# Compressed hydrogen: An alternative approach to shipping hydrogen

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**Summary**
Compression is often an overlooked method of transporting hydrogen from 'port to port' and is not as common as ammonia or liquefied hydrogen as a future hydrogen carrier. The technical and commercial feasibility of exporting compressed hydrogen was explored for a proposed green hydrogen production facility in Western Australia. The study comprises the full compressed hydrogen supply chain, which includes work from the onshore compression facilities up to the receiving terminal.

*Keywords: hydrogen, compression, shipping, offshore loading*

## Introduction

The world is on a path to global decarbonisation and there is increasing investment to renewable green energy sources. Hydrogen is a highly versatile energy fuel and is one of many that can be developed through a renewable process. Hydrogen can be produced by electrolysis which is a process of separating water into hydrogen and oxygen. When this process is performed using electricity generated from renewable sources such as solar and wind the hydrogen produced is considered green and effectively contributes to reduction in carbon emissions produced from power generation.

Provaris Energy (PV1, formerly known as Global Energy Ventures) is an energy transition company with a vision of developing compressed hydrogen shipping solutions. Compression is a simple and efficient method of marine transport of hydrogen and does not require energy intensive or complex processes to convert hydrogen into a liquid or chemical state. Compression is already proven as a safe and reliable method of storing and transporting hydrogen upstream and downstream of marine shipping and can accelerate the development of greenfield hydrogen export projects with minimal technical barriers, small environmental footprint, and ability to be flexible to cater for variable renewable energy production profiles. PV1 recently has obtained Approval in Principle from the American Bureau of Shipping to develop their 2,000 t and 430 t compressed hydrogen vessels. The mature level of the ship design has allowed PV1 to effectively engage with shipbuilders, regulatory authorities, and other industry stakeholders.

A feasibility study has been undertaken to explore the viability of utilising PV1's compressed hydrogen shipping solution to export hydrogen from a proposed green hydrogen production facility in Western Australia. The study includes a comprehensive analysis of the full compressed hydrogen supply chain. The scope includes:

- Onshore compression facilities;
- Offshore loading system;
- Shore crossing subsea pipeline;
- Market study for receiving terminals;
- Cycle time analysis;
- Commercial modelling;
- Environmental constraints assessment;
- Job creation assessment.

This paper will provide an overview of the feasibility study and compressed hydrogen shipping. A focus will be given to the onshore compression facilities, the offshore loading system and cycle time analysis.

## Onshore compression facilities

The compressors are designed to accommodate a flow of 200,000 tpa of green hydrogen produced from electrolysis. The compressors which will raise the pressure of hydrogen to 250 bar, suitable for loading onto the PV1 compressed hydrogen vessels. Double acting reciprocating compressors with variable frequency drive (VFD) motors were selected to provide flexibility in compression rate to accommodate variability in hydrogen production. Multiple compression and cooling stages are also incorporated in the design to control and limit discharge temperatures.

## Offshore loading

As the surrounding waters to the project site are relatively shallow and environmentally sensitive, the project considered an offshore loading system consisting of a single anchor loading (SAL) system developed by APL NOV, shown in Figure 1.

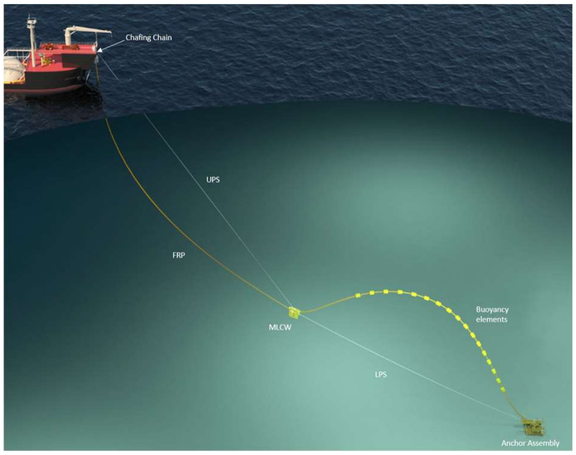


Figure 1 Single anchor loading system components (Source: [1])

The offshore loading location is relatively distant from the coastline, approximately 15 km away but is well protected and sheltered from swells by surrounding islands. The SAL system is also high adaptable and allows loading to place under wave conditions of $H_s$ = 3.5 m.

### Shore crossing and subsea pipeline

Environmental sensitivities are present along the project coastline and limit the pipeline shore crossing options. The adopted shore crossing methodology is horizontal directional drilling (HDD) to minimise environmental impacts. The HDD will terminate approximately 2.5 km from the shoreline and will transition into a trenched and buried segment.

### Cycle time analysis

One of the most critical elements to this study was the cycle time analysis which was used to determine the hydrogen throughput as probability functions. The assessment considered:

- Failure rates and downtimes of equipment onshore and on the vessel
- Vessel speed as a function of $H_s$ probabilities over various segments of the transit
- Cyclone probabilities
- Vessel maintenance and resupply times as probabilities

The cycle time analysis was performed using the Monte Carlo method, assessing the hydrogen throughput for a number of vessel scenarios and sensitivities. An example output of the Monte Carlo simulations is provided in Figure 2.

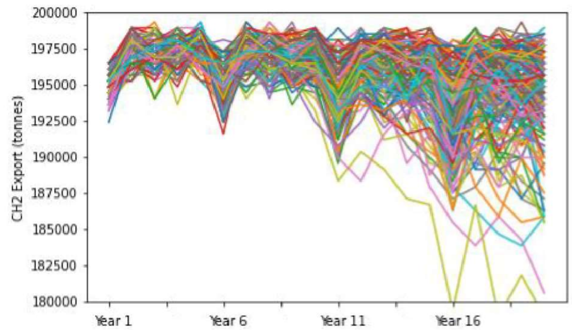


Figure 2 Hydrogen throughput for 250 simulations over 20 years

The assessment was highly critical as it fed into the commercial model to help determine the optimal number of ships for the cycle (by a cost benefit analysis).

### References

[1] APL NOV (2022). Single Anchor Loading. Available at < https://www.nov.com/products/single-anchor-loading >