NT Resources Week - Environmental Management & Decarbonization Forum

C.M. (Costa) Tsesmelis

Project Director - LH2 Energy Pty Ltd

Darwin Green LH2 Export Project and Domestic H2 Hub Development

International Joint Development Project to deliver Large-Scale LH2 Shipping

AGENDA

Darwin Conference 13th September 2023

- Business Model: similar to the way the Australian LNG Export Industry developed in the 1980s
- Overview: Key Technologies for a safe & efficient commercially-viable LH2 Shipping Industry
- Highlights: Important supply-chain Project Economics and Costs for Large-Scale LH2 Shipping
- Current informal membership & partners of the Darwin International Joint Development Project
- Next Steps: Project Timeline and further collaboration needed to “kick-off” the Darwin Project

Darwin Project - International JDP - Business Model and Partnerships

A new LH2 Export Industry for Australia

very similar Business Model to that required at beginning of the LNG Industry in the 1980ies

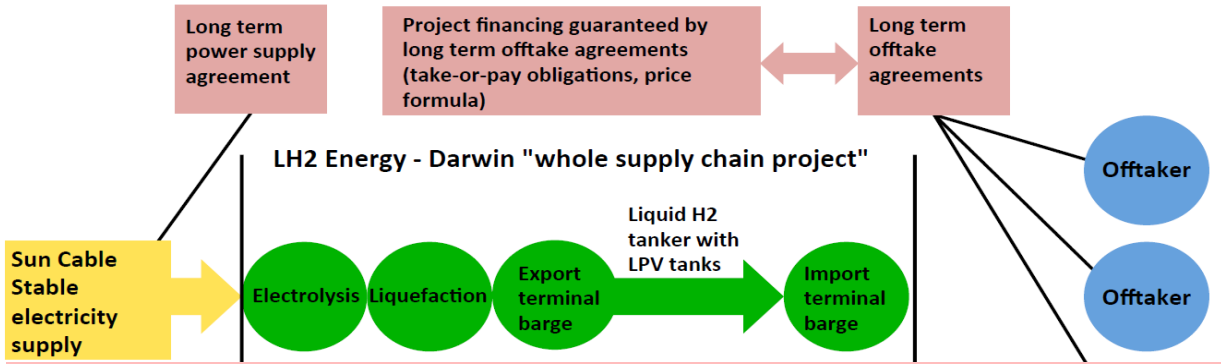
Project has NT Government support. Currently seeking recognition & support from the Commonwealth and Government agencies to "mobilise" Stage 1 - Basic Design/FEED

Straightforward basis for LH2 pricing formula based on Platts FOB Singapore Premium Gasoline

Project has Korean Government support with funding already provided for design of Green LH2 Transportable Barge Export/Import terminals (the KETEP Project)

MOU / LOI in-place with Sun Cable

anticipated NT Government regulations & agreements will in effect provide "Behind the Meter" supply in collaboration with the MASDP Development



MOU / LOI in-place with KOMIPO

anticipated law changes by 2030 to allow KOMIPO (Korea Midland Power) to be allowed entry into Korean FCEV domestic market (the 'premium' market for Green H2 imports)

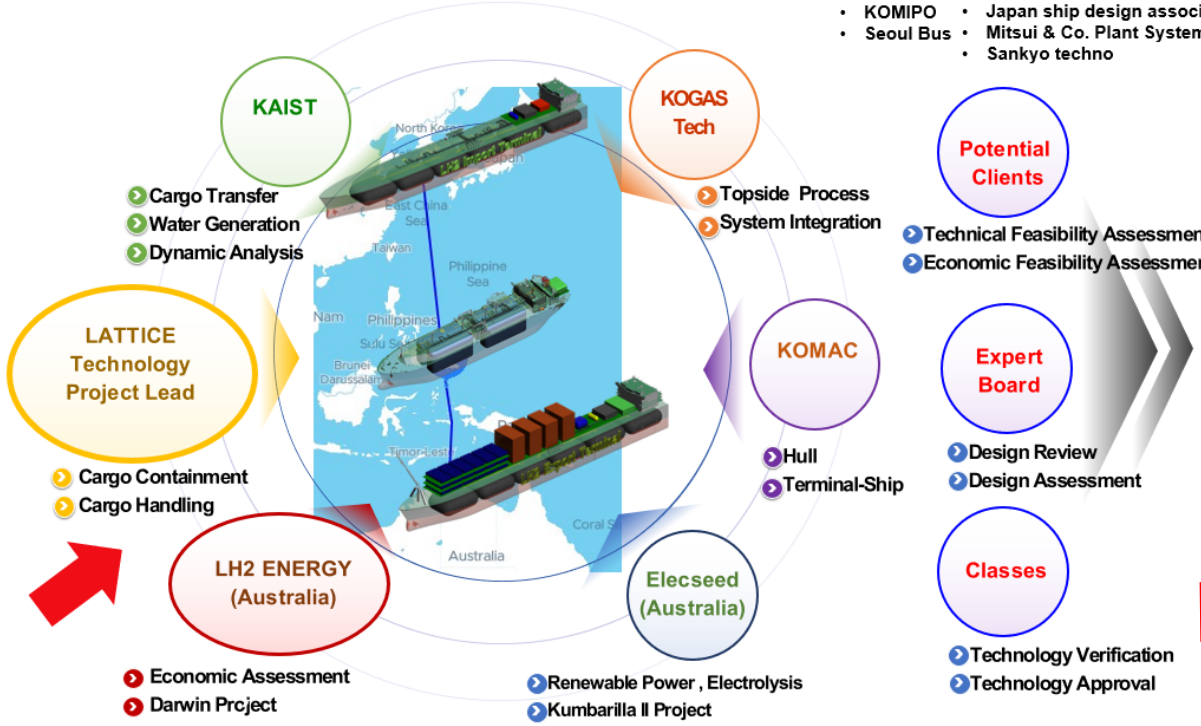
Latest Project News: Pleased to announce that the Basecase Sensitivity Case for 60 tpd LH2 with a 25,000m3 LH2 tanker has now been selected for the Darwin Project Concept Design to progress the "whole supply chain" project. The 25,000m3 LH2 tanker will be chartered to or owned by the Darwin Project. The reason for 'scaling-down' the Darwin Project Concept Design is the latest market analysis of global Electrolyser & Liquefaction capacity, which show delays and potentially 4-5 year delivery times for the large units required. It would mean the Darwin Project could not be 'fast-tracked' which is a pre-requisite if Green LH2 deliveries to Korea and Japan are to be achieved by 2030.

LH2 Energy is part of the Korean Government - KETEP Project Consortium

Pre-FEED of Sea-borne LH2 Supply Chain: Barge terminals and ships

- Korea-Australia Joint Project
- Fully funded by Korean Government
- Period: 2021 ~ 2024

- KOMIPO
- Seoul Bus
- Japan ship design association
- Mitsui & Co. Plant Systems
- Sankyo techno

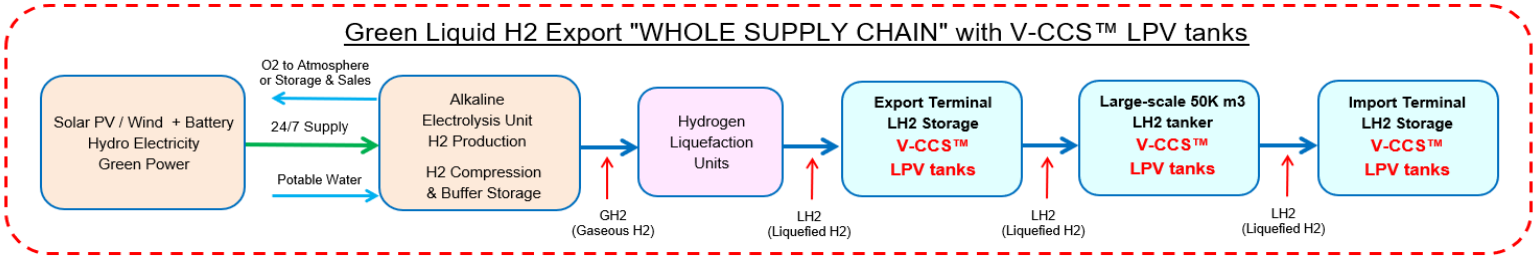


Fast-Track Solution To Intercontinental LH2 Shipping

- LH2 Export Terminal
  - ✓ Storage: 75,000 m3
  - ✓ Production: 120 ton/day
- LH2 Import Terminal
  - ✓ Storage: 75,000 m3
  - ✓ Production: 120 ton/day

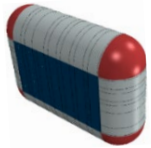
Latest: Japanese interest in the Fast-Track Solution for large-scale LH2 Shipping - will help build the Darwin Project JDP initiative

The Darwin Project - “Whole Supply Chain”

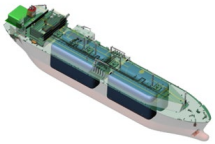


- **V-CCS™** is the **CORE technology for LH2 containment** in the Concept Design, enabling large-scale LH2 shipping
- Two additional key technologies required are the **LH2 “in-tank” transfer pumps** and **LH2 Loading Arms**

The Commercially proven, Prismatic, free-shape, IMO Type C equivalent, Lattice Pressure Vessel (LPV)



new 6,250m3 V-CCS™ LPV (Vacuum-insulated Cargo Containment System)



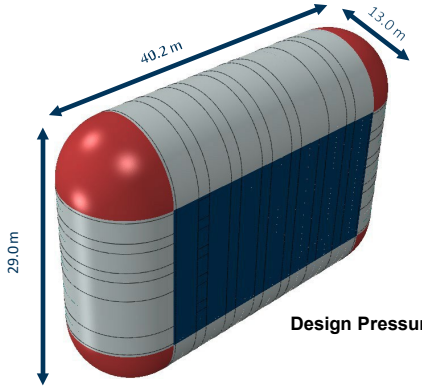
Large-scale 25,000 m3 LH2 Tanker
4 x 6,250 m3 V-CCS™ LPV tanks for Liquid H2 “cargo containment”

Please Note: The Darwin Project, with Barge Export and Import Terminals and a large-scale LH2 tanker, is based on the commercially proven LPV tank from Lattice. Other technology companies have recently received their AiPs for their own LH2 cargo containment systems, for example, **GTT**, **McDermott (CBI)**, **C-JOB in Holland** and the **Chinese Design Institute**. The most advanced technological development for large-scale LH2 shipping being from **Kawasaki**, who are leading the global race to demonstrate large-scale LH2 shipping.

The **Joint Development Partners** look forward to engaging with all of these vendors and technology companies during the early part of the BOD documentation, to compare their “whole supply chain” solution with the proposed **Darwin Project Concept Design**.

V-CCS™ for large-scale LH2 containment

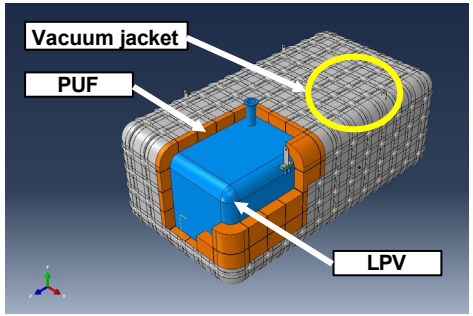
AiP Approval from Lloyds Register
21 August 2020



Design Pressure: 2.0 barg

12,500 m3 LH2 V-CCS™

(please note: The LPV tank is commercially proven in marine environments and is approved by all the major ship classification societies)



200 m3 **V-CCS™** Pilot Tank with new Polyrethane Foam (PUF) vacuum insulation system and Flexible SS vacuum insulation jacket testing complete by mid-2024

V-CCS™

Vacuum-insulated Cargo Containment System

Inner Pressure LPV tank

- Commercially proven
- Volume-efficient
- Limitlessly scalable
- With pressure-loading capability

(contains the inevitable production of H2 Boil-Off Gas during marine transport. Every tonne of LH2 loaded at the Export Terminal is delivered to the customer in Korea).

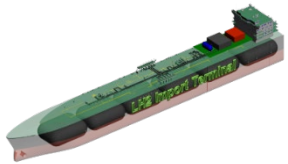
+ New PUF Vacuum Insulation System

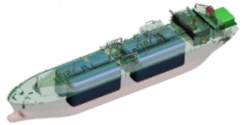
- Vacuum-insulated
- Limitlessly scalable
- Not the conventional tank-in-tank type
- Does not requiring deep vacuum
- Easy to fabricate and implement

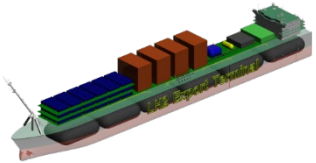
International JDP “know-how”: Integration of LH2 Export & Import Terminals

- The **“All-Seaborne Solution”** with Barge Export and Import terminals, provides **fabrication quality assurance, short delivery time**, **minimal land use** with less environmental impact, and a fast approvals process through to commissioning.
- **Most importantly,** the “All-Seaborne Solution” provides high public acceptance both in Australia, Korea and Japan, ensuring:
- **Social Licence to Operate (SLO)**
- A key success factor for the Darwin Project is the JDP ‘know-how’ & design capability, that will integrate important interfaces between the terminal & tanker and the cargo handling systems, in a safe and efficient manner.

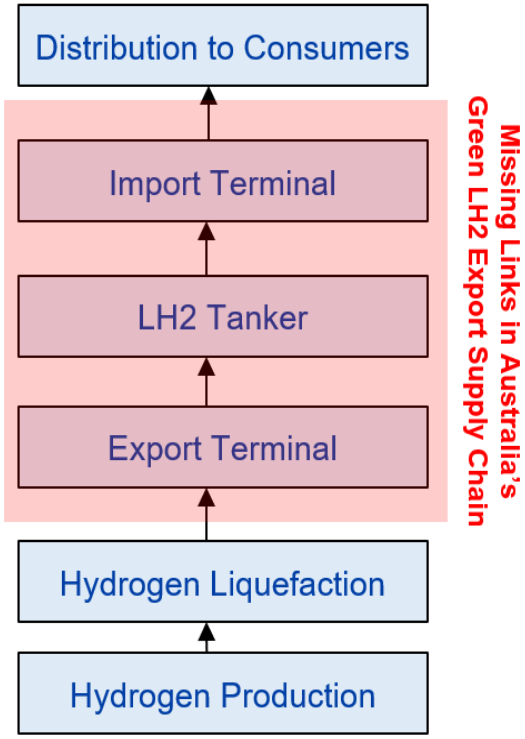
Barge Import Terminal



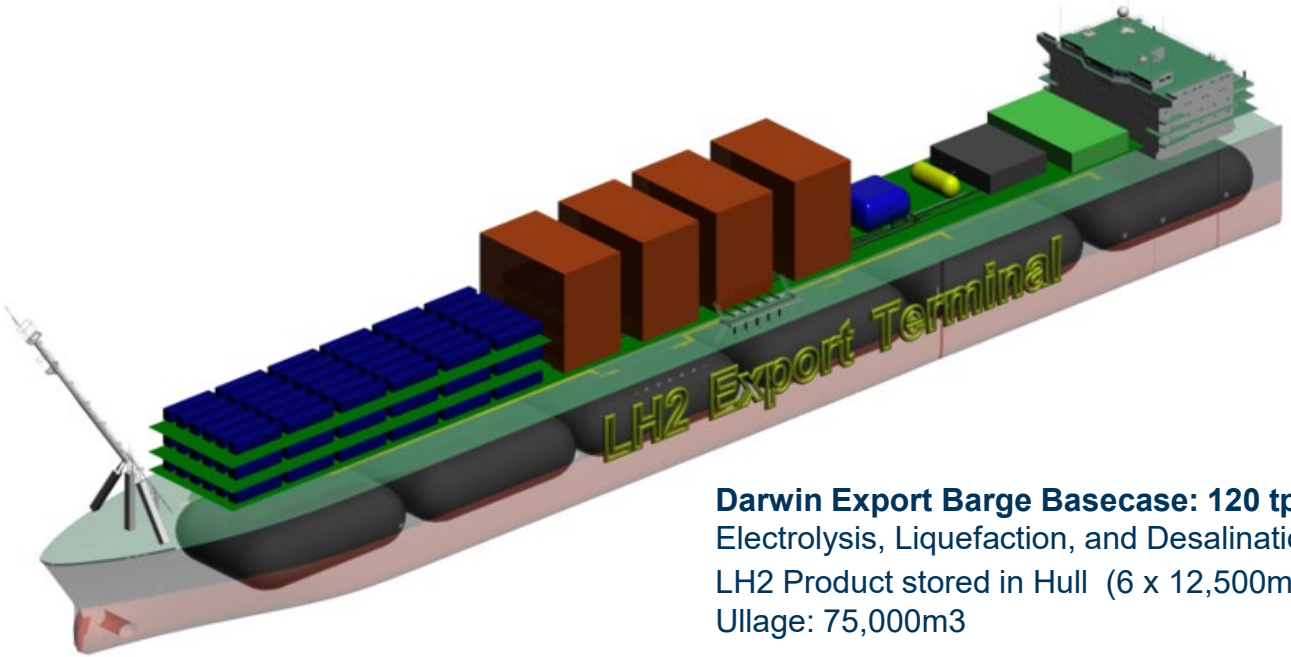




Export Terminal with H2 production processing facilities on the Topsides with LH2 Product stored in the Hull.



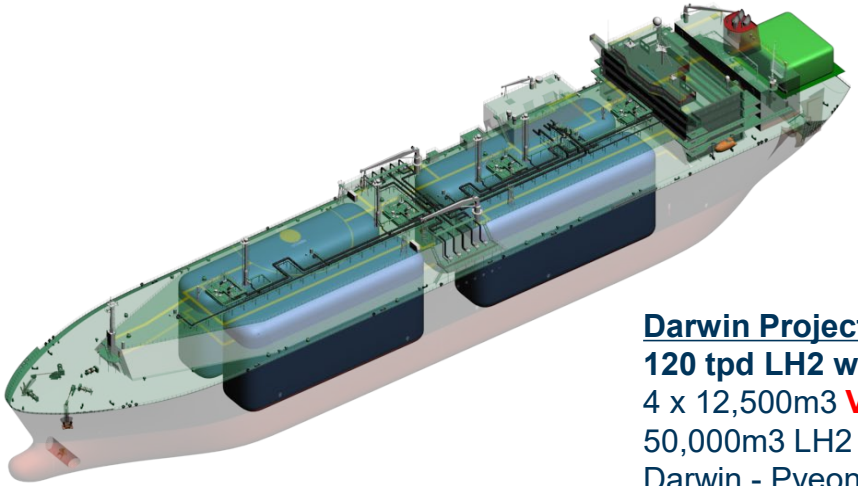
Darwin, NT Australia - Green LH2 Export Terminal



Darwin Export Barge Basecase: 120 tpd LH2 production
Electrolysis, Liquefaction, and Desalination on Topsides
LH2 Product stored in Hull (6 x 12,500m3 **V-CCS™** LPVs) Total Ullage: 75,000m3

Basecase Sensitivity Case: 60 tpd LH2 for 'fast-tracked' project
Again, Electrolysis, Liquefaction, and Desalination on Topsides
LH2 Product stored in Hull (6 x 6,250m3 **V-CCS™** LPVs) Total Ullage: 37,500m3

Darwin Project - 50,000m3 and 25,000m3 large-scale LH2 tanker options



Darwin Project Basecase:

120 tpd LH2 with 50,000m3 LH2 Tanker

4 x 12,500m3 **V-CCS™** LPVs Cargo Containment System

50,000m3 LH2 tanker fully utilized, with about 15 round trips per year

Darwin - Pyeongtaek - Darwin (total of 25 Days for each round trip)

Basecase Sensitivity Case has been adopted for the Darwin Project following equipment market analysis review in August 2023:

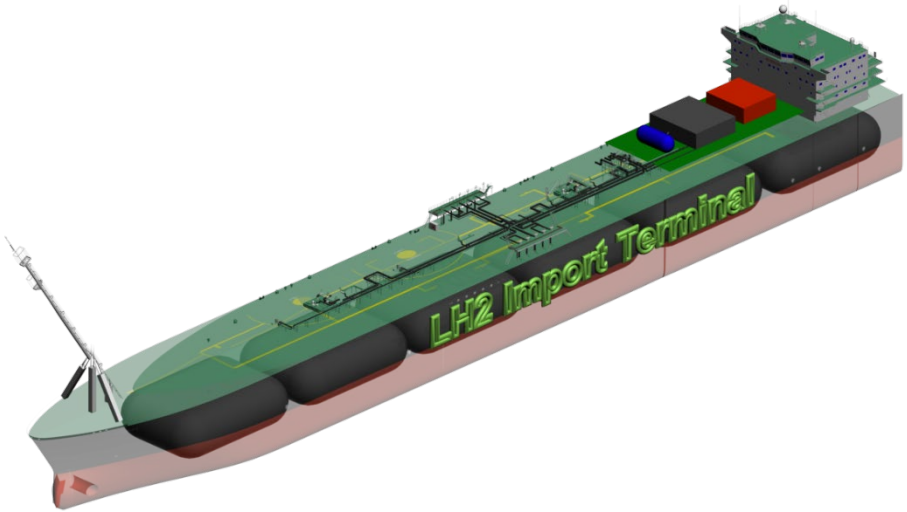
60 tpd LH2 with 25,000m3 LH2 Tanker

4 x 6,250m3 **V-CCS™** LPVs Cargo Containment System

25,000m3 LH2 tanker is again fully utilized, with 15 round trips per year

Darwin - Pyeongtaek - Darwin (total of 25 Days for each round trip)

Pyeongtaek Port, Korea - Green LH2 Import Terminal



Pyeongtaek Import Barge: Much simpler design - Facilitates additional Import Barges “plug & play”.

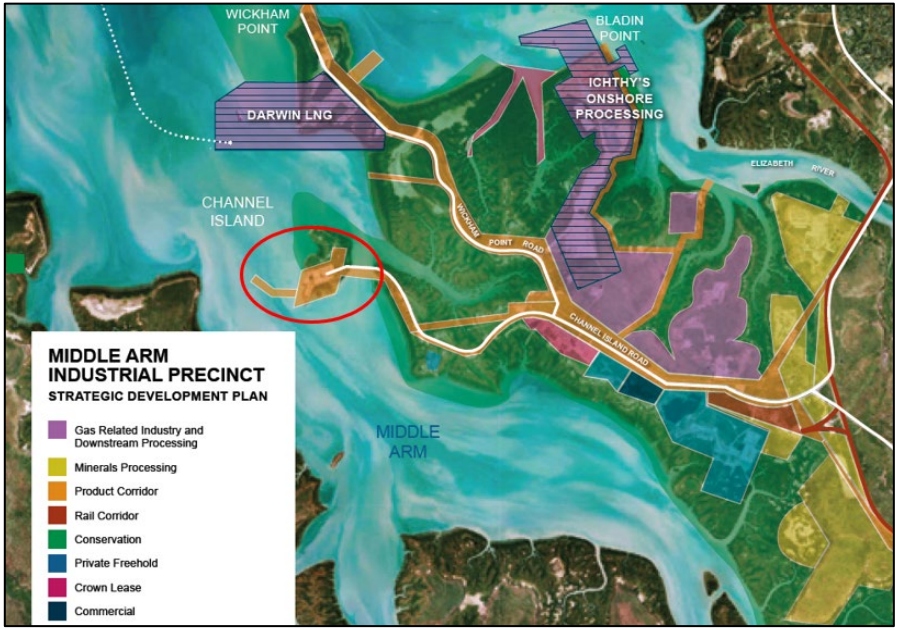
<u>For Darwin Project Basecase Concept Design:</u>
6 x 12,500m3 **V-CCS™** LPVs in the Hull
Total Ullage: 75,000m3 to receive the 50,000m3 LH2 tanker’s cargo when it comes alongside.

<u>For Basecase Sensitivity Case selected:</u>
6 x 6,250m3 **V-CCS™** LPVs in the Hull
Total Ullage: 37,500m3 to receive the 25,000m3 LH2 tanker’s cargo when it comes alongside.

A two Import Barge configuration for the Darwin Project is also possible to facilitate “part-cargo” drop-offs, to help the logistics of supply into domestic FCEV markets.

Benefits to the NT Economy

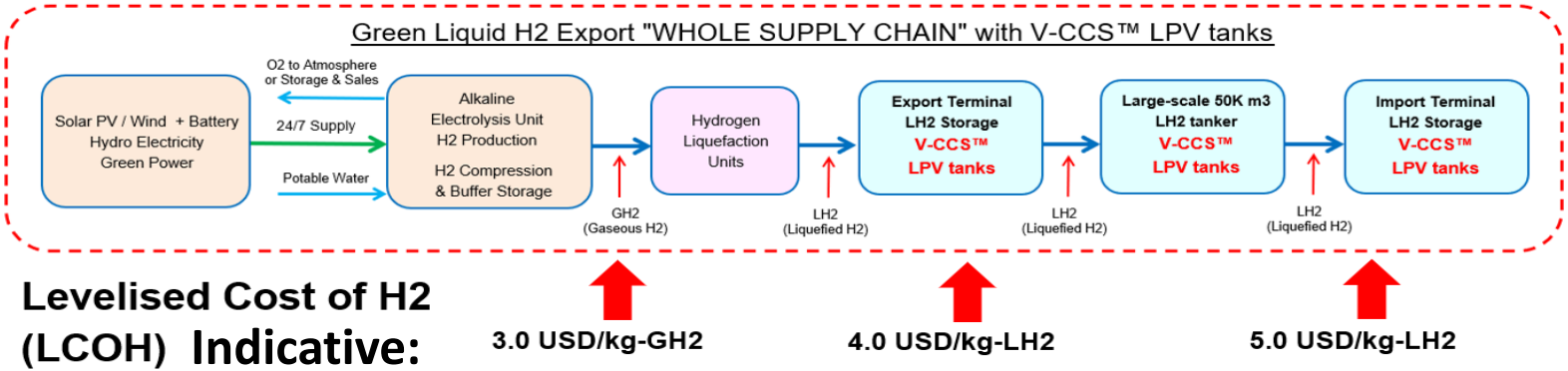
- The Concept Design for the Darwin H2 Hub includes **Green LH2 supply** to the following domestic H2 projects:
  - A multi-user Green LH2 Fuel Cell Vehicle refuelling terminal, potentially at MASDP
  - Charles Darwin University for their micro-grid and small H2 Gas Turbine development
  - Territory Generation for Green Power and potential blending into natural gas
- **Solves the Chicken & Egg dilemma** of how to match domestic Green H2 supply with domestic demand.
- Domestic buyers able to secure Green LH2 supplies from LH2 Energy on a long-term, low cost pricing basis, providing the certainty investors need to develop staged domestic H2 projects in the NT.



Export Barge Terminal site at Channel Island close to the Middle Arm Industrial Precinct has been renamed as the 'Middle Arm Sustainable Development Precinct' (MASDP)

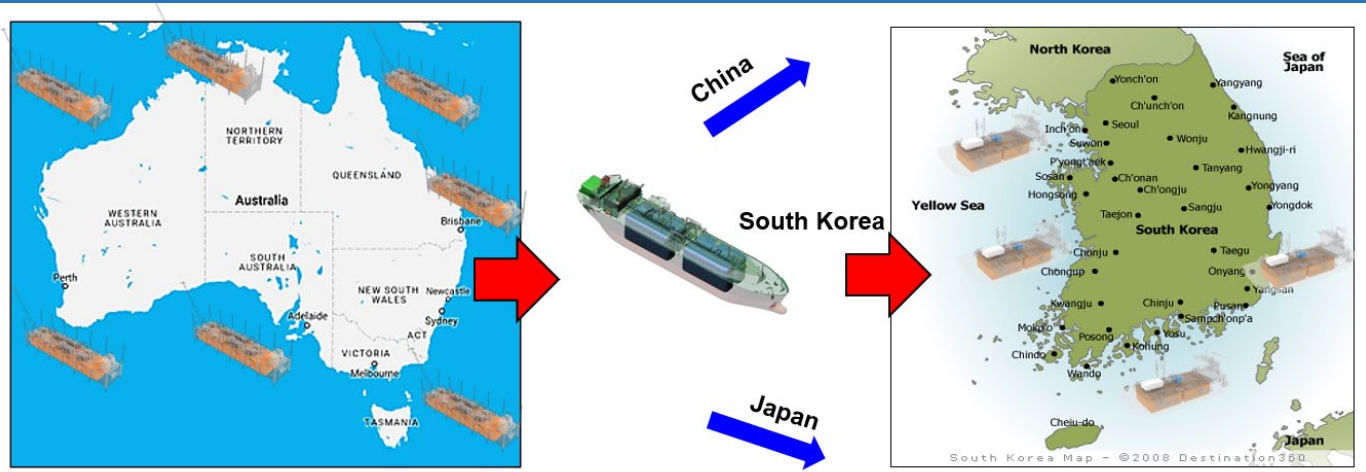
- The **Darwin Export Project & Domestic H2 Hub** development we estimate will generate more than **500 permanent jobs.**
- Future Phase 2 & 3 expansions would take the total LH2 Energy production capacity to **126,000 tonnes/year** of Green LH2.
- This future Green LH2 Export from Australia to Korea & Japan is valued on a GGE basis at over **USD 1 billion / year.**

Financial Highlights



- The **V-CCS™** delivers Green LH2 to the 'premium' H2 market for Fuel Cell Vehicles in Korea and Japan.
- **Channel Island site** is ideally situated for the JDP development, and **Darwin** is the closest to these markets.
- Project is **commercially-viable** requiring **no subsidies** other than a Gasoline transport tax / excise rebate.
- **Basecase Capex is USD 700m** (+/- 25% Budget estimate) (70% Debt 30% Equity financing).
- Basecase gives a Positive NPV and a **Project IRR of 19.5%.** No carbon credits are included. For the **High-Capex** scenario (USD 1 billion+) the rate of return drops to **15%**
- **Sensitivity Case for 60 tpd LH2 production and a 25,000m3 tanker** - selected for the Darwin Project to maintain 'fast-track' status for the project - will inevitably incur economies of scale losses and the rate of return drops further to around **10%.**

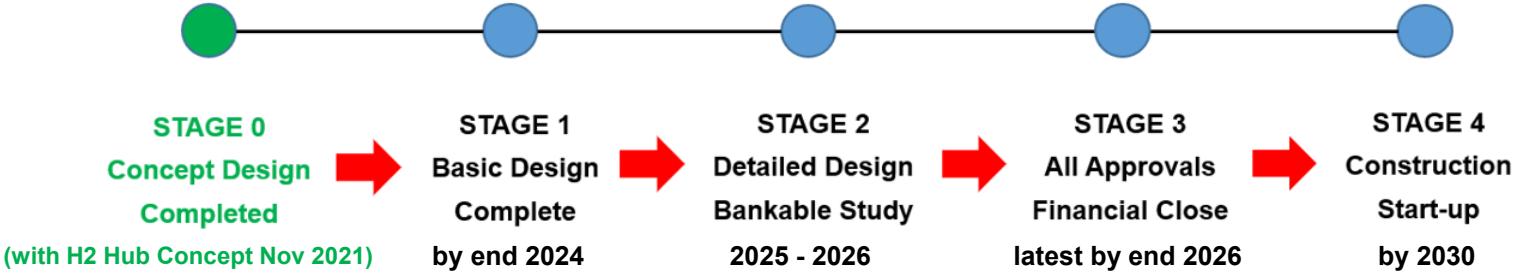
All-Seaborne Solution: Advantages for both Exporting & Importing countries



- **Export Barge Terminals** can be deployed around Australia in the future where commercial volumes of Green LH2 are available.
- **"Fast-tracks" large-scale Green H2 production & liquefaction.**
- Saves on the massive investment and time needed to build equivalent on-land port facilities to accommodate H2 export.
- Standardised "plug & play" **Import Barge Terminals** can be built at major ports in South Korea, Japan and China.
- **Presents a cost-effective solution for South Korea and Japan to access Renewable H2 from Australia**, contributing to these countries' National H2 Economy Plans.

- **Current informal members** of the Darwin International Joint Development Project (JDP) aiming to realize the "All-Seaborne Solution" include: **LATTICE Technology** (Korea), **KAIST** (Korea Advanced Institute of Science and Technology), **KOMAC** (Korea Maritime Consultants), **GPA Engineering**, **Phronis Consulting** and **Charles Darwin University** from Australia, and for Liquefaction technology, **Chart Industries Inc** from the USA. We continue to build the JDP, with interest also from potential partners from Japan and Europe.

NEXT STEPS - Project Stages and Timeline



Final comments: Where Green H2 Gas is produced at a centralized point in one country with delivery required to a customer overseas, the Green H2 exporter has basically two options for commercial-size operations: **Build a Haber Bosch plant** to export H2 as **Green Ammonia** or **Build a H2 Liquefaction plant and export H2 as Green Liquefied H2.**

Although no large-scale LH2 shipping exists today, the above Timeline shows that commercial-size Green LH2 Exports by 2030 is a feasible proposition. This timing around 2030 is similar to the delivery timelines anticipated for the first Green Ammonia exports from Australia. (Please see Appendix for H2 shipping cost comparisons and the Lattice LPV tank design principles).

A successful Darwin JDP Development and "commercial-demonstration" of large-scale LH2 shipping can lead the way to **a new multi-billion-dollar export industry for Australia.** The advantages and benefits of the **"All-Seaborne Solution"** using Barge Export and Import Terminals with the Lattice V-CCS/LPV or other large-scale cargo containment system for LH2, can also be applied to other large-scale Green H2 production & export projects planned for development around Australia.

Next Steps: Engage further with the Australian and Korean Governments and continue to build & develop the International JDP.

LH2 Energy - Executive Team and Management

TECHNICAL
SUPERVISOR

Daejun Chang received his doctorate in chemical engineering at KAIST (the Korea Advanced Institute of Science and Technology) in 1997 and began his professional career with Hyundai Heavy Industries where he served as the leader of R&D projects.

These included eco-friendly propulsion options for ships, offshore LNG, boil-off gas reliquefication, safety systems and fire/explosion risk analysis. He has participated in joint shipping development projects with internationally recognized industrial leaders such as the CNG carrier with EnerSea, the methanol plant ship with StarChem and Lurgi, and large-size LNG carriers with QatarGas.

Dr. Chang is a Founder of Lattice Technology and a world leader in developing disruptive technologies critical to the mega-trends in the energy, marine, and offshore industries.

PROJECT
DIRECTOR

Costa Tsesmelis has over 40 years technical, managerial & commercial experience with major oil companies, independent refiners, consulting firms & engineering companies, **covering gas processing, LNG, refining, petrochemicals and alternative fuels.**

Over the past 4 years Costa has also added H2-from-Electrolysis and Power-to-Liquids to his engineering and consulting portfolio. His expertise includes front-end process design, engineering & construction projects, and extends to oil trading, operations planning & scheduling, and supply chain optimisation.

He is also a Director of LH2 Energy Pty Ltd and a shareholder in the Darwin Project. He has a Bachelor's (Honours) degree in Chemical Engineering and Fuel Technology, and a Postgraduate Diploma in Business Studies from Sheffield University UK. He is a life-long supporter of Sheffield United and a Fellow of the Institution of Chemical Engineers (FIChemE) and a Chartered Engineer (CEng) registered in the UK..

DIRECTOR
MARINE OPERATIONS

Ian Brokenshire is an Australian Master Mariner working as a Senior LNG Marine Pilot within the Port of Darwin. With an extensive background in commercial shipping and in particular, Liquefied Natural Gas (LNG), Ian is well placed to support the Darwin Renewable Liquid H2 export facilities, shipping infrastructure, port and shipping safety and legislative requirements.

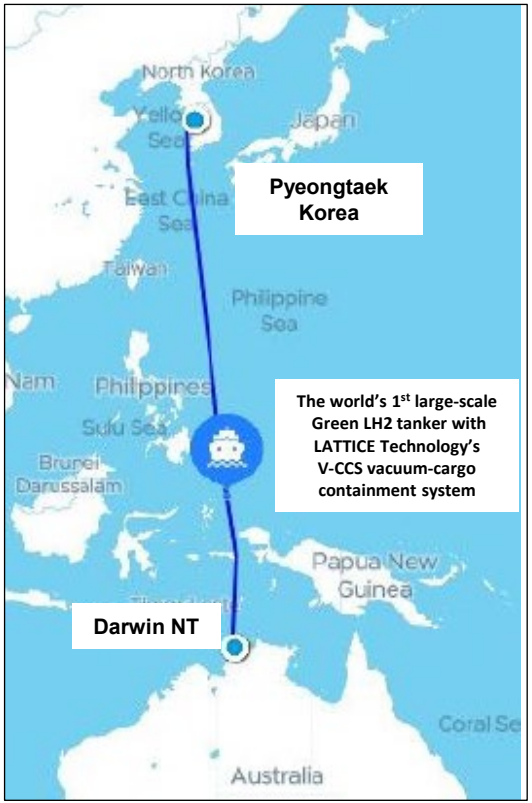
Ian's maritime background is also well supported by accounting and business experience gained in prior employment with Price Waterhouse, Sydney. He has also gained experience in Port Management, within BHP Transport, Port Kembla.

Ian comes to LH2 Energy Pty Ltd with a long-established passion to see the development of a sustainable, Renewable Hydrogen based economy around the world.

For more information on the Darwin Project - please contact:

Costa Tsesmelis, Project Director, Darwin Green LH2 Export Project
+61 (0) 409 288 458 costa.tsesmelis@LH2energy.com

Thank You!



All-Seaborne Barge Export / Import Terminal Design

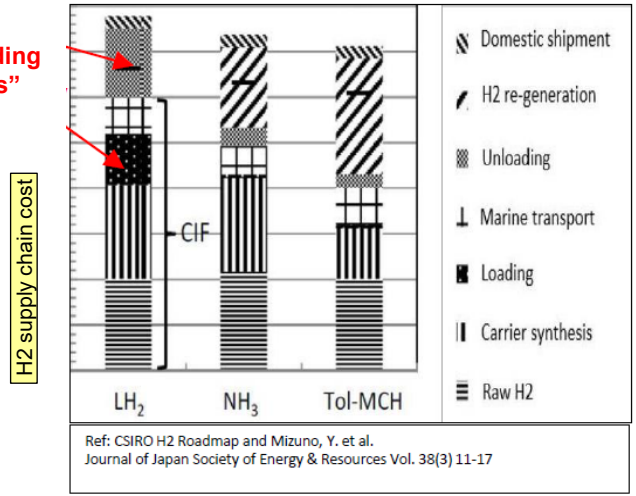
Darwin LH2 Export Project and H2 Hub Development

Appendix

Dispelling the “High Cost” myth for LH2 shipping

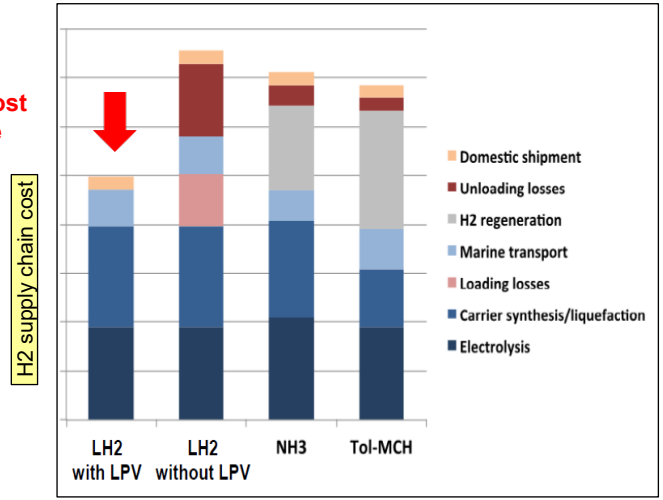
- **Studies in the past** from Japan and the CSIRO, and recently from Advisian and McKinsey, have made estimates for LH2 shipping ad supply chain costs **today** that include LH2 cargo **Boil-off Gas “Losses”,** expected from a non-pressure tank containment system, similar to today’s LNG membrane tanks or Type B spheres.
- **McKinsey’s H2 Cost Model** however shows LH2 shipping becoming the most cost-effective of all the shipping options from 2025 onwards, as commercial-size LH2 tanker designs reduce loading/unloading Boil-off Gas “Losses”.
- The LATTICE Technology **V-CCS™** LPV is at the forefront of the “race” to cost-effectively ship Green LH2, since it ensures there are **Zero Boil-off Losses** of the valuable LH2 cargo, significantly reducing the overall “H2 supply chain cost”.

loading & unloading Boil-off “losses” assumed

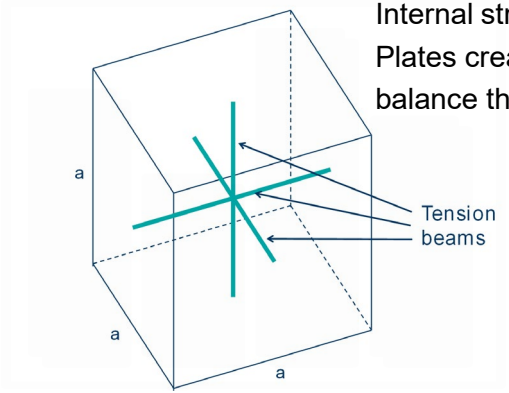


Ref: CSIRO H2 Roadmap and Mizuno, Y. et al.
Journal of Japan Society of Energy & Resources Vol. 38(3) 11-17

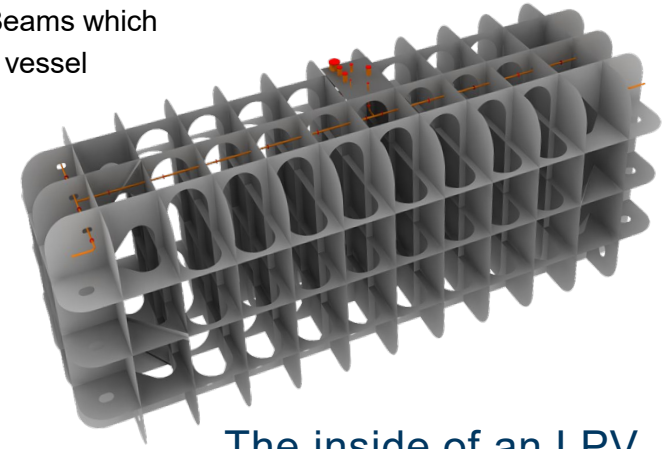
LH2 supply chain cost is lowest with the V-CCS™ LPV



Design Principles of the LPV (Lattice Pressure Vessel)



Internal structures of Beams and Plates create Tension Beams which balance the load on the vessel



LEGO-design allows the LPV beams & plates as units to be readily expanded in any direction

The inside of an LPV

$A = \frac{pa^2}{\sigma_A}$ ~ Thickness independent of tank size (limitless scale-up)

- The LPV design results in the thickness of the shell and internal structure of the tank being invariant with size → **which means in practice Limitless scale-up for the LPV** (very important for scaling up LH2 cargo containment systems for the new LH2 shipping industry in a seamless manner with maintained safety and reliability).
- In addition, the geometric shape is flexible with a LEGO-type design principle → **which provides perfect space utilization** (facilitates transport and mobility applications where LH2 is preferred to compressed H2 and also provides for less steel for new-build ship constructions giving substantial Capex savings).