ERM Dolphyn Commercial Scale Demonstrator (CSD) and Small Scale Trials (SST)

Final Project Report – Public

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Executive Summary

ERM has developed the Dolphyn process for the production of 'green' hydrogen at scale from offshore floating wind. The technology innovation has been developed by ERM over the last 7 years, and a new company, Dolphyn Hydrogen Limited, has been established to take forward the commercialization of the technology in the UK and overseas.

Dolphyn's development has been supported and accelerated by the Hydrogen Supply Competition, funded by the BEIS Energy Innovation Programme (2016-2021) and the DESNZ Low Carbon Hydrogen Supply 2 Programme (2022-2024).

During **Phase 1** of the programme, the Dolphyn concept was compared to alternative centralized and decentralized options both onshore and offshore and was found to be the most economically advantageous solution for generating hydrogen at multi-GW scale. Subsequently a 2MW prototype design solution was developed to FEED stage.

During **Phase 2**, the design was de-risked to the extent that it could be moved forward confidently from the previous 2MW unit to a 10MW unit. The current phase has significantly derisked elements from the earlier phases and taken the 10MW **Commercial Scale Demonstrator (CSD)** unit design further forward as follows:

- **Development of Targeted FEED** - The design activities for the 10MW CSD unit have been successfully completed, resulting in approximately 500 engineering deliverables being produced, including a wide range of studies and engineering drawings such as layouts, 3-D models, Process Flow Diagrams (PFDs), Piping and Instrumentation Diagrams (P&IDs), Single Line Diagrams (SLDs) and equipment specifications / datasheets;
- **Design Independently Verified** - The design process has been critically reviewed and independently verified by Lloyd's Register to provide confidence that a robust hazards management process is being followed during the design. Lloyd's Register had unrestricted access to all design documentation developed by the project team.
- **Roadmap to Consenting** – Building on a programme of engagement with key regulators and government bodies, consenting strategies have been developed, consulted on and refined, to account for modifications to the UK

regulatory system and the untested approach of consenting offshore hydrogen production and hydrogen pipeline to shore. Extensive effort on planning and consenting for deployment of Dolphyn Hydrogen has involved both onshore and offshore workstreams. Work has progressed through onshore EIA screening and regulator engagement to undertaking onshore baseline surveys and preparation of offshore environmental scoping material. Following the Government response to consultation on Offshore Hydrogen Regulation, in which ERM Dolphyn was an active participant, comprehensive consenting roadmaps have been developed establishing a robust pathway to consent across the marine planning and oil and gas regimes for offshore hydrogen production and transport. Determining the appropriate consenting strategy for ERM Dolphyn in the context of evolving regulations, parallel consenting regimes and with multiple key stakeholders has established a valuable precedent in the application of appropriate methods to consent offshore hydrogen projects in the UK. A regulator workshop planned for September 2024 will play a vital role in building on earlier dialogue with statutory consultees and setting the future pathway for consenting.

- **Supply Chain -** ERM has conducted a comprehensive assessment of the floating offshore wind and hydrogen production supply chains. The assessment has culminated in a database of suppliers tracking the capabilities, experience, and location of individual companies. To date, the project has recorded more than 190 equipment suppliers, 201 Service providers and 35 manufacturing facilities with capacity to support the development of commercial projects. ERM has invested significant effort in creating the supplier database and categorizing the capabilities of suppliers. The database is a tool that will be continuously used moving forward and will grow in value as further suppliers are added. Engagement with suppliers of equipment and services to date has proven extremely useful to the project. ERM Dolphyn is committed to maximizing UK content as far as is economically practicable.
- **Commercial Development Plan** – Dolphyn Hydrogen (Limited) has been established by ERM, with the sole objective of maximizing the commercial opportunity associated with the Dolphyn Technology. We see clear potential for scaling the technology to GW scale over the next 10 years, via a serious of steppingstone developments, as shown below:

Figure 1 Dolphyn Hydrogen Global Business 10-Year Development Plan

Our first commercial project in the Celtic Sea is the pivotal next step in realizing Dolphyn's full commercial potential. Along with a number of project partners, we have submitted a successful funding application to Innovate UK to support and advance the development of the project concept

To deliver any project in a timely (accelerated) manner, with maximum impact on 2030 hydrogen and decarbonization targets, will also require strong support from key regulators and stakeholders. We very much welcome the Governments stated commitment to liberalization and acceleration of planning approvals.

- First of a kind trials were undertaken this year whereby a **Small-Scale Trial (SST)** hydrogen from seawater demonstrator was developed, constructed and deployed offshore at Pembroke Port. Flexible Riser Trials (FRT) have also been undertaken whereby materials were tested for hydrogen transport suitability. Elements of the SST and FRT included the following:
- **FEED and Detailed Design** – The design activities for the SST unit resulted in approximately 200 engineering deliverables being produced,

including a wide range of studies and engineering drawings such as layouts, Process Flow Diagrams (PFDs), Piping and Instrumentation Diagrams (P&IDs), Single Line Diagrams (SLDs) and equipment specifications / datasheets.

- **Consenting** – To allow the Small-Scale Trial to take place, ERM worked with three main stakeholders: National Resources Wales (NRW), Milford Haven Port Authority (MHPA) and Marine Energy Test Area (META). The main permitting authority for the trial area was National Resources Wales (NRW), however given the nature and short operational duration of the trial it was agreed that the consented aspects of the META site were sufficient. Coordination and communication were maintained between META, MPHA and ERM during the course of the trials.
- **Delivery** - Following the end of the design phase, the SST unit was assembled in the Altrad Babcock factory in Scotland before being transported to Pembroke Port and installed on the trial barge. Excepting the electrolyser, which was manufactured in the United States, all equipment has been built and assembled in the United Kingdom. Once fully installed on the trial barge, commissioning activities took place before moving to the trial phase. The trial operation took place in June/July 2024 and was completed successfully.
  The unit was then decommissioned, dismantled and stored.
- **Health and Safety** – The Health and Safety processes put in place for the Small-Scale Trial were designed based on Offshore Wind standards. The quality of the systems, documentation and procedures created for this trial will be the basis for the CSD delivery phase. No major incidents were reported on site during the delivery phase, involving over 14,000 hours exposure.
- **Technical Learning** – The production of hydrogen from the fully integrated power, desalination and electrolysis system, was successfully demonstrated in the offshore environment under a range of sea conditions. Sea conditions were reasonably varied given the time of year and led to regular noticeable pitching and rolling motion on the barge with several large movements accentuated by passing vessels. The project included development of a data storage and visualization application (Digital Twin), which was used to identify areas of further design improvement and

demonstrated the operation of the trial system to a wide audience. Different areas of the application were used to present the data to varying levels of detail, for audiences of different technical interests. Overall, the small-scale trial was a great success, yielding important results and data that further strengthens understanding and the viability of the Dolphyn technology. Key processes such as sea water desalination and hydrogen production via Proton Exchange Membrane (PEM) Electrolysis, were demonstrated to be able to operate safely and reliably in the offshore floating marine environment. The lessons learned and data obtained from this project are highly valuable and will inform the next phase of the Dolphyn development plan.

- **Flexible Riser Trials (FRT)** - Although rigid pipework suitable for hydrogen duty is readily available and well-studied, a flexible riser is required for the Dolphyn facility to allow connection between the floating platform and the fixed transport system on the seabed. This trial aimed to ensure that the flexible riser technology to be deployed for the Dolphyn project was suitably qualified for hydrogen duty, with the mechanisms with the highest potential for failure identified and used as a basis for specifying the trails. ERM contracted National Oilwell Varco (NOV) to undertake specific testing on their riser to validate their use using Hydrogen gas. The equipment tested passed all trials to conditions exceeding those expected to be met by Dolphyn at the 10MW scale and at scales that are reasonably anticipated in the future. The trials have shown that the technology proposed is suitable for hydrogen duty associated with Dolphyn projects and similar applications. These trials were targeted at specific unknowns associated with hydrogen use. 3rd party verification is required before deployment, these trials give a high degree of confidence that 3rd party verification will be achieved. 3rd party verification is now planned by NOV following this project with a high confidence in success.

The project overall has provided significant technical, safety and supply chain learnings which will help realize and accelerate the commercial scale rollout of the Dolphyn Technology. The completion of targeted FEED and the success of the offshore trails also provides confidence for potential investors, who are looking to take a financial stake in the Dolphyn Hydrogen business.

It is important to recognize that the Dolphyn process has been developed with input from a wide variety of organizations with relevant experience and

knowledge across a range of established sectors including oil and gas, renewables, chemicals, hydrogen production, energy, construction, trading, and marine operations. ERM is extremely grateful for the support and input from all organizations and in particular, we would like to acknowledge the considerable support, knowledge and expertise provided by our project sub-contractors, namely:

Nel Hydrogen	Principle Power
Tractebel	Doris Group (Formerly ODE)
Altrad Babcock	Lloyd’s Register

1. Background

1.1 Company/Consortium Information

ERM has developed the Dolphyn technology to produce 'green' hydrogen at scale from offshore floating wind. The technology has been designed and developed by ERM over the last 7 years and has recently been successfully tested at a small scale in an offshore environment.

The Dolphyn process has been developed with input from a wide variety of organizations with relevant experience and knowledge from a range of established sectors including oil and gas, renewables, chemicals, hydrogen production, energy, construction, trading, and marine operations. ERM is extremely grateful for the input from all organizations, in particular the support of the following sub-contractors who have all been involved in the core project delivery:

Table 1 Project Consortium

DORIS WE ENABLE CHANGE	**Doris Group (Formerly ODE)** – Designing the topsides including desalination unit, electrolyser interface, hydrogen storage, stand-by power unit and export pipeline
Principle Power	**Principle Power** – Technology provider of the substructure system based on the proven Wind Float Atlantic design
TRACTEBEL ENGIE	**Tractebel** – Lead Engineer, also responsible for Constuction Engineering, Value Engineering, Safety Engineering and Operatbility/Maintainability.
nel	**NEL** – leading European Electrolyser Technology company developing electrolysis using their experience of electrolysis at sea (ships, submarines)

ALTRAD	**Altrad Babcock (formerly Doosan Babcock)** – Leading integration and marinisation engineering for the PEM electrolyser working alongside NEL
Lloyd's Register	**Lloyd's Register** – Independent 3rd party verification of the design

1.2 Project Background

The Dolphyn technology employs a modular design, integrating desalination, electrolysis and a wind turbine on a moored floating sub-structure to produce hydrogen from seawater using wind power as the energy source.

The component parts of the concept are all at a high 'technology readiness level' prior to commencing the project, providing a good degree of confidence that the solution will work at scale; however, they have not been proven in combination as an entire system or in the expected operating environment for Dolphyn. The development of the Dolphyn technology has been accelerated under the Hydrogen Supply Competition, funded by the BEIS Energy Innovation Programme (2016-2021) and the DESNZ Low Carbon Hydrogen Supply 2

Programme (2022-2024). Public funding such as this project is critical to bridge the gap between offtaker market expectations and the cost of production for early-stage projects. The funding provided by DESNZ helps us to successfully demonstrate the concept and move more quickly to commercial scale projects, with their associated cost savings.

Illustrations of the Dolphyn Commercial Scale Demonstration (CSD) unit are shown below.

Figure 2 Dolphyn Commercial Scale Demonstrator (CSD)

A summary of the previous phases of work is presented below, with details of the current phase, including objectives, presented in the next section.

1.2.1 Summary of Previous Phases

ERM developed the Dolphyn technology (Dolphyn – Deepwater Offshore Local Production of HYdrogeN) for the large-scale production of 'green' hydrogen from offshore floating wind. This solution has been compared to alternative offshore options and found to be the most economical way of producing hydrogen at scale in deep water at long distances from shore. The initial design was subsequently further explored and developed to Front End Engineering

Design (FEED) stage for a 2MW prototype. This was completed under Phase 1 of the Hydrogen

Supply Competition, funded by the BEIS Energy Innovation Programme (2016-2021). The Dolphyn design was then further developed to get to the stage where a financial investment decision could be made for construction and deployment.

The phased work was split into the following parts:

- Concept Select
- FEED and Forward Development Plan
- 2MW Prototype Development to Final Investment Decision

1.2.2 Concept Select

The 'concept select' stage of the project consisted of an evaluation of the technical and economic feasibility of selected design concepts for producing bulk scale hydrogen from offshore floating wind. It presented a review of the status of relevant technology as well as predicted future technology and manufacturing enhancements and cost improvements. Gaps in technology identified as necessary to commercialize or enhance the design options were assessed and incorporated. The work resulted in a predicted cost of hydrogen for the Dolphyn semi-sub option which when produced at scale which would be affordable (i.e. comparable with the cost of natural cost). It is also the most technically feasible option, with the required topside equipment being relatively easy to install in the shipyard prior to being towed to location. This decentralized option, of individual floating hydrogen production units sending hydrogen back to shore via a single pipeline, was therefore selected as the option that provides the most economic and sustainable solution for large scale production of green hydrogen for the UK.

1.2.3 FEED and Forward Development Plan

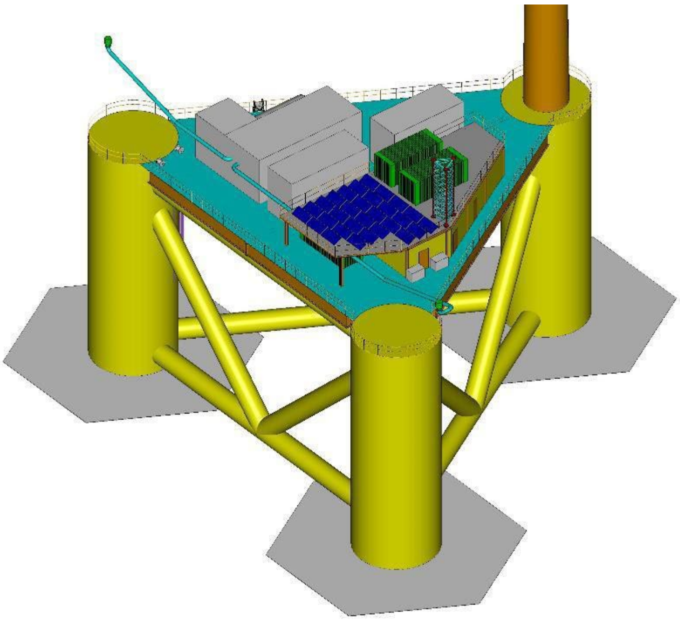
The FEED and Forward Development Plan' stage of the project included a summary of the design activities to be undertaken to bring the concept design to a point where it is technically and economically viable. It included the following activities:

- Front end engineering design (FEED) for a 2MW prototype;
- Detailed financial modelling including sensitivity of alternate commercial scale units involving larger (e.g., 10 or 15 MW) turbines;
- Project Development Plan

The FEED work determined that the design was technically and economically feasible. The engineering, financial, and development planning were developed sufficiently to enable the next phase of engineering to be undertaken with a high degree of confidence of reaching a final investment decision by Spring 2021 for building a 2MW prototype facility. A 3D visualization of the prototype design developed is shown below:

Results of work carried out during phases 1a and 1b were reported in the Dolphyn Phase 1 report [1].

Figure 3 2MW Prototype Design Illustration



The cost estimates established during the concept select were refined, with the base costs for the 2MW and 10MW scales remaining consistent, apart from the effects of inflationary factors and the “cost of money”, which are temporal and market wide. The estimates showed a clear commercial advantage of moving from a 2MW unit to a 10MW.

1.2.4 2MW Prototype Development to Final Investment Decision

The ‘2MW Prototype Development to Final Investment Decision’ stage of the project included completion of technical and commercial developments to bring the 2MW prototype design to a point where a final investment decision could be made. It included the following activities:

- Detailed design of the 2MW prototype;

- Regulatory compliance;
- Site finalization and consenting;
- Pre-procurement and supply chain readiness;
- Financial modelling.

Results of the work carried out are reported in Dolphyn Phase 2 Final Report [2].

2. Project Overview

2.1 Aims and Objectives

The Dolphyn Commercial Scale Demonstrator (CSD) project represents Phase 3 of the development of the Dolphyn process. It builds on the work carried out in earlier phases and progresses the design to a 10MW production unit which has clear commercial advantages over a 2MW unit and is more likely to attract external investment. Additionally, as the offshore wind and hydrogen markets are maturing a degree of standardization is emerging making c. 10MW units a more desirable scale for key supply chain members. This phase of the project involved developing the design to completion of targeted FEED, carrying out initial offshore tests of the Dolphyn integrated system and providing the necessary information to enable a financial investment decision. The primary objectives of the overall commercial scale demonstrator project include:

- Demonstrating the ability of all technological components to perform together in an offshore environment to reliably produce hydrogen at the specified rate and pressure through a pipeline connected to shore.
- Providing confidence that the facility can be scaled-up further from pre-commercial scale without requiring major technology changes. Assessing the performance of the floating facility under offshore wind and wave conditions, with ongoing remote monitoring of all key process parameters and potential to develop a digital twin.
- Demonstrating that green hydrogen from offshore floating wind can be generated at a cost as estimated from the financial model and can be competitive compared to other technologies.
- Identifying opportunities for design optimization at a commercial scale including design simplification, constructability, and operational efficiency improvement.
- Identifying the optimal operating parameters for a commercial scale project, considering the project drivers to maximize production rates, minimize construction cost and time, minimize scheduled and unscheduled maintenance activities, maximize system autonomy, minimize shut-down time, and minimize risk from identified hazards.
- Promoting the Dolphyn technology and engaging with and preparing the supply chain required for commercial scale development.

The current phase of works builds on earlier phases and has the following primarily elements:

- **Commercial Scale Demonstrator (CSD) Design** - *Develop a commercially ready design for the offshore hydrogen production unit;* and
- **Floating Hydrogen Production System Small Scale Trial (SST)** - *Produce hydrogen in an off-shore environment (off Milford Haven) and test the operating constraints of the principal hydrogen production system.*
    - Demonstrate production of green hydrogen from seawater in an offshore floating marine environment
- Test the performance of key elements of the marinised systems (e.g. the liquid/gas phase separator)
- Identify areas for further innovation or modification and early-stage troubleshooting
- Develop a generalised model for internal fluid behaviours suitable for application on all floating marine environments
- Develop of a digital process model to enable optimised control system definition at commercial scale production for all floating marine environments
    - Replicate variable power input to the electrolyser from the WTG and test overall reliability of system
    - Additionally, a section of flexible export riser will be tested to assess operational performance for hydrogen duty.

2.2 Project Schedule, Deliverables and Financial Information

The CSD project commenced on 1st May 2022 and was completed on 26th July 2024. Key project milestones are listed as follows, together with original milestone dates:

Table 2 Key Project Milestones

Milestone number	Milestone Description	Original Milestone Date	Date Completed
MS1	Contract Signed	01/04/22	01/04/22
MS2	Kick off Meeting	14/02/22	14/04/22
MS3	Trial – Finalize Engineering Specifications	23/12/23	24/03/23
MS4	Trials of Flexible Risers Completed	14/10/22	21/07/23
MS5	Trial – Construction Facility Review (PreConstruction)	23/03/22	04/09/23
MS6	Trial – Construction Facility Review (PreTransport)	30/06/23	19/12/23
MS7	Trial – Site Start-Up Review	28/07/23	28/06/24
MS8	Trial – Site Review at End of Trial	22/09/23	26/07/24
MS9	Trial – Summary Report Issued	22/09/23	26/07/24
MS10	CSD2 - Definition Decision Gate – Basis of Design Issued	02/09/23	08/09/22
MS11	CSD4 – Onshore Town & Country Planning Application (Note, not submitted)	30/06/23	20/10/23
MS12	CSD2 – Onshore and Offshore Design for Detailed HAZOP Review	08/12/22	17/01/23 (Deliverable package 24/03/2023)
MS13	CSD – Submission of Design Notification	20/04/23	06/10/23
MS14	Project Investment Gate (10MW Demonstration)	20/06/23	20/6/23

MS15	Issue Final Report	22/09/23	22/08/24

As shown above there were several programme changes, which led to key milestones being achieved later than planned, largely relating to the SST aspects, notably with the trials being deployed later than planned. Overall, there were 11 change requests (CRs) agreed with DESNZ throughout the project, with a summary of issues/reasons for this as follows:

- CSD – Delays in initial engagement of subcontractors, reflecting availability and contract sensitivities;
- CSD – Design challenges for this innovative project, such as increases in topside weights leading to floating substructure structural redesign. Increased design costs as a result;
- CSD – Challenges with respect to engagement with the offshore windfarm operator in Scotland. Ultimately this resulted in a shift of focus to the Celtic Sea;
- SST – Delays in initial engagement of subcontractors and overall delivery delays due to poor performance of one of the key subcontractors;
- SST – Lead times of key components, such as the electrolyser and the bespoke water treatment unit;
- SST - Design challenges for this innovative project, including those identified through HAZOPs. Increased design costs as a result; and
- SST – Increase in cost of capital items.

In total, 82 reports have been delivered to DESNZ, and are listed in Appendix A. Within the SST and CSD design packages there have been upwards of 600 additional Drawings, PIDs, Specifications and Datasheets etc. produced, as detailed in the relevant design sections of this report.

The DESNZ funding offered cost for the project was £8,624,629.21 and this equals the final invoiced expenditure. As noted above, there were increased design costs across the CSD and SST aspects of the project, with an increase of capital costs also seen for the trials. These were managed within the DESNZ awarded budget, with costs for some key aspects towards the ultimate delivery of the CSD borne/to be outside the DESNZ funding.

3. Design Considerations and Challenges for the Commercial Scale Demonstrator - CSD

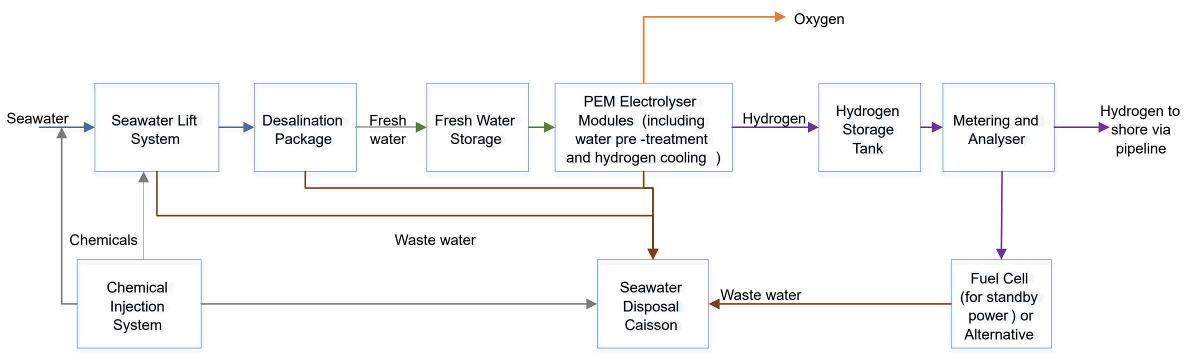
3.1 CSD2 – Engineering

Individual Dolphyn production units will be powered by a Wind Turbine Generator (WTG) to produce hydrogen, with oxygen as a by-product and brine / water as waste. An overview of the major process units is shown below. The main process equipment shall be able to withstand extreme platform deflection and inertial forces during extreme weather exposure. As discussed in Section 4.1.3, CFD modelling has been completed to assess the impact of a 50-year wave event, however further definition of platform motions is required once the final platform design has been developed.

Discussions with some OEMs suggest that a maximum deflection of ±3° is typical for a floating wind turbine platform during normal operation. Certain designs of platform may experience deflections outside this range during certain periods of operation.

Deflections of the trial barge were typically lower than this, with some excursions outside the ±3 range. Mean significant wave height during the trial varied from 0 to 0.4m.

Figure 4 CSD Process Flow Diagram



This process starts with Seawater Lift Pumps, pumping seawater from a unit inside the substructure's 2nd column. The seawater is routed through a set of strainers and filters before entering the desalination package. Bars shall be fitted to the seawater inlet for the protection of divers and marine life.

For the desalination process, thermal vapour compression technology has been selected. The filtered seawater enters the Desalination Package, where salt is removed to produce fresh water for feed to the PEM Electrolyser Package. The desalination package produces two waste streams of filtered seawater and brine that are mixed with other wastewater streams before disposal into the sea via a caisson.

The fresh water is fed into the PEM electrolyser and hydrogen is produced. Oxygen and purged water are also produced from the electrolyser, with oxygen emitted to the atmosphere, and the purge water is disposed into the sea via a caisson. The hydrogen product is cooled before being transferred to a hydrogen storage tank.

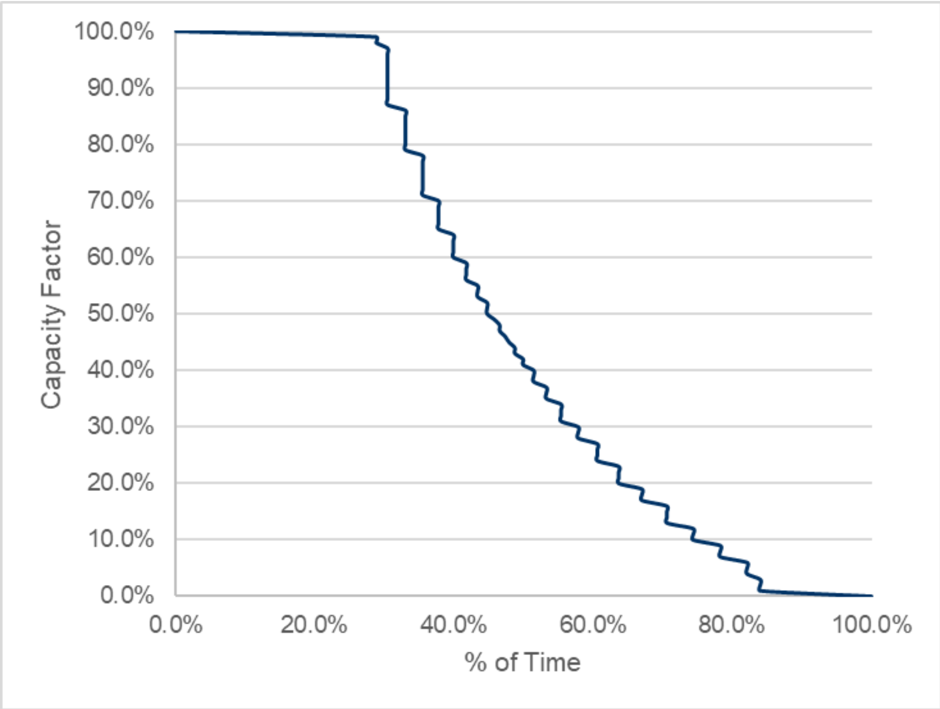
The hydrogen is then passed through allocation metering, with samples being taken for analysis before export to shore. When the WTG power generation is very low (full standby mode), export of hydrogen to shore will be stopped; the hydrogen will then be directed to a fuel cell instead to generate power during standby condition.

The hydrogen product will be exported to shore via a riser and export pipeline. It will be either blended into the existing natural gas distribution networks, supplied into new hydrogen distribution networks, or used as hydrogen fuel for vehicles. The hydrogen product specifications have been developed to allow for grid injection.

The onshore facility will be provided with a pressure reduction skid, metering and analyser, storage and compression.

Hydrogen generation will depend on wind speed conditions as per WTG power curve. An indicative load duration graph has been provided below. The graph has been developed based on the site-specific wind speed data and a generic 9.5 MW WTG power curve data provided by the National Renewable Energy Laboratory (NREL) due to unavailability of the specific 9.5 MW WTG power curve data at this stage.

Figure 5 WTG Power Curve



During the trial, the operation of both the desalination package and the water polishing unit was always in batch (on/off) mode, driven by the level of water in the internal electrolyser tank. The period between on/offs would vary depending on the water consumption rate of the electrolyser which was proportional to its output.

The electrolyser was able to operate with variable output, which could be adjusted by the operator. This mode of operation would be used when connected to a variable power source.

3.1.1 Design Review and Process Hazard Assessment

A design review was undertaken to consider:

- Suitable design philosophies to suit system purpose.
- System sizing, input, output, operating set points.
- Technical constraints relevant to system operation.
- Assumptions / holds / interfaces.

A desktop review was completed, followed by a workshop involving the key project partners on 26th May 2023. The review broke the systems into 9 main areas:

1. Wind Turbine

2. Primary Structure
3. Secondary Structure
4. Electrical Design
5. Dolphyn Main Processes
6. Auxiliary Processes
7. Supervisory Control and Data Acquisition (SCADA) / Control and Communication
8. Onshore Facilities
9. Onshore Pipeline

The design review was intended to demonstrate that the initial design input requirements were met and to identify gaps, issues and further actions for improvement and development of the design.

A HAZID study was conducted on the 17th and 18th of January 2023, with an additional session online on 24th January 2023. The main objective of the study was to identify the potential hazards and their respective mitigations along with any actions or recommendations for further revision of the project. The scope of this study was limited to the offshore aspects of the Dolphyn CSD.

A HAZOP study was conducted between the 18th and 20th of January 2023, with further sessions online on 23rd and 24th January 2023. The objective of this study was to identify the hazards and operability issues along with any actions or recommendations for further investigation associated with the proposed process. The scope of this study was limited to the offshore aspect of the Dolphyn CSD.

Some of the key design issues identified from the design review and Process Hazard Analysis (PHA) workshops are outlined in the following section.

3.1.2 Engineering Design Issues

Operation and Control Philosophy

Dolphyn will be operated as a normally unmanned fully automated platform which can be controlled from startup to hydrogen generation to shutdown (including turndown operations during the peaks and troughs of WTG). The system is designed for full automation between generation phase and standby mode. This is inherently safer and minimizes operation costs.

A key design objective is to minimize personnel intervention at the floater, resulting in the following key design considerations:

- The equipment and inventory of hazardous substances on the floater is minimized.
- Equipment has been selected for sufficient levels of availability, reliability and low maintenance requirements.
- Only proven technology has been adopted, delivering reliability and availability based on track record from previous use.
- The facility has been designed for full remote operation from an onshore control room, with minimal requirements for local intervention.

An Integrated Control and Safety System (ICSS) will be provided for control and monitoring of
Dolphyn. The ICSS will comprise Process Control System (PCS), Emergency Shutdown System (ESD) and Fire & Gas (F&G) functionality. The ICSS will have the capability of being operated when the floater is manned or unmanned. Normal monitoring and control, during unmanned condition, shall be from an onshore control room. The ESD system is provided to protect the site personnel and facilities from potentially adverse effects due to unexpected emergencies with minimal impact on the environment. Emergencies include hydrogen gas releases, fires, explosions and abnormal process conditions such as over-pressure or high / low liquid levels.

Under normal shut-down conditions there is no need for operators to start-up again in person since it can be done remotely. In most instances if there is a trip then the cause of the trip could be analysed remotely in the onshore control room, however there may be the requirement for an offshore visual inspection to ensure safe re-start.

In order to minimize the frequency of visits to the platform, Safety Management Systems and maintenance procedures will be developed further in future phases of the project engineering design and this challenge will be reviewed and discussed.

Wind Turbine Generator (WTG)

It is intended to operate the WTG in isolated operation. The production unit power system is intended to control the frequency of the AC part of the unit and also to manage power imbalance for the electrolyser. This will be achieved using battery / supercapacitors. This has been subject to initial design work. Further potential exists for optimization as part pf full commercialization.

From previous experience there may be issues with de-rating different parts of the process and therefore further investigation is required. Operation of the Dolphyn platform may require derating at different points depending on the mode of operation.

It is also noted that the assessed WTG was a 10 MW unit, which is smaller than the current standard offshore WTGs being produced by Siemens, Vestas and other vendors. Increasing the WTG rating to 15 MW would be beneficial as it is the current industry standard size for offshore wind turbines.

Floating Foundation

The sub-structure provided to support the topside and the WTG is a semi-submersible type floater of a proven design. The floater is based on the WindFloat Kincardine floater currently in use on the Kincardine Offshore Windfarm (KOW) Project, comprising 3 vertical stabilizing columns that are supported on a submerged horizontal Water Entrapment Plates (WEP), a station-keeping system and an offshore wind turbine located on one of the columns. The respective size and shape of the columns and water entrapment plates are designed to provide sufficient buoyancy to carry the weight of all equipment on the floater, the mooring lines, the riser (and umbilical) attached to it, and to minimize the platform motion during normal operations.

A key uncertainty at this stage is the final weight of equipment and materials to be deployed on the topsides. The addition of the hydrogen generation system introduces significant additional weight compared to a ‘standard’ WTG, affecting the stability of the floating system in both positive and negative ways.

With regards to potential safety issues identified, chemicals / fuels should not be placed directly above the columns in the marine system to minimize the risk of fire in the electrical systems. The potential for leakage of water from the ballast system piping into the electrical system was also identified as a risk to be considered in design. Location of the oxygen and marine systems vents was also reviewed to ensure a minimal risk of explosive atmosphere.

Marine motion is an important consideration associated with the floating foundation and protection against backflow of material to other areas of the plant during excessive marine motion will be implemented.

Electrolyser and Hydrogen Generation Package

The current design allows for all electrolyser stacks to run simultaneously at the same flow. Further refinement of the design based on minimum and the maximum flow between the stacks is planned. It is not apparent if there is an option to operate a single stack or pair of stacks in isolation when there is low load from the wind turbine. There may be the ability to run one stack at a time and then run only water through the other stacks, however it should be noted that there might be issues with increasing the water temperature to the optimal level in this scenario and further assessment is required.

Another key issue identified is that in the absence of water flow while the current is still running, there could be a possibility of rapid temperature rise and fire. Safeguards must be implemented which can respond promptly enough to prevent a hazardous event.

Overpressure in the electrolyser in the event of blockage was also identified as a key risk to be considered in design, and measures to detect partial blockages and hot spots in the electrolyser are under review.

Overpressure of the electrolyser may also be expected during start-up, due to excess differential pressure between the hydrogen and water sides of the membrane (e.g. due to blocked stack outlet). This may result in crossover of hydrogen into the water / oxygen side of the stack, with potential hazardous consequences. This is mitigated by engineered safeguards relating to pressure and composition in the stack.

Furthermore, a scenario where the oxygen separator is overfilled leading to flow of oxygen-rich water back to the stack was identified. This is effectively mitigated by high level trips, and further work has been proposed to confirm that the layers of protection are sufficient.

The layout and elevations of each vessel within the system are also key considerations, for example ensuring that water can drain into the electrolyser by locating the oxygen separator at a higher elevation.

In the current design, hydrogen passes from the stack to the storage tank, and also potentially to the fuel cell to generate energy in case there is no electricity. The sizing of the fuel cell and storage tank must ensure power is provided to the pumps for safe and controlled shutdown of electrolysers.

3.2 CSD3 – Regulatory Compliance

The Dolphyn process is an innovative process looking to produce offshore from floating wind technology. The HSE's Control of Major accident Hazards Regulations (COMAH) 2015 are the principal regulations for onshore facilities and the HSE's Pipeline Safety Regulations (PSR) 1996 are the principal regulations for the offshore pipeline. No regulatory framework currently exists specifically for the development of offshore hydrogen production facilities. However, the Dolphyn process is related to two existing industries and looked to learn from their experience of safe practice:

1. Offshore renewables (offshore floating wind in particular)
2. Offshore oil and gas (flammable fluid production and control)

The Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 states that "Offshore oil and gas operations" refer to activities associated with the production of petroleum where petroleum refers to "any mineral oil or relative hydrocarbon and natural gas." The offshore production of hydrogen does not fall under this definition however we believe that best practice is to follow these regulations.

Therefore, the project developed a Design Notification assessing the design at the targetedFEED stage. The Design Notification, along with supporting safety studies, will be updated with any changes made to the design during FEED and prepared for submission to the UK Offshore Safety Directive Regulator (OSDR). Whilst the Dolphyn process does not formally fall within the OSCR and Design Notifications do not require formal acceptance, the project team valued having an early and constructive dialogue with the Competent Authority. The main objectives of the Design Notification were to demonstrate that:

- The development process complies with all relevant regulations applying to Offshore Installations in the UK sector of the North Sea;
- The management systems are adequate to ensure compliance with the relevant statutory provisions for the Dolphyn development and any activities associated with it;
- All hazards with the potential to cause a major accident and a major environmental incident (MEI) are identified and appropriately managed;
- Appropriate measures are being taken and will continue to be taken to reduce risk to personnel and the environment to a level that is As Low As Reasonably Practicable (ALARP);

- The risk reduction is preferentially achieved through the application of the concept of inherently safer design; and
- The Health, Safety and Environmental Management System (HSES-MS) is adequate for managing the hazards and control all consequences of major accidents.

3.2.1 Current ALARP Demonstration

The Design Notification made the following key conclusions:

- The Dolphyn process is based on a combination of proven technologies, and the team has worked with, and will continue to work with, leading engineering firms to develop the design.
- During targeted FEED risk management has been focused on the 'Minimize' and 'Substitute' aspects of the inherently safer design principles.
- The development of the Dolphyn process is being conducted in line with an established HSE Management System.
- Adequate control of hazards is managed through the appropriate completion of all recommendations raised during the HAZID, HAZOP and Safety Studies. These recommendations are being tracked through a live Action Tracking Register. At the end of targeted FEED there were approximately 115 actions from these workshops for review during the next phases of the production development.
- Following the HAZID workshop, the Major Accident Hazards (MAHs) associated with the offshore platform were defined and two key assessments were completed to assess the risks associated with these MAHs; a Fire and Explosion risk assessment and Non-Process Major Accident Hazards risk assessment. The assessments found that the highest contributors to overall risk to personnel are from a loss of containment of hydrogen from the storage tank, ship collisions and/or structural failure of the platform. However, a summation of the assessments found that the overall risk to personnel on the platform is currently considered to be 'Tolerable if ALARP' and very close to being considered 'Broadly Acceptable'. It is worth noting that these assessments are presently based on conservative assumptions. During final FEED for commercial projects these assessments will be updated with more detailed design data, and it is expected that risk levels will be reduced further.

- Appropriate barriers were identified through bowtie analysis and a list of these barriers, also known as Safety and Environmental Critical Elements (SECEs), was defined. For each SECE a Performance Standard was written to define the purpose of the SECE completely and establish the methodology for ensuring its availability in the event of an emergency. Following the completion of the SECE List and the subsequent Performance Standards, the Independent Verification Body reviewed and approved the list of identified SECEs and their Performance Standards.

For the reasons above the project team is confident that the CSD design is inherently safe, and the risks associated with the offshore Dolphyn platform are 'As Low As Reasonably Practicable'.

3.2.2 Future ALARP Demonstration

During final FEED for future projects, further design decisions will be made which include continuing to ensure that risks are ALARP. An ALARP process will be developed that will be key to the overall development of compliant, best-practice engineering and decision making for the project overall.

Additionally, when progressing to detail design the following should be noted:

- The ALARP process will be used wherever new decisions are being made with potential safety impacts; and
- The outcomes of any FEED phase ALARP reviews and resultant decisions should be respected and not reversed or changed without another review to justify the change in decisions.

The FEED Formal Safety Assessments, along with the ALARP process described above, will ensure that the risks associated with the Dolphyn platform will continue to be reduced to 'as low as reasonably practicable' (ALARP).

3.3 CSD4 – Consents and Permitting

The initial intent of the Dolphyn project was to locate a 10MW CSD at the Kincardine Offshore Wind Farm approximately 12km off the coast of Aberdeen, where there is an 'available slot' for an additional wind turbine.

In discussion with potential investors in 2023 it became apparent that an improved commercial opportunity for Dolphyn, where the CSD location could be extended into a commercial field of nine units, existed at Milford Haven in South Wales. The site was also in close proximity to where the small-scale offshore trials were planned. This altered the priority of the project, and it was decided to develop the South Wales opportunity first. Opportunities in Scotland and elsewhere will be brought forward at a later stage as commercially attractive opportunities become available. From mid-2023 onwards all planning and consent development work has therefore been focused on Milford Haven (under separate funding from this project).

The consenting and permitting strategy presented in **Error! Reference source not found.** provides a valuable framework for any future deployment opportunities in Scottish waters. This process also established the basis for engaging in the regulatory consultation process led by DESNZ and subsequently defining a workable consenting strategy for deployment in the Celtic Sea building on the approach described in **Error! Reference source not found.**. The consents and permitting work presented in **Error! Reference source not found.** provides a summary of the approach taken to progress consenting at the Kincardine Offshore Wind Farm. This informed the change to the regulatory framework for offshore hydrogen transport and storage, as well as the basis for ongoing consenting in the Celtic Sea.

The text below demonstrates the value of the previous consenting work and the progress made to-date in advancing the consenting pathway for deployment in the Celtic Sea. This includes baseline surveys and visualizations, consenting strategy development, detailed planning for an Offshore Hydrogen Consenting Roundtable and also parallel baseline studies to progress deployment in the Celtic Sea led by Celtic Sea Power.

Celtic Sea Consenting

Deployment in the Celtic Sea has entailed several workstreams that build on the consenting work previously carried out for Kincardine. The goal of undertaking these further workstreams is to validate and streamline the consenting process for offshore hydrogen in UK waters, with a view to accelerating options for deployment of Dolphyn Hydrogen in the Celtic Sea. The primary areas where consenting has been advanced are:

- Environmental Consenting Strategy – Celtic Sea;
- Baseline studies by Celtic Sea Power at the Pembrokeshire Demonstration Zone;
- Dolphyn Hydrogen Celtic Sea visualizations;
- Offshore Hydrogen Consenting Roundtable with key regulators and Government bodies; and

Further details for each of these areas are provided below.

Environmental Consenting Strategy – Celtic Sea

In order to take account of changes to the regulatory framework for offshore hydrogen transport and storage proposed by DESNZ under the Government response to the offshore hydrogen regulation: legislative proposals for offshore hydrogen pipelines and storage consultation (April-May 2023), a Dolphyn Hydrogen Consenting Strategy was prepared specifically for deployment in the PDZ. The Dolphyn Hydrogen Consenting Strategy reviewed the proposed legislative changes, (subsequently set out in the Energy Bill and carried forward under the Energy Act 2023), to extend existing oil and gas pipeline and storage regulatory frameworks to cover hydrogen. The Strategy also considered the existing regulatory framework for marine infrastructure, given this would be the regime under which the floating Dolphyn units would be consented.

The consenting strategy provides a clear pathway for consenting floating offshore wind with combined production of hydrogen and transport to shore via pipeline. It considers potential risks and constraints, areas of uncertainty and the likely role of different regulators under this new twin-track regime. Specifically, the Consenting Strategy is structured as follows:

- **Key Planning Legislation**
    - International Context
    - UK Context
    - Welsh Context
    - Policy & Plans
    - Local development Plans
    - Future Considerations
- **Project Consents and Supporting Documents**
    - Section 36, Electricity Act 1989
    - Marine Licence
    - Pipeline Works Authorization
    - Environmental Impact Assessment
    - Habitats Regulations Assessment
    - Secondary Consents

Baseline Studies by Celtic Sea Power at the Pembrokeshire Demonstration Zone

Celtic Sea Power has been undertaking baseline studies and information gathering at the PDZ for several years, working closely with organizations such as Natural England and The Crown Estate to increase baseline coverage and improve the level of certainty in environmental datasets. A summary of the topic-specific investigations and baseline data sets collated by CSP for the PDZ is provided below. The Dolphyn Hydrogen team is working closely with CSP via the Milford Haven: Hydrogen Kingdon project to further enhance data certainty and compile a robust body of environmental baseline data to support an acceleration of the offshore consenting process, which currently takes limited account of the high level of marine environmental data which has been, and continues to be, acquired for this area.

- **Survey scopes:**
  - CSP are coordinating with Natural England (NE) and The Crown Estate (TCE) to discuss regional survey coverage of key data sets, including deployment of floating LiDAR (Light Detection and Ranging) and separate wave buoys in the surrounding area (under Round 5);
  - Data sharing agreement with Floating Offshore Wind sites including geophysical data.
- **Offshore Wind:**
  - Regional Wind Resource Model and Metocean Data acquired via LiDAR and data sharing agreements.
- **Geophysics and benthic data:**
  - Regional geophysical survey data available for the Round 5 PDAs via TCE;
  - OneBenthic Programme coordinated by CEEFAS (Centre for Environment, Fisheries and Aquiculture Science), includes raw benthic data, grabs and cores.
- **Birds and Marine Mammals:**
  - Digital Aerial Survey, airborne LiDAR and data sharing agreements to produce Celtic
  - Sea bird distribution and density model in partnership with POSEIDON project (Natural England, CEEFAS and JNCC (Joint Nature Conservation Committee));
  - Regional Digital Aerial Survey via data available for the Round 5 Project Development Areas) PDAs from TCE;

  - Digital Aerial Survey to produce Celtic Sea marine mammal distribution and density model in partnership with POSEIDON project (Natural England, CEEFAS and JNCC);

Information sources reviewed as part of an environmental baseline data gap analysis exercise by ERM also included:

- CSP – Floating Offshore Wind in the Celtic Sea – Supporting a Standardized Approach to EIA Scoping (2023);
- CSP Pembrokeshire Demonstration Zone Scoping Report (2023);
- Erebus Scoping Report and Environmental Statement;
- Greenlink Interconnector Marine Licence; and
- Llŷr 1 Floating Offshore Wind public consultation material.

Dolphyn Hydrogen Celtic Sea visualizations

In order to inform stakeholders and provide key bodies with an early understanding of the scale, position and visual context of deploying up to nine Dolphyn Hydrogen units at the PDZ site, a Seascape, Landscape and Visual photographic survey was undertaken, with the results modelled to provide photomontages of the likely appearance of Dolphyn Hydrogen units deployed at the PDZ.

Rather than meeting a statutory requirement, the focus of the photomontages is to provide key stakeholders, such as The Crown Estate and Pembrokeshire Coast National Park Authority, with an early indication of how deployment of up to nine Dolphyn units would appear from key visual receptors along the coast. Visual modelling of the units has been based on a maximum consenting envelope for the turbines of 15MW and includes modelling of the semi-submersible substructure. Viewpoints were selected based on previous Seascape, Landscape and Visual Impact Assessment (SLVIA) undertaken during the Erebus Floating Offshore Wind (FOW) consenting process in the Celtic Sea, as these provided a good initial indication of sensitive locations which were selected taking into account stakeholder feedback and responses to scoping.

Figure 6 below shows the locations selected for viewpoints which form the basis of the Dolphyn Hydrogen photomontages.

Figure 6 Dolphyn Hydrogen Initial Viewpoint Location Plan

The outputs of the visualizations will be used to inform early consultation and demonstrate the suitability of the PDZ site for initial deployment of Dolphyn Hydrogen in the Celtic Sea. A full SLVIA would be undertaken later as part of the consenting process, following scoping submission and receipt of scoping responses from stakeholders.

Offshore Hydrogen Consenting Roundtable with Key Regulators and Government Bodies

Based on the Dolphyn Hydrogen Consenting Strategy for deployment at the PDZ in the Celtic Sea, recognizing that this is a new and untested consenting regime, it was concluded that all relevant parties would benefit from a workshop to consider how the regulatory framework would work in practice.

Following several rounds of engagement with DESNZ, the Dolphyn Hydrogen team compiled a list of those organizations with a key role in consenting and permitting for deployment of Dolphyn Hydrogen in the Celtic Sea (both Welsh Territorial Waters within 12nm of the coast and UK Exclusive Economic Zone (EEZ) waters beyond 12mn). The objective of the Consenting Roundtable is to align the different regulatory processes and expectations across the marine planning and offshore O&G regimes as they apply to offshore hydrogen production, storage and transportation in the Celtic Sea. Using the Dolphyn Hydrogen example, it is proposed to review how the two consenting regimes can fit together under a 'whole project' approach.

A key element of the Consenting Roundtable is providing the forum and detailed project example to allow key stakeholders to discuss and agree where responsibilities begin and end, identify any gaps and overlaps and consider mechanisms for an efficient, streamlined consenting approach which meets the requirements of both the marine planning and oil and gas regimes. Each key stakeholder was invited to present how their organisation aligned with the new regime and what their key roles and responsibilities would be for offshore hydrogen.

The agenda was therefore developed as follows:

Table 3 Consenting Roundtable Agenda

Session 1	
11:30 – 11:50	Introductions
11:50 – 12:10	Dolphyn Hydrogen project parameters
12:10 – 12:30	DESNZ – basis for changes to the regulatory system for offshore hydrogen transport and storage
12:30 – 12:40	NRW – Role and responsibilities (hydrogen production from FOW)
12:40 – 12:50	NSTA - Role and responsibilities (hydrogen pipeline to shore)
12:50 – 13:00	OPRED - Role and responsibilities (hydrogen pipeline to shore)
13:00 – 13:40 Lunch	
Session 2	
13:40 – 13:50	HSE – Role and responsibilities (offshore hydrogen production)
13:50 – 14:00	Recap on the morning session
14:00 – 15:00	Practical application / Consenting risks and scheduling

As well as Dolphyn Hydrogen, the organizations confirmed to attend the workshop are:

- The Department for Energy. Security and Net Zero (DESNZ)

- Natural Resources Wales (NRW)
- The North Sea Transition Authority (NSTA)
- The Offshore Petroleum Regulator for Environment and Decommissioning (OPRED)
- The Health & Safety Executive (HSE)
- Net Zero Industry Wales (NZIW)
- Celtic Sea Power (CSP)

The Consenting Roundtable forms a critical early step in aligning the applicable regulatory regime and the roles of the various authorities. The output of the Roundtable includes a Position Paper on the consenting pathway for Dolphyn Hydrogen based on the outcomes of the discussions.

Update following the Offshore Hydrogen Consenting Roundtable

Under the Milford Haven: Hydrogen Kingdon project (MH:HK), Dolphyn Hydrogen convened a one day Consenting Roundtable in Cardiff. The event was well attended by offshore regulators and government bodies. Attendees actively participated in the sessions and excellent feedback was received regarding the value of convening a focused face-to-face discussion. The session was highly productive, resulting in a number of actions and a commitment to continue the momentum. There was clear recognition from all attendees that 'first-of-a-kind'/pathway projects are critical for attracting investment and contributing to the UK's Hydrogen economy.

The objective of the Roundtable was to align the different regulatory processes and expectations across the marine planning and offshore oil and gas regimes as they apply to offshore hydrogen production and transportation in the Celtic Sea. Using Dolphyn Hydrogen as a First Of A Kind example, the aim was to review how the two planning regimes could fit together under a coordinated consenting approach.

The Consenting Roundtable demonstrated active participation and real enthusiasm from regulators and governments to iron out uncertainties and agree a consenting pathway.

Key Points and Areas for Further Work:

Following presentations on their respective remits and responsibilities from DESNZ, NRW, NSTA, OPRED and the HSE, as well as a summary of the regulatory frameworks they operated under, the roundtable considered the practical application of consenting requirements for the deployment of Dolphyn Hydrogen within the Pembrokeshire Demonstration Zone (PDZ) in the Celtic Sea. The following key aspects were discussed:

Pipeline Works Authorisation (PWA) – under Section 14 of the Petroleum Act 1998 for the construction and use of a pipeline. It was confirmed that having a PWA in place for the hydrogen pipeline would supersede the need for a Marine Licence from NRW. Review of the EIA thresholds with OPRED confirmed that under the PWA regime, 'Pipelines with a diameter of more than 800 mm and a length of more than 40 km' would be classed as Schedule 1. Pipeline start and end point under the PWA was discussed in order to avoid both gaps and duplication.

Marine Licence – under Part 4 of the Marine and Coastal Access Act 2009 to carry out certain activities in the marine environment. Required from NRW as the Licensing/Consenting Authority for Welsh Waters. Confirmed that Welsh Waters encompasses both the inshore and offshore regions (i.e. beyond the territorial limit).

Section 36 Consent - under the Electricity Act 1989, to construct and operate a generating station (with devolved powers under Section 39 of the Wales Act 2017). Section 36 Consent applies offshore in UK waters. Definition of a 'generating station' has not yet been tested out where electricity is being produced but not exported i.e. Dolphyn Hydrogen.

EIA and HRA – Different regulations enact the EIA and HRA requirements under the Marine Licence regime administered by NRW, and the offshore oil and gas regime administered by NSTA and OPRED. For this reason, deferral of powers across the two regimes is unlikely. An EIA is unlikely to be required for the pipeline but would be needed to support the Marine Licence for the Dolphyn units. Habitat Regulations Assessment Screening would be needed for all elements of the project. A coordinated HRA Screening process with a lead authority would be preferable and will be the subject of follow-up discussions.

Permitting – Within Welsh inshore waters (i.e. to 12nm) authority for permitting activities would lie with NRW as the delegated authority. Beyond 12nm, the legal requirement and likely authority responsible for permitting an activity requires further clarification given that hydrogen production does not fall under the oil and gas regime administered by OPRED.

Infrastructure (Wales) Act - the Infrastructure (Wales) Act 2024 received Royal Assent and became law on 3rd June 2024. This Act aims to streamline the consenting process for significant infrastructure projects (SIPs) in Wales but is still awaiting the necessary secondary legislation. Welsh infrastructure consent for a SIP eliminates the need for separate planning permissions and related approvals. The criteria for projects that would be classed as SIP includes; "the construction of…(ii) a generating station in the Welsh marine area, that is expected to have an installed generating capacity of between 50 and 350 megawatts…". As with S.36 Consent, the definition of a generating station warrants further investigation.

Consultation Requirements – Further work is underway to confirm consultation requirements across the different consents, lists of statutory consultees and consultation periods, as well as opportunities to align consultation and public notices.

4. Demonstration Study – Small Scale Trial

The Dolphyn Small Scale Trial, including all on-site construction activities, took place between August 2022 and July 2024.

Delivery of the SST aspect of the project was broken down into the following 5 Work Packages (WP). A full list of all the work packages across the whole project is provided in Seton 7, Table 10:

- WP1 Programme management
- WP2 Trial Design and Implementation
- WP3 Design and Development Package for Offshore Skid
- WP4 Flexible Riser Trial
- WP5 Trial HS&E and Consenting

ERM had responsibility for all Work Packages apart from Work Package 3, for which lead EPCI contractor, Altrad Babcock, had responsibility.

Overall, the project was comprised of the following phases:

- Trial specification and set-up
- Front End Engineering (FEED)
- Detailed Design
- Procurement
- Test skid construction and commissioning
- Trial Operation
- Decommissioning

Project management and health and safety management were provided throughout (under work packages 1 and 5 respectively). Several supplementary projects were completed under WP2 including University engagement, literature review, carbon foot printing study and creation of a "Digital Twin", final data analysis and reporting.

4.1 Trial Specification and Set Up

During this phase the following main activities were completed:

4.1.1 University/Research Engagement

A programme of university engagement was carried out. Over 20 universities in the UK and abroad were contacted and researchers with relevant expertise to Dolphyn were identified.

Multiple team interviews were held with researchers from key organizations.

The engagement led to identification of experts at Plymouth, University of Strathclyde, Newcastle University, Bath, Cardiff, University of Nottingham and Imperial College and engagement continued for the remainder of the project.

ERM worked with Southampton University to steer a group of 6 MSc Students in defining their project “Design of a Floating Green Hydrogen Production System” [3].

ERM worked closely with Plymouth University to obtain funding to carry out a small research project based around the trial barge. A scale model of the trial barge was created for testing in the water tank, as well as carrying out numerical modelling on likely barge movement given site metocean conditions. The engagement has successfully identified an early career researcher who is keen to work with ERM on Dolphyn. Together we have developed research work packages as well as securing several thousands of pounds to support research into outstanding questions for follow on phases of Dolphyn.

ERM has continued to work closely with University of Strathclyde and Newcastle University, through sitting on an Ocean REfuel working group. This group shares a common interest with Dolphyn and meets every fortnight.

Conversations with Swansea University resulted in contacts being identified at Marine Energy Engineering Centre of Excellence (MEECE), the Offshore Renewable Energy Catapult’s (OREC) flagship hub for advancing the Welsh marine and offshore renewable energy sectors. ERM and OREC used funding from the Welsh European Regional Office (WEFO) to produce a document for potential future use of the electrolyser [4]. The document contained 3 main sections:
possible electrolyser test protocol, integrated wind turbine-electrolyser testing and development of a wind turbine protocol.

4.1.2 Literature Review

A review of relevant literature weas carried out looking in detail at electrolyser and sea water desalination technologies [5].

The review also looked at lessons learned from case studies around the world where hydrogen was generated from renewable (variable) power sources as well as looking at some of the key players and planned projects for offshore generation of hydrogen (although it was noted that Dolphyn in the UK was largely ahead in this respect). Aspects of the literature review were used to inform the test programme (e.g. typical platform motion, issues with low output operation).

4.1.3 CFD Study for the Oxygen Water Separator

A Computational Fluid Dynamics (CFD) study was undertaken by Altrad Babcock modelling the behaviour of the oxygen/water separator under marine motion, accessing part of the SST budget [6].

The study looked at the Oxygen separator package for the CSD and the preliminary assessment was carried out for a basic vessel with no baffles.

The results of the CFD modelling showed a significant degree of sloshing which may lead to liquid carryover to the gas side.

4.1.4 Carbon Footprint Study

A carbon footprint study was added to the scope of WP 2 and was completed by a consultant at ERM [7]. The study was a predictive "look ahead", carried out during the FEED stage of the project, with the intention of completing a second "as realized" study at the end of the project.

4.1.5 Data Collection and Visualisation (Digital Twin)

The project included development of a data storage and visualization application, which would be used to identify areas of further design improvement and demonstrate the operation of the trial system to a wide audience. Different areas of the application were used to present the data at different levels of detail, for audiences of different technical interests.

Figure 7 Digital Twin Main Page

Figure 8 The Analysis Page

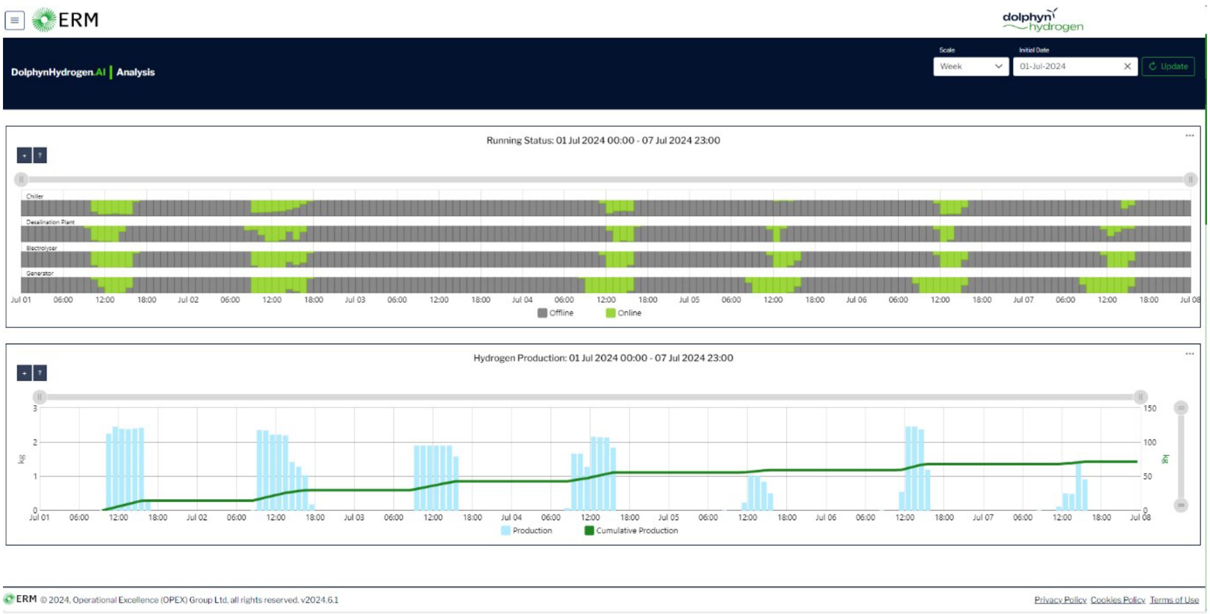
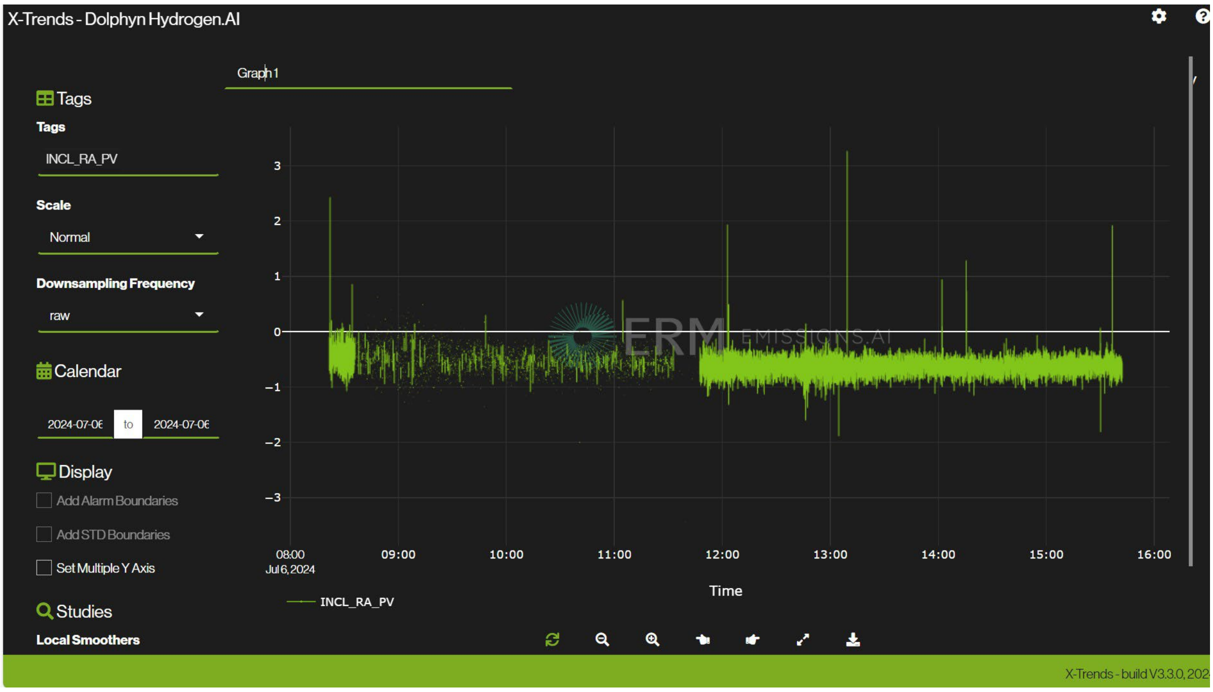


Figure 9 X-Trends Page



The knowledge gained by working on the tool during the trial will be used to develop it further into a "Digital Twin" for further phases of the Dolphyn development. At this point the tool will be enhanced to include live data and machine learning to aid in control optimization, decision making and preventative maintenance.

4.1.6 Trial Front End Engineering (FEED) Specification Document

A document containing the specification for the trial and barge equipment was created and issued to the subcontractor and as a deliverable to DESNZ as the Trial Front End Engineering Design Specification [8]. This was a working document throughout the design phase and was the technical basis on which the trial and equipment was to be designed.

4.1.7 Contractor Minimum Requirements Document

A document containing the minimum contractor requirements was created and issued to the subcontractor as well as to DESNZ. The Minimum Health, Safety and Environment (HS&E) Requirements for Suppliers [9] specified the Trial's general health and safety requirements relating to its planning, design, construction, and execution.

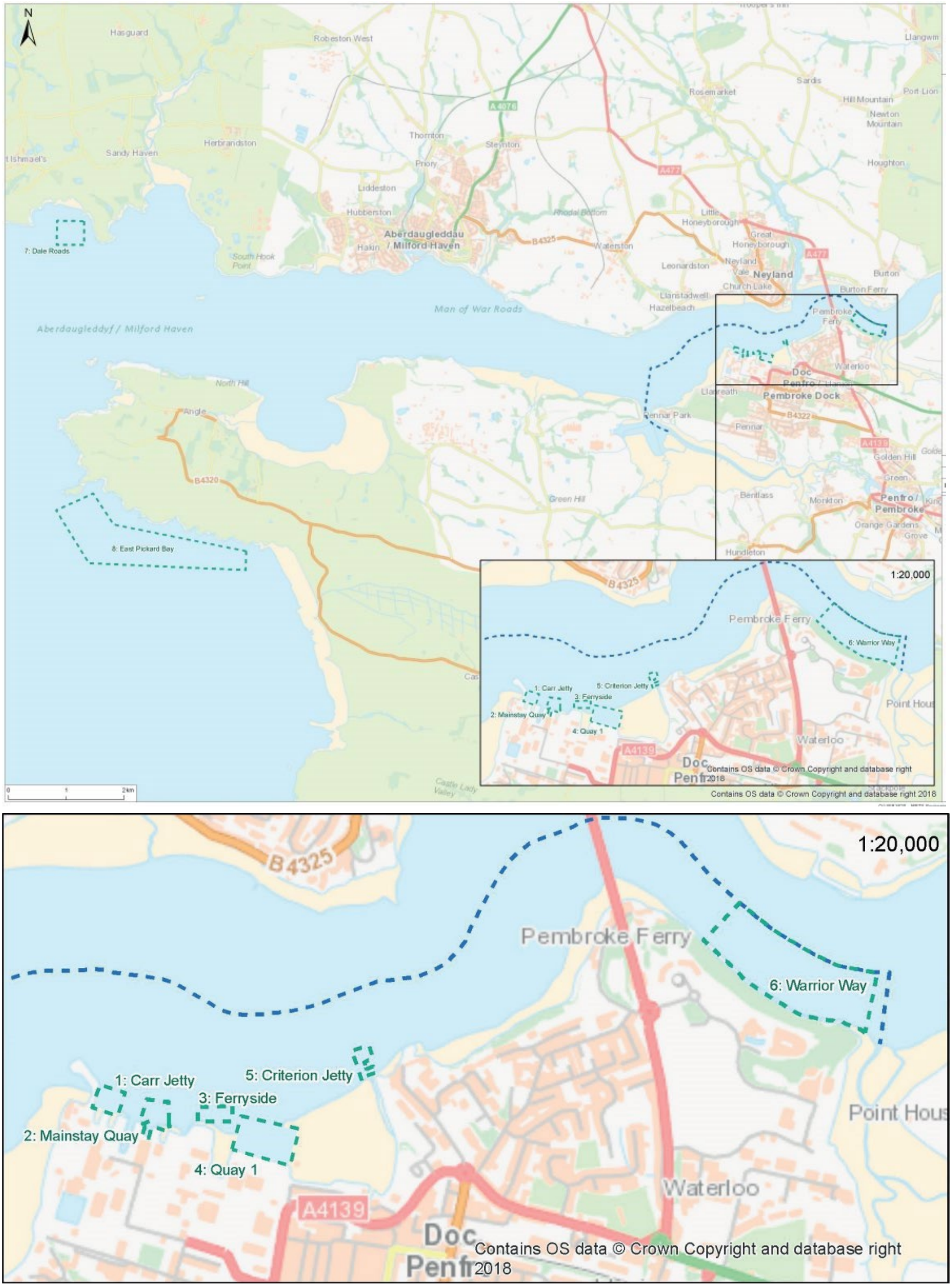
The purpose of the requirements was to achieve a healthy and safe working environment and to prevent incidents, illness, and accidents.

The Trial believed that all injuries and occupational illnesses, safety and environmental incidents are preventable. Our goal was that all personnel worked in a safe, healthy, and motivating environment. This was achieved with completion of over 14,000 hours recorded exposure.

4.1.8 Consents and Permitting

The trials were operated in a controlled area facilitated by Marine Energy Wales (MEW). MEW developed a Marine Energy Test Area (META) project in and around the Milford Haven Waterway, in Pembrokeshire. The META project provides sites for testing marine energy equipment near Pembroke Port. All of these areas fall within the Milford Haven Port Authority (MHPA) jurisdiction.

Figure 10 Pembroke Dockside and Nearshore Locations (META)



4.1.8.1 Permitting Routes and Consultations

The main permitting authority for the trial area is National Resources Wales (NRW). Discussions and Teams meetings have been held with National

Resources Wales who are responsible for the permitting of potentially polluting activities, such as the operation of electrolysers.

The usual route for permitting involves applying for an Environmental Permit, which covers aspects of abstraction and discharges/emissions to water and air.

The permitting activities have a minimum 16-week application process. In order to be proactive for use of the emerging technology that is hydrogen production, NRW developed a rapid deployment procedure for this activity.

Following discussions in November 2022 with NRW representatives, it was identified that a bespoke permit would need to be developed as the setting was not included in any pre-existing process, if the system was to go full scale. However, in the case of the SST given its short operational duration, the NRW representatives agreed they would use the NRW governance process and provided ERM with a position decision to enable the system to operate. This provided regulatory approval and oversight without applying for a bespoke permit.

4.1.8.2 META Berth Reservation

In order to secure access to the META sites, META and ERM entered into a Berthing agreement. This Berth reservation allowed ERM to secure the Site 5 – Criterion Jetty for a period of two months, in June and July 2024.

4.1.8.3 MPHA Requirements

The MHPA requirements included day and night-time lighting and marking requirements for the barge and its associated moorings, and any exclusions considered necessary. The Port Authority issued a temporary 'Notice to Mariners' to advise users of the port as to the works and the presence of the stationary barge and moorings.

4.2 Front End Engineering Design (FEED)

EPCI Front End Engineering Phase was carried out over the period August 2022 to Jul 2023.

In total over 100 design documents (in multiple revisions) were provided by the subcontractor Altrad Babcock from the process, piping, electrical, control and instrumentation mechanical, civil and structural and safety disciplines.

Once documents were issued by Altrad they were reviewed by ERM, including a specialist from each discipline where possible.

A HAZID/ENVID workshop was held (in 3 sessions) on the 8th and 15th December 2022 and 12th January 2023. The workshop chair and scribe were provided by Altrad Babcock.

Hazards in relation to the following discrete processes were considered during the study and treated as nodes:

- Water Treatment
- Hydrogen production
- Diesel generation / storage
- Control Room

The HAZID/ENVID study resulted in 62 actions which were captured then resolved during the detailed design phase.

A HAZOP study was also completed during the FEED phase – this was held at Altrad Babcock premises in Renfrewshire on the 4th and 5th April 2023.

6 general, 2 node-specific and 17 process hazard actions were raised then resolved during the detailed design phase.

Both the HAZID/ENVID and HAZOP sessions were well supported by ERM, Altrad and NEL.

During this phase, three options were looked at regarding the use of the hydrogen produces:

- Bring hydrogen to shore through a pipeline.
- Store the hydrogen on the barge and transport it to shore at the end of the trial.
- Vent the hydrogen to the atmosphere.

Due to the relatively low amount of hydrogen produced, the construction of a temporary pipeline to accommodate the trial was discounted. The storage of hydrogen on the barge was also discounted due to the added risks it created to the team and skid in terms of health and safety (e.g., fire, explosion, transport of pressurized bottle). This led to define the venting option as the only one feasible for this phase.

The Detailed Design Phase took place between August 2023 and February 2024 with additional design engineering support provided during construction and commissioning phases.

During the Detailed Design phase there were more than 70 technical documents generated by the subcontractor. Again, the documents were reviewed by a member of the team, calling on expertise when needed.

A second “Detailed Design” phase HAZOP study was carried out on the 12th and 29th November (in person at Altrad offices) and completed on the 10th of January 2024 remotely.

An additional 55 actions were raised and then resolved.

The second HAZOP was supported by ERM and Altrad with representatives from all package vendors (AWT, ICS, NEL, Aggreko) joining the meeting as required.

4.3 Procurement

4.3.1 NEL Hydrogen

Equipment

Early in the project, the risk of long lead time was identified. To mitigate this risk, ERM decided to order the Electrolyser unit directly from NEL Hydrogen and provided it to Altrad Babcock.

Altrad Babcock developed and provided a Technical Specification to ERM to support them in their purchase. This specification was reviewed by both NEL Hydrogen and ERM and the following items were purchased on the 1st of September 2022:

- C30 Low Voltage 50 Hz, Cold weather -10C to 40C, In Line Orientation, Integrated Hygrometer, ICMD
- Hydrogen Generator Start Up and Commissioning, Operation and Maintenance Training (International)
- Kit, Vertical Coolant Distribution & Isolation, C Series 3
- Calibration Kit
- Kit, DI Water, Elga, Centra, 230V, 50 Hz, 120 LPH
- Regulator, Pressure Reducing, 0-500 PSI, 3/8" CPI, 316L SS
- Kit, Recommended Spares, C Series 3
- UKCA Certification for C Series Hydrogen Generator
- Assy, Cable, C Ser 3 CellStack, DC Positive, DC Negative
- Kit, Inline Wireway Assy & Loose parts, CSer3

- Assy, USB, Customer Documentation, C-Ser 3
- C Series 3 Factory Witness Acceptance Test Procedure (ATP)

C30 Electrolyser

The Electrolyser unit purchased for this project is a NEL C30 Pem Electrolyser. It is rated at around 180kW and can produce up to 30m3/h (64 kg / day) hydrogen at a purity of 99.9998% [10].

Factory Acceptance Testing of the electrolyser took place at NEL w/c 17th July.

The electrolyser was shipped from the US to the Port of Southampton on the 06/08, arriving on 01/09/23.

Figure 11 NEL C30

Design and Integration

Bi-weekly technical meetings were held by ERM with the attendance of both NEL Hydrogen and Altrad Babcock. These meeting were used to align the technical requirements from Altrad Babcock to integrate the Electrolyser kit within the EPCI skid.

NEL provided a suite of documentation as follows. All of which were provided to AB to inform their design:

- Electrolyser maintenance, operation and installation manuals;
- Information related to the ancillary equipment;
- The water purification system immediately prior to the electrolyser;
- Cooling system;
- Gas monitor;
- Vent stack; and
- Relevant software.

4.3.2 Trial Barge

The company Williams Shipping was identified as the barge provider. This company is an approved supplier in the Marine Energy Test Area (META) site.

Williams Shipping provided several facilities that were used for the trial (e.g., quayside access, cranes, refuelling facilities, work vessels etc.).

The barge (Wilcarry 504) was identified as suitable for the project. William shipping provided the following information:

Table 4 Willcary 504 Barge Specifications

General	
Type of Vessel	Flat top pontoon
Builder	Neptune Marine Services
Class	Bureau Veritas I 3/3 (-) Pontoon deep sea
Certification	International Loadline

Dimensions	
Length Overall	30.0m
Beam Overall	11.2m
Moulded Depth	2.5m
Light Draft	0.3m
Loaded Draft	1.96m
Deck Load	6 tons/m^2

4.3.3 Water Treatment Unit

The water treatment unit was provided by Advanced Water Treatment Limited (AWT) and was designed to treat seawater to a quality of 5 μS/cm which was then further treated at the downstream Water Polishing step. This water treatment system included: Seawater Uptake and Storage, multimedia filter, reverse osmosis, pretreated water storage and a pretreated water transfer pump.

4.4 Test Skid Construction and Commissioning

4.4.1 Construction Phase

Construction was carried out between February 2024 and June 2024 at Pembroke Dock, where ERM had a site presence of at least one staff member at all times.

A site supervisor from Altrad was present (who carried out daily toolbox talks, coordinated deliveries and provided a daily report) together with various trades at various times.

All ERM and Altrad staff were accommodated in "Willbox" temporary work units located in the Williams Shipping operations area.

Quay 3 and the barge to be used for the trial, with access, was designated as Altrad's "Site" under the Construction Design and Management (CDM) regulations and access to the site was restricted to those with the appropriate training / permit to work and who had undergone Altrad and Port Authority inductions.

4.4.2 Commissioning Phase

Commissioning was carried out between April 2024 – June 2024.

The commissioning phase was complex with multiple activities happening simultaneously. Operations were handled well by the site commissioning team. All safety critical commissioning activities were completed satisfactorily, prior to barge deployment.

4.4.3 Lessons Learned

The trials were carried out successfully and provided the information and data required. Several important lessons learned have been documented and will help inform the development and construction of the first Commercial Scale Dolphyn facility. Some of the key learnings are listed below:

- The main learning that arose during this phase related to changes in staffing levels and turnover in the subcontractor design team. This led to delays in deliverables having a knock-on effect to other activities. More detailed project planning with resources allocation could have prevented some of the delays.
- Early in the project, the risk of long lead time for the Electrolyser was identified, and to mitigate this risk ERM purchased the equipment directly from NEL hydrogen. Early supply chain engagement continues to be a priority requirement for future developments.
- Where significant specific project-critical expertise is they need to be identified early, and the necessary individuals engaged and included in the project team so as to allow them more autonomy with respect to owning of their part of the project (e.g. the data team).
- ERM (as Client) had an obligation to review and approve subcontractor Risk Assessments and Method Statements (RAMS) prior to allowing work to start on site. There was considerable delay in receiving suitable RAMS from the subcontractor prior to construction work commencing resulting in timeline slippage. Better appreciation of the high levels of safety expected for hydrogen projects is required throughout the supply chain.
- Construction was delayed due to non-availability of key resources and materials. Better planning and scheduling of resources by the subcontractor could have avoided this.

4.5 Trial Operation

Figure 12 Trials in Operation

4.5.1 Test Variables

4.5.1.1 Test Programme

A duration of approximately 2 weeks was chosen for the test programme to give a good chance of experiencing as varied environmental conditions as possible at the META Criterion Jetty location, whilst retaining the availability of key operational staff.

To demonstrate the safe and reliable production of hydrogen a series of 4-hour steady-state tests were chosen, to be repeated with different environmental conditions as far as possible within the available environmental window. Testing at full available output, supported by a hydrogen sample was prioritized towards the start of the trial.

Thereafter the programme included testing with variable power and variable demand operation, testing the performance of hydrogen production again under different environmental conditions.

Several ramp up and down tests were carried out to demonstrate the system response across the range of operation, which were successful and showed that the unit could respond quickly to changes in simulated demand and ICDM set point.

4.5.1.2 Variable Power Operation

The output of the diesel generators used in the trial was load driven and changed automatically in response to changes in load, therefore it was not possible to simulate intermittency of supply (e.g. from a wind turbine) using the generator.

When coupled to a renewable (or variable) power source, the ICMD feature on the C30 is used to match available power to electrolyser output. The output of the C30 electrolyser could be limited to between 35% and 100% of full output using this feature. The 35% minimum set point value was a feature specific to the C30 electrolyser and as a packaged unit the operator was not able to adjust this minimum set point.

During the trial the ICMD feature was manually adjusted by the operator via the control laptop to create rapid and gradual changes in electrolyser output.

4.5.1.3 [11] Variable Load Operation

The electrolyser’s ability to change output in response to changes in the demand was tested using a controlled valve on the outlet line to simulate variations in demand.

4.5.1.4 Variable Environmental Conditions

A daily assessment was made of the sea and weather conditions, with the programme adjusted where necessary in response to changing conditions, for example, repeating previously completed tests if sea conditions were significantly different.

Tests were repeated on days with different conditions as far as possible to investigate the affect the impact of sea state on system performance.

4.5.1.5 Control of Equipment

The small-scale trial was a manned trial, with equipment only being used with operators present on board. All trial equipment was controlled manually by operators, firstly by starting the generators and the activating the appropriate 400 and 215V circuit breakers to supply power to the barges. Individual pieces of equipment were then started, controls and stopped using switches and touch screens displays local to each piece of equipment. Approved start-up shut- down and process variation sequences/procedures were followed. The maximum output of the electrolyser was controlled remotely by the operator using MODBUS over ethernet protocol.

The CSD is designed to be a normally unmanned installation, and all control functions will be available locally to operators on the platform as well as remotely to on shore operators via a Process Control System (PCS).

Remote control functions provided by the PCS will include activation of breakers as well as interfacing with individual packages to control process parameters.

The CSD utilises variable speed pumps for the sea water lifting, freshwater delivery and glycol/water circulation, meaning these systems are capable of variable output operation, in addition the desalination unit is also capable of variable output operation. The SST, in contrast had fixed speed pumps which operated at fixed output turning on and off as needed. The highpressure R/O pumps and centra unit also turned on/off as needed to supply potable and fresh water as needed, driven by level switches in the tanks downstream of the process.

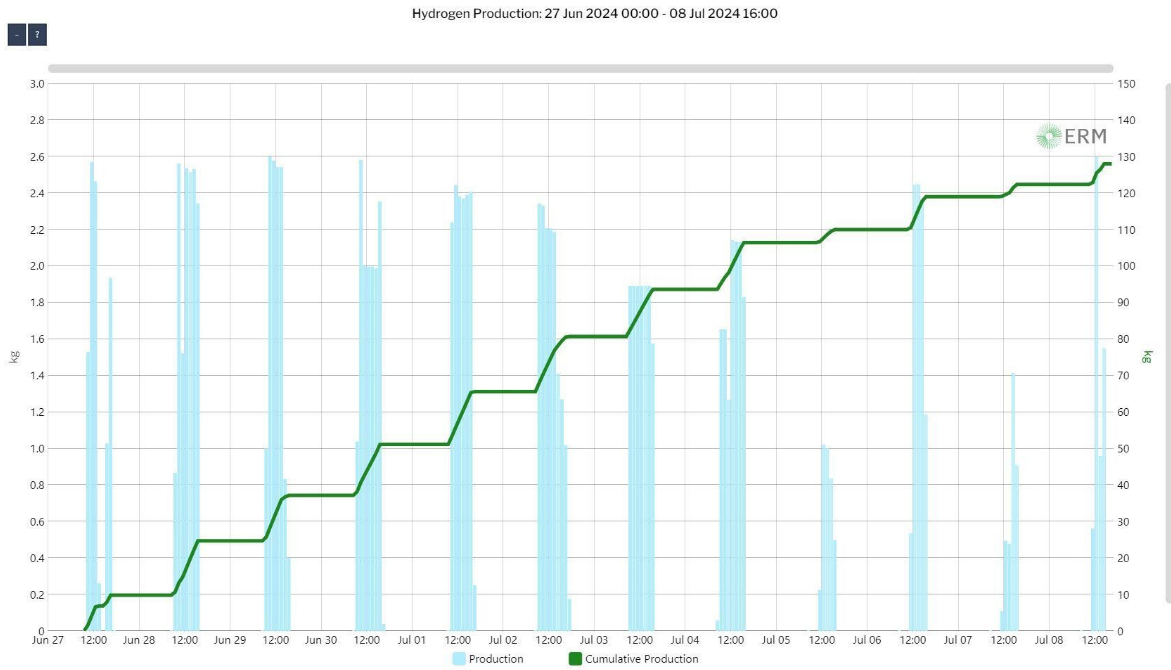
4.5.2 SST – Outcomes

4.5.2.1 Headline Results

- The operational part of the Dolphyn Small Scale trial ran for a period of 12 days from the 27th of June to the 8th of July.
- All process equipment was operated daily throughout the trial. Over 127kg[1] of hydrogen was produced

[1] Conservative value due to patchy data for some days of trial

Figure 13 Daily and Cumulative Hydrogen Production Over Trial Period



- Average hydrogen purity over the trial period was 99.9967% (including start-ups and shutdowns)
- Average hydrogen purity over the steady state operational periods was 99.99998% or higher.
- Independent laboratory analysis of 3 hydrogen samples showed greater than 99.99% purity at starting, low output operation and at the end of trial operation, showing consistency of hydrogen purity levels.
- The system was demonstrated to operate successfully in a range of sea state and weather conditions, with no material impact on quality or rate of hydrogen production.
- The system was demonstrated to be able to operate for extended duration at a range of power levels and outputs from 2.58kg/h (approx. 95% of manufacturers maximum declared value [1]) to 0.47kg/h (approximately 17% of manufacturers declared maximum, this was the minimum level where we were able to accurately measure the rate of hydrogen production)
- No unresolvable shutdowns or errors were experienced during the operational period.

Table 5 Summary of Test Plan

Day	Date	Tests achieved			
1	27/06	100% output – 1 hour	Ramp test		
2	28/06	100% output (4 hour)			Hydrogen sample 1
3	29/06	100% 4 hour (repeat)	Ramp Test repeat		
4	30/06	75% 4 hour			
5	01/07	92% 4 hour			
6	02/07	83% 4 hour	Ramp test repeat 2	ICMD Trial 100% - 35%	
7	03/07	75% 4 hour (repeat)		ICMD Trial 100% - 40%	
8	04/07	83% 4 hour (repeat)		ICMD 78% 1 hour	
9	05/07	40% 4 hour		ICMD 38% 1 hour	
10	06/07	92% - 4hour (repeat)		ICMD 86% 1 hour	
11	07/07	17% 4 hour		ICMD 60% 1hour	Hydrogen sample 2
12	08/07	100% 4-hour repeat)			Hydrogen sample 3

4.5.2.2 Result Summary

A series of 4-hour "steady state" tests were carried out at different outputs in response to simulated demand variation using the PCV as control. These tests were carried out at between nominal 20% (1.5 turns open) to 100%, using the information on PCV position obtained during the Ramp Tests.

Table 6 provides a summary of key performance metrics from select tests, where hydrogen samples were also taken.

Table 6 4-Hour Tests – Selected Results

Date	PCV Setting (turns open)	Nominal output (%age)	Average stack current (Amps) [3]	Average stack voltage (Volts) [4]	Average flow rate achieved (kg/h)	Hydrogen produced (kg)	Average Purity [5] (%)	Generator output over test (kWh) [2]	kWh / kg H_2	H_2 Sample taken
28/06	7	100	1201	123	2.53	10.11	99.99998	776	76	Sample 1
07/07	1.5	20	326	105	0.47	1.88	99.99999	218	116	Sample 2
08/07	7	100 (repeat 2)	1203	122	2.58	10.32	99.99999	772	75	Sample 3 – end of test

[2] Based on manual reading taken around start/end time of test
[3] Based on C30 Internal current meter
[4] Based on C30 Internal voltage meter
[5] Based on C30 Internal moisture meter

Testing was carried out using ICMD control at 60% and 86% for a period of 1 hour. Additional attempts to operate the system at lower set points resulted in the unit shutting down on **E10 Low Pressure PT307 System** error caused by the system pressure dropping below 26.2barg for longer than 50s.

To enable successful operation of the system at 60% and 86%, the PCV had to be closed to increase the back pressure on the product line.

Table 7 ICMD Tests

Date	Sea state	PCV Setting (turns open)	ICMD set point	Stack Current (amps)	Average Flow rate over Test (kg/h)
06/07	Rough	6 3/8	86%	1120	2.33
07/07	Calm	4 ½	60%	777	1.56

4.5.2.3 Conclusions

The production of hydrogen from the fully integrated power, desalination and electrolysis system was successfully demonstrated in the offshore environment under a range of sea conditions. Sea conditions were reasonably varied given the time of year and led to regular noticeable pitching and rolling motion on the barge with several large movements caused by passing vessels.

The system was able to operate across its whole output, in response to changes in simulated demand, with the flow measured successfully from 17% of manufacturers declared maximum, up to the maximum available (2.58kg/h). The system performed consistently (in terms of purity) over the tested range.

The maximum output of the unit could be limited successfully using the ICMD feature and was shown to reliably operate at 86% and 60% capacity.

4.5.2.4 Lessons Learned/Next Steps

The overall pitching and rolling motion of the barge was likely to be significantly different to that of a full size Dolphyn platform out at sea. Wave heights at sea are far greater than in the Haven, although the smaller size of the barge meant that smaller waves had a proportionally greater effect. The next stage for Dolphyn will be to build a full scale (Commercial Scale Demonstrator) located offshore in deep water that would be exposed to the maximum range of sea states with the electrolyser designed accordingly. The results of these small -scale trials demonstrate that electrolysers can be designed to manage motion conditions without impairment to levels of hydrogen production and that the overall integrated desalination and electrolysis design for Dolphyn is robust.

With a correctly ranged flow meter and the unit operating with all PSUs, hydrogen can be delivered and measured at all production outputs from maximum to approaching zero.

Variable output testing using ICMD was impacted due to the electrolyser being in a "degraded PSU" condition. The effect of this was to restrict very large instant changes in ICMD set point as well as reliable operation at levels below 60%.

Future testing should look to resolve the degraded PSU condition and revisit these ICMD tests with full PSU availability.

The system performed across the range of environmental conditions available at the test site without noticeable impact on performance. Further testing could explore testing under more dynamic conditions, either in a laboratory or at a more exposed offshore location to identify any limits to operation.

The electrical architecture for the CSD includes several other components such as batteries, super capacitors, fuel cells as well as overall power being supplied from a wind turbine as well as being operated in "island" mode, with no connection to a power grid.

The operation of the electrolyser and the other electrical components that form the "microgrid" could be tested either in a simulation or when connected to physical equipment.

Some initial work has been completed with the Offshore Renewable Energy Catapult (OREC), looking at some potential tests that could be undertaken with the C30 (or other) electrolyser and their e-grid and mini e-grid test facility.

4.6 Health, Safety and Environmental

The Health and Safety processes put in place for the Small-Scale Trial were designed based on Offshore Wind standards. The quality of the systems, documentation and procedures created for this trial will be the basis for the CSD delivery.

By conclusion of the Project the key lagging indicators showed the following performance:

- 0 Major Incidents

- 0 Lost Time Incidents
- 0 Instances of Asset Damage Incidents
- 0.15 Incidents per month during the trial.
- 1 Near Miss reported (during commute to accommodation)
- 2 Environmental Incidents (Diesel spills during refuelling of office generator)

Figure 14 Observation Summaries

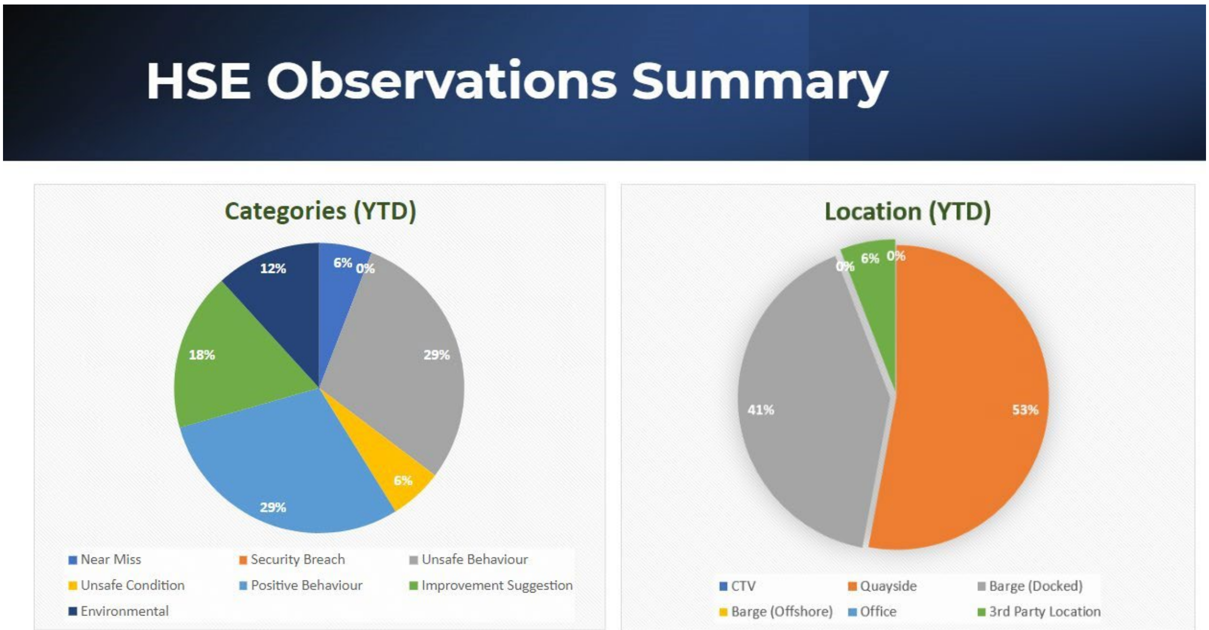
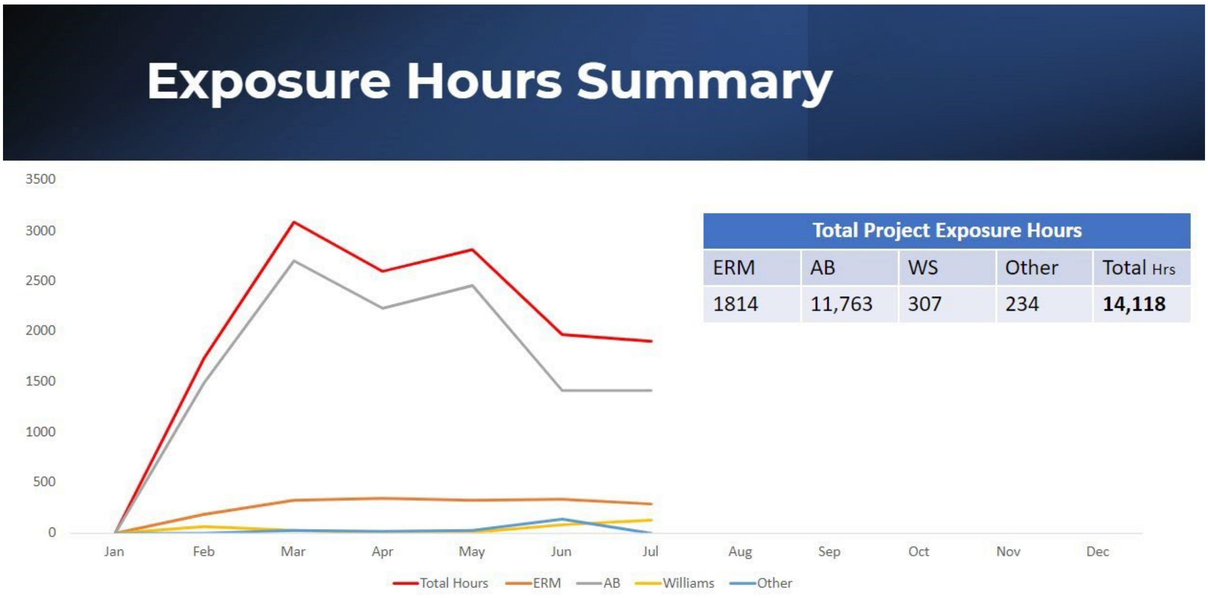


Figure 15 Exposure Hours Summary



Total Project Exposure Hours				
ERM	AB	WS	Other	Total Hrs
1814	11,763	307	234	**14,118**

4.7 Recommendations for the Next Phase

Overall, the small-scale trial was a great success and has yielded important results and data that further strengthens our understanding and the viability of the Dolphyn technology.

Key processes such as sea water desalination and hydrogen production via PEM, were demonstrated to be able to operate safely and reliably in the offshore floating marine environment.

The electrolyser was procured from Nel in a straightforward manner as discussed and expected. The equipment operated as designed at all times, successfully being manufactured, shipped, transported, stored, commissioned, and delivered. All equipment operated as anticipated. Some points of note during the process are as follows:

UKCA certification is required for all hydrogen producing equipment, not all models have UKCA certification in place. This is not unique to any equipment manufacturer, the UKCA process is straightforward, but it is a point that needs building into early project delivery plans

The electrolyser manufacturers raised concerns about projects trying to mobilise commissioning engineers before the site is ready for electrolyser commissioning. As such they now require proof of readiness of the site before commissioning engineers can be scheduled. There is a high demand for commissioning engineers and there can be a lead time of weeks/months after scheduling is approved.

Water desalination plants are commonly used for offshore production work (e.g. Oil and Gas), very small-scale desalination is commonly used for marine operations (e.g. vessels). The scale and specification required for the trials was slightly unusual, and whilst confidence in delivery was high this proved more challenging in practice. Future larger scale projects would benefit from aligning the desalination plant scale with existing equipment.

The small-scale trial project team has demonstrated the practical and engineering knowhow to safely build and operate a floating hydrogen production facility, reflected in the fact that project was completed without any major HS&E incidents and received positive feedback from stakeholders, including META, Williams and MHPA). The next important step towards full commercialization is the development of an additional larger scale trial ahead of the Phase 1 (CSD) development at PDZ. We feel this is necessary as a steppingstone to full scale development and we are currently advancing discussions with Milford Haven Port Authority (MHPA) to identify funding and potential partners for this trial.

It is envisaged that the trial would use a renewable power source, most likely a land-based wind turbine and incorporate a storage and offtake facility. This would provide us with the opportunity to test clean-power integration aspects over an extended timeframe for a fully integrated end-to-end system, which would be of great value ahead of constructing the fullscale demonstrator. The system as used has proven the suitability of hydrogen production in a floating marine environment, future scale up of the Dolphyn system will focus on the end-toend system integration to support the development of a commercial hydrogen economy.

The intention is for the hydrogen, generated from the trials, to be used for fuelling first-of-akind hydrogen powered marine vessels at Milford Haven port. There is an identified need for such vessels to be developed for use in the construction of the Round 5 offshore windfarms. These trials would therefore not only serve the purpose of advancing the Dolphyn technology, but also would contribute to the future decarbonization of the local marine fleet.

The Dolphyn Commercial Scale Demonstrator (CSD) will employ some different technologies to those on the recently completed small scale trials (e.g. thermal rather than reverse osmosis desalination) as well as additional processes (e.g., including the inclusion of a fuel cell) and a power source with increased variability (i.e. wind turbine). These will require demonstration as part of the larger scale trial in addition to the CSD’s control system. The small-scale trials data, learnings and experience will inform the design of this trial and of the overall Dolphyn commercial development plan.

4.8 Flexible Riser Trials (FRT)

Although rigid pipework suitable for hydrogen duty is readily available and extensively studied, a flexible riser is required for the Dolphyn facility to allow connection between the floating platform and the fixed installation on the seabed. There is currently no flexible riser product on the market that has been fully tested and qualified for hydrogen service.

This work package aimed to ensure that the flexible riser technology to be deployed for the Dolphyn project is suitably qualified for hydrogen duty.

The key objectives of the flexible riser trial were as follows:

- Development of an appropriately approved test programme for flexible riser suitability for hydrogen duty based on identified failure modes and effects.
- Safe implementation of the trial.
- Provision of clear results for each of the tests performed.
- Identification and clear articulation of further requirements (if any).
- Approval of riser for hydrogen duty from independent body.

4.8.1 Management

ERM contracted National Oilwell Varco (NOV) to undertake specific testing on their riser to validate their use using Hydrogen gas.

NOV is an international company providing oilfield equipment, technologies and expertise that answer the challenges of oil and gas customers worldwide. NOV manufacture risers of offshore environment.

NOV used pre-selected labs to undertake tests and provide impartial results. Each test was supervised by a dedicated resource within NOV.

NOV undertakes 3rd party verification for its products using a proven verification protocol. It was considered unnecessary and detrimental to alter this verification process as part of this project. As such verification was not included in this contracted scope, with the focus being on derisking the 3rd party verification process to enable suppliers (including NOV) to undertake 3rd party verification with confidence. NOV anticipate completing 3rd party verification following the success of this trial. All trials were conducted independently with a 3rd party verifier witnessing and endorsing as appropriate to support 3rd party verification of the entire system.

4.8.2 Delivery

The trial was focused on the aspects of the riser operation which are specific to hydrogen; i.e. permeability of the inner liner and ensuring material compatibility of all components of the riser system. The key components of the riser which would be in contact with hydrogen during operation are the inner liner, carcass and end fittings and therefore these were prioritized for testing.

External loads, due to factors such as waves, currents, platform motions and the weight / buoyancy of the riser, are not the focus of the trial as these are not unique to hydrogen and are already considered within general riser design.

The tests to be conducted were identified using a Failure Modes and Effects Analysis (FMEA). The FMEA was conducted by a multidisciplinary team of engineers considering the flexible riser system (i.e. including the flexible riser and end fittings). The FMEA identified the following tests of the flexible riser system as of highest value:

- Rapid Gas Decompression Test of High-Density Polyethylene (HDPE) Inner Liner
- Permeation Test of HDPE Inner Liner
- Rapid Gas Decompression test of Elastomer End Fitting Seal
- Autoclave Test of Duplex Steel 2101 Carcass

4.8.3 Trial Conclusion and Next Steps

The tests completed on the NOV flexible riser components can be summarised as below:

Table 8 NOV Flexible Riser Components

Test	Component	Material	Result
Rapid Gas Decompression	Inner Liner	HDPE	PASS
Permeation Test	Inner Liner	HDPE	PASS – Comparable results to CO2 and CH4 were found for H2, indicating that performance would be the same as typical oil & gas production applications of the riser technology.
Rapid Gas Decompression	Sealing	FKM (V9T82) Elastomer	PASS
Autoclave Test	Carcass	Duplex 2101	PASS

Following completion of this test programme, there is a high level of confidence that the riser is suitable for hydrogen duty, and for use on the Dolphyn project specifically.

NOV have indicated that formal 3rd party certification of the flexible pipe for hydrogen transport is currently in progress following the results of this test programme. Further tests required to pass 3rd party verification are not considered to present a significant risk of failure.

5. Project Benefits

5.1 Stakeholder Engagement

Consultation and engagement with a range of stakeholders throughout Dolphyn's development has been multifaceted and central to all project activities. The project team has worked collaboratively with stakeholders to influence the technology development, continue building its business case, identify acceleration opportunities, reduce risks, share knowledge and improve productivity and capacity building among the Dolphyn team, across ERM and through our supply chain.

5.2 Social Impact

Since 2022, the Dolphyn team has contributed to over 250 hours of learning development and knowledge sharing among UK, European and International groups. This has included contributing to STEM and renewable energy-focused initiatives and programmes such as:

- Pembrokeshire College's Destination Renewables 16-18 year cohort
- Lead partner to SPARC initiative including initial development of the curriculum to support women obtain STEM skills for jobs in renewables
- Hydrogen skills workshop at Cardiff and Vale College

The project team is engaged in contributing to a Hydrogen Safety course at the Cardiff and Vale College and Hydrogen awareness courses at Riverside College in Runcorn. Utilizing connections within the ERM business, Dolphyn has supported delivery of workshops and classroom sessions around green technologies as well as wider environmental legislation and sustainability legislation.

Dolphyn has committed match funding to support the Renewable Horizon project through the
Swansea Bay City Deal Skills and Talent Programme Pilot Project. The project seeks to develop STEM materials for the classroom including physical model build of a model Dolphyn turbine.

5.2.1 Knowledge Sharing

Dolphyn is committed to a knowledge sharing strategy that shares its knowledge capital and technical expertise in hydrogen technology. The team has worked closely with industry, academia, research and hydrogen innovation hubs and energy clusters.

Responsibilities for overseeing maximization and contribution to memberships are divided among the project team. This includes to a range of regional and international professional memberships and organizations including World Hydrogen Leaders Alliance, North East Scotland Hydrogen Ambition Steering Group, Hydrogen South West, Net Zero Industry Wales, Celtic Sea Developers Alliance and Marine Energy Wales.

Through the project, Dolphyn has used a range of methods and materials to share the project's development and maximize knowledge sharing across stakeholder audiences. This has included setting up a Dolphyn Hydrogen project website, using videography and drone footage, using virtual illustrations, creating animations of the technical hydrogen production process, creating a Dolphyn model Lego set and creating a physical model turbine.

5.2.2 Events

Through 2023 and 2024, the Dolphyn team has contributed to a wide range of industry events. These have included taking the opportunity to present Dolphyn as a case study on different aspects of its innovation and development from hydrogen safety to hydrogen consenting. The team contributed to panel discussions and chaired workshop groups. Example key events Dolphyn from 2023 and 2024 include:

- ORE Catapult's Hydrogen in Innovation (HII) Launch Day
- Renewable UK's Future Energy Wales, Hydrogen Showcase
- International Energy Week
- Renewable UK's Green Hydrogen 2023 Conference
- The Next Generation for Energy in the East of England
- The North Sea Decarbonization Conference
- Hydrogen Gateway Conference 2023
- Innovation Zero 2024 Net Zero Innovation Portfolio Showcase
- UKRI's 2024 NZIP Innovation Showcase

Figure 16 Dolphyn Event Team Attendance

5.3 Partnerships

Since 2022, Dolphyn has continued to work in partnership and contribute support and collaboration wherever possible to like-minded organizations across the public, private and third sectors. This has included working with organizations and alliances in a variety of ways to support knowledge sharing and build social capital:

- The team has continued engagement with over 21 Universities across the UK to share learnings, support successful funding application unlocking, and identify research collaborations.
- Ireland Regional collaborations including Aberdeen's Energy Transition Zone, Working with Milford Haven Port Authority on hydrogen for marine vessels, Wales & West Utilities Hyline Cymru project and Milford Haven: Hydrogen Kingdom (MH:HK) regional hydrogen study.
- Research organizations contributing to renewable energy innovations include OREC, Ocean Refuel, Marine Energy Centre of Excellence (MEECE) and others.
- Industry and supply chains including HyCymru's Hydrogen Day, Bristol Centre of excellence, National Manufacturing Institute Scotland (NMIS) and Manufacturing Skills Academy (MSA).

5.4 Intellectual Property (IP) Generated

Extensive arising IP has been generated throughout this and other associated Dolphyn projects. A detailed log of this commercially sensitive information is maintained.

5.5 Supply Chain Development

5.5.1 ERM'S Supply Chain Database

ERM has conducted a comprehensive assessment of the floating offshore wind and hydrogen production supply chain. The assessment has culminated in a database of suppliers tracking the capabilities, experience, and location of individual companies. The capability identification of companies utilized input from the companies themselves and the experience of ERM's team, many of whom have worked for offshore wind developers and suppliers, and thus have experience on both sides of contracting procedures, in the UK and in worldwide markets. The database enables ERM to:

- Identify companies with the necessary capabilities to supply the different packages or components for the Dolphyn CSD.
- Establish and record contact information of key personnel working at suppliers.
- Take a holistic view of the capability within the supply chain and identify areas of strength and gaps where further engagement with and identification of suppliers is required.
- Identify areas where the UK supply chain is strong and areas where ERM should support/promote the growth of the UK supply chain.

Due to the volume and broad spectrum of companies that could provide services to support the Dolphyn CSD, the mapping was initially based on companies that contacted ERM expressing interest in the project through direct methods and by registering for a supply chain webinar run by ERM. The total number of companies that have been assessed to date is shown below. The technical FEED process will refine the design and scope of the CSD, and hence the supply chain requirements will be better defined. Additional companies are expected to be researched and identified following this maturation of the design and in coordination with stakeholder engagement activities.

Table 9 Companies Assessed by ERM

Supplier type	Number of companies
Equipment suppliers	190
Service providers	201
Manufacturing facilities	35

Other	88

ERM has conducted extensive desk-based research on each company outlining the company profile, details on capability and industry track record. The following categorization of suppliers is used to understand their capabilities:

Table 10 Categorisation of Components and Subcategories

Category	Sub-category
Development	Legal and accountancy
	Consulting and advisory
	Meteorological and oceanographic surveying
	Environmental surveys
	Seabed surveys
	Vessels and UAVs
	Consenting and permitting
	Project management and execution
OSW components	Floating substructure
	Mooring and anchoring
	Turbine
	Offshore installation support services
H2 components	Onshore facilities
	Electrolyser system
	Desalination unit
	Offshore pipelines
	Hydrogen storage

	Standby power unit
Operation	Condition monitoring
	Vessel providers
	Port services

The track record of suppliers was also important to know whether suppliers were already active in the sector, or how applicable their experience is, if it was founded in another industry. The following categorization was used to designate track records to suppliers:

- **Floating OSW** – for companies focusing on floating wind sector rather than on bottomfixed.
- **Large-scale OSW** – for companies that have been involved in a substantial number of OSW projects.
- **Small-scale OSW** – for companies with involvement in the OSW sector but haven't provided services to large-commercial scale OSW projects (> 1 GW / project)
- **Nearshore** – for companies that have been involved with nearshore or intertidal OSW projects.
- **Onshore Wind** – for companies with no OSW experience, but active in the Onshore Wind sector.
- **Onshore Industry** – for companies that focus on onshore industries.
- **O&G** – for companies with no OSW experience, but active in the O&G sector
- **Other Marine** – for companies with no OSW experience but have supported other marine infrastructure projects (i.e. interconnectors, installation of telecommunication cables).
- **Demo-scale H2** – for companies with involvement in the H2 sector but only in demonstrator projects.
- **Commercial-scale H2** – for companies with involvement in large-scale projects (assumed to be 100 MW for green hydrogen).
- **Other Electrical** – for companies with no OSW electrolyser experience, but active in other electrical industries.

- **Desalination** – for companies with no experience with desalination linked to H2 production, but active in desalination for other purposes.
- **Other** – for companies with no OSW experience but have provided services to other industries, for example Solar PV and other onshore infrastructure projects.

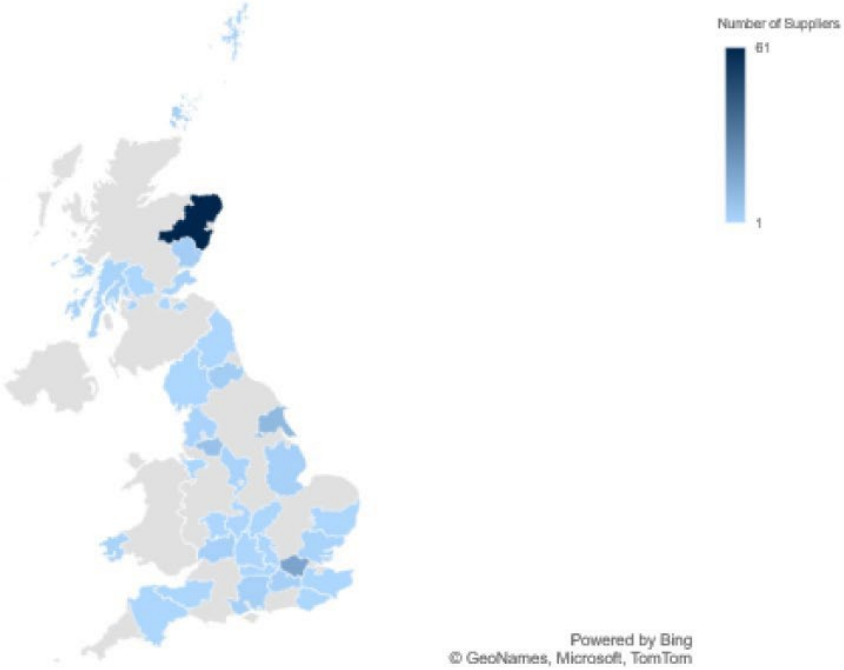
ERM has invested significant effort in creating the supplier database and categorizing the capabilities of suppliers that have engaged with ERM to date. The database is a tool that will be continuously used and will grow in value as further suppliers are added. ERM has created a template that interested suppliers will complete meaning that they can be added directly into the database. Further companies will be identified through the following methods:

- Dolphyn supplier portal (updated website which is due to be released)
- Engagement at events and conferences
- Dolphyn supply chain webinars

5.5.2 Supply Chain Capabilities

This section of the report outlines the current findings of the database of supply chain that have been identified to date, noting as mentioned that it will be further refined as the CSD design matures. The areas of the supply chain have been identified where capability is strong and areas where further supplier engagement will be required. Figure 17 below shows where the suppliers identified to date are located within the UK.

Figure 17 Distribution of UK Supplies by Country



The UK is one of the world's most mature offshore wind markets and its waters are home to 47 operational wind farms totalling 13.5 GW of operational capacity. The track record of offshore wind farm development in the UK provides significant in-country knowledge and experience across project development, which ERM aims to leverage in the development of the CSD.

The development process of an offshore wind farm requires a range of different activities, particularly when considering additional hydrogen production and export. Typically, companies are contracted directly by the developer through a multi-contracting approach by which specialist companies are tasked with specific areas of the development process. While Tier 1 contracts in the construction phase tend to be relatively standardized in offshore wind and completed by large firms, early-stage development works are more bespoke to the site location.

Floating offshore wind has a much smaller track record than fixed bottom, with only 78 MW of floating capacity operational in the UK. The Dolphyn CSD requires hydrogen production in addition to the floating wind technology, resulting in additional requirements for the design, development, supply and construction process. However, the same fundamental principles and processes for development used successfully in offshore wind projects in the UK and internationally can be applied for the CSD. The companies identified for offshore wind development have the expertise to support the development of the Dolphyn concept.

Figure 18 and Figure 19 below depict the number of suppliers identified at this stage of supply chain engagement. The first one portrays the split of companies that are lead contractors and expected to be capable of managing the entire package and that are expected to be subcontractors. However, this metric is less applicable to the "Consulting & Advisory" and "Project Management & Execution" packages since there are many differing roles withing them meaning that there will be lead contractors for specific jobs rather than the sub-category as a whole. The second one shows that the list of companies currently identified in the development phases is heavily weighted towards companies based in the UK. The lists are not exhaustive and for certain packages further supply chain engagement will be required to ensure there is sufficient competitive tension in tenders, where support is required. Pre-FEED, FEED and detailed design of components are part of the development process but are considered separately in the section of the relevant components.

Figure 18 Breakdown of Development Subcategories by Lead Contractor and Subcontractors

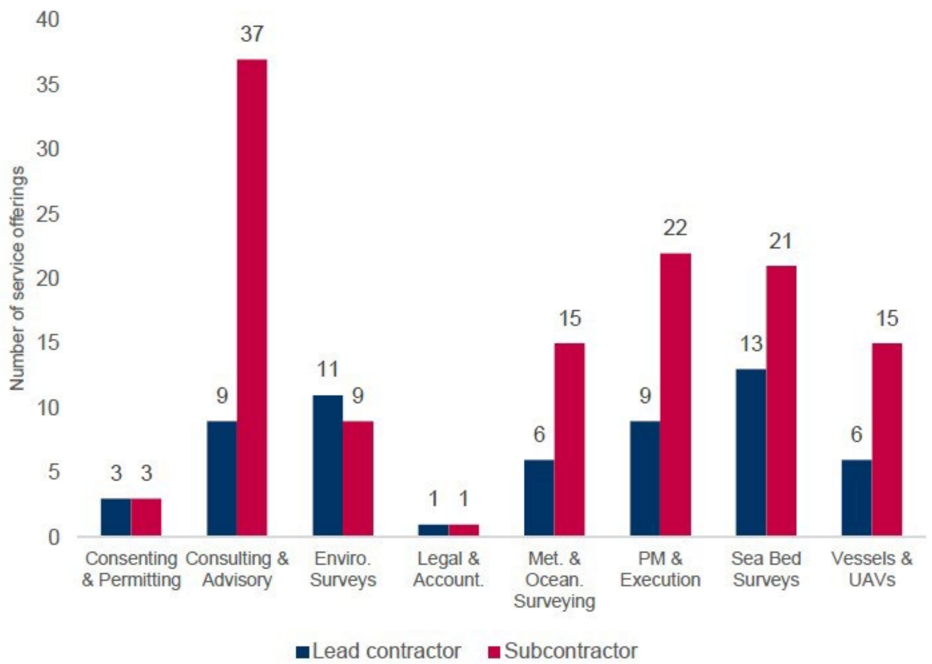


Figure 19 Breakdown of Development Subcategories by Location

5.5.3 Key Suppliers

In developing the Supply Chain Database ERM identified over 500 companies that could potentially support the development of Dolphyn. To streamline the engagement and procurement processes ERM narrowed down the pool for suppliers for initial engagement, focusing on those with capabilities and qualities most pertinent to realizing Dolphyn. Further, supply chain engagement will take place throughout the procurement process strengthening ERM's view on the most competitive suppliers.

To identify key suppliers within each procurement package ERM used the following metrics to assess suitability:

- **Track record:** Proven ability to execute the required services or supply the required components is a leading driver of procurement. This considered what projects suppliers have previously worked on, with floating offshore wind farms and hydrogen electrolysis as the required scale being most desirable.
- **Location:** Companies based in Scotland were originally prioritized. Not only due to the expected benefits in cost of procurement but also to ensure that local content targets can be met. Companies not founded or headquartered in Scotland, but with offices or facilities in Scotland, were also prioritized. However, as the focus for the commercial field has shifted to South Wales, we are expanding the supply chain in that region, recognizing that many

major suppliers have bases in both areas due to energy opportunities centred on the major ports in Aberdeen and Milford Haven.

To assess the identified metrics for companies ERM followed the methodology outlined below:

- **Existing engagements:** To date ERM's wider Dolphyn team has already engaged with a range of companies across the supply chain. Through these engagements ERM already has a view on the interest and capability of these companies.
- **Desk based research:** To supplement existing engagement, ERM's team undertook deskbased research assessing suppliers in the identified metrics.
- **Further and ongoing engagement:** Further to this ERM has continued to engage with supply chain companies to better understand their interest and capability through reaching out directly, being contacted by companies, and presence at conferences.

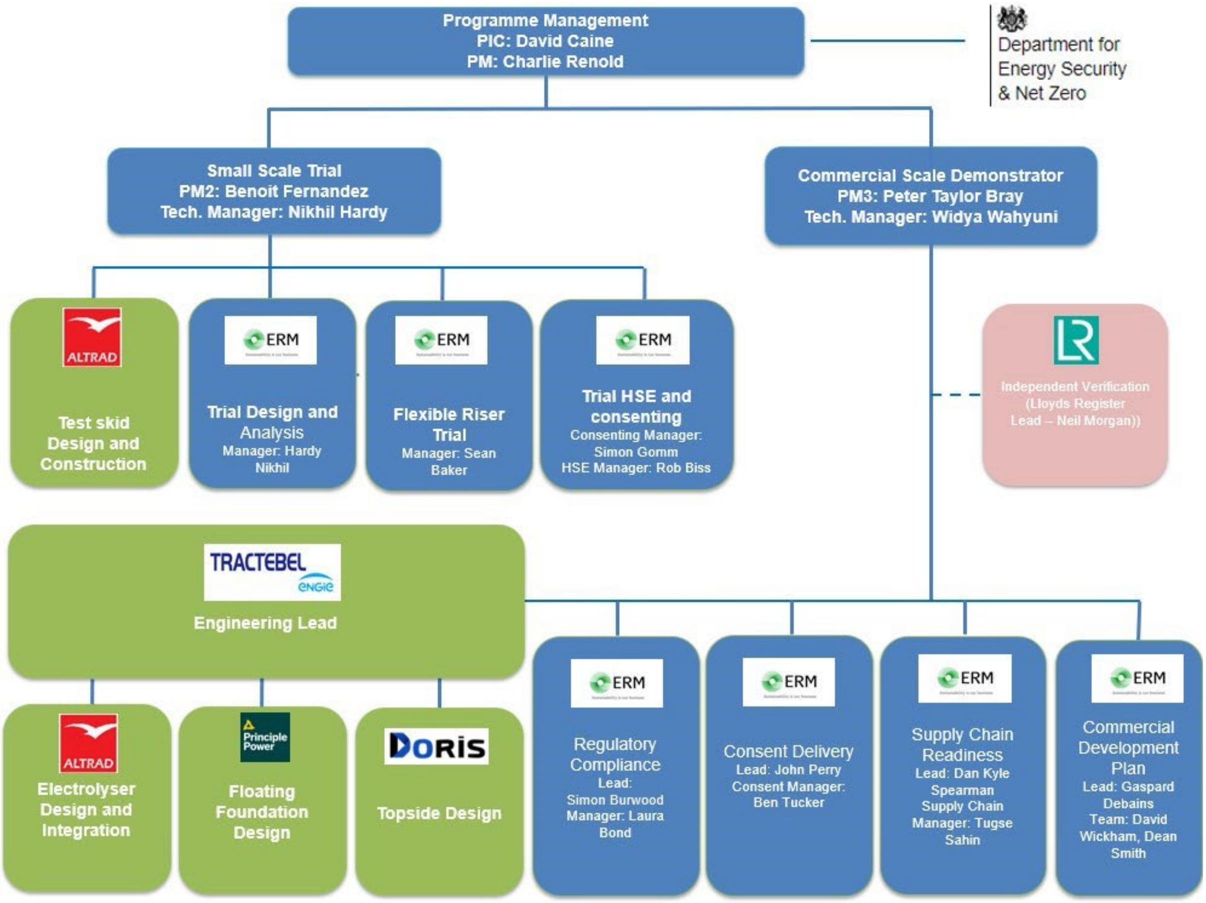
6. Project Management

The Dolphyn project has been managed as a program. Two different projects were run in parallel:

- Commercial Scale Demonstrator – CSD
- Small Scale Trial – SST

6.1 Organisation and Structure

Figure 20 Organisation Chart



The projects were divided into work packages with specific tasks and objectives as follows.

Table 11 Work Package Breakdown, Tasks and Objectives

DESNZ Work package number	Ref	Title	Tasks and Objectives
1	PM1	Programme Management	• Develop programme plans, philosophies and specifications • Manage project partner relations and contracts (technical/progress/budget reviews) • Manage interfaces between functions and flow of information • Allow project risks to be identified, assessed, managed, and mitigated • Accountable for safe delivery of project in line with project objectives • Coordinate function reviews and action closeout • Develop and follow appropriate stakeholder management • Assure project quality • Report progress, risks, and issues to BEIS in a timely manner
2	SST1	Trials Management	• Develop project plans, philosophies and specifications; • Management of onsite delivery, logistics, and coordination of workpacks; • Accountable for successful completion of project in line with performance expectations; • Responsible for the safe delivery of trials; • Allow project risks to be identified, assessed, managed, and mitigated; • Coordinate function reviews and action closeout; • Develop and follow appropriate stakeholder management; and • Report progress, risks, and issues to programme team in a timely manner.

3	SST2	Trial Design and Implementation	• Finalize trials objectives and specification; • Develop trial data requirements; • Literary research to provide context to findings; • Collaborate with other workpacks to develop a practical and safe trial approach; • Accountable for quality and usability of data collected; and • Accountable for drawing of clear conclusions.
4	SST3	Offshore Testing Rig EPCI	• Design, procurement, construction and assembly of containerized test rig in line with project requirements; • Responsible for transportation and assembly of test rigs at site location; • Responsible for safe operation of trial; and • Responsible for decommissioning and removal of trial equipment prior to completion.
5	SST4	Flexible Riser Trial	• Development of an appropriately approved test for flexible riser suitability for hydrogen duty; • Implement the trial safely; • Responsible for trial providing clear results; • Clearly articulate further requirements (if any); and • Obtain approval from an independent body.
6	SST5	Trial HS&E Management	• Implement a clear and robust HS&E Management System; • Champion safety throughout the project; • Drive safety culture in all project participants; • Develop and implement an HS&E Assurance program; and • Identify and meet all HS&E licensing, consenting, and regulatory requirements.

7	CSD1	Development Management	• Develop project plans, philosophies and specifications; • Manage project partner relations and contracts (technical/progress/budget reviews); • Manage interfaces between functions and flow of information; • Allow project risks to be identified, assessed, managed, and mitigated; • Coordinate function reviews and action closeout; • Develop and follow appropriate stakeholder management; • Coordinate function reviews and action closeout; • Report progress, risks, and issues to programme management team in a timely manner; and • Assure project quality.
8	CSD2	FEED	• Commercially ready offshore floating hydrogen production unit (10MW ERM Dolphyn Unit); • Subsea pipeline to landfall; • Pipeline landfall; • Onshore pipeline to reception facility; and • Onshore hydrogen reception facility.
9	CSD3	Regulatory Compliance (H&S)	• Design the project is appropriately to meet applicable regulations; • Develop and implement compliance management strategies in line with regulator expectations; • Develop regulatory documentation based around the development of a Design Notification and Operational Safety Case; and • Facilitate an independent review of the design process to enable an independent body to verify the design.
10	CSD4	Consenting and Licensing	• Work with the Kincardine site to develop an integrated licensing and consenting strategy; • Gain agreement from regulatory bodies over the required consenting and licensing information;

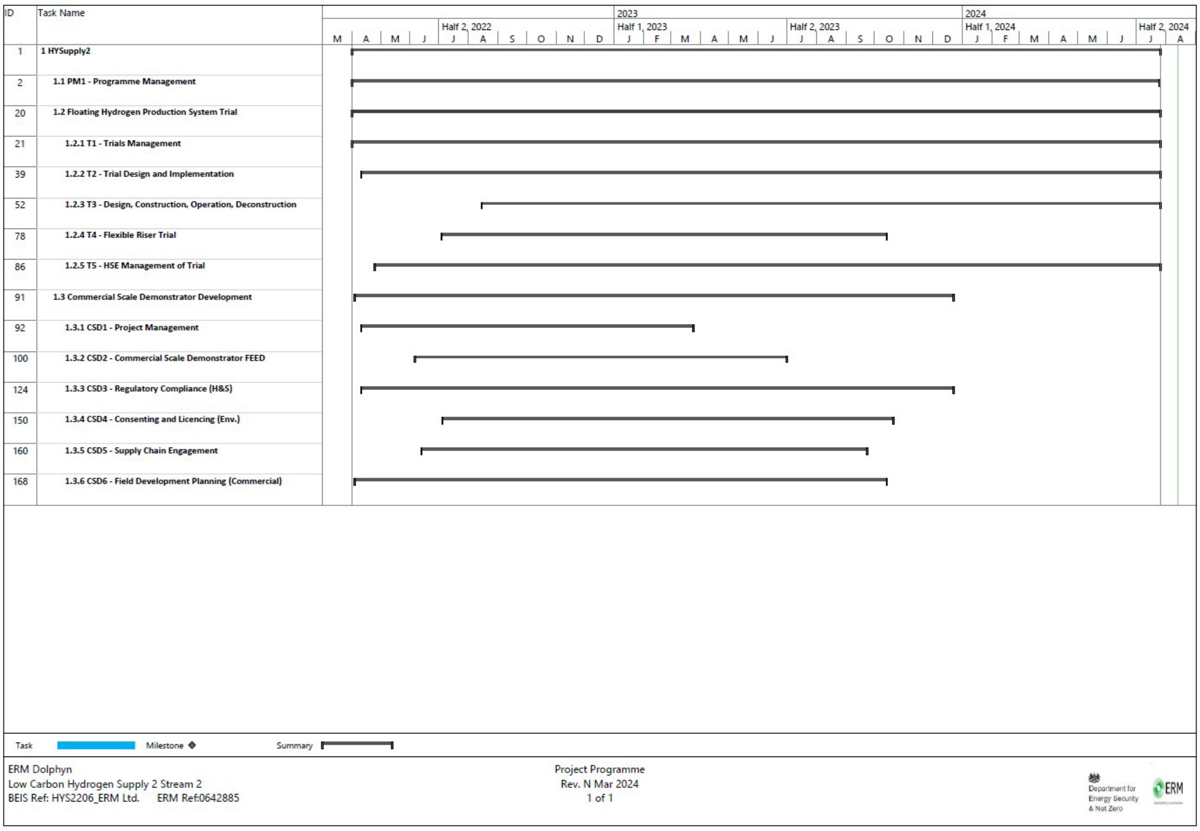
			• Facilitate and conduct surveys as appropriate to meet site and regulatory requirements – existing survey information for the Kincardine development is expected to be broadly appropriate for use for offshore portion of the development; and • Manage project partner relations and contracts (technical/progress/budget reviews).
11	CSD5	Supply Chain Engagement	• Provide assurance that a range of vendors in the supply chain are ready and available to competitively deliver the 10MW scale design in line with the long-term development plan; • Develop and implement the industry engagement plan to disseminate information and raise awareness of upcoming opportunities across the Oil and Gas, Renewables, and Energy Sectors; • Identify and pre-screen potential vendors and suppliers; • Work with key UK suppliers to align development roadmaps; • Identification and management of project risks from the supply chain; • Act as a technical interface point between the design team and the supply chain; • Develop vendor scope of work and specification packs; and • Implement system for supply chain engagement in line with ERM, BEIS, and industry good practice (i.e. transparent and ethical).
12	CSD6	Commercial Development Plan	• Maintain and update the financial model for the 10MW commercial scale development unit; • Maintain and update financial model for onshore portions of the demonstrator project, including tie-in to potential offtakers; • Provide information to support offtake negotiation and funding for risk-based

			development planning of future phases; and • Updated development plan and financial models for early commercial (200MW+) fields, and longer term mature commercial fields.

6.2 Schedule

The program started in April 2022 and was complete in July 2024.

Figure 21 Program Schedule



6.3 Project Management Methodology

6.3.1 Programme Governance and Assurance

The project's partner interfaces were managed through several work groups and committee structures already established during Phase 1 and 2 and indicated hereunder:

- Programme Leadership Team: Entire senior Programme Team will meet on a quarterly basis; and
- Commercial Committee: Monthly meeting of commercial team.

6.3.2 Systems and Procedures

The Programme Manager ensured that adequate programme and project processes and procedures were in place and updated throughout the projects.

The following key documents have been developed at the start of the programme and were revised/maintained throughout as appropriate:

- CSD Project Execution Plan;
- SST Project Execution Plan;
- Work Programme and Budget;
- CSD Consolidated Basis of Design;
- SST Consolidated Basis of Design;
- Programme Schedule;
- Programme Risk Register; and
- Programme Master Document Register.

6.3.3 Sharepoint

A SharePoint site has been set up to be used as a common depository for correspondence, programme calendar, working documents, reports, organisation charts, registers and other project working documents as required. All approved documents were uploaded to the SharePoint site and access provided for all project work packages.

Access and permissions were closely regulated.

6.3.4 Action Tracking

All Dolphyn actions requiring follow up and closure were recorded in the Action Tracking Register. The system allows actions to be created and managed within a simple format enabling actions to carry a comprehensive set of information, any required attachments and an auditable trail. It is the responsibility of the programme manager to ensure the action tracking system is kept up to date and actions implemented.

Actions resulting from the following were captured in the action tracking system:

6.3.5 Documents and Data Control

All deliverables were tracked and recorded in the master document register. All deliverables were submitted to the project document control email address for monitoring and review: doc.control_ermdolphyn@erm.com

Each deliverable received at least one independent review, and a formal comment resolution sheet provided. All reviews were completed within 1 week of receipt (Dolphyn document control internal guide). The Master Document Register (MDR) was the central record of the status and revision of all formal deliverables.

Requests and queries from each work pack were formally raised using the technical query template.

Any communications or reports issued outside of the above process were not considered to have been formally issued.

Additionally, a record of the following was maintained by the project management team:

- Minutes of Meetings;
- Project risks;
- List of Intellectual Property – it was the responsibility of each work package manager and subcontractor project manager to identify any arising intellectual property and formally communicate to the Project Manager;
- Formal Letters;
- Supply Chain documentation include tender evaluations, tender papers, contract clarifications, contracts, variation orders etc.;
- Audit Reports;
- Project Presentations;
- Management of Change requests; and
- HS&E incident reports.

6.3.6 Document Numbering

Each formal deliverable was assigned a document number and logged in the MDR. Any requests for a new document number (i.e. for documents previously unregistered on the MDR) were sent to the project document control email address, doc.control_ermdolphyn@erm.com.

Documents were numbered using the below format:

- Project Number - Project – Organisation – Workstream - Type - Number

Details for each section of the numbering format are given below:

Table 12 Document Numeration Structure

Project Number	Work-pack	Org	Activity	Type	Number
0642885	PM1 T1 T2 T3 T4 T5 CSD1 CSD2 CSD3 CSD4 CSD5 CSD6	ERM TBL ODE PPI DBL VES	TSE (Test Skid EPCI) TDA (Trial Design and Analysis) THC (Trial HSE and Consenting) FRT (Flexible Riser Trial) SST (Substructure) WTG (Wind Turbine Generator) FRG (Frequency Regulation) AAM (Anchoring and Mooring) TST (Topside Structure) FWP (Fresh Water Production) HYP (Hydrogen Production) HYC (Hydrogen Conditioning) ELE (Electrical Engineering) AUS (Auxiliary Systems) EMS (Emergency Systems) ERP (Export Riser and Pipeline) ORF (Onshore Reception Facility) CAC (Control and Communication) COE (Construction Engineering) VAE (Value Engineering)	D (Drawing) N (Technical Note) P (Presentation) Q (Query) R (Report) S (Spreadsheet) L (Letter) M (Minutes) T (Tender)	####

			SAE (Safety Engineering) OAM (Operability and Maintainability) PAE (Piping and Electrical Global Connections) OPE (Overall Project Engineering) LDE (Lead Engineering) RGC (Regulatory Compliance) COD (Consent Delivery) SCR (Supply Chain Readiness) CPD (Commercial Development Plan)		

6.3.7 Progress Tracking

Keeping Project Stakeholders informed in a timely manner was an essential aspect of good Project Management. Open and efficient communications were essential and were given high priority. Regular progress meetings were held, and active participation was encouraged.

Quarterly reports were prepared and issued to partners. The quarterly progress meeting checklist defined all activities to be conducted and provided a summary of the repeated agenda. Fortnightly progress meetings were completed for each work pack.

- Financial progress against budget;
- Key milestones;
- Status of deliverables against project plan;
- Current project Risks;
- HS&E Incidents; and
- Action tracking status.

The intent of the Meeting Minutes was to capture the date and location of the meeting, names of persons in attendance, key issues, actions agreed and name of person responsible for each action, planned completion date and the distribution. A MOM register was maintained so that copies of MOM can be found easily for future reference.

6.3.8 Risk Management

A detailed Risk Register was developed and maintained throughout the project. This identified key risks, provided a high-level assessment of their respective probability of occurrence and impact and further identifies potential means of mitigation and impact post mitigation.

The register was multi-discipline/functional and was therefore a single repository for all project risks and opportunities.

The management of the Risk Register remained the responsibility of the Programme Manager with support from the allocated engineers. Updates of the register were made in close cooperation with the Stakeholder Lead to ensure appropriate input from the Stakeholder engagement process, when relevant.

6.4 Key Risks and Mitigation

As discussed above, a detailed Risk Register was developed and maintained throughout the project. Key risks identified, with mitigation measures introduced are listed as follows:

- **Supply Chain/Procurement –** Early engagement with the supply chain is key, as further explored in the next section. This was particularly important with respect to procurement in the SST part of the project where the long lead in for delivery of the electrolyser from the US was identified early on as a risk to deployment of the trials.

  As a result, the electrolyser was ordered early in the programme, shipped and delivered to enable deployment of the trials within the programme; and
- **Consenting** – Issues with deployment of the CSD at Kincardine were identified partway through the project. At this point, the project pivoted to focus on de-risking pathways to consenting that could be utilized at other UK sites.

6.5 Project Management Lessons Learned

The project required extensive management to ensure successful implementation. Key lessons learned are listed as follows:

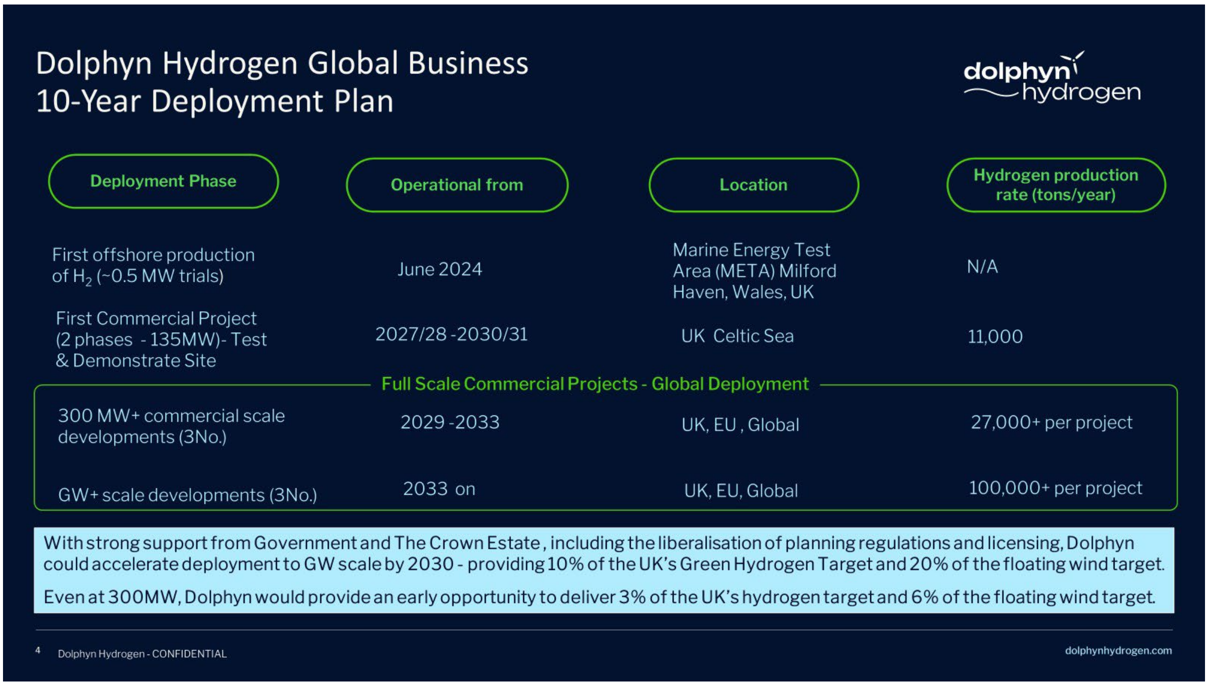
- **Supply Chain** – Design teams should be engaged early, as contract negotiations can be protracted, especially around IP. The role of robust delivery contracts is also of utmost importance;
- **Supply Chain/Procurement –** As highlighted for the SST aspect of the project above, early procurement of long lead items, and indeed construction facilities, is key to successful project delivery;
- **Consenting** – Pathways to consenting of hydrogen projects is evolving and sufficient periods need to be allowed for in larger scale projects going forward;
- **Team Management –** Management of multidisciplinary teams, internally and externally, is highly complex and requires clear work package definition, rigorous review procedures, resource allocation and other rigorous delivery procedures to enable a successful outcome. This is particularly important as parties evolve towards delivery of renewable energy projects from backgrounds such as is oil and gas. The role of a lead engineer is also of utmost importance to manage technical excellence and alignment; and
- **Programme –** Innovation projects are challenging to deliver. Detailed programming should be completed at the outset and robustly challenged from varying perspectives.

7. Commercialisation Plans

Dolphyn Hydrogen has been established by ERM, with the sole objective of maximizing the commercial opportunity associated with the Dolphyn Technology. We see a clear potential for scaling the technology to GW scale over the next 10 years, via a series of stepping-stone developments.

The figure below illustrates the scale of our ambition over the next 10 years.

Figure 22 Dolphyn Hydrogen 10-year Development Plan



We are also currently looking to advance larger scale trials ahead of the construction of the full-scale CSD in the Celtic Sea. These are detailed in the section below.

Our first commercial project in the Celtic Sea is the pivotal next step in realizing Dolphyn's full commercial potential. Over the last 18-months, we have advanced this project in parallel with the work being undertaken to complete FEED and the trials. Along with our project partners Celtic Sea Power (CSP), Wales & West Utilities (WWU) and ORE Catapult, we have submitted a funding application to Innovate UK to support and advance the development of the project concept (known as Milford Haven Hydrogen Kingdom – MH:HK). The project will be located in the Pembrokeshire Demonstration Zone (PDZ). This application was successful, and the concept studies are now underway, and due for completion in the next 6 months. A Special Purpose Vehicle (SPV), Dolphyn Hydrogen Celtic Sea SPV Limited, has been established to advance the project and this company has submitted an application under HAR2 for revenue support for the project. More information on the MH:HK project is included in the next section.

For all prospective developments, we are identifying opportunities that have the potential to scale-up, through a series of steps from 300MW to GW scale. The fundamental requirement of all project developments is to deliver an end-to-end solution, where the level of generation matches the identified hydrogen market demand. We are working closely with transport and industrial offtakers and key stakeholder to map out the principal components of such end-toend plans, including the associated onshore and offshore infrastructure required to connect generation sites to offtake locations. On the Celtic Sea project, we have offtakers options and outline agreements in place. These will be further advanced and formalized through the MH:HK project.

Delivering any project in a timely (accelerated) manner, with maximum impact on 2030 hydrogen and decarbonization targets, will also require strong support from key regulators and stakeholders. We very much welcome the Governments stated commitment to liberalization and acceleration of planning approvals. In September 2024 ERM will be hosting a roundtable/workshop with all key regulators involved in the Celtic Sea project. This will be a key test of willingness and direction.

8. Conclusions and Next Steps

8.1 Conclusions from the FEED and Trials

The project to date has made excellent progress in the design and initial testing of the Dolphyn Technology and met all of its stated objectives. The designs of a 2MW and 10MW (full scale commercial) unit have now been taken through FEED and the small-scale offshore testing of the hydrogen production system (integrating seawater desalination and electrolysis at varying power levels offshore) has been successfully completed. The trials were the first time in the UK that hydrogen has been produced in a floating offshore environment, a significant achievement. They resulted in a large amount of highly valuable data and demonstrated that seawater desalination and electrolysis can work reliably together under the type of motion (displacement and acceleration) conditions found offshore.

The full-scale commercial unit (10MW) has been developed through front end engineering design (FEED) to a technical level that is suitable for investment. The design work was completed in close partnership with leading technology providers from both the hydrogen sector (NEL) and also the floating offshore wind sector (Principle Power). No technical barriers to continued development were identified and approval in principle was granted by an independent verification body (Lloyd's register).

During the design work a number of technical areas of particular interest were identified and these were used as the basis for the small-scale trials. The development of the design included the technical design, safety engineering and regulatory compliance, permitting and consent, constructability and supply chain, and financial modelling. In all of these areas a viable route to production was identified, but as a first of a kind project several areas for refinement and lessons learned were identified:

- The equipment required for development of Dolphyn units is commercially available, however both the hydrogen and floating offshore wind sectors are immature with impacts on the speed, scale, and cost of development;
    - Wind turbine generators (WTGs) are a major bottleneck for renewable wind project development in general, and offshore floating wind in particular. There are a very limited number of proven suppliers globally, and none with a primary focus on the offshore floating UK market, or hydrogen market. The demand for wind turbines for renewable electricity projects already exceeds the supply, this is a

barrier to large scale deployment of offshore floating wind projects and specifically for wind to hydrogen projects.

  - Construction of floating substructures and support operations for offshore floating wind farms is feasible from a number of UK Ports. Work is ongoing to prepare these ports for large scale development and operation of offshore floating wind projects and the progress made in the past 18 months is encouraging, however that work is not complete and projects (such as Dolphyn) passing final investment decision with committed spend is required to underwrite the ongoing investment at ports. Barriers to projects passing FID include site availability, grid availability, permitting and consenting risk, and offtake certainty. Dolphyn provides an off-grid solution but is considered high risk for current investment by most offshore wind developers.
  - Electrolysers are commercially available at the scale required for Dolphyn type projects, and electrolyser manufacturers are making progress to increase their manufacturing output and reduce costs globally. The lead time for electrolysers remained high at the time of project completion. Global competition for electrolysers is increasing as the projects are being announced.
- The roadmap to permitting and consenting floating offshore hydrogen projects is complex but great progress has been made during this project in collaboration with key stakeholders to clarify and de-risk the process. The stability of the UK regulatory regime is a significant benefit to giving confidence to project plans; however, the timescale for achieving consent remains significantly longer than in many countries impacting the development time of UK projects and impacting the competitiveness of attracting UK funding.

The offshore trials represent a first, but highly significant, step in the testing of the Dolphyn Technology. As the first 'real-life' testing of the system, they were conducted within a Port with relatively mild sea conditions (but on a smaller platform base) and utilized an onboard generator to replicate the varying power loads of the wind turbine. The size of the electrolyser (0.2MW) was small compared to the full-scale commercial design (10MW).

Whilst a cautious approach to testing was taken, the ability of the team to take the Dolphyn design, reduce the scale and implement offshore, and for it to work first time and continuously throughout the trial programme, provides increased confidence in the ability to scale up incrementally toward building the full scale Commercial Scale Demonstrator (CSD).

The learnings and data obtained from the project is significant and will strongly inform the next stages of the Dolphyn development. Data from instruments on board the test rig is being analysed to identify further opportunities for optimizing the design, addressing any potential weaknesses and identifying the potential for additional innovation to streamline the system to enhance efficiency levels. The learnings covered technical issues, project management, interactions with the supply chain and regulatory hurdles. Many of these are described in detail within the body of this report and related documents, but to summarize some of the key learnings. These included:

- Importance of close management of subcontractors and the need to have fully prepared procedures which are adhered to. The construction and quay-side testing of the facility took much longer than we had anticipated and resulted in a shorter test schedule.
- Early engagement of supply chain was successful, particularly for the long-lead items. However, the complexity of the supply chain needed for the full scale CSD is recognized and will involve Port and infrastructure changes. These need to be started now if we are to stay on schedule for building the CSD and operating it in the Celtic Sea.
- Engagement with regulators has been proactive and positive throughout the project, but requirements for generating hydrogen offshore at scale are still being formulated. An acceleration of regulatory development and understanding is required to ensure that the timeline for gaining consent is not prohibitive.
- Several technical improvements to the design were noted during the trials and these are now being implemented.

Table 13 Review of Project Objectives

Objective	Comment
• Demonstrate production of green hydrogen from seawater in an offshore floating marine environment	Objective met - The trial successfully demonstrated the production of high purity hydrogen over a period of several days under varying environmental conditions

• Test the performance of key elements of the marinised systems (e.g. the liquid/gas phase separator)	Objective met – successful operation of all key components of the system was demonstrated through the production of hydrogen at the required purity and flow rate
• Identify areas for further innovation or modification and earlystage troubleshooting	Objective met – the project produced several lessons learned to be carried over to the next phases. These are summarised in this report.
• Develop a generalised model for internal fluid behaviours suitable for application on all floating marine environments	Objective met - The main chemical process flow modelling has been completed end to end (and can be replicated with confidence for other design permutations/locations), the primary demonstrating output is the Heat and Material Balance sheet (HMB) in combination with the process flow diagrams (PFDs). In addition, one of the main concerns was sloshing in the separators and CFD completed in this respect. The CFD modelling work performed on the Oxygen Separator for CSD concluded that the inclusion of two weir plates notably lessens the extent of sloshing and eliminates liquid carryover at the gas outlet.
• Develop of a digital process model to enable optimised control system definition at commercial scale production for all floating marine environments	Objective met – A "digital Twin" application was created for this phase of the project. This was designed to collect and display operational and performance data from the trial barge. Future phases will see this tool developed further to be compatibility with the CSD

• Replicate variable power input to the electrolyser from the WTG and test overall reliability of system	Objective partially met. The output of the diesel generators used in the trial was load driven and changed automatically in response to changes in load. It was not possible to simulate intermittency of supply (e.g. from a wind turbine) using the generator. When coupled to a renewable (or variable) power source, the ICMD feature on the C30 is used to match available power with maximum electrolyser output – the performance of the system was tested using the ICMD feature to vary the maximum electrolyser output.
• Additionally, a section of flexible export riser will be tested to assess operational performance for hydrogen duty.	Objective met Tests were successfully completed on components of the flexible riser system. All tests were passed, and the riser was determined as suitable for operational duty for Dolphyn. The test laboratory has indicated that formal 3rd party certification of the flexible pipe for hydrogen transport is currently in progress following the results of this test programme

8.2 Next Steps

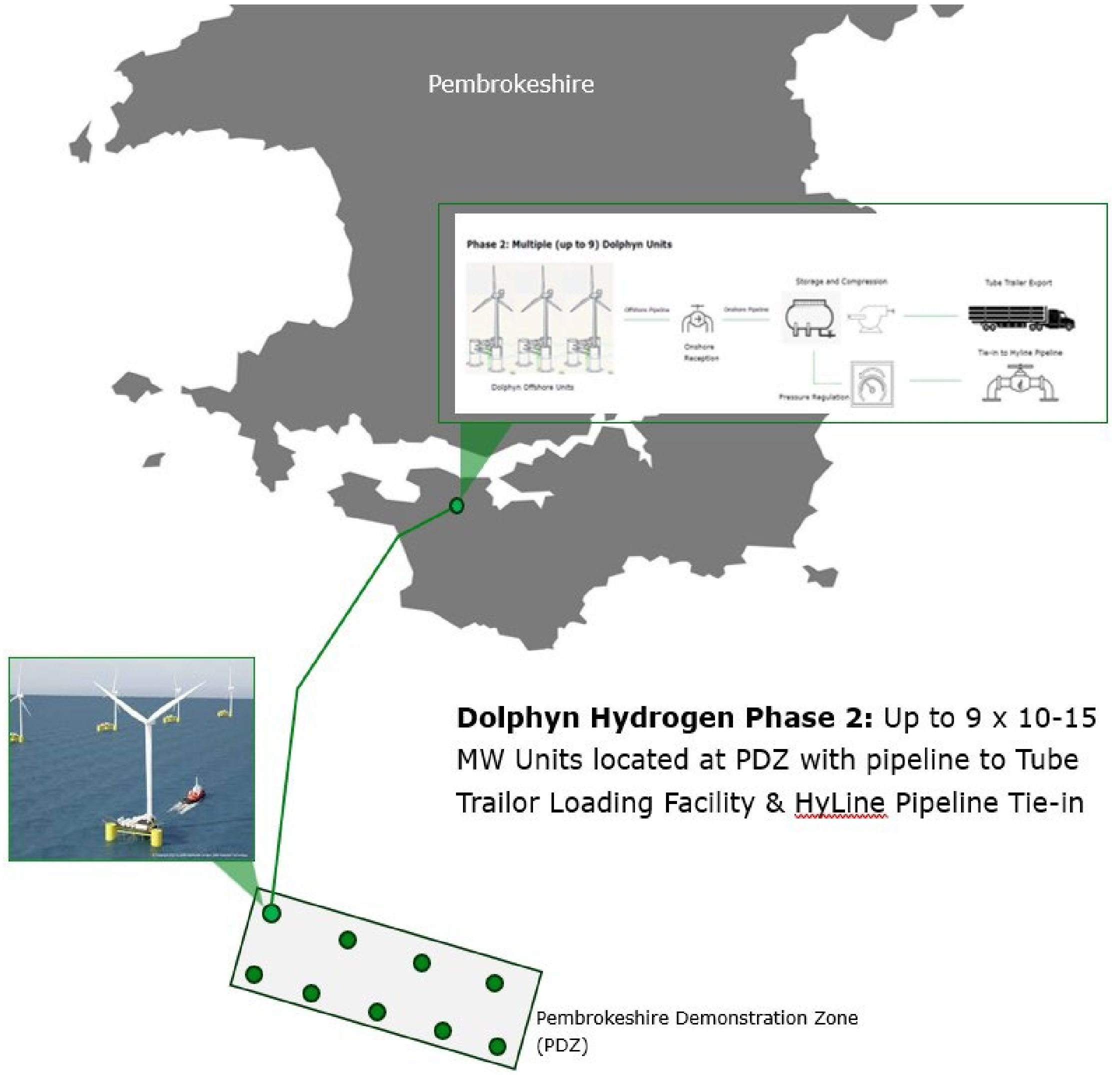
There are 2 key steps that we will now be progressing. The first is the advancement of the concept design for our proposed Celtic Sea development. This will be undertaken as part of the Milford Haven Hydrogen Kingdom (MH:HK) Project (co-funded by Innovate UK). The second is a larger-scale trial, which we aim to undertake in 2025, ahead of the actual development in the Celtic Sea.

The MH:HK project will be advanced over the next 6-months. Our project partners include
Celtic Sea Power (CSP), who are responsible for managing the PDZ site, Wales and West Utilities, who will be developer and operator of HyLine Cymru (the

South Wales hydrogen pipeline), and ORE Catapult, who will take a project management role for the commission.

A wind turbine capacity up to 135MW and an average hydrogen production rate of 33te per day. This level of hydrogen will be too high for road transport and the capacity of the storage facility and so a tie-in to the local 80km HyLine hydrogen pipeline facility being developed by Wales and West Utilities (WWU) is proposed. This pipeline is planned to run from Pembroke to Port Talbot and link all of the major South Wales cluster major industries. The Dolphyn team is currently working with WWU on designing the tie-in facility and location under a separate project. An illustrative diagram showing the outline plan for Phase 2 is presented in Figure 23 below (routes and locations still to be confirmed through the MH:HK study).

Figure 23 Future Dolphyn Development Phase 2 (Illustrative Only)



The scheme design that is being further developed through the MH:HK project is also the basis for a funding application that has been submitted as part of the HAR2 process. The funding application is for both phases. Success in the HAR 2 process is fundamental to the project and to the completion of funding discussions with potential investors.

Liberalization and streamlining of planning and permitting aspects would also reduce uncertainties over the deployment timetable, which is key to the achievement of the Government’s hydrogen and decarbonization targets.

The second important step towards full commercialization is the development of an additional trial ahead of the Phase 1 development at PDZ. We feel this is necessary as a steppingstone to full scale development.

The current aim is to scale up the system to form a larger longer-term trial at Milford Haven during 2025, ahead of the CSD.

The trials would use a renewable power source, most likely a land-based wind turbine. This would provide us with the opportunity to test clean-power integration aspects over an extended timeframe, which would be of great value ahead of constructing the full-scale demonstrator.

9. References

[1] ERM, Dolphyn Hydrogen Phase 1 – Final Report, 09/10/2019

[2] ERM, Dolphyn Hydrogen Phase 2 - Final Report, 02/07/2021

[3] Sura, Abadi, Gan Ming De, Tzeat, Jeswani, De Guzman, Design of a floating green hydrogen production system, 11/05/2023

[4] Offshore Energy Catapult, Exploring options for advanced electrolyser testing, 15/09/2023

[5] ERM, Dolphyn Small Scale Trial Literature Review, 17/03/2023

[6] Altrad, Dolphyn CSD FEED O2 Separator Vessel CFD Modelling

[7] ERM, Dolphyn Trial – Carbon Footprint, Predicted Carbon Footprint Calculations for Dolphyn Offshore Testing Rig, 15/05/20223

[8] ERM, 4.1_0642885-SST-ERM-OTR-R0005_Trial Skid Front End Engineering Specification Rev 0 100%, 27/02/2023

[9] ERM, 6.1_0642885-SST-ERM-THC-R0003_Minimum Health and Safety and
Environment (HSE) Requirements for Suppliers, 10/10/22

[10] NEL, C:Series Datasheet: https://nelhydrogen.com/resources/c-series-spec-sheet

[11] NEL, C series 3 Hydrogen Generator Remote Operation Instructions, October 2020

Appendix A Example Key Reports Delivered

Table A 1 Commercial Scale Demonstrator Targeted FEED

Area	Title
Project Management	Overall Programme Execution Plan
	CSD Project Execution Plan
	Project Quarterly Progress Reports
Topside Facilities	Offshore FEED – Topside Facilities Design
	Relief and Blowdown Philosophy
	Dolphyn CSDU FEED - Mechanical Handling Report and Equipment and Operations Lifting Study
	Waste & Emissions Schedule
	Project integrated list of codes and standards
	Preliminary Hazardous Area Classification
	Cause and Effect Charts
	Hazardous Material Schedule
	Process Basis of Design
	Electrical Basis of Design
	Electrolyser Structural Basis of Design
	Dolphyn CSDU FEED - Process Control Philosophy - Overall
	Process Structures (PAU1) Primary Steelwork Plan
	Process Structures (PAU1) Mezzanine Steelwork Plans
	Process Structures (PAU2) Primary Steelwork Plans
	Cooling Medium Supply and Return Piping and Instrumentation Diagram
	Plot Plan PAU1 & PAU3 Main Deck Level

	Plot Plan PAU1, PAU2 & PAU3 Mezzanine Levels
	Electrical Equipment Layout Main Deck Level
Wind Turbine Generator	Offshore FEED - Wind Turbine Generator Design
Floating Foundation and mooring system	Offshore FEED - Floating Foundation and Mooring System Design
	Offshore Marine Engineering FEED Report/Package
	Hull & Mooring Design Basis
	Hull Principal Dimensions
	Global Performance Report
	Mooring System Configuration Drawings
	Mooring System Design Report
Export Pipeline and Riser Design	Offshore FEED - Export Pipeline and Riser Design
	Dolphyn CSDU FEED - Pipeline Construction Philosophy
	Dolphyn CSDU FEED - Preservation philosophy for J-tube
	Dolphyn CSDU FEED - Pipeline Wall Thickness Sizing
	Dolphyn CSDU FEED - Export Pipeline System - Material Take Off (MTO)
	Dolphyn CSDU FEED - Riser J-tube Installation Storyboard
Construction engineering	Offshore FEED – Construction Engineering Design
	Hydrogen Pipelay Installation Assessment
	Overarching Construction Methodology
Onshore facilities	Onshore FEED – Definition of Onshore Concept
	Onshore FEED Site Options Appraisal
	Onshore FEED - Onshore Facilities Design
	Preliminary Civil Design Philosophy

	Onshore Facilities - Layout
	Preliminary Civil Design Philosophy
	Electrical Onshore Substation Layout
	Onshore FEED - Landfall Pipeline Design
	HDD Feasibility study
	Onshore facility layout, pipeline and landfall general arrangement for HAZOP
	Offshore Engineering Marine Survey - Planning and HS&E
	Basis of Design_Rev2
Regulatory Compliance	H&S Philosophy 10MW_Rev1
	Safety Engineering and Loss Prevention Plan
	Technical Safety Plan
	Dolphyn Design Notification - Offshore
	Verification Basis of Design
	Independent Verification Body Letter of Approval
	Independent Verification Report
	Collated design package for HAZOP review
	Piping and Instrumental Diagrams - SEAWATER DISPOSAL CAISSON AND OPEN (Water) DRAINS
	Desalinated Water Polishing - Deionized Feed Beds Piping and Instrumentation Diagram
	Desalinated Recycled Water Polishing Piping and Instrumentation Diagram
	Oxygen Separator Piping and Instrumentation Diagram
	Electrolyser Cells A-H Piping and Instrumentation Diagram
	HP Hydrogen Separator Piping and Instrumentation Diagram

	HP Condensate Separator Piping and Instrumentation Diagram
	LP Hydrogen Separator Piping and Instrumentation Diagram
	Hydrogen Drying A-B Piping and Instrumentation Diagram
	Hydrogen Vent to Atmosphere Piping and Instrumentation Diagram
	HAZOP Terms of Reference
	HAZOP Report
Consenting	Onshore Env Appraisal Scoping
	Environmental Appraisal
	Planning Statement
	Offshore EIA Screening and Scoping
	Offshore Env App
	Offshore Environmental Survey Planning
	Onshore EIA Screening
	Offshore Engineering Marine Survey - Planning and HS&E
	Marine Survey Scope of Works
CSD 5 Supply Chain Readiness	Tender Evaluation Report_
	Supply Chain Report
	Pre-Procurement Pack
CSD 6 Commercial Development Plan	Updated Financial Model_V3_App
	ERM Dolphyn Commercial Plan
	Commercial Plan-R0002
	Field Dev.Plan-R0001
	Financial Model-R0004

Table A 2 Small Scale Trial

Area	Title
Civil / Structural Engineering	Preliminary Sizing Calculations
	Container 2 Frame for Lightning Rod and Vent Pipe support
	Specification of structural steelwork
	Structural MTO
	Plinth for Hydrogen Production/Metering Equipment in Container 2
	Sea Fastenings Door Framework for container 2 &3
	Barge Deck Fastenings Key Plan
	Barge Deck Fastenings Details
	Plot Plan/Layout
	Support steelwork for vent pipes and lightning rods container 2
Electrical Engineering	End of FEED Report
	Electrical Load Summary
	Material Take Off (Class II only)
	Basis of Design
	Equipment Sizing/rating calcs
	Lighting Levels calc (external)
Control and Instrumentation engineering	Instrument Basis of Design
	MTO
	Instrument Schedule
	Cable Block ESD and Fire and Gas
	User Requirements Specification for ICSS Hardware
	C&I Scope of Work
	Termination Drawings
	Loop Drawings

	Hook Up Drawings -
	Instrument datasheets

	Instrument technical Specifications
	Technical Specification - Fire Detection Panel (TS)
Mechanical Engineering	Combined Mechanical & HVAC Basis of Design
	General Technical Requirements - RO Water Treatment Package
	General Technical Requirements – Diesel Generator
Piping Engineering	Piping basis of design
	Bulk Material Take Off
	Manual Valve Schedule
	Plot Plan
	Equipment layout
	Electrolyser container – piping layout
	Barge Piping layout
	Piping and inspection testing ASME B31.3 - 2022
Process Engineering	Process Basis of design
	Heat and Materials Balances
	Process Flowsheet (PFD)
	Vent Sizing calculations
	Calculations - Vent Noise assessment
	Chiller Specification
	Electrolyser Specification
	Water treatment package specification
	Drainage Philosophy
	Cause and Effects charts
	Process P&IDs

	Utility List
	Hazardous Materials Schedule
	Waste and Emissions Schedule
	Sampling System Specification
	Winterization Philosophy
	Start-up/Shutdown Procedure
	Safety Philosophy
	HAZID / ENVID Report/
	Vent Dispersion Assessment
	Terms of reference FEED HAZOP
	Terms of Reference for EPC Stage HAZOP
	HAZOP (FEED Stage) Report
	HAZOP (EPC Stage) Report

Table A 3 Program Management

Area	Title
WP 1 Project Management	Trial project execution plan
	Trial Management Plan
	Preconstruction Facility review
	Construction Facility Review Report (mid construction)
	Construction Facility Review Report (pre-transport)
	Trial Site Pre-Installation Review_100%
	Trial Site Start-Up Report
WP2 – Trial definition and Design	Trial Definition and Design Report
	Test Skid Development Quarterly Reports 1, 2, 3, 4 and 5
WP3 – Test Skid EPCI	Trial Skid Front End Engineering specification
	Design Package for Skid
	Procurement Summary Report
	Skid Detailed Design and Construction Report
	Deployment and Commissioning
WP4 – Flexible Riser Trial	Riser Trial Design Definition Specification
	Riser Trial Design Package
	Riser Trial Summary Report
WP5-HS&E and Consenting	HS&E Management Plan
	Trial Licences and Permits
	Project Quarterly progress reports (DESNZ Deliverable)
(WP6) Equipment Resale	Dolphyn Electrolyser Package Sale

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