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

**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

• Introduction
  David Bentley

• Ardent and Abergeldie Complex Infrastructure
  Mick Boyle

• Ardent Underground Hydrogen Storage
  Keith Lovegrove

• Blind boring technology
  John Zeni

• Questions and Answers
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ABOUT ABERGELDIE

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

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

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

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

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

**REMEDIATION**
Hydrostatic concrete, pipelines, tanks and reservoirs; concrete and brick work; and metal structures and cladding.
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 dependent on river transport logistics.

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.
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.

REMEDIAITON

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.
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.

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.

- 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 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.

THE NEED FOR 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.
HYDROGEN STORAGE IMPACT ON GREEN AMMONIA ECONOMICS

• 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

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
Supporting existing ammonia production in Australia with a 2 day buffer = 3000t H₂
Supporting announced green hydrogen/ammonia projects in Australia with a 2 day buffer = 43,000t H₂
OTHER HYDROGEN STORAGE SYSTEM OPTIONS

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

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?

Supporting existing ammonia production in Australia with a 2 day buffer: 3000t H₂

OR

× 6

× 6000
Safety the First Priority

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

Gangneung in South Korea
more cost effective than any above ground option whilst offering modularity and site independence over bespoke lined rock or salt caverns.
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
• Typical cutting head
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

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

Moderator

Andrew Dickson
Development Manager, Green Hydrogen and Ammonia Projects

https://ardentunderground.com//