HORIZON 1
Oort Energy Ltd

BEIS Red Diesel Replacement Phase 1
RDR/P1/L3/6294

Dodwell, James
j.dodwell@oortenergy.com

Horizon 1 publicly disseminated report

1 CONTENTS

2 SUMMARY

Horizon 1 was a project aimed towards developing a low-cost, high-performance Proton Exchange Membrane (PEM) electrolysis solution for green hydrogen production in the non-road mobile machinery (NRMM) sector, which is crucial for the UK's efforts to achieve net-zero carbon emissions by 2050.

PEM electrolysis is a clean technology that uses an electric current to split water into hydrogen and oxygen, with the hydrogen being used as a clean energy source. However, the high cost of PEM electrolysis has been a significant barrier to the widespread use of hydrogen as a clean energy source. Horizon 1 aimed to address this issue by further developing Oort Energy's low-cost, high-performance PEM electrolysis solution.

The project started with a feasibility study to identify the technical and economic challenges in developing Oort Energy's low-cost PEM electrolysis solution. Based on the findings, Oort Energy refined its existing PEM electrolysis technology and optimized its production processes to reduce the cost of PEM electrolysis further and to increase the technology from TRL 4 to TRL 6.

The Horizon 1 project is an essential step towards the development of a cost-effective and reliable PEM electrolysis solution for green hydrogen production, which is essential for the UK's transition to a low-carbon economy. The success of the project will help the UK to achieve its ambitious net-zero carbon emissions target by 2050 and promote the development of a clean and sustainable energy system.

3 PROJECT OVERVIEW

The aim of Horizon 1 was to develop, and assess the feasibility of, Oort Energy's green hydrogen solution in the NRMM sector. In this Phase (Phase 1), the company conducted a feasibility study and experimental development to establish the potential of the green hydrogen solution in terms of market and decarbonization potential. The feasibility study covered important aspects such as sizing, location, power, and hydrogen generation capacity of a green hydrogen electrolyser designed to refuel NRMMs in different settings. The study also included a life-cycle assessment to determine the reduction in CO_2 emissions achieved. Oort Energy also performed practical development to test the limits of pressure that the system can operate at and developed a rig to demonstrate high-pressure operation of the electrolyser stack.

In this project, Oort Energy have demonstrated that our electrolyser technology meets the key criteria for scale-up operations. We have demonstrated that our system has very high performance (Figure 1), and is capable of maintaining high performance through both continuous and intermittent operational regimes.

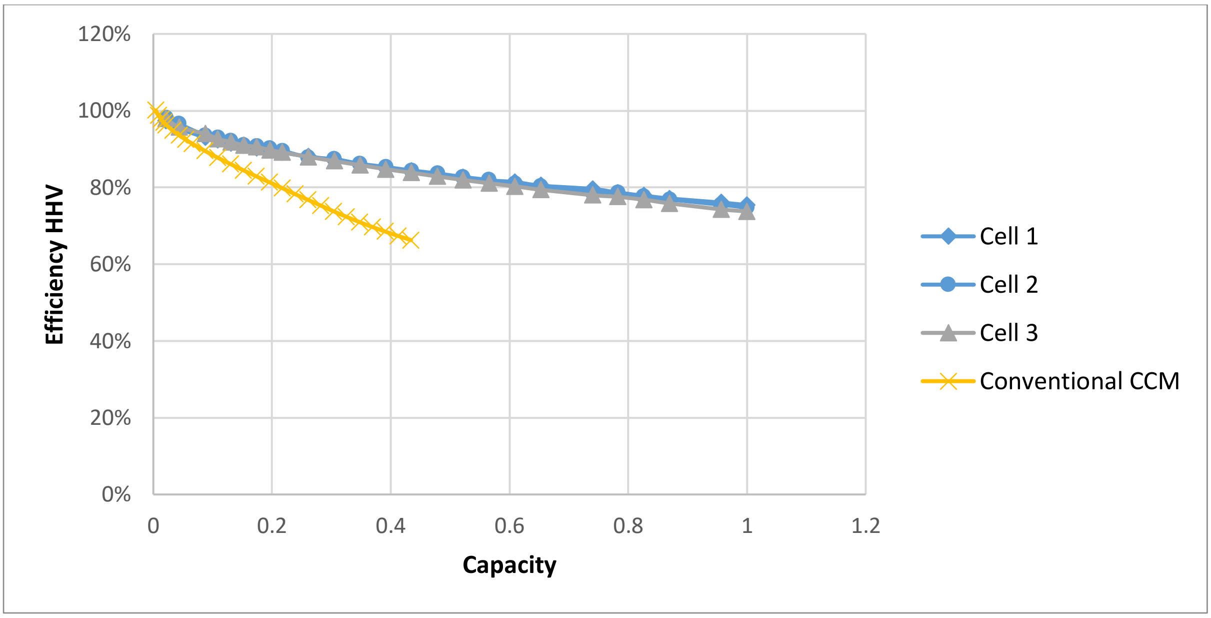

Figure 1. IV curve of the 3-cell stack in comparison to a conventional PEM system

In the RDR project also, we have developed both the stack and balance of plant for a full, 250 kW demonstrator system. This is a fully compliant system and will be demonstrated at a NRMM site in the Phase 2 project. Going forwards, Oort Energy will be commercializing 250 kW electrolyser systems as a minimum commercial offering.

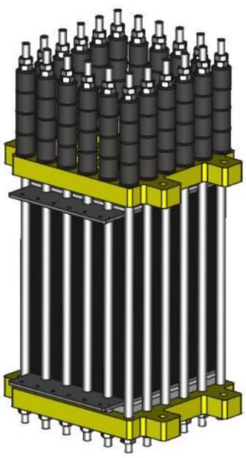

Figure 2. Oort Energy's' 250 kW electrolyser stack

4 WORK PACKAGES AND PROGRESS

The project was outlined in three main work packages. Work Package 1 focused on the development of test rigs designed to test the stack at high pressure using hydraulics. This was a system designed to operate under two modes – yield pressure testing and fatigue testing. Yield testing proceeds by ramping up the pressure of the electrolyser stack until components of the stack fail. This takes places at an undetermined pressure, and so the system was designed to ensure failure by overengineering the system to be capable of 300 bar operation. Fatigue testing involves more moderate pressures, up to the operational limit of the electrolyser, but this repeats so that the components of the stack are pressurized and depressurized many times. The hydraulic test system was built with this consideration in mind. This system was built early in the project, and has proved to be a highly useful tool in aiding the stack development for higher and higher pressure. This has enabled iterative design changes on the stack for high pressure operation.

Work Package 2 has focused on the development of a test station to operate the stack (produce hydrogen) at high pressure. Two modes of stack operation were undertaken. Intermittent operation, which simulated connection to solar / wind, and continuous operation. Both modes are well known to stress electrolysers in different manners, but both modes did not present any lifetime issues for the stack. In brief, in intermittent mode, a lifetime estimate of approximately 16 years was given, and no appreciable decay in operational mode was given. In the field, PEM electrolysers typically have a lifetime of 10 years (as it is economical to replace them after this point), and we anticipate a similar replacement also. Therefore, our technoeconomic modelling has been based upon a 10-year lifetime.

Figure 3. High pressure operational test bench

The IV curve produced from the stack is as follows:

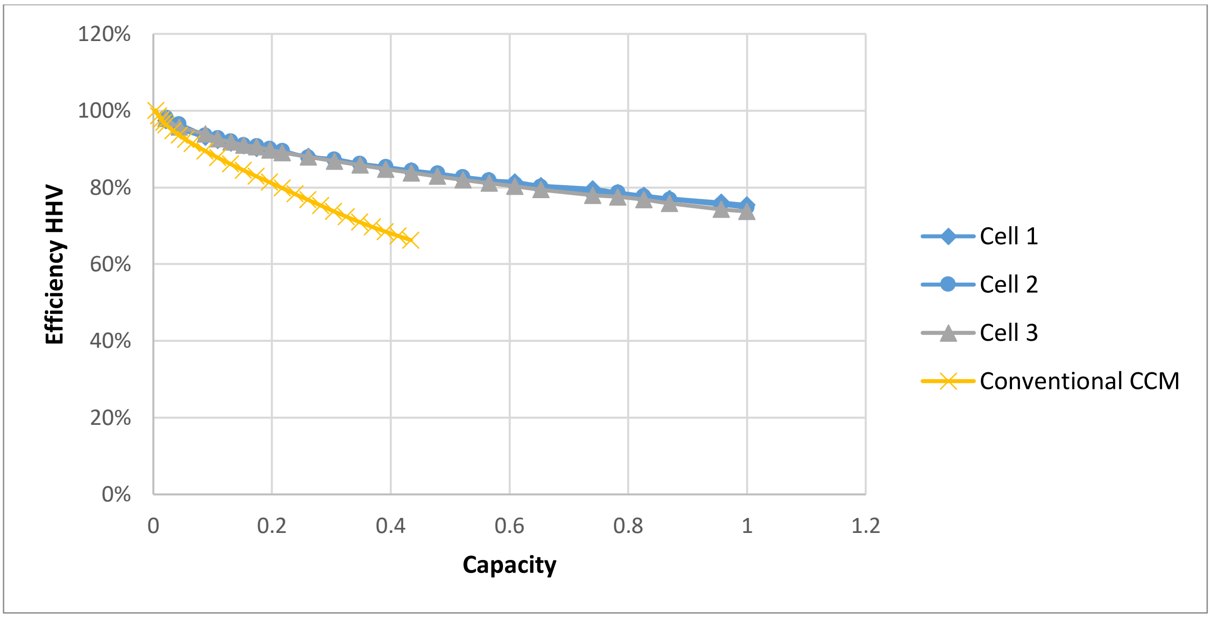

Figure 4. IV curve of the 3-cell stack in comparison to a conventional PEM system

Higher voltage means greater inefficiency, and so the hydrogen produced is more expensive (as more of the energy is wasted as heat). Electrolyser systems inherently waste more energy when operated at a higher current density, but as our electrolyser is found to be more efficient then we can operate at higher current densities with reduced inefficiencies. This enables us to both reduce our stack size and / or to operate more efficiently than the competition. A 3-cell stack provides enough confidence that our full-sized, 80-cell stack will operate equivalently (Figure 2).

Work Package 3 was a comprehensive project focused on developing our green hydrogen solution, and to provide the route to raise the TRL, from 6 (at Horizon 1 conclusion) to 7. This work package consisted of three main components: designing a 250 kW electrolyser system, conducting techno-economic modelling to estimate the levelized cost of hydrogen and performing a life cycle analysis to determine the carbon emission equivalent of the green hydrogen solution.

The first component of the package involved designing a 250 kW electrolyser system. This system will contain the electrolyser stack and included the creation of P&ID and process flow diagrams, safety cases, and rough estimations for bill of materials and system cost. The goal was to design a safe and efficient system that could produce green hydrogen at a reasonable cost. The safety cases were particularly important since the system involved the handling of hydrogen, which is a flammable gas. HAZOPS and LOPA were used to identify potential hazards and assess the risks associated with the system. These analyses were used to develop a comprehensive safety case that could be used to demonstrate the safety of the system to regulatory bodies and potential customers.

The third component of the package involved conducting a life cycle analysis to determine the carbon emission equivalent of the green hydrogen solution. The analysis involved estimating the carbon footprint of the system, which was then used to calculate the carbon equivalents for the green hydrogen solution. The results indicated that the carbon equivalents for the green hydrogen solution were in the range of 0.6 to 2.4 kg CO_2e per kg of H_2. This places the green hydrogen solution within the "green hydrogen" category, which means it has a significantly lower carbon footprint compared to other hydrogen solutions currently on the market. Additionally, the team had identified several innovations that could further reduce the carbon footprint of the system, such as reducing the use and recycling of the Nafion polymer and removing titanium from the system.

5 BEYOND NRMM

Although Horizon 1 has got a specific focus in the NRMM sector, electrolysers have potential, and are being demonstrated in some of the following sectors currently. Oort Energy intends to expand into these sectors:

- Heavy industry: Green hydrogen can replace fossil fuels in energy-intensive industries such as steel and cement production, where decarbonization is particularly challenging due to the high temperatures required for manufacturing processes.
- Power generation: Hydrogen can be used in fuel cells to generate electricity with zero emissions, providing a clean energy source for stationary power applications, such as backup power for data centers or remote power for off-grid communities.
- Transportation: Green hydrogen can fuel a range of transportation modes, including cars, buses, trains, and even airplanes, helping to reduce emissions in the transportation sector.
- Buildings and heating: Hydrogen can be used as a fuel for heating and cooking in buildings, either directly or through conversion to electricity using fuel cells. This could help decarbonize the heating sector, which is a significant contributor to greenhouse gas emissions.
- Energy storage: Hydrogen can be used to store excess renewable energy generated during periods of low demand, providing a way to balance the grid and increase the penetration of intermittent renewable energy sources.