ARDENT UNDERGROUND
HYDROGEN STORAGE

Providing the missing link to a green hydrogen future - economical large scale underground hydrogen gas storage.

Ammonia Energy Association
Roundtable Event 27th August 2021

Panel Introduction

ARDENT UNDERGROUND
HYDROGEN STORAGE

David Bentley – Chief Executive Officer Ardent Underground has over 30 years experience in the energy sector in both generation and demand side. David has extensive experience building and managing global business within the energy and defence sectors. David leads Ardent Underground's objective to have a proven, economical, large scale, hydrogen gas storage technology in advance of the predicted growth in the hydrogen market post 2025

Mick Boyle – Executive Chairman Ardent Underground and Abergeldie Complex Infrastructure which he established in 1994. Abergeldie employs nearly 500 people and has offices in Auckland, Brisbane, Newcastle, Sydney, Canberra and Melbourne and carries out complex engineering projects throughout Australia and New Zealand

Dr Keith Lovegrove – Technical Director Hydrogen Storage Ardent Underground and Managing Director ITP Thermal has over 30 years experience in energy research and teaching. Has pioneered work on the application of thermochemical energy storage using ammonia and advocated for the development of export industries for renewable hydrogen and ammonia.

John Zeni – Technical Director Drilling Ardent Underground expertise in the design, development and operation of large diameter shaft drilling rigs and associated drilling tools for blind boring shafts up to 6.8 metres in diameter and 1,000 meters deep, including assessing and managing all associated safety, environmental and commercial risks. Projects have included shaft drilling and lining for mines in the USA, Papua New Guinea, France and Australia.

Agenda

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HYDROGEN STORAGE

• **Introduction**	**David Bentley**
• Ardent and Abergeldie Complex Infrastructure	Mick Boyle
• Ardent Underground Hydrogen Storage	Keith Lovegrove
• Blind boring technology	John Zeni
• Questions and Answers	

Ardent Underground

ARDENT UNDERGROUND
HYDROGEN STORAGE

2016 USA DOE Funded research project UCLA and ITP

2020 Ardent Underground Incorporates

2020 receives grant from ACT Govt Renewable Energy Innovation fund

2021 Successful capital raising, new board and CEO

2022 Engineering completed

2023 First contract executed

2025
First Large scale hydrogen storage completed

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ABOUT ABERGELDIE

ABERGELDIE
COMPLEX INFRASTRUCTURE

Abergeldie has 25 years' industry experience and is a leading civil engineering contractor in Australia and New Zealand.

We design and deliver projects in the utilities, energy and infrastructure sectors.

Projects include dams, bridges, tunnels, water and wastewater treatment process facilities, rail infrastructure, mining infrastructure, electrical substations, marine works and pipeline rehabilitation: **the complex infrastructure needed to build better communities.**

ABERGELDIE
COMPLEX INFRASTRUCTURE

WATER

Potable, wastewater treatment, storage and distribution infrastructure. Sewer Rehabilitation.

UNDERGROUND

Operators of blind boring rigs, large road header and both AVN and EPBM tunnel boring and jacking rigs.

BRIDGES

Roads and bridges ranging pedestrian overpasses to multi-lane highways and rail corridor bridge crossings.

ENERGY

Traction power substations, zone substations, buried and overhead cables, cable tunnels and conduits.

TRANSPORT

Reconditioning and maintenance of rail track, bridges, stations, buildings and civil structures.

REMEDIATION

Hydrostatic concrete, pipelines, tanks and reservoirs; concrete and brick work; and metal structures and cladding.

BRIDGES

Parramatta Escarpment Boardwalk

Construction of three critical missing pedestrian and cyclist links to the Parramatta Valley Cycleway, involving installation of prefabricated steelwork, landscaping and associated works, with critical components predominantly dependant on river transport logistics.

RAIL AND TRANSPORT

ARTC Track Reconditioning Package 19/20

Rail track formation reconditioning at several locations in the Hunter Valley as one package of works within ARTC's year-long program of maintenance and upgrade works across the Hunter Valley network. Included rail removal and replacement, track formation excavation and reconditioning, geotechnical testing and spoil management.

ABERGELDIE
COMPLEX INFRASTRUCTURE

ENERGY

Southern Oil Refineries

Construction of 20 million litre per year oil refining plant, including a vacuum distillation column, vacuum pumping system, evaporators, a solvent extraction system and storage tanks. Systems integration, testing and commissioning to refinery quality standards.

REMEDIATION

Williamstown Sewer Main Rehabilitation

Abergeldie was awarded the Williamstown Sewer Main refurbishment project under a design and construct contract to refurbish 3.6km of the 4.4km sewer main on Melbourne Water’s Williamstown Sewer.

WATER

Springvale Mt Piper Water Treatment Plant

Construction of a 14.8km Water Transfer Scheme from Springvale Mine together with a new Water Treatment Facility at Mt Piper Power Station to treat up to 48ML per day of water produced from mining operations for use in the power station.

UNDERGROUND

Central Interceptor

Construction of the Central Interceptor, a 14.7km long, 4.5m diameter tunnel from which will run underground from Grey Lynn to Māngere Wastewater Treatment Plant. It will have several link sewers and shafts along the route for collecting and transferring wastewater into the tunnel.

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ITP Energised Group

https://itpenergised.group a world-leading consultancy offering energy, environmental, engineering, technical advisory and renewables asset management services in more than 150 countries for over 35 years.

ITPENERGISED

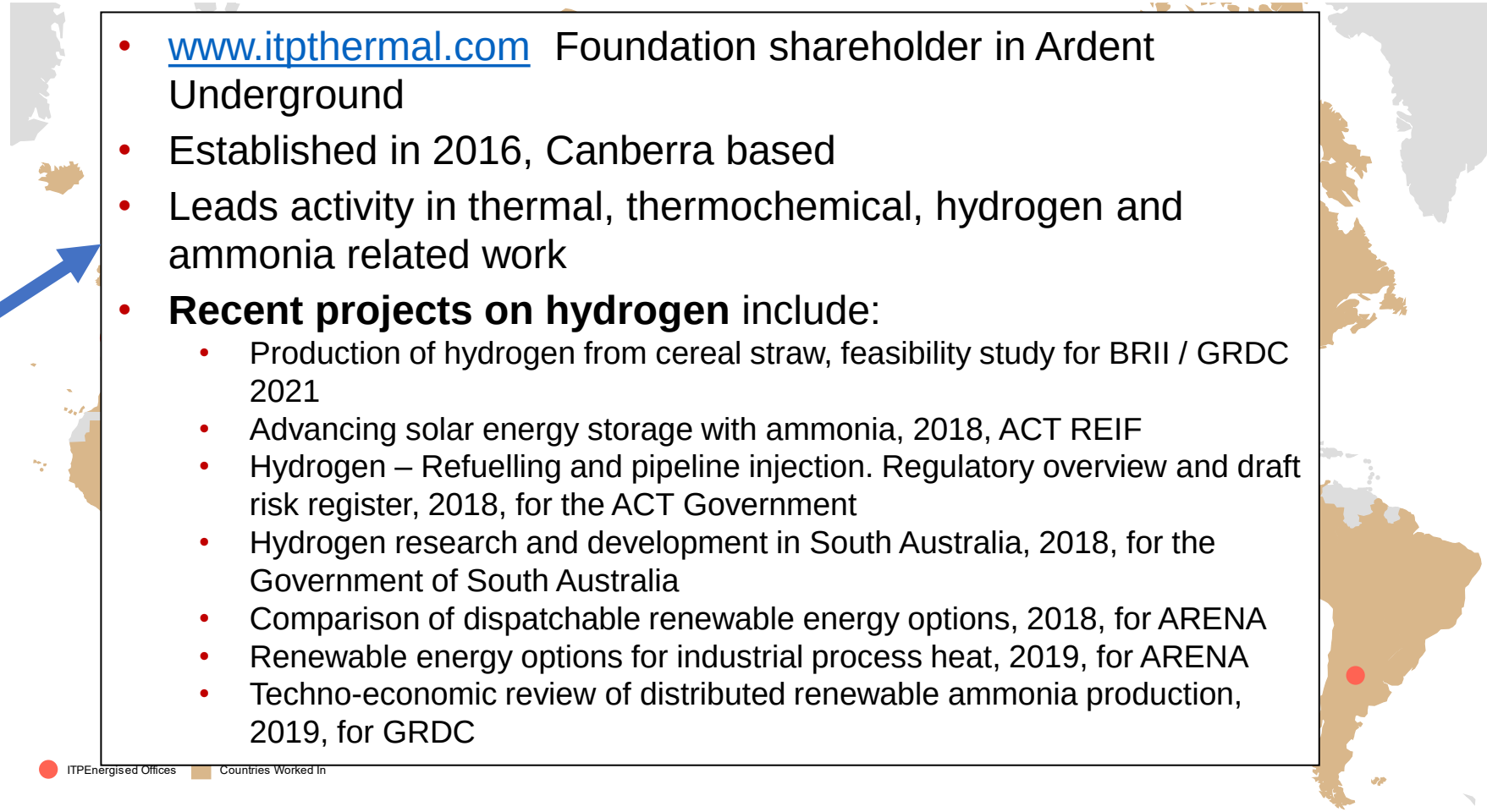
itp RENEWABLES

itp THERMAL

itp INDIA

itp DEVELOPMENT

- www.itpthermal.com Foundation shareholder in Ardent Underground
- Established in 2016, Canberra based
- Leads activity in thermal, thermochemical, hydrogen and ammonia related work
- **Recent projects on hydrogen** include:
  - Production of hydrogen from cereal straw, feasibility study for BRII / GRDC 2021
  - Advancing solar energy storage with ammonia, 2018, ACT REIF
  - Hydrogen – Refuelling and pipeline injection. Regulatory overview and draft risk register, 2018, for the ACT Government
  - Hydrogen research and development in South Australia, 2018, for the Government of South Australia
  - Comparison of dispatchable renewable energy options, 2018, for ARENA
  - Renewable energy options for industrial process heat, 2019, for ARENA
  - Techno-economic review of distributed renewable ammonia production, 2019, for GRDC



THE NEED FOR HYDROGEN STORAGE

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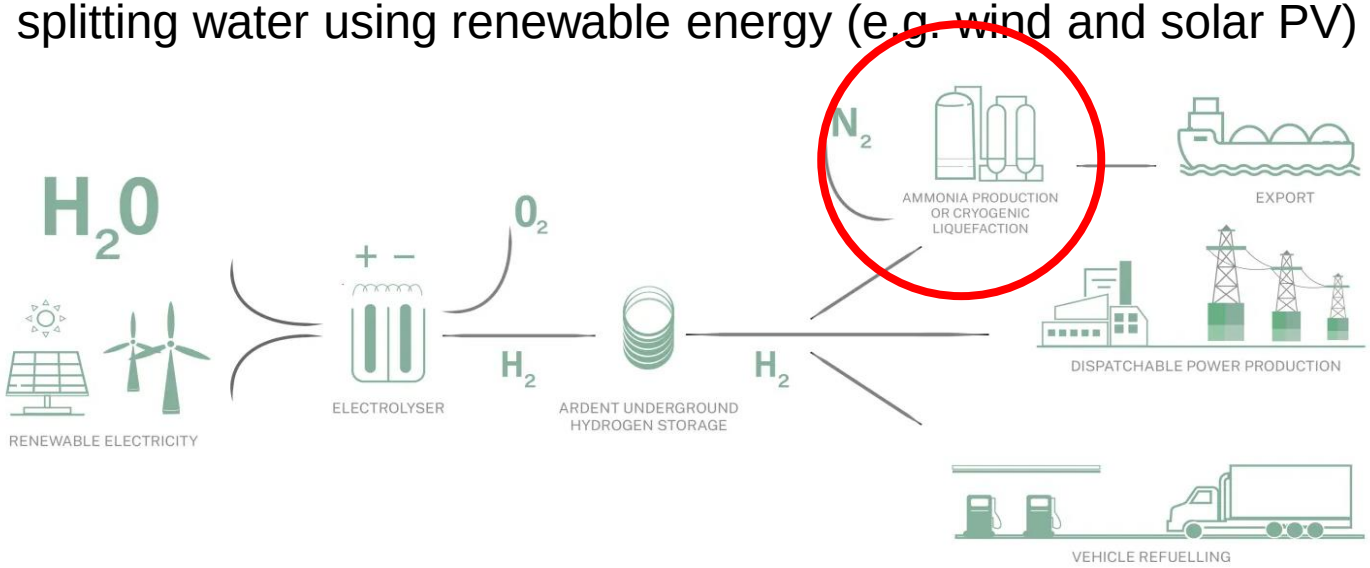
HYDROGEN STORAGE

GREEN HYDROGEN: zero emissions hydrogen, produced by splitting water using renewable energy (e.g. wind and solar PV)



- Wind and solar PV power production is **intermittent** and so is the hydrogen production.
- Every hydrogen application requires a **stable flow of hydrogen.**
- **There is no green hydrogen application without green hydrogen storage.**

THE CHALLENGE OF STORING HYDROGEN

- Hydrogen has a very low volumetric density.
- In order to store a considerable amount of hydrogen in a vessel, hydrogen needs to be compressed to high pressures (up to 700 bar).
- Pressure vessels capable of withstanding such pressures are typically small and expensive.
- In order to achieve the transition to a green hydrogen economy, **a low cost, large scale, replicable storage technology is needed.**

HYDROGEN STORAGE IMPACT ON GREEN AMMONIA ECONOMICS

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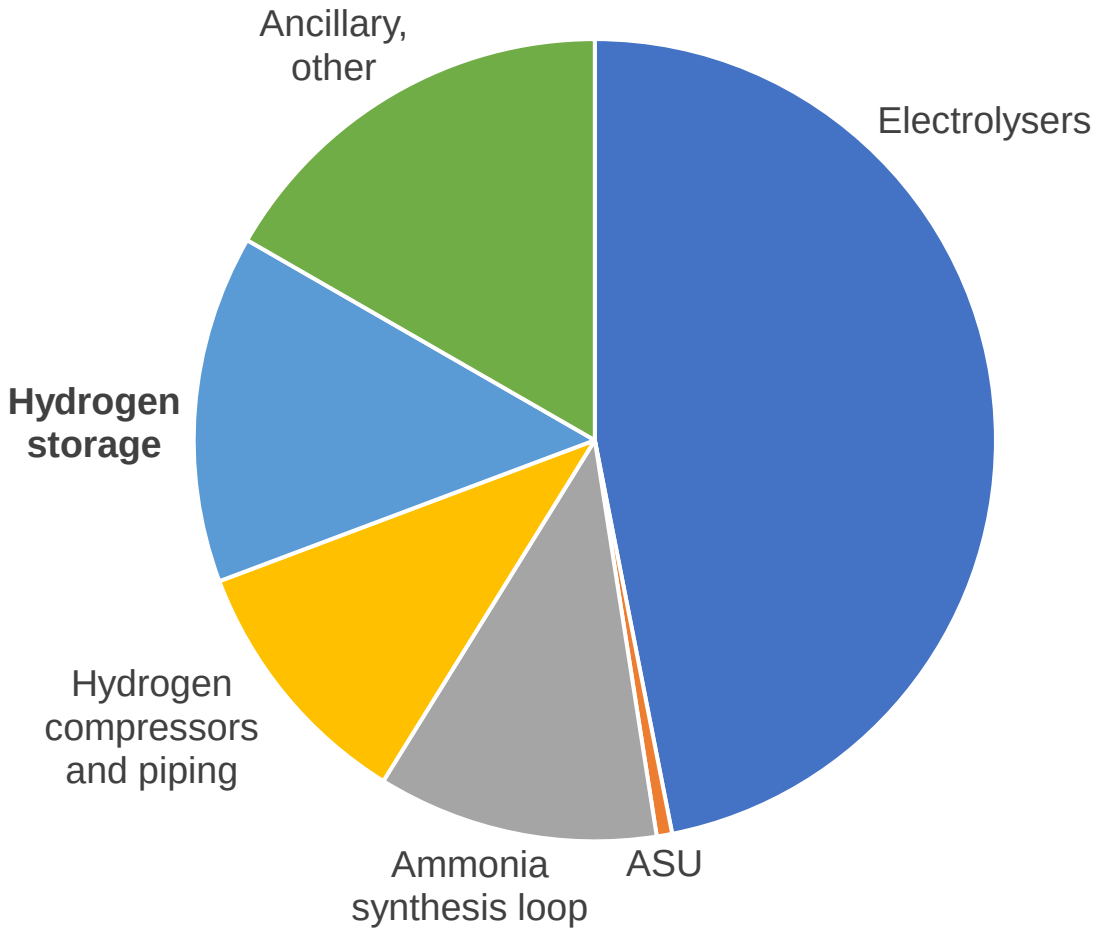
- Storage is needed as buffer between variable hydrogen production and continuous product synthesis both for process and capital efficiency

- Hydrogen storage is a **significant** (but not dominant) capex item
- Estimated specific cost of hydrogen storage vessels in Dyno Nobel feasibility study is $1,207/kg, *("53T Hydrogen Storage – 260 x 20ft containers holding 204 kg each @ 250 bar")*
- Specific cost of Ardent Underground storage for same size: $400/kg, reducing after 1st project
- Single point hydrogen storage, reduces piping, valves and land footprint.
- No fixed storage size – lower cost storage feeds into overall system optimization for minimum LCOA

Example Green Ammonia CAPEX breakdown



Capex data adapted from: ANT Energy Solutions and Dyno Nobel Moranbah, July 2020, *DNM Renewable Hydrogen Feasibility Study*

Ammonia synthesis loop data from: ITP Thermal cost model

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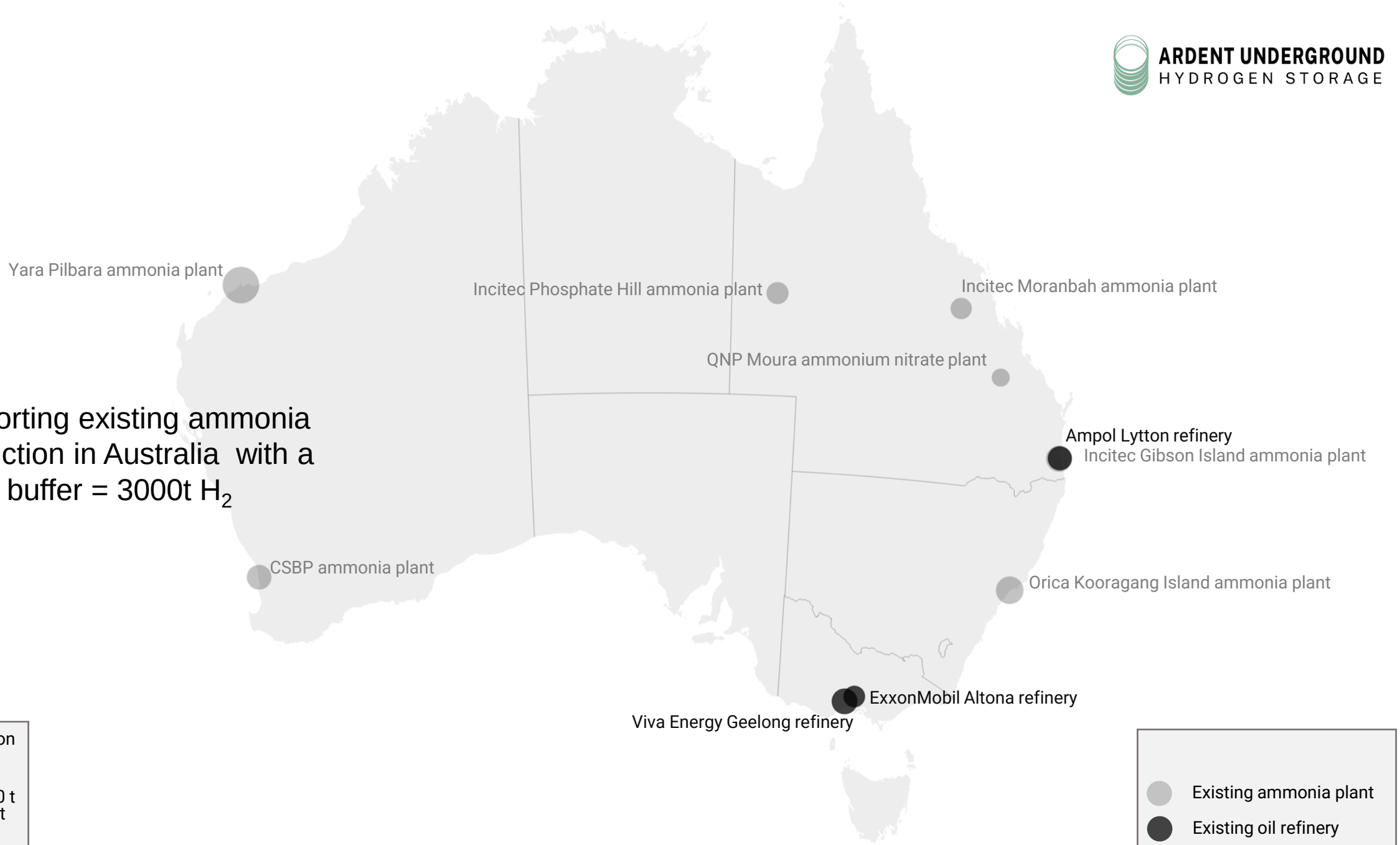
Supporting existing ammonia production in Australia with a 2 day buffer = 3000t H_2



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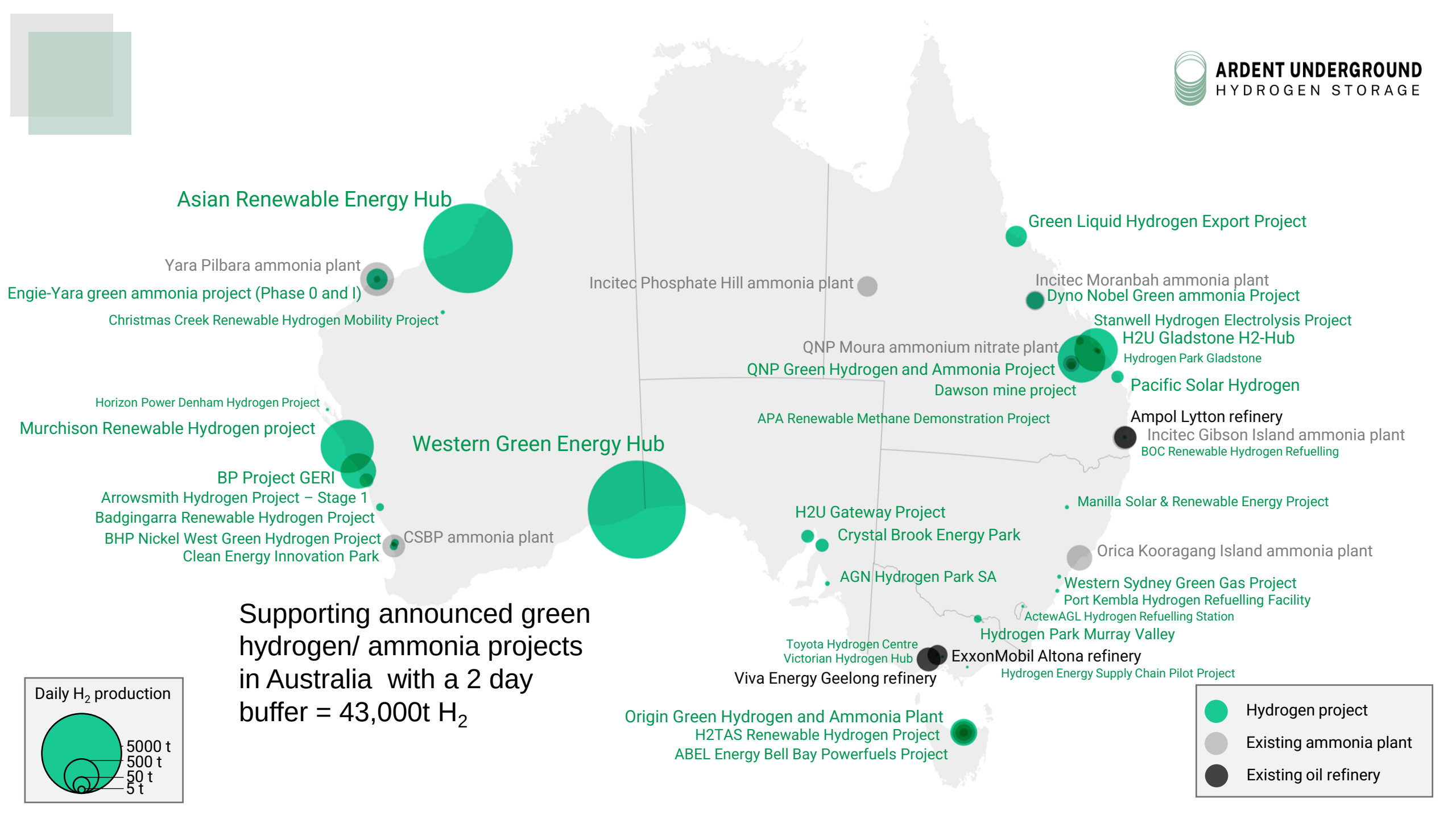

Supporting announced green hydrogen/ ammonia projects in Australia with a 2 day buffer = 43,000t H_2

Daily H_2 production

OTHER HYDROGEN STORAGE SYSTEM OPTIONS

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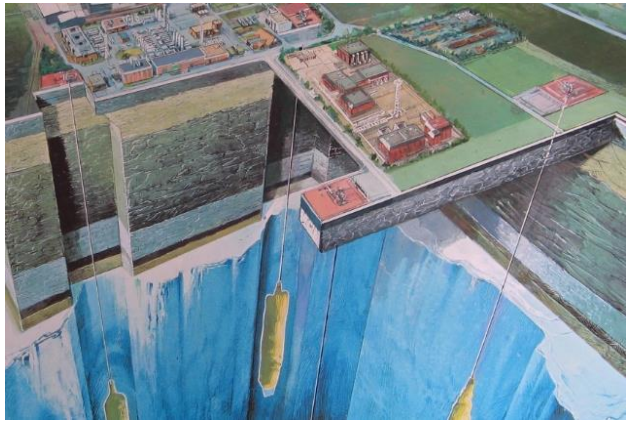
HYDROGEN STORAGE

ALREADY IN USE

Composite Pressure Vessels

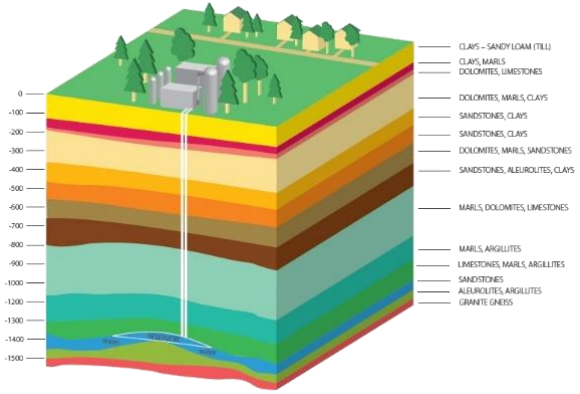
Salt Cavern



UNDER DEVELOPMENT

Concrete – Steel Vessels

Aquifer



Underground Pipe Storage

Rock Cavern

OUR TECHNOLOGY:
VERTICAL SHAFT HYDROGEN STORAGE

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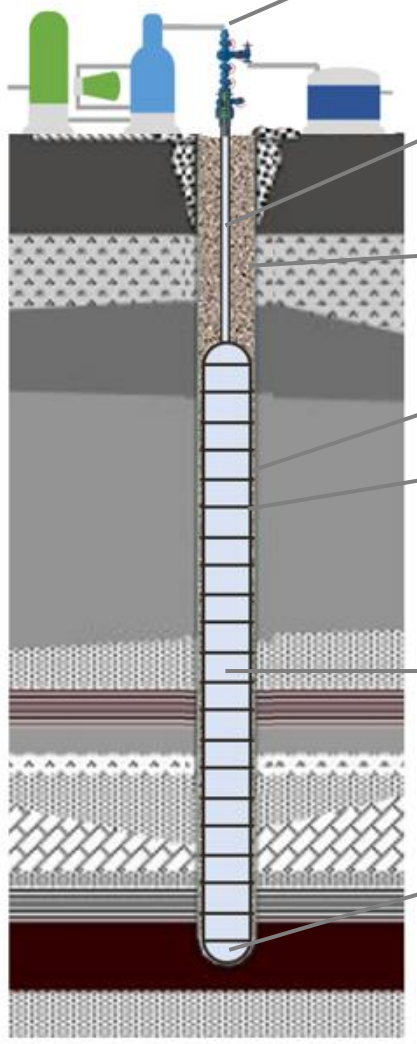
Adapting proven shaft drilling techniques from the mining industry to storing hydrogen in a purposely built underground cavity.

CHEAP
The surrounding rock takes on the duty of containing the hydrogen pressure – **no need for costly pressure containment materials.**

REPLICABLE
The shaft storage construction process can be reproduced in different locations with minimal design adjustment.

LARGE SCALE
Hydrogen storage sizes of **50 to 500 tonnes per shaft.** For larger storage, multiple shafts can be built in the same location.

SMALL FOOTPRINT
The above ground footprint is very small compared to equivalent pressure vessel storage.



MARKET FOR HYDROGEN STORAGE?

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Supporting existing ammonia production in Australia with a 2 day buffer: 3000t H_2

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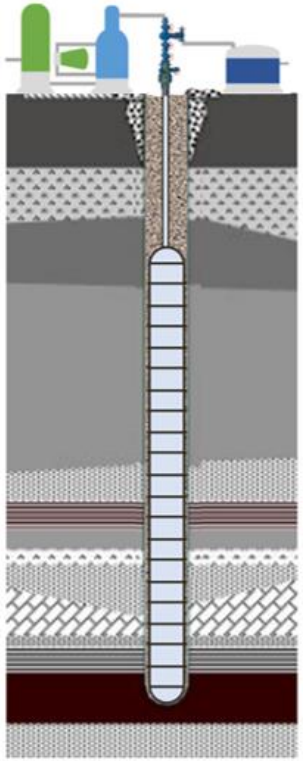
OR



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Safety the First Priority

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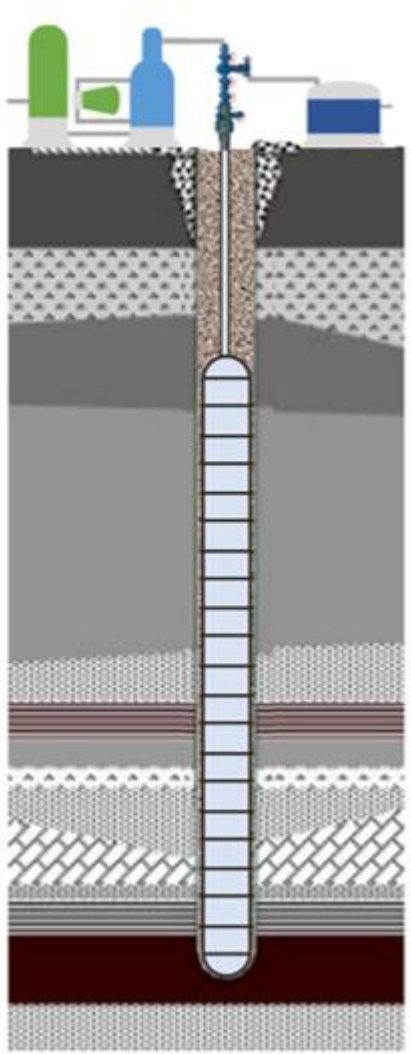
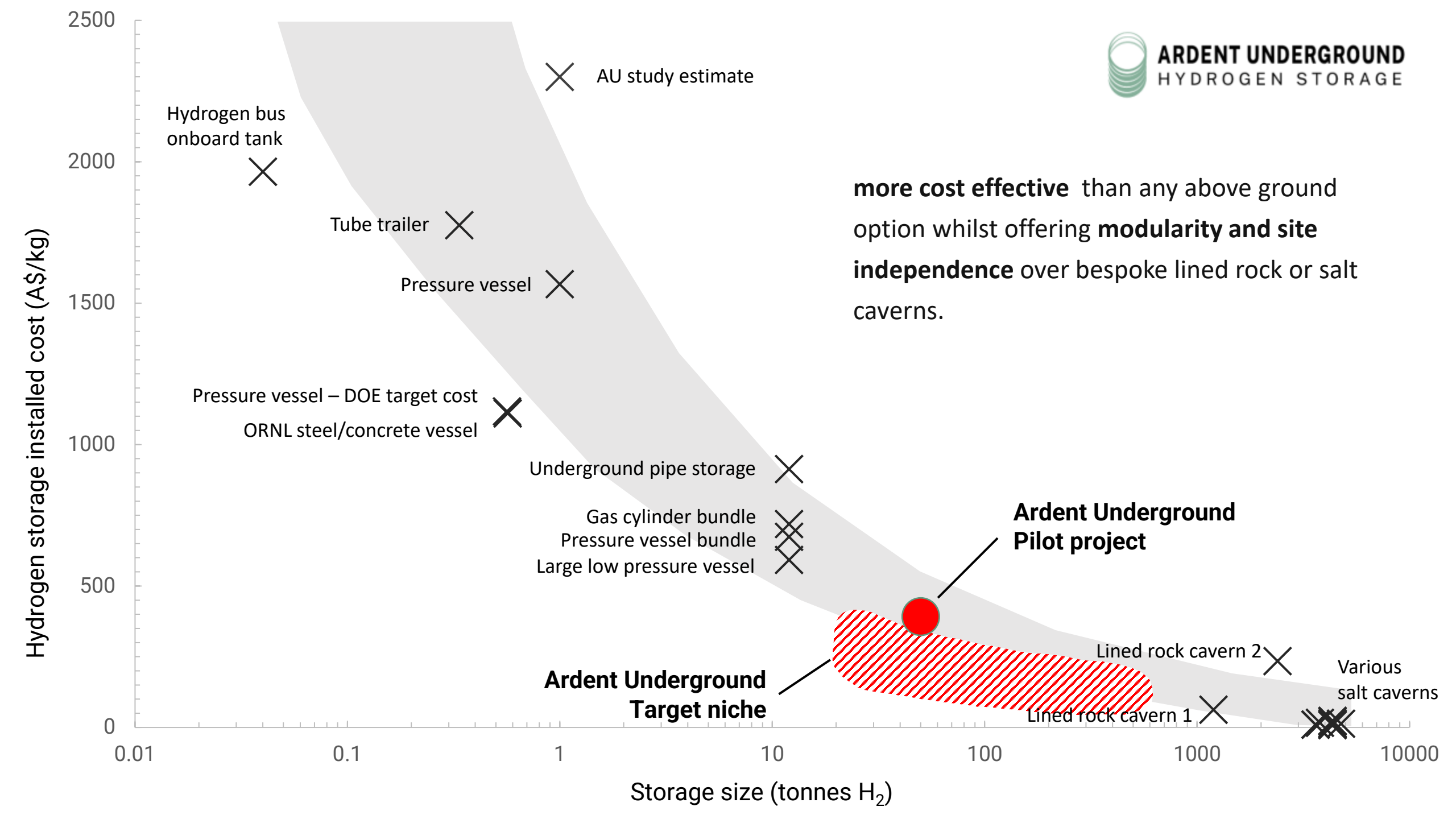
HYDROGEN STORAGE



Ardent Underground safely stores large quantities of hydrogen gas in deep underground purpose built cavities

Gangneung in South Korea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HYDROGEN STORAGE
AU study estimate
Hydrogen bus onboard tank
Tube trailer
Pressure vessel
Pressure vessel – DOE target cost
ORNL steel/concrete vessel
Underground pipe storage
Gas cylinder bundle
Pressure vessel bundle
Large low pressure vessel
Ardent Underground Pilot project
Ardent Underground Target niche
Lined rock cavern 2
Lined rock cavern 1
Various salt caverns
more cost effective than any above ground option whilst offering modularity and site independence over bespoke lined rock or salt caverns.
Hydrogen storage installed cost (A$/kg)
2500
2000
1500
1000
500
0
0.01
0.1
1
10
100
1000
10000
Storage size (tonnes H_2)

HOW IT WILL BE DONE

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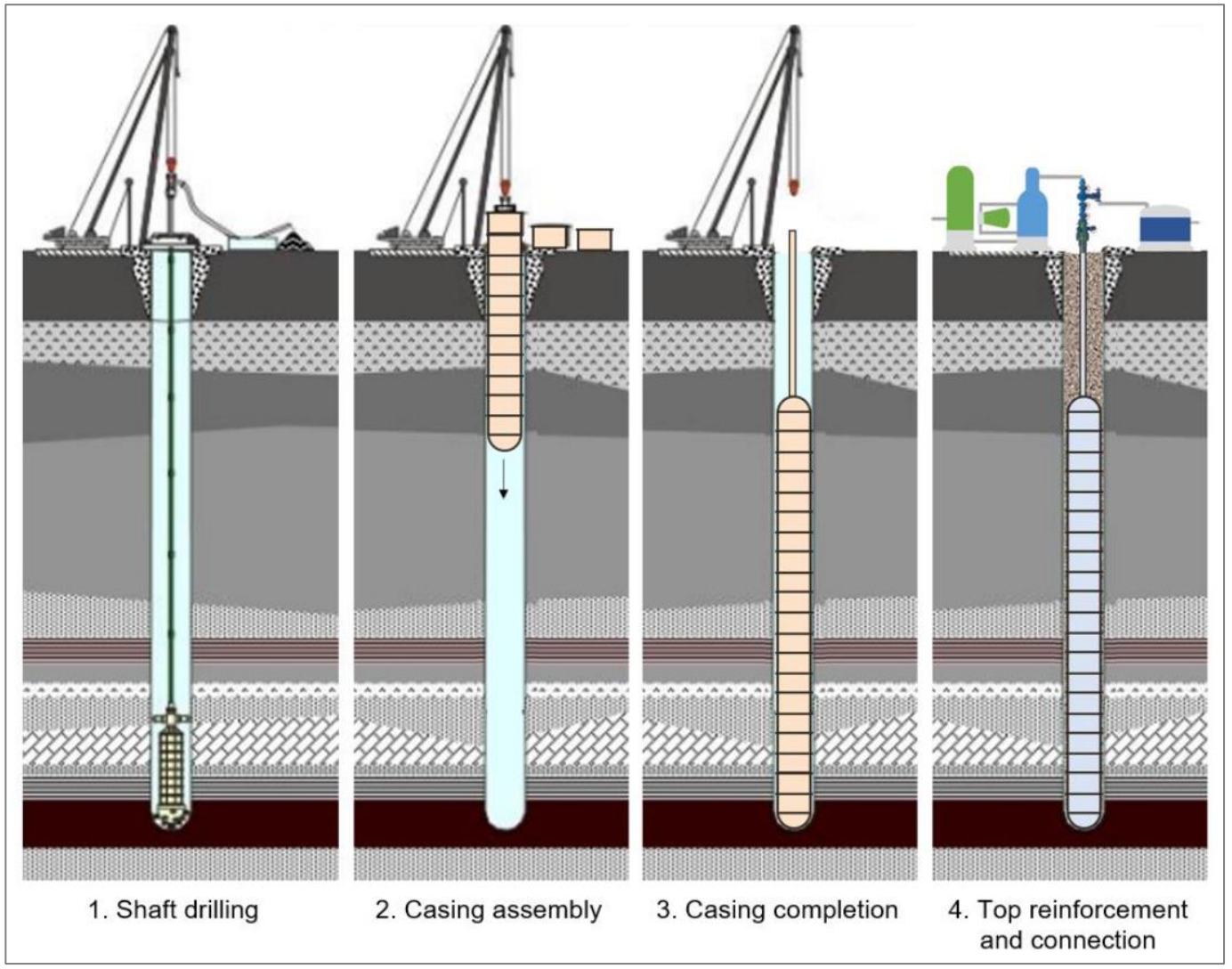
1. **Shaft Drilling**
   A rotating large diameter drilling assembly is lowered into the rock

2. **Casing Assembly**
   A casing with a steel liner (approx. 12mm) is assembled and lowered into the shaft

3. **Casing Completion**
   The cap is installed to the top of the casing and it is connected to ground level with a pressure pipe.

4. **Top Reinforcement and Connection**
   The space between steel liner and rock is filled with grout and the shaft storage is connected to the above ground facilities.



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BLIND BORE SHAFT DRILLING
A proven technique

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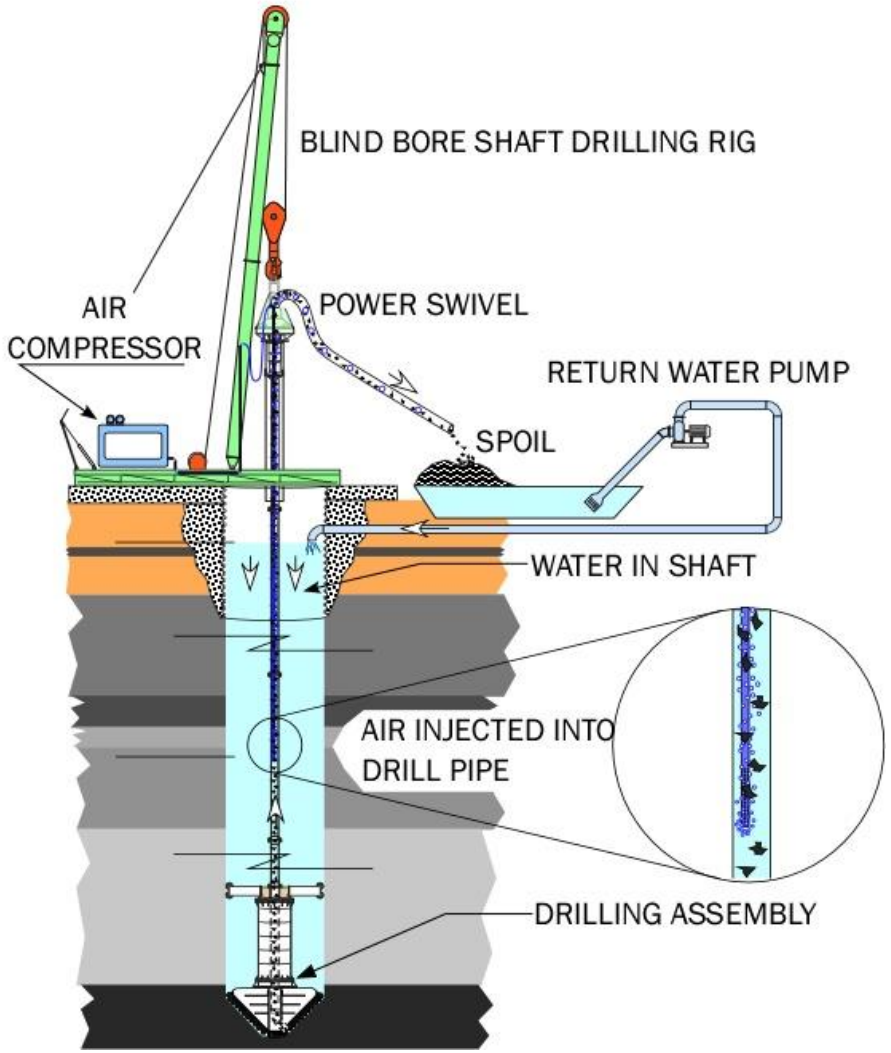

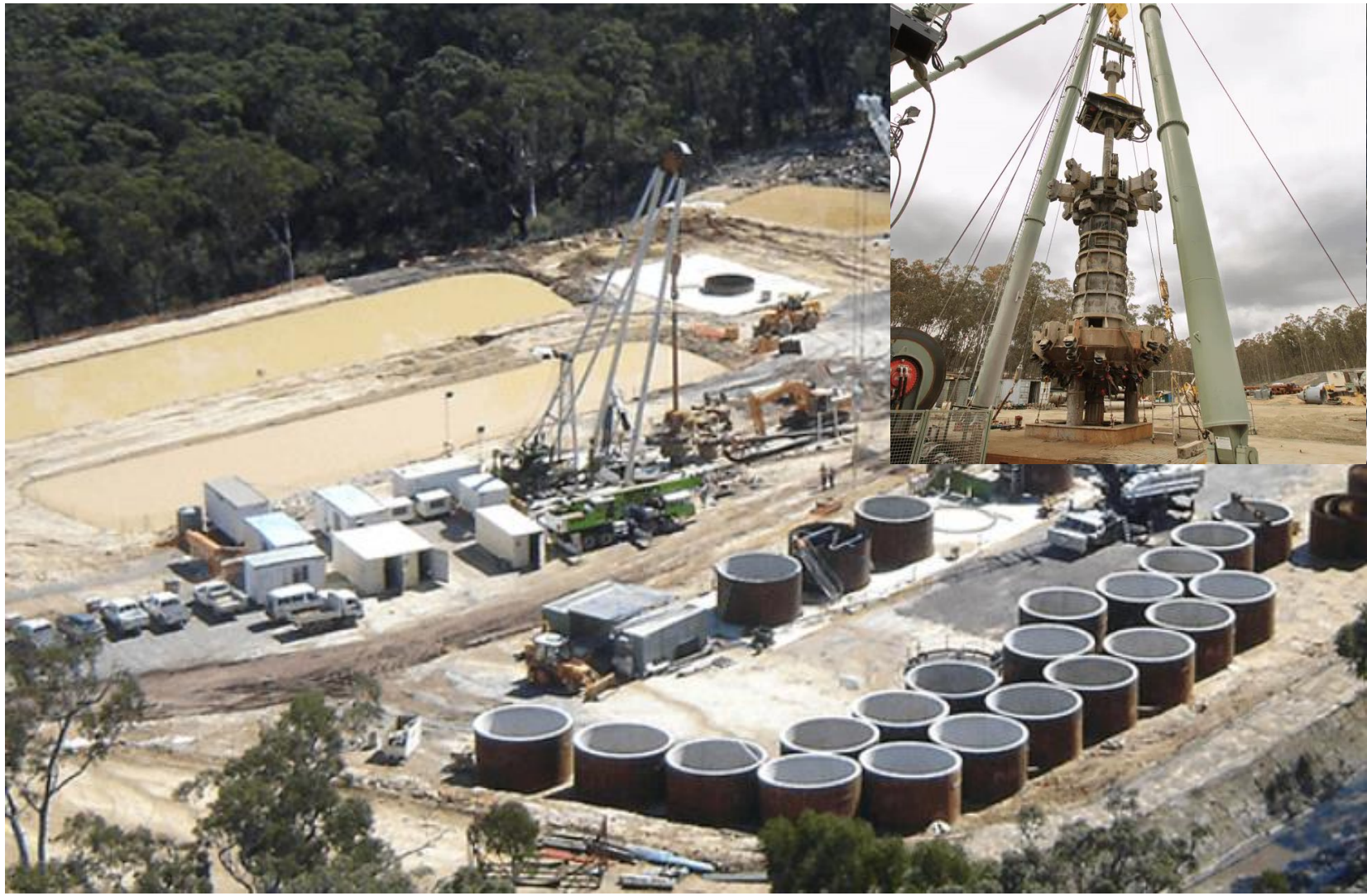

- **Typical cutting head**

BLIND BORE SHAFT DRILLING

ABERGELDIE
COMPLEX INFRASTRUCTURE

- Shafts are bored and lined entirely from the surface
- During construction the shaft remains full of water which provides stability to the shaft
- Cuttings are removed through centre of drill pipe using reverse circulation
- No personnel enter the shafts during any phase of the work

BLIND BORE SHAFT DRILLING

ABERGELDIE
COMPLEX INFRASTRUCTURE

- Our drill rigs have been designed using innovative technology and set a benchmark for blind boring shaft construction capability.

- Shaft drilling capacity ranges from 2.5 to 6.5 metres diameter up to 700m deep

- Our methods and equipment are particularly effective through poor ground conditions

ARDENT UNDERGROUND

HYDROGEN STORAGE

COMPLETED SHAFTS

- Abergeldie has completed over 20 shafts over the last 25 years has won several engineering awards.

https://abergeldie.com.au/ventilation-shafts/

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Moderator

CWP GLOBAL

Andrew Dickson

Development Manager, Green Hydrogen and Ammonia Projects

https://ardentunderground.com//