Workshop on Hydrogen and Fuel Cells in maritime applications

15-16 June 2017

Valencia, Spain

The workshop on Hydrogen and Fuel Cells in maritime applications, which saw the participations of 115 attendees, was organised by the Fuel Cells and Hydrogen Joint Undertaking, the Valencia port authority, Fundacion Valencia Port and the Joint Research Center (JRC).

This event can be considered a follow-up of a similar workshop held in Venice in 2013, and also comes on the heels of the workshop organised in Lyon in 2015 on Smart Specialisation. In addition, there was also interest shown by many cities and regions across Europe towards the deployment of hydrogen applications in the framework of the initiative organised by the FCH JU.

While the interest shown by stakeholders in this domain is high, there are a number of issues to be addressed on how the technology could be concretely deployed, which are the costs involved and possible financing opportunities, which would be the deployment timeframe and which actors need to be involved and, finally, whether the regulatory framework is favourable for the deployment of these technologies. Throughout the workshop, several speakers from the industry, local authorities and EU institutions shed some light on these issues with a focus on maritime applications.

Establishing stronger links between port operators and authorities and the fuel cells and hydrogen (FCH) industry was the other objective of the event. The active participation of both communities allowed end-users active in the maritime sector to provide a clear overview of their operations, needs and constraints, while representatives of the FC and hydrogen industry presented which solutions are already commercially available and a technology development outlook. Local and European authorities completed the discussion recalling the regulatory framework in which innovative decarbonisation technology solutions will need to be deployed.

The event was favourably evaluated by all participants who saw it as a unique occasion to get a comprehensive update on the state of the technology and as an occasion for networking and B2B opportunities.

Introductory remarks

The event opened with an overview of the EU legislation impacting port operations. Both climate and energy goals and quality of air regulation were referred to as the key drivers for the uptake of clean technologies such as FC and hydrogen, as recalled by **Ramon Gomez Ferrer, Deputy Director of** the port authority of Valencia. Port operations will play a key role as they are responsible for a large chunk of the maritime CO2 emissions and have a negative impact on quality of air as well. Hydrogen applications, therefore, are bound to become increasingly interesting as they can help ports to become compliant with the regulation without impacting negatively the efficiency of the operations.

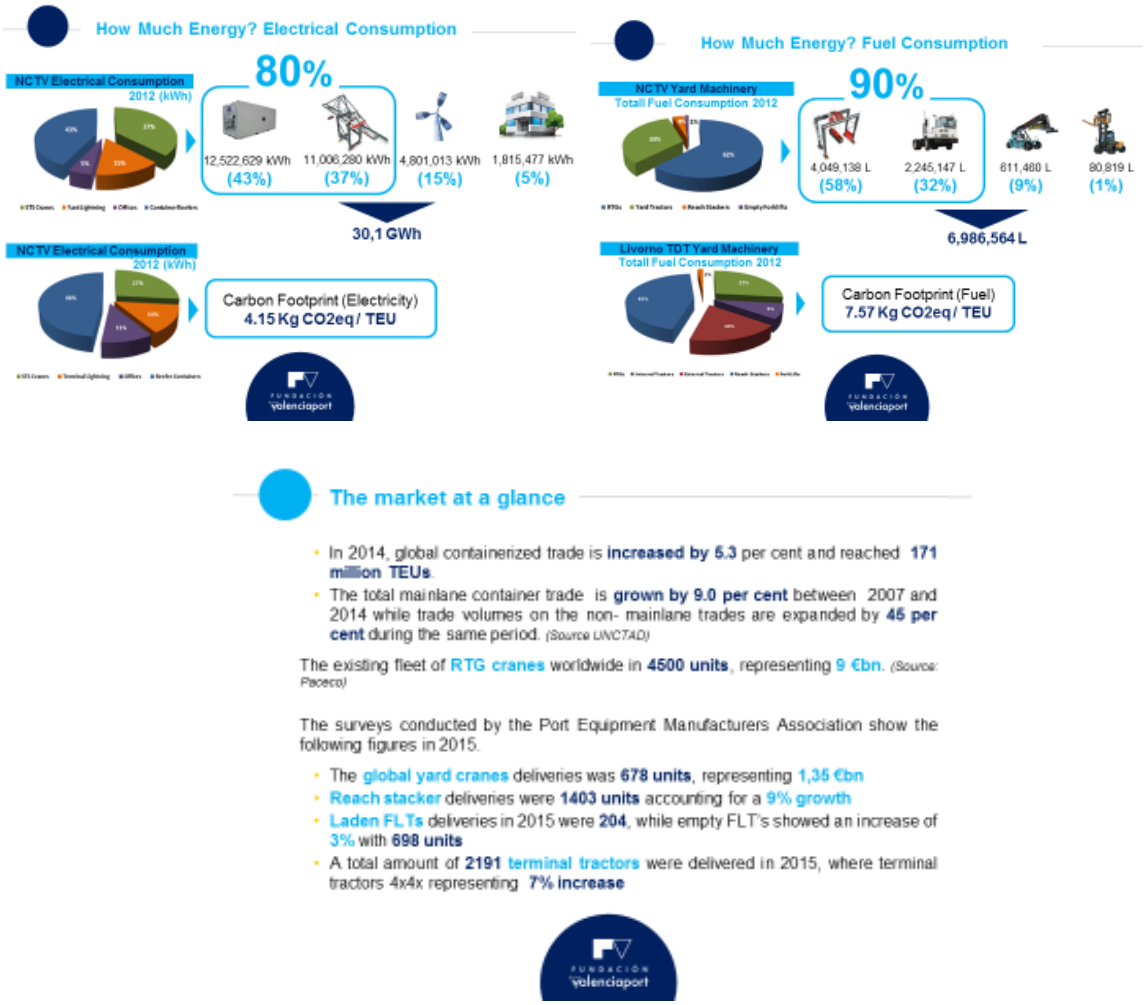
Alejandro Cros Bernabeu from the Spanish ministry of Economy, Industry and Competitiveness presented that the national plans submitted by Spain to the EC in 2016 contain a special chapter on hydrogen, highlighting the interest of the Spanish government toward this technological option. He explained that the vision of the government is that hydrogen is not a tomorrow's technology, but a technology that can and needs to be used already.

The EU climate and energy goals were recalled by **Katarzyna Drabicka,** policy officer at DG RTD, who presented the evolution of the overarching climate goals from 2020 to 2030. Transport decarbonisation represents a clear challenge as in 2014 only 6% of the energy used was from renewable sources and transport was still representing 30% of the overall EU emissions. Furthermore, almost the entirety of the oil used by the EU transport is imported creating a challenge also from the point of view of energy security. Maritime transport represents today ~2.5% of the global GHG emissions, but these are expected to grow up to 250% by 2050. In light of these elements the EU decided to mark the maritime sector as a priority area for action in its European Strategy for Low-Emission Mobility adopted in July 2016. The EU has deployed a number of financial tools and programmes which will facilitate the uptake of low carbon technologies including the European Structural & Investment Funds, CEF & TEN-T, Green Shipping Guarantee as well as the H2020 and FCH JU.

Mirela Atanasiu, head of operations and communication at the FCH JU, presented the structure, activities and goals of the FCH JU and recalled the purpose of the workshop. She underlined that it is necessary to create stronger links between the hydrogen industry and port operators as well as the local authorities. Draft plans already exist for the next round of priorities to be financed, however, the feedback of the interested parties participating at the workshop will be key in adapting these plans.

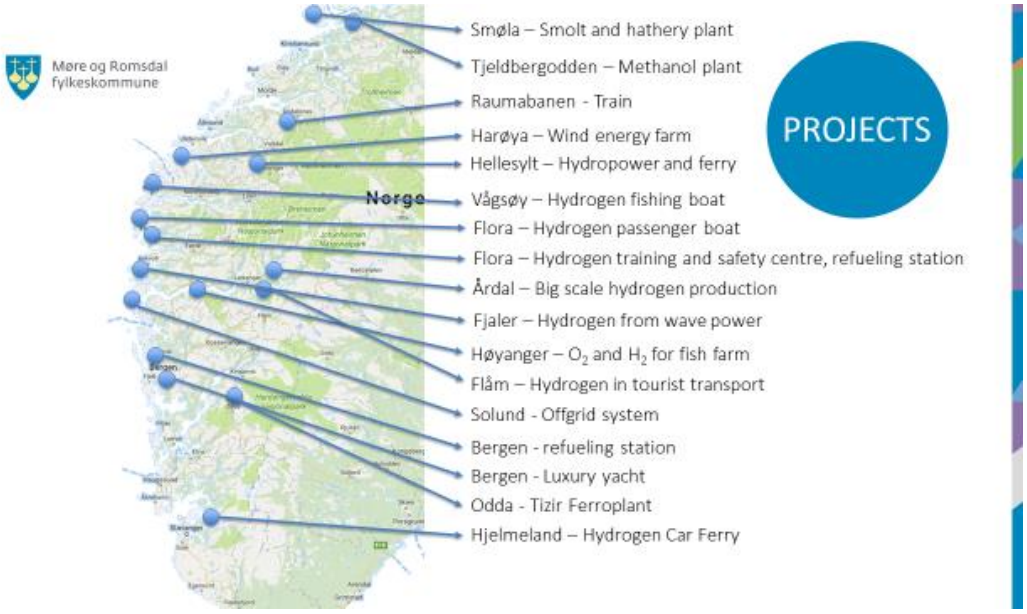
During the following session **"Perspectives, opportunities and challenges for H2 in maritime"** representatives of the hydrogen and FC industries and the maritime sector tried to identify points of contacts and a possible way ahead to cooperate.

Mercedes de Juan project manager at the Port of Valencia started by detailing the activities of the port and its impact in terms of trade, jobs, growth as well as more problematic aspects such as energy consumption and emissions. An important trend discussed was the evolution of container traffic; 0.709 million TEU (Twenty-Foot Equivalent Unit) were handled in the Valencia port in 1996 and the number increased to 4.722 million TEU in 2016. Container traffic is expected grow worldwide and clean solutions, such as hydrogen applications, will be needed in order to decouple growth in operations from emissions. For this opportunity to materialise, however, it is important that the hydrogen sector understands the energy consumption profile of the harbours and familiarises with its activities and dedicated regulatory framework in order to develop tailor-made solutions.



Lina Jonasson, energy advisor at the Møre og Romsdal county presented a wide range of projects involving the use of hydrogen and FC in her county. In this particular case, hydrogen projects was supported by the local authorities due to a number of elements such as: the abundance of renewable energy generation and the risk of curtailment, the prospect of costly upgrades of the local electricity grid and the presence of hydrogen generated as by-product by the local industries. One of the projects foresees retrofitting of a ferry (30 meters, 100 passengers) with a hydrogen powertrain by 2021. Thanks to 3 tanks containing each 150 kg of hydrogen, the ferry is expected to refill once every night. Such application will be suitable for many other places in Norway once proven on the ground.

A number of additional projects are under way in Norway, as shown in the figure below.



Heinrich Klingenberg, hySOLUTIONS went on presenting the "e4ships" a project partially financed by public funds with the goal of decreasing GHG emissions, pollutants and noise, involving yards, ship operators, FC manufacturers, equipment suppliers. The project concerns 3 main areas of applications. The first one focuses on the development of FC applications for supply systems on ships. The case of the Hamburg port was mentioned as an example. Each year the port hosts around 200 cruise-ships and this constitutes a problem in terms of emissions of CO2 and pollutants (NOX, SOX, PM) as well as noise since the ships auxiliary power units (APU) operate on fossil fuels. The use of high-temperature FC (SOFC and PEM) for APUs would contribute to substantially decreasing these problems. An APU operating on methanol is already present on a ferry (MS Mariella, Viking Line) and in the next phase of the project the optimisation of the system will be analysed (specific goals: increased performance and lifetime). The demo project "SchIBZ" is testing a SOFC fuelled by low-sulphur diesel, while "RiverCell" is developing a hybrid power plant for a river cruise vessel.

Mr Klingenberg concluded his presentation launching a clear message to regulatory bodies; in order to support the use of alternative fuels and FC technologies in the maritime sector the industry needs:

- Support in research and development projects as well as demonstrations,
- Establish a clear, stable and long term ambition for emission reductions (MARPOL Annex VI, EU and IMO sulphur requirements),
- Support innovations spurring from IMO work on innovative safety requirements for the building and retrofitting of ships,
- Prepare a regulatory framework favourable to the testing and introduction of innovative technologies.

The following session focused on "**H2 and fuel cells for clean ships**". A number of policy drivers for the uptake of alternative fuels and innovative propulsion systems were recalled throughout the presentations. One of these being the MARPOL convention which mandates the use of fuels with no more than 0.5% of sulphur content by 2020. As it is expected that provision of these low sulphur fuels may not meet the demand, the adoption of alternatives are considered, the main ones being scrubbers and LNG.

Due to increasingly tight regulation, on air pollution in particular, the shipping sector is indeed exploring the development and deployment of alternative independent propulsion technologies

including FC. A number of challenges, however, must be overcome in the technical, regulatory and safety domains (as highlighted in the EMSA, "Study on the use of fuel cells in shipping"). Furthermore, it will be necessary to reduce drastically the costs of the technology. Besides the policy drivers, the uptake of innovative and clean technologies will also need to take into account upcoming megatrends impacting the shipping sector such as digitalisation, urbanisation, carbon free resources, automation, global economic shift and environment. By simplifying the design of the ships, eliminating rotary components and therefore diminishing maintenance costs, the use of FC, in particular, is complementary with the ongoing automation of the sector.

On their end, FC technology providers are continuously working on the development of products that can answer to the above-mentioned technical challenges while lowering costs. Even though the experience of the FC industry in the transport area is linked mostly to road applications, the easiness of integration of FC solutions in different vehicles makes marine applications a suitable match. The integration of FC solutions in vessels, however, must take into account a number of maritime specific challenges, such as operation in saline environments, shock and vibration, testing and certifications as well as dedicated regulation.

A number of projects are demonstrating what FC technologies can already offer today and the maturity of these solutions. Since 2008, the "Zemphis" project, for example, demonstrated the viability of a propulsion system based on FC and hydrogen for a small passenger boats (100 passengers) by accumulating 4,000 hours of operations and a total of 50,000 passengers transported. The project Maranda is demonstrating the capability of a FC system to power the electric equipment of the Aranda vessel operating in artic marine environment. Special attention is given to marine application requirements such as resistance to shock, corrosion, power range and lifetime.

Which fuel is to be used in combination with FC remains one of the key challenges to be resolved (supply, distribution and costs), with liquid fuels considered as a potential intermediary step toward the exclusive use of hydrogen.

The session "**H2 and fuel cells for clean material handling vehicles**" was moderated by Jose Gimenez from the port authority of Valencia. In his introductory remarks he recalled how material handling operations are responsible for a great deal of CO2 emissions, pollutants as well as noise. Ports on the other hand offer known energy consumption patterns, rely on several types of material handling machineries with a wide variety of power requests and end users that favour scalable solutions. Ports, in other words, represent an interesting environment for developers of H2 solutions.

Sven Valentin, terminal manager at MSC, presented the key elements of container handling operations in ports. According to the profile of the terminal (traditional, semi/full automated) machineries and operations can differ. In case of a traditional terminal, such as the one operated by MSC in Valencia, RTG cranes and yard tractors are those polluting the most. In their terminal all machineries were originally propelled by diesel engines; however, at present already 60% of the stacking area has been electrified and by 2018 the plan is to phase out completely diesel engines from RTG yard cranes. Yard tractors will follow. While in theory these could represent opportunities for hydrogen applications, it was explained that the technology of choice for the time being was LNG due to the greater amount of information available for this technology and greater maturity compared to hydrogen solutions. Furthermore, it was noted, that the footprint of hydrogen refuelling stations is a potential concern given the value of surface space in terminals.

Following the point of view of the ports, FC suppliers took the floor to explain what the technology can offer today. Throughout the presentations a number of advantages offered by FC and hydrogen

technologies were presented. Concerning mobile applications, FCs allow for continuous operations which are compatible with the 8 hours shifts of several machineries. The refuelling times are similar to these of diesel (~ 3 minutes). Forklifts with lift capacity of 18 tons powered by FC are already commercially available. In terms of refuelling, ports can already choose among several solutions: mobile refuelling, onsite storage or onsite generator (reformer or electrolyzer). This allows a port to choose the solution that better fits its needs in terms of optimal distribution of refuelling points and minimal footprint. While it was highlighted that hydrogen and fuel cells are a commercially available reality, a number of hurdles that need to be overcome were mentioned as well (i.e. putting in place an appropriate hydrogen distribution infrastructure, continuous dialogue between FC providers and end-users to develop tailor-made technology solutions).From a regulatory point of view policy makers will need to support the uptake of clean technologies in ports. This needs to be done by pushing for the decarbonisation of material handling operations, but also by developing suitable permitting procedures and safety protocols.

Safety and regulation issues were tackled by the speakers of the following session: "**Horizontal considerations: RCS, regulations safety, environment**".

In order to set the scene for the following discussion the main hydrogen properties and specific handling requirements were recalled. Millions of tons of hydrogen have been used by the industry for decades and while hydrogen is a flammable gas, any risk of accident can be eliminated by establishing simple guidelines. In this sense hydrogen is not that different from natural gas or any other low flashpoint fuel. At the same time, however, it was noted that the number of hydrogen applications is growing rapidly in several sectors and the regulation is not keeping up. As a result there are today a number of gaps in regulations, codes and standards (RCS) hampering the deployment of hydrogen.

RCS, however is not completely still and a number of changes are taking place. Of particular interest to hydrogen is the IGF code developed by the IMO, which will provide mandatory provisions for the installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuels. The code provides details only for natural gas, however hydrogen and other low flashpoint fuels can be approved based on alternative designs. One of the gaps that still needs to be addressed is the bunkering of low flashpoint fuels (including hydrogen) other than natural gas.

It is important that RCS continues to evolve so as to ensure homogeneous safe handling of hydrogen and provide a clear framework for the development of innovative hydrogen applications. In terms of storage, for example, simple guidelines will allow developers to minimise or eliminate any risk via innovative designs (i.e. appropriate location of storage facility).

The activities of the IEA task 39: Hydrogen in Maritime Transport can provide an important contribution in this sense. Scope of this grouping, in fact, is to investigate the hydrogen uses in the maritime sector, identify challenges and opportunities, disseminate knowhow, contribute to safety and risk regulation and facilitate links among international demo projects.

During the **"H2 and fuel cells for clean stationary applications and H2 infrastructure**", industry players provided an overview of the technology solutions available to ports for the refuelling of hydrogen powered fleets and provided their views on how to speed up the uptake of the technology.

From the hydrogen production point of view, the industry representatives presented a variety of technologies used to produce and distribute different gases, which can be used a fuel for the fuel cells, including hydrogen. In this regard, while it is clear that the final goal is to displace propulsion based on diesel with hydrogen, different options of how this transition could happen were discussed. One option is to go through the use of greener gas, while another is to use green electricity (while hydrogen

costs production decrease and supply network expands). Intermediate fuels such as CNG/LNG/methanol are already broadly used, present a TCO cost similar to diesel, are easier to store and would support the transition toward hydrogen by improving gas related technologies. Transition through green electricity would instead support transition toward hydrogen by ameliorating electro-technology. Other industry representatives presented a transition vision where hydrogen could become a viable option without necessary additional intermediary steps. One of the key elements of hydrogen competitiveness vis-à-vis incumbent technologies is the cost. With hydrogen at 5€/kg, competitiveness is already within reach. Potential end-users should consider the whole cost of the technology (TCO) chosen. While it is true that hydrogen production coupled with renewable electricity presents a higher CAPEX, the OPEX will be lower and stable for the whole operating life of the equipment.

Focusing on technical aspects, speakers noted that much of the experience accumulated by the hydrogen and FC industries in the power or road sector can be used to develop maritime solutions. The fuelling process is well established, but it is necessary to establish standards and protocols in order to provide guidance for those developing refuelling applications and ensure the safety of those handling refuelling operations in ports. Storage pressure, fuelling speed, break away coupling at vessel and liquid hydrogen fuelling systems and speed, training of personnel are some of the specific elements mentioned.

The concluding session **"Smart specialisation: programs and funding opportunities on H2 and fuel cells"** focused on the funding opportunities available at EU level for the deployment of clean technologies and related infrastructure. **Rafael Ortiz Cebolla** took the floor again to introduce the concept of smart specialisation and how it can assist EU regions to develop their innovation strategies. There are 3 platforms: Energy, Industrial Modernisation and Agri-food. These platforms can provide a variety of benefits including finding synergies between EU funding, facilitating links among cities and shared innovation infrastructures among them. **Karolina Horbaczewska** and **Mathieu Doussineau** from the JRC completed the overview presenting the synergies between the European Structural and Investment Funds and other European funds and programmes such as the Horizon 2020 (including the FCH JU) or other financial facilities offered by the EIB.

Carlos Navas from the FCH JU and **Markus Kaufmann** from Roland Berger presented jointly the ongoing initiative involving regions and cities interested in developing business cases for FC and hydrogen applications. The pan-European initiative involves more than 70 regions from 20 countries with a variety of interests for FCH applications (more than 30 are considered). The initiative also represents an occasion for the FCH industry to find out which solutions are needed by the local authorities.

During the concluding remarks the audience had the opportunity to express their satisfaction with the event, which was considered by the participants as very informative and useful in terms of building bridges between the port and the fuel cells and hydrogen industries.

Outlook

Carlos Navas (FCH JU) and **Vicente del Rio**, president of Fundacion Valencia Port, provided a short summary of conclusions for the workshop.

The level of interest from the port and maritime industry was shown to be quite high. At the same time, more information is needed to fully understand the advantages and challenges facing the

integration and FCH products into their daily operations. The workshop provided a comprehensive first look at a number of ongoing projects and experiences thereof where FCH technologies are already proving early positive results. A number of challenges remain, perhaps the most significant ones being cost and an appropriate framework that supports the introduction of these technologies.

Some industry representatives from port and maritime operations expressed interest in participating in the working group set up under the initiative of the FCH JU, which is specifically looking at business cases for port and maritime applications.