project consortium should include at least one of each of the following: vessel owners or operators, fuel cell system providers, shipbuilders or shipyards; cooperation with Classification Societies is also encouraged.

The construction of the demonstration vessels' hull, superstructure and other components unrelated to the FC propulsion system, as well as operational costs such as crew are not considered eligible costs.

For the various FC types and fuels (storage and bunkering solution) which are eligible (as described above), the TRL varies widely, so no TRLs at project start and end are included here. The proposals should nevertheless clearly describe the targeted TRL advancements.

Any safety-related event that may occur during execution of the project shall be reported to the European Commission's Joint Research Centre (JRC) dedicated mailbox JRC-PTT-H2SAFETY@ec.europa.eu, which manages the European hydrogen safety reference database, HIAD and the Hydrogen Event and Lessons LEarNed database, HELLEN.
Test activities should collaborate and use the protocols developed by the JRC Harmonisation Roadmap (see section 3.2.B ""Collaboration with JRC – Rolling Plan

2019""), in order to benchmark performance of components and allow for comparison across different projects.

The maximum FCH 2 JU contribution that may be requested is EUR 10 million. This is an eligibility criterion – proposals requesting FCH 2 JU contributions above this amount will not be evaluated.

Expected duration: 4 - 6 years.

In 2018 the International Maritime Organization (IMO) adopted a global strategy to reduce greenhouse gas (GHG) emissions from international shipping by at least 50% by 2050 (compared to 2008). Given the long lifetime of ships (typically 25-30 years) and the strong reliance of the sector on fossil fuels, meeting the IMO's ambition will require a rapid introduction of both alternative fuels and electrification of the powertrains. Moreover, EU transport GHG emission reduction targets for 2030 along with policies that aim at boosting inter-modality underline the urgency of introducing ultra-low and zero-emission solutions for shipping. There is an increasing trend to electrify ships using diesel-electric propulsion systems. Such systems offer the possibility to incorporate a range of fuels, energy management systems and batteries to provide peak power shaving for the main engines to reduce GHG emissions and improve efficiency. Fossil based Liquefied Natural Gas (LNG) can also be deployed as a commercially available solution to reduce air pollutants (SOx, NOx, PM), but it is less effective at reducing GHG emissions and would not be able to contribute substantially towards achieving the aforementioned IMO GHG reduction target. Several pure battery-electric ships have also been introduced in recent years, but the amount of battery storage capacity required and the very high electrical demands when charging make such solutions unsuitable for long-distance shipping.

Fuel cell technology using hydrogen or another alternative carbon neutral fuel can enable shipping to achieve a very large reduction (>90%) in both GHG and pollutant emissions. However, so far only several small, low speed vessels have implemented fuel cells (of up to a few hundred kW) for demonstration purposes.

There are several challenges associated with taking larger fuel cells into use in shipping. First, fuel cell systems need to be scaled up to the desired MW scale while simultaneously addressing durability, compatibility with maritime conditions (saline air, shock, rolling & vibration). Second, refuelling facilities and high-volume fuel bunkering systems will be required, particularly for larger vessels and this poses a significant challenge for the less mature fuel options. Moreover, the total propulsion system's energy and power density as well as redundancy should be adequately secured for the specific applications. Third, immature regulations, codes and standards (RCS), apply to hydrogen in particular, but also alternative fuels and FC technologies. The time consuming Alternative Design process may exhibit an unavoidable challenge, as IMO rules are not yet in place. Fourth, market deployment, cost reduction strategies (including maintenance for marine environments) leading to viable business models need to be developed. Last, but not least, the public domain needs to be addressed, ensuring the acceptance of these new propulsion systems.

The total minimum of 2 MW FC installed power is expected to be an early stepping-stone towards meeting larger vessels' power requirements of typically 20 MW or more for environmentally sound, safe and reliable operation. It provides a significant step towards the implementation of multi-MW FCs and their zero-emission fuels in shipping as the main energy source. The project should also strengthen the EU supply chain both for FCs and identify the steps that are needed in order to develop sustainable low-emission bunkering solutions for FC powered vessels. If other fuels than hydrogen are chosen, should demonstrate a significant improvement in fuel efficiency over the current state of the art. Additionally, the project should identify viable business models for large vessel applications. It will moreover provide for increased visibility of the potential of FCH technologies as a means for de-carbonising shipping. The demonstration will also provide important empirical evidence to IMO, Classification Societies, Flags Administration and the whole community for the development of underlying regulations, codes and standards, best practices, business cases, and so on.

More specifically, the expected impact include:

- Successful demonstration of MW-scale FC system(s), alternative fuel storage, bunkering and refuelling for shipping that, compared to current state of the art diesel engine technology, reduces GHG emissions by >70% and each atmospheric pollutant (NOx, SOx and particulates including ultrafine particulates) by >80% for the selected modes of operation;
- Identification of a route for scalability to 20 MW FC power, associated bunkering and system integration for large long-range vessels;
- FC Module durability of at least 25,000 h;
- Tank to propeller electrical efficiency of >48% (LHV) for relevant operation profile(s);
- FC system availability of at least 95 %, and operational strategies for meeting commercial ship requirements for propulsion, auxiliary load or port/pilotage operation;
- Technical solutions that meet all local safety requirements concerning refuelling, fuel storage and bunkering within the operational environment;
- Systems design life of at least 7 years to fit service intervals between major vessel overhauls (servicing allowed) in line with the typical 25-30 years vessel lifetime;
- Provision of empirical evidence and lessons learnt from implementing and operating FC ships and use of alternative fuels, identification of bottlenecks – technical, organisational, structural, financial including RCS and formulation of recommendations on how to address these;
- Increased public awareness about zero emission initiatives in the marine segment;
- De-risking further commercialisation of FC and alternative fuels technologies;

- Contribute to significant further capital cost reduction of fuel cells and refuelling infrastructure.

Type of action: Innovation Action

The conditions related to this topic are provided in the chapter 3.3 and in the General Annexes to the Horizon 2020 Work Programme 2018-2020 which apply mutatis mutandis.

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