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Concept Design Study reaffirms compressed hydrogen is an energy-efficient supply chain for regional Europe.

Provaris Energy Ltd (the Company; ASX PV1) is pleased to announce the completion of its Concept Design Study (Study) for bulk-scale hydrogen export and import compression facilities. The findings of the Study reaffirmed the low energy use and low capital of Provaris' compressed hydrogen supply chain for regional marine transport of hydrogen in gaseous form.

The Study, the fourth in a series of techno-economic studies developed by Provaris, was based on a 540MW capacity reservation export site, producing 10 tonnes of hydrogen per hour (equivalent to 87,000 tpa); with an intra-Europe shipping distance of 1,000 nautical miles using the H2Neo carrier to deliver gaseous hydrogen to the customer at 70 barg.

A leading original equipment manufacturer of high pressure compressor equipment (**Compressor OEM**) supported the preparation of this Study with the selection of optimal compression equipment to ensure the project's feasibility.

Key outcomes include:

- Reconfirmed low energy use with only **~1.5 kWh per kg of hydrogen required for storage and loading compression** (Export Terminal), and only 0.2 kWh/kg for unloading compression (Import Terminal).
- **Compression energy use represented only ~2.8% (15MW) of all power requirement for the export site**, with the remaining 97.2% (525MW) available for hydrogen production (via electrolysis).
- Concludes that **compression has up to 5 times less energy use** than required for ammonia synthesis (7.5 kWh/kg H2 or 65MW), leaving only 470MW available for electrolysers after ammonia synthesis.
- Capital cost of compression facilities was €120 million, representing less than 7% of the total capex of the hydrogen supply chain.
- Low energy use of compression, with little or no hydrogen losses, results in **~50% greater hydrogen volumes** delivered to the customer when compared to ammonia supply (Refer to Figure 1 below).
- Supported by the Study scope and outcomes, compression's superior capital and energy efficiency could result in a ~**20% lower delivered price at €6/kg** compared to regional supply ammonia post cracking back to hydrogen at €7.4/kg (refer to Figure 2 below).
- Europe's recent H2Global and EU Hydrogen Bank auction results allocating **€1.1 billion funding** to green ammonia and hydrogen projects demonstrated a **hydrogen supply cost range of €6-10/kg** further highlighting the competitiveness of compression.

Provaris' Garry Triglavcanin, Product Development Director, commented: *"The Concept Design Study reconfirmed the superior energy efficiency and low capital cost associated with compression for marine transportation of hydrogen. It is pleasing to receive detailed costings and equipment selection from the Compressor OEM, supporting our development case in Europe.*

This Study has increased our confidence and understanding that many regional-European sites with a material level of renewable power reservation can significantly benefit from compression, when compared to the alternative of converting hydrogen into ammonia for marine transport. The benefits of compression include delivering more hydrogen in volume, using less capex, and boosting the financial returns to the producer whilst maintaining a highly competitive delivered cost to the customer."

The results of the Study will be used as a basis to support and develop site specific compression facilities now underway for both export terminal feasibility studies for sites identified in Norway and the Nordics along with import site locations such as Port of Rotterdam as part of our collaboration with Global Energy Solutions. Development activities with Uniper also include the review of multiple import site locations where compression will be required.

Fig 1. Delivered Hydrogen Volumes (tpa)

Compression vs. Ammonia (540MW)

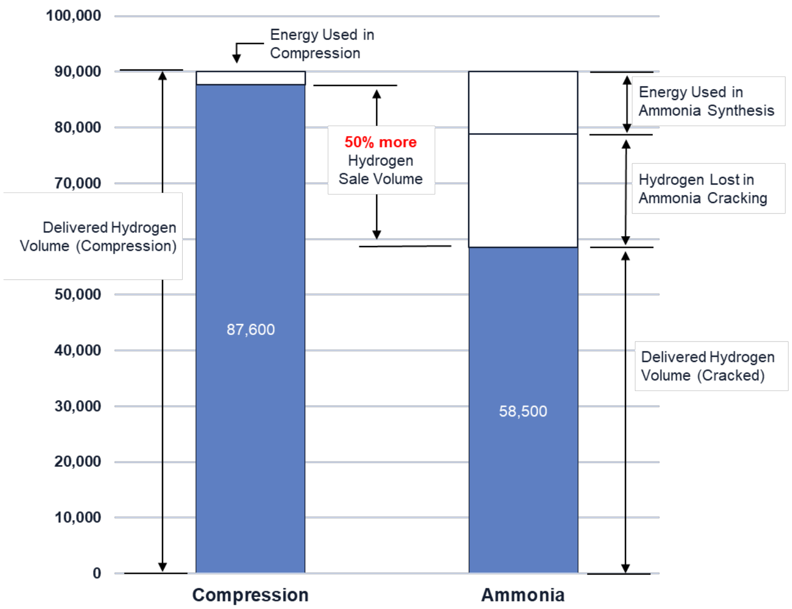
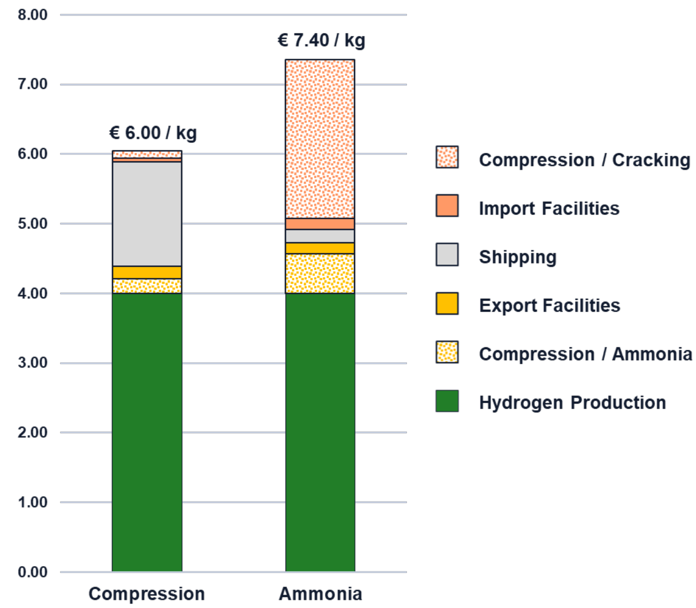


Fig 2. Delivered Price of Hydrogen (€/kg)

Concept Design (540MW), 20 Yrs / 12% IRR



All equipment selection and costs align with a level 3 project feasibility assessment, with the capital and operating costs, compression capacity (MW), and energy use (kWh) provided by a globally recognised Compressor OEM working with Provaris on the selection of high-pressure compressors for industrial gases, including hydrogen.

All compressor equipment selected for the Study is compatible with hydrogen at scale and commercially available with no further research and development or certification to operate up to 250 barg. **A summary of the Study report is provided in Appendix A which follows.**

Illustration of regional hydrogen supply locations in proximity to the German offtake market

Study outcomes demonstrate competitive pricing compared to recent European hydrogen auctions: EU Hydrogen Bank and H2Global Pilot

The delivered hydrogen price shown in Figure 2 above excludes any assumption for available subsidies from the increasing number schemes available in Europe for both development capital expenditure or import pricing support.

In 2024, there have been two distinct pilot subsidy programs for hydrogen in the European industry:

- **April 2024: EU Hydrogen Bank awarded a combined €720 million across 7 projects;** set to produce a collective 158 ktpa of hydrogen by 2029. Portugal, Spain, Norway and Finland were the selected locations. Winning bids submitted to the auction suggest **average levelized costs between €5.8/kg and €8.8/kg.** A second €1.2 billion auction is planned for late 2024.

- **July 2024: Germany's H2Global pilot auction** awarded Fertiglobe as the sole recipient of €394 million to support a 7yr supply contract of at least 259,000 tpa of NH3 (equivalent to 37,000 tpa of H2). A comparison between the Study outcomes and Germany's recent H2Global pilot auction outcomes below further demonstrate the competitiveness of Provaris' regional supply model.

	Germany's H2Global Pilot Auction *		EU Hydrogen Bank	Provaris Compressed H2 ^
	Fertiglobe	H2Global Average		
NH3 €/t	1,000	1,294		
H2 Equivalent €/kg	5.56	7.19	5.80 – 8.80	6.00
Cracking				
Capex	*0.51*	*0.51*		-
Opex	*0.12*	*0.12*		-
Losses	*1.94*	*2.52*		-
Delivered gaseous H2 (€/kg) ^	**8.13**	**10.34**	**5.80 – 8.80**	**6.00**

Source: * H2Global, BloombergNEF; ^ Provaris Analysis

For more details of the Concept Design Study scope and findings, please contact Provaris Energy info@provaris.energy

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This announcement has been authorised for release by the CEO of Provaris Energy Ltd

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About Provaris Energy

For more information: www.provaris.energy

Provaris Energy Ltd (ASX: PV1) is an Australian public company developing a portfolio of integrated green hydrogen projects for the regional trade of Asia and Europe, leveraging our innovative compressed hydrogen bulk storage and carrier. Our focus on value creation through innovative development that aligns with our business model of simple and efficiency hydrogen production and transport can establish an early-mover advantage for regional maritime trade of hydrogen and unlock a world of potential. In August 2022 Provaris Norway AS was established to advance the development of regional hydrogen supply in Europe.

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APPENDIX A – SUMMARY OF CONCEPT DESIGN STUDY

SCOPE AND KEY ASSUMPTIONS

The Concept Design Study is the fourth of series of papers prepared by Provaris to analyse the capital and energy efficiency the overall hydrogen supply chain based on compressed hydrogen and compared to other carriers including liquefaction and ammonia. Summaries of each report are available on request.

- Scoping Study (2021);
- Comparison Report (2023);
- Thermodynamic Whitepaper (2024); and
- **Concept Design - Compression Facilities (2024) – this Paper.**

The third paper, Thermodynamic Whitepaper, was undertaken by Provaris to determine the temperature and pressure conditions prior to (and during) both loading and unloading.

Provaris selected a leading Compressor OEM for high pressure industrial gases, including for hydrogen applications, capitalizing on their extensive experience across various industries. The selected Compressor OEM provider supported the preparation of this Study by selecting the optimal compression equipment to ensure the project's feasibility.

The installed compression capacity (MW) and energy use during storage, loading, and unloading (kWh) were in line with the Compressor OEM's expectations based on the compression equipment selected. Capital and operating cost estimates were provided for the assessment of project feasibility (level 3) and were non-binding. Any firm bid package would be submitted by the Compressor OEM, subject to further site-specific requirements.

Further details of this paper are available upon request.

KEY ASSUMPTIONS

The Study examined the compression requirements, both installed capacity (MW) and energy use (kWh), for the loading and unloading of compressed hydrogen from Provaris' H2Neo compression hydrogen carrier, and was based on the following project assumptions:

EXPORT (LOADING) TERMINAL

Reservation Capacity: **540 MW** (supplied to site, base load)

Hydrogen Production: **87,600 tpa** ex-electrolysers (**10 tph**[1] at **20 barg**)

Storage: **450 tonnes** of hydrogen using Provaris' H2Leo barge (net storage capacity)

Export Compression Facilities: consisted of two sub-facilities, being:

i) For Storage: compressed produced hydrogen for storage in the H2Leo storage barge by increasing the pressure from 20 barg to up to **250 barg**. Hydrogen assumed to be refrigerated to 5ºC prior to storage.

ii) For Loading: transfer and then compress hydrogen from the H2Leo storage barge to the Provaris' H2Neo carrier within **24 hours**, net cargo capacity of **450 tonnes** of hydrogen, and maximum allowable operating pressure (MAOP) of **250 barg**. Refrigeration of hydrogen to 5ºC prior to loading.

[1] Based on a conversion efficiency of 52.5 kWh/kg of hydrogen for the electrolyser facility (including balance of plant use), which is a Provaris internal assumption, together with 1.5 kWh/kg of hydrogen for compression usage.

IMPORT (UNLOADING) TERMINAL

Delivery: to the Customer's pipeline, which was assumed to have a MAOP of **70 barg**.

Scavenging Compression: transfer and then compress hydrogen from the H2Neo carrier directly to the customer's pipeline within **24 hours**. The heel pressure of the H2Neo carrier was assumed to be **10 barg**. No refrigeration required.

Storage: no hydrogen storage assumed (direct unloading into customer's pipeline)

SUMMARY OF STUDY OUTCOMES

	EXPORT TERMINAL	IMPORT TERMINAL	
LOADING/UNLOADING PERIOD	24	24	hours
INSTALLED CAPACITY	19.5	10.0	MW
ENERGY USE [2]	1.50	0.21	kWh/kg H2
CAPEX [3, 4]	76.8	39.5	€ million
OPEX	4.0	2.7	€ million pa
OVERALL FOOTPRINT	240 x 150	160 x 150	meters

ENERGY EFFICIENCY

Export Terminal: compression required 1.5 kWh/kg H2 loaded or **2.8% of the power reservation energy,** allowing a greater percentage (97.2%) of the power supplied to site to be used for hydrogen production (via electrolysis). Compression had 5 times less energy requirement than ammonia synthesis (7.5 kWh/kg of hydrogen) and therefore enabled 13% more hydrogen to be produced – based on a set reservation capacity (MW) delivered to site.

Import Terminal: compression required only 0.21 kWh/kg of hydrogen unloaded. This was deemed materially insignificant. This figure compares to a 5% hydrogen loss/usage for liquefaction, and a ~26% loss/usage for ammonia cracking.

Summary of the Export Terminal

Two separate compression sub-facilities were assumed at the Loading Terminal, being the:

- "**STORAGE**" compression facility: the purpose of the "Storage" compression facility was to compress the hydrogen production (10 tph, 20 barg) for storage directly to the H2Leo storage barge (up to 250 barg), even during the H2Neo carrier loading operation. Hydrogen assumed to be refrigerated to 5ºC prior to storage.

  The storage cycle under this Study was determined to be **45 hours**, consisting of 24 hours for H2Neo loading and a further 21 hours of continued electrolyser production storage in order for the H2Leo storage barge to attain its pre-H2Neo loading temperature and pressure condition (i.e., ready for the next loading cycle).

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[2] Based on an electrolyser outlet pressure of 20 barg
[3] For the entire compressor facility, includes balance of plant, buildings, civils, etc
[4] Level 3 capital cost estimates

- "**LOADING**" compression facility: in the first 5 hours of loading, no compression was required as hydrogen at a rate of ~45 tph free flowed from the high pressure H2Leo storage barge to the low pressure H2Neo carrier. During this "free flow period", 230 tonnes of hydrogen was loaded.

  Post this free-flow period, the purpose of the "Loading" compression facility was to compress hydrogen from the H2Leo storage barge in order to continue loading the H2Neo carrier at a rate of ~12 tph over the remaining period of 19 hours. During this compression period, the remaining 220 tonnes of hydrogen was loaded. Hydrogen assumed to be refrigerated to 5°C prior to loading.

  The entire loading cycle was therefore **24 hours**, completed when the H2Neo carrier had reached its maximum allowable operating pressure of 250 barg.

Summary of the Unloading Terminal

As the H2Neo's cargo pressure upon arrival is ~ 250 barg, and the customer's pipeline pressure assumed to be at a lower pressure of 70 barg, the H2Neo carrier unloaded 305 tonnes of its 450 tonne net hydrogen cargo in the first 9 hours of the unloading (~35 tph) - without the need for any compression.

For the remaining 15 hours, a constant unloading flow rate of ~10 tph was assumed during which the H2Neo's cargo pressure decreased from 70 barg to its heel pressure of 10 barg. No refrigeration was assumed prior to delivery to customer's pipeline.

For more details of the report scope and findings, please contact Provaris Energy info@provaris.energy

About Provaris Energy

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