Submission
No 6

INQUIRY INTO DEVELOPMENT OF A HYDROGEN INDUSTRY IN NEW SOUTH WALES

Organisation: Ardent Underground

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ARDENT UNDERGROUND
HYDROGEN STORAGE

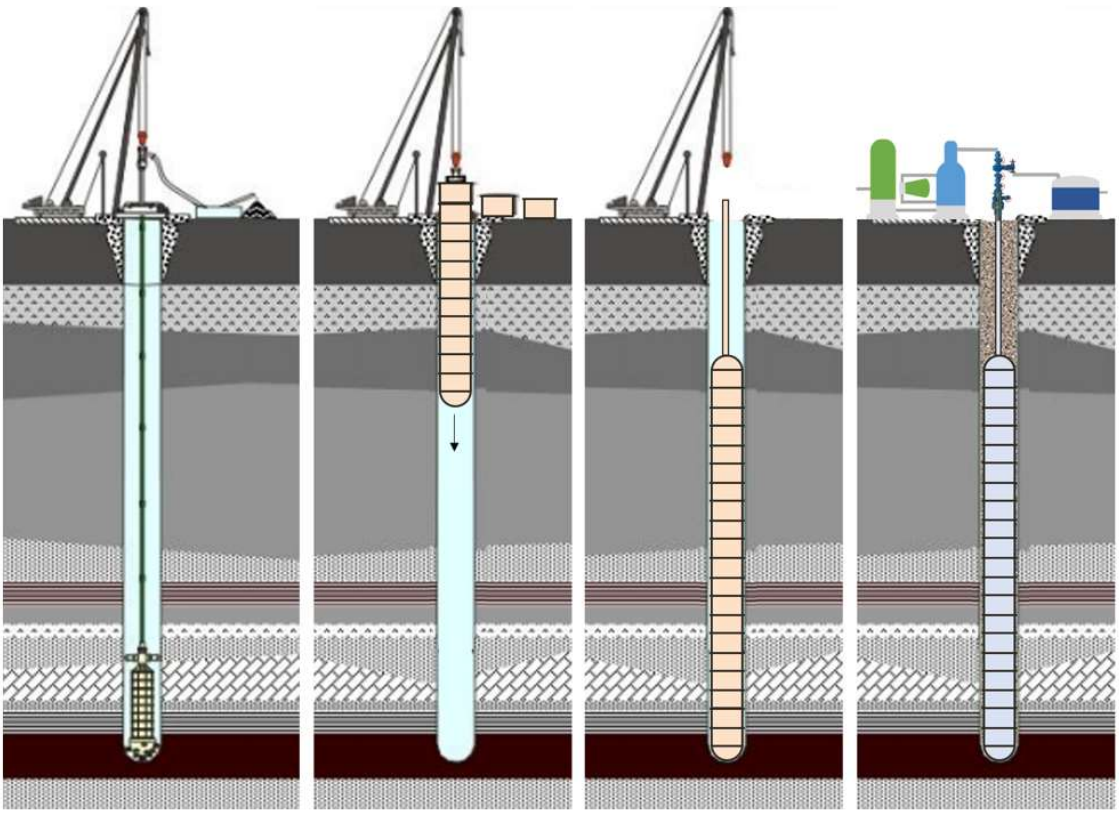
23rd February 2021

Submission for the State Development Standing Committee inquiry into

Development of a hydrogen industry in New South Wales

Large scale hydrogen storage in vertical shafts

The missing link for the hydrogen transition



1. Shaft drilling 2. Casing assembly 3. Casing completion 4. Top reinforcement and connection

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1. INTRODUCTION

Ardent Underground is providing this submission to the Standing Committee on State Development under the terms of reference for the **Inquiry into the development of a hydrogen industry in New South Wales**. Ardent Underground is progressing its business initiative that addresses a missing component of the Hydrogen value chain, to develop and commercialise a novel, cost effective, low environmental impact solution to storing large volumes of hydrogen.

The innovative large-scale hydrogen storage technology that Ardent Underground is developing consists of storing compressed hydrogen in modular underground purposely built cavities. This technology takes advantage of established engineering techniques and is based on the concept of vertical shaft blind boring. Considerable design and development work has already been undertaken and we are currently seeking a pilot project to produce detailed design, construct, commission and demonstrate the technology.

This submission is to demonstrate to the Standing Committee the capability that exists within NSW to support the implementation of a Hydrogen Industry.

The overall objective of the submission is to demonstrate:

- a safe, reliable and durable hydrogen energy storage technology with potential for global reach.
- a hydrogen gas storage technology also applicable to other gases, potentially as an intermediate step to hydrogen storage.
- facilitating the production of green commodities like green ammonia and green steel, both for domestic use and export
- opportunity for investment in large scale hydrogen storage project.
- an important technology to be implemented in the transition towards zero-emission economies (including green ammonia, green steel, zero-emissions transport, green gas grid, long-term energy storage)
- minimising the environmental impact and risks of large-scale major hazard hydrogen storage facility

The specific benefits to NSW highlighted in this submission include:

- Responding to the emerging domestic and international trends in the production and demand for hydrogen
- As a long-term exporter of energy, the NSW Government could support a pilot project cementing NSW's as a leading renewable energy exporter.
- Contributing to the flow of ideas needed for a vision of emissions free energy and industrial sectors for NSW, the nation and globally.
- Creating a growing number of NSW based jobs in the renewable hydrogen area.

2. HYDROGEN FUTURE

The development of hydrogen-based energy systems has recently gained unprecedented momentum both in Australia and abroad.

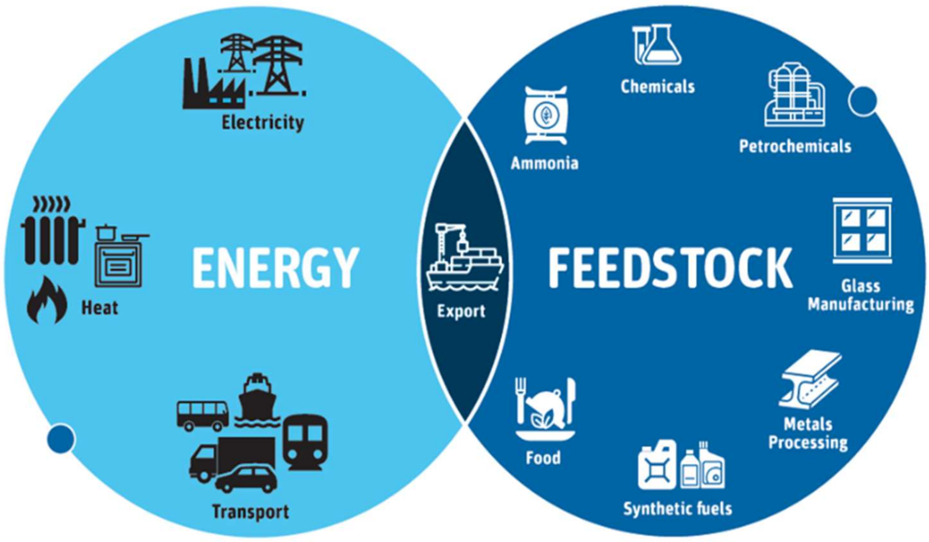

Figure 1 Applications for Hydrogen

Hydrogen, when produced using zero emissions sources (green hydrogen), is a versatile energy carrier and feedstock that can enable deep decarbonisation across the energy and industrial sectors. When produced through electrolysis using wind and solar PV energy its production is variable and a hydrogen buffer storage becomes essential for any application.

Countries like Japan have issued specific hydrogen strategies with long term targets in the development of a zero-emission hydrogen supply chain and large-scale imports. Australia has the resources and technical skills needed to grow a strong hydrogen industry and to focus on the export of this fuel.

The hydrogen industry is not new. Currently global hydrogen production is around 70 million tonnes a year[1], although it is almost entirely produced from high emission-intensive sources like natural gas (also referred to as grey hydrogen). As of today, most of the hydrogen is used as feedstock in the oil refining and the chemical industry. The production of ammonia alone is responsible for almost half of the hydrogen world demand (and around 1% of global GHG emissions).

The uses of green hydrogen can be much broader. Apart from replacing grey hydrogen and hence decarbonising sectors like ammonia production, green hydrogen can substitute for conventional fuels in the transport and energy sectors, act as a long-term energy storage medium and provide a green alternative to coal in the production of steel.

[1] IEA (2019), The Future of Hydrogen, https://www.iea.org/reports/the-future-of-hydrogen

***"A hydrogen economy will address some of the most intractable and challenging problems of climate change"*[2]**.

Hydrogen is very versatile, with potential applications in electricity production, direct combustion and as a transport fuel in fuel cell electric vehicles. This range of applications across energy sectors gives flexibility in being able to meet the demands of the importing country, provides opportunities for wide decarbonisation, and reduces the risk of oversupply and stranded assets, as uptake markets are diverse.

*"**the global market for hydrogen is expected to reach USD155 billion by 2022, with a number of Australia's existing trading partners, who are comparatively resource constrained, implementing policy commitments for hydrogen use**"*[3].

[2] Energy Transition Hub (2018), Australia's Hydrogen Future
[3] CSIRO's National Hydrogen Roadmap

3. HYDROGEN IN NSW

NSW has an opportunity to benefit from the transition to renewable energy and can play a key part in pioneering the domestic use and export of clean hydrogen produced from abundant renewable, yet intermittent energy. One of the key barriers to the widespread integration of renewable energy is its intermittency and unreliability. Therefore, a key enabler is the cost effective, safe, reliable and durable storage of energy to ensure continuity of service. Currently there is considerable focus on the application of battery storage however this technology has its limitations which are well documented. This submission will demonstrate capability existing in NSW that offers a clean, low environmental impact and cost effective solution to large scale storage of Hydrogen.

The proposed hydrogen storage solution occupies minimal space above ground, can be readily duplicated, is cost effective, safe and does not suffer from cycling degradation over time. By implementing large scale Hydrogen storage in NSW the state can participate in and benefit from the transition to clean renewable energy. Listed below are some of the opportunities that could benefit NSW as an early adopter of this technology.

Export

The Australian economy has a high dependency on fossil fuel exports. In 2019, around 380 million tonnes of coal and 110 billion cubic metres of natural gas were exported from Australia. As our trading partners look to progressively decrease their emissions, the future trade in energy is likely to increasingly be in low and zero emissions energy. Australia has very large renewable resources, a well-established track record of exporting energy and long-standing trading relationships with key energy importers. Australia is therefore well positioned to become a significant exporter of low or zero emissions energy.

"The potential to export clean hydrogen is substantial, with the International Energy Agency and the World Energy Council both identifying Australia as a potential hydrogen production powerhouse. We can become a leader in the new industry I call 'shipping sunshine', with our hydrogen exports being additional to our other energy exports"[4].

Green hydrogen offers a potential solution for the large-scale export of low or zero emissions energy. Unlike renewable electricity which would have to be transferred through high voltage direct current cables over enormous distances to specific locations, hydrogen can be stored at relatively low cost, exported to any destination with appropriate import facilities, and is less dependent on a single piece of infrastructure. Compared with biofuels and synthetic fuels, hydrogen supply chains produce fewer lifecycle GHG emissions, with none produced at the point of use.

Hydrogen will be exported in a liquefied form. This will either be by converting it to ammonia or else cryogenic liquification. This will require the implementation of infrastructure that will include hydrogen liquefying plants, shipping harbours and liquefied hydrogen carriers. Ammonia has the advantage that it is already shipped and traded around the world at scale. Japan showed their

[4] Australian Chief Scientist Alan Finkel

commitment to the hydrogen economy and in particular to the import of hydrogen by launching the world's first liquefied hydrogen carrier at the end of 2019 (Figure 2).

Cost effective buffer storage of hydrogen is essential as ammonia production or liquification plants need to run continuously and their high capital cost means that the final product is produced at lower cost under continuous operation.

Figure 2: Left; conventional ammonia transport ship, Right; Suiso Frontier, the world's first liquefied hydrogen carrier, launched in Japan in December 2019.

Stationary electricity

In the electricity sector hydrogen can be applied to firming variable renewable power or to seasonal energy storage (Figure 3).

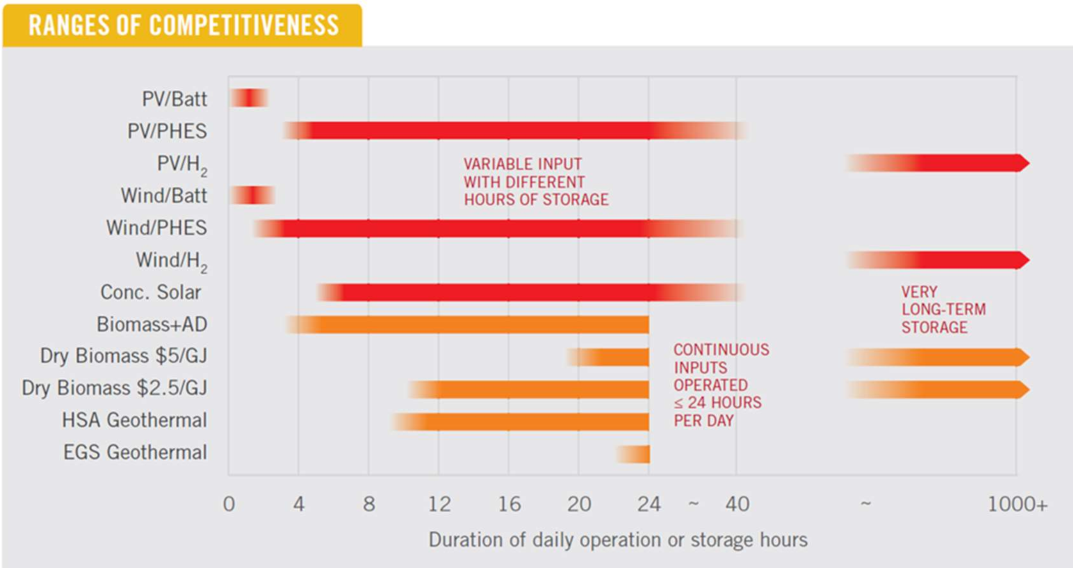

Figure 3: Range of competitiveness of different forms of electricity storage[5].

To offer energy storage for the electricity sector hydrogen must be compressed and stored in appropriate storage systems. (Figure 4)

[5] Comparison of dispatchable renewable electricity options (2018), ITP Thermal for ARENA

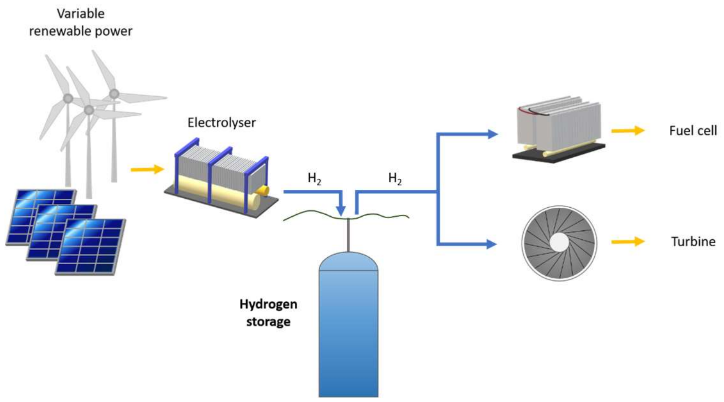

Figure 4: Potential stationary hydrogen electricity system.

When electric power is required, the hydrogen is withdrawn from the storage system and converted back into electricity by means of fuel cells or a gas turbine. Despite the current low roundtrip efficiency of hydrogen storage (approx. 35%), the relatively low cost of scaling up the size of the storage makes this technology attractive. In particular, hydrogen storage appears to be competitive for very long-term storage (seasonal storage).

Transport

Hydrogen fuelled vehicles (FCEV) became commercially available for passenger transport in 2013[6]. They consist of an electric drive train powered by a fuel cell stack and hydrogen storage tank pressurised to 700 bar.

FCEVs are seen as a complementary technology to battery electric vehicles (BEVs). They may be more suitable for applications that:

- travel longer distances (i.e. 400 - 600 km without refuelling),
- need shorter refuelling times,
- are without easy access to electrical recharging infrastructure (eg apartment dwellers without off street parking).

Currently, a 6 kg tank can allow light FCEVs to travel between 500-800 km. Heavier FCEVs such as trucks and buses are particularly competitive as a form of low-emissions transport as they benefit from faster refuelling and for the same amount of energy stored, hydrogen tanks are considerably lighter than batteries and this means an increased commercial payload.

[6] Information Trends 2018, Hydrogen Fuel Cell Vehicles - A Global Analysis.

Figure 5: One of the 56 hydrogen buses operating in Europe for the Clean Hydrogen in European Cities (CHIC) project.

The higher hydrogen demand of heavy vehicles and typical ‘back to base’ transport routes can make them a more favourable target market than passenger vehicles during the scale up of refuelling stations.

Similarly to long haul trucks, hydrogen can be a suitable fuel for transport on rail when it is used to substitute other fuels like diesel. There are several examples of companies developing hydrogen trains and a similar number of countries considering its implementation. Hydrogen passenger trains are already a reality in Germany, where hydrogen trains are substituting conventional trains on non-electrified rail lines.

Figure 6: Alstom's Coradia Ilint hydrogen passenger train, operative in Germany since 2018.

In all transport applications, filling stations need buffer storage of hydrogen.

Heat

Another sector where green hydrogen can play an important role in the future energy mix is in the generation of heat. Heat is required both for industrial manufacturing processes but also for domestic use (room heating, cooktop appliances, hot water heating).

As shown in Figure , in South East Australia during winter months the energy demand from natural gas is comparable to the energy use from electricity. This can give an indication of the required investments on the power generation and transmission infrastructure if the heat now provided by gas had to be produced from electricity. Other challenges associated with electrification include the variability in demand for heat in winter and summer.

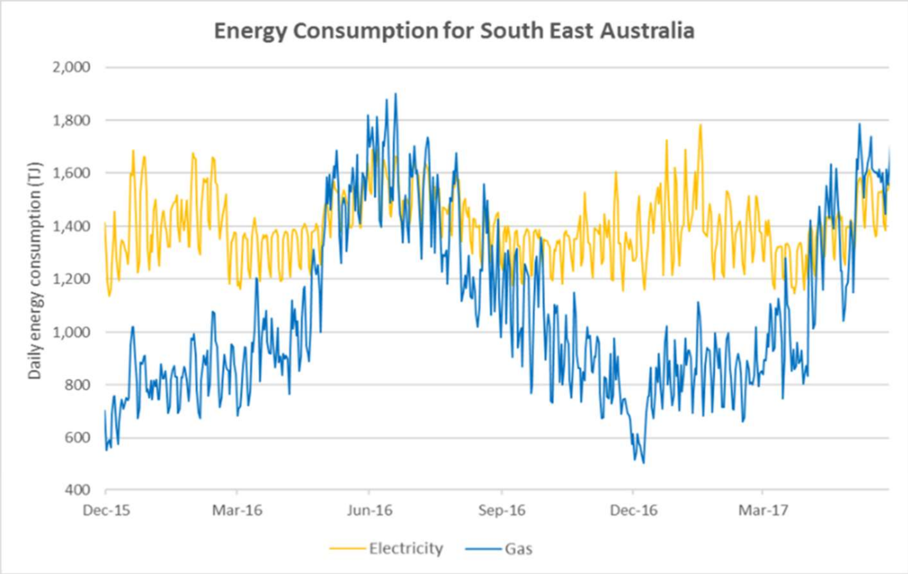

Figure 7: Gas and electricity daily consumption for South East Australia (ACT, NSW, VIC, SA)[7].

While in some instances electrification may prove economically favourable, complete substitution of energy provided from the gas network is unlikely to be feasible, due to the increase in demand and consequent cost of reinforcing the electricity network.

An alternative to the shift towards electricity for heat would be to gradually transition from natural gas to green hydrogen. The injection of 5 to 10% of hydrogen into the gas grid could already be realized without requiring modifications to the natural gas infrastructure, while most of the distribution network can already accept much higher hydrogen percentages. Transmission pipelines and gas appliances would likely need to be replaced before being able to accept 100% hydrogen gas.

On top of making use of exisiting infrastructure, the use of green hydrogen in the natural gas network would provide an easier solution to the problem of seasonal variation in energy demand thanks to the low cost of large scale storage.

Large volumes of hydrogen storage will be required to match production to consumption of heat.

[7] Energy Networks Australia, https://www.energynetworks.com.au/news/energy-insider/staying-warm-this-winter-and-keeping-bills-down/

Industrial feedstock

Green hydrogen can readily substitute grey hydrogen as the feedstock in a number of industrial processes:

- Petrochemical processes
- Ammonia production
- Methanol production
- Glass manufacturing.

On top of these sectors, green hydrogen can also be used in the production of steel as an alternative to coal.

Buffer storage of hydrogen is required to allow industrial processes to be carried out independently of the variable renewable input.

5. CAPABILITY

Ardent Underground

Ardent Underground www.ardentunderground.com is a joint venture between ABERGELDIE Complex Infrastructure and ITP Thermal Pty Ltd. The company has been set up with a specific focus on the transition to a green hydrogen economy by providing a cost effective, large scale, environmentally sustainable, replicable hydrogen storage technology. Ardent Underground is resourced by its joint venture partners and can scale up as required to meet project specific demands.

Abergeldie Complex Infrastructure

Abergeldie Complex Infrastructure www.abergeldie.com was established in 1994 with offices in Sydney, Brisbane, Melbourne, Canberra and Auckland (New Zealand) as a broad based contractor focussed on complex projects with expertise in rail and transport, energy, water, dams and marine, trenchless technologies for pipe re-lining, structural remediation, tunnelling, pipe jacking and mine shafts.

Abergeldie has designed and built three 450 t blind bored rigs and successfully delivered 15 blind bored shafts in Australia over the last 15 years with shaft depths ranging from 165 m to 517 m and finished diameters ranging from 3.5 m to 6.5 m. The majority of the completed shafts have a diameter of around 5 metres and are drilled to a depth of around 300 metres.

ITP Thermal Pty Ltd

ITP Thermal Pty Ltd www.itpthewrmal.com is one of six companies in the ITP Energised group. The group, originally founded as IT Power in the UK in 1981, has a strong presence in Australia, UK, India and a smaller presence in China and Argentina. ITP Thermal leads activity in thermal, thermochemical, hydrogen and ammonia related work for the ITP Energised group globally. All the ITP Energised group companies work collaboratively and share staff resources as needed. ITP Thermal's core business to date has been consulting for government and private clients. ITP Thermal has plans to expand into technology development and /or project deployment in collaboration with suitable partners. To this end ITP Thermal brings:

- A large track record of completed consulting projects in the field
- Access to technical expertise and reputation across the ITPE group (approx. 70 staff)
- The Company MD is an acknowledged expert in the field globally
- Known to all significant global CST research groups
- Strong working relationship with Australian Renewable Energy Agency (ARENA)
- Relationships with Australian state and territory governments
- Partnership with University of California (UCLA).

Key personnel

Keith Lovegrove (ITP Thermal)

Dr Keith Lovegrove is the managing director of the ITP Thermal Pty Ltd (https://itpthermal.com/). He has over 30 years of experience in Solar Energy combined with 15 years of teaching experience in undergraduate and postgraduate courses in Energy Systems and Systems Engineering. He was previously the leader of the Solar Thermal Group at the Australian National University. In that role he was the lead inventor and design and construction team leader of the 500m2 (world's largest) Generation II Big Dish solar concentrator. He 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

He has authored or co-authored more than 170 publications including 2 patents and 7 books chapters and major public reports. Dr Lovegrove has represented Australia as IEA Solar PACES (Power and Chemical Energy Systems) Solar Chemistry task representative over many years and currently as the alternative executive committee representative. He has also contributed extensively to media interviews on renewable energy. He is currently a member of the University of Adelaide's Centre for Energy Technology advisory board, serves on the Australian Renewable Energy Agency's project advisory panel, is the chair of the steering committee of the Australian Solar Thermal Research Institute (ASTRI) and is a board member of the Australian Solar Thermal Energy Association (http://www.austela.net.au/)

Mick Boyle (Abergeldie)

Mick Boyle is the Executive Chairman of Abergeldie Complex Infrastructure.

He has a civil engineering career from 1982, initially with major contractors Dillighams, White Industries, Thiess and Costain, working on mining, marine and large infrastructure projects in Australia and, for several years, in England and Scotland. His roles included field engineer, site engineer, project engineer, and project manager.

Founder and Managing Director until 2015 of Abergeldie Complex Infrastructure Pty Ltd, which he established in 1994. Abergeldie employs nearly 350 people and has offices in Brisbane, Newcastle, Sydney, Canberra and Melbourne and carries out complex engineering projects throughout Eastern Australia. In addition to completing many complex civil engineering projects such as dams, tunnels and bridges, the company has developed world leading technology in blind bore shaft drilling for the mining industry. It also has in-house design and construct capabilities for process engineering projects and has particular expertise in water processing plants and pipe relining. Abergeldie Complex Infrastructure has been recognised by its peers in the Industry with twelve CCF Earth Awards, three Engineering Excellence awards, two Australian Water Industry Awards and a Mining Prospect Award in the last five years.

Frank Starr (ITP Thermal)– commercialisation strategy

Frank is the Chair of the board and a shareholder of ITP Thermal. He has Bachelor and Master of Commerce Degrees, is a Fellow of the Institute of Chartered Accountants, a Registered Company Auditor and a Registered SMSF Auditor. He is the managing director and principle of Axxon Chartered accountants. He has been in practise as a Chartered Accountant for 30 years in Canberra, Sydney and rural NSW and have provided services to many NFP's and charities.

Frank has held numerous board positions, including a publicly listed Wine Company in the Hunter Valley of NSW, which had its own vineyards, production, domestic & international marketing and distribution facilities. While a Director he assisted in the successful capital raising of $AUD 120M for a takeover/merger bid of Evans & Tate. He served for five years as Chairman of the Owners Corporation of The York, 5 York Street Sydney, and is currently serving on several other Boards of client Companies.He previously assisted the ANU Vice Chancellor's Office with advice on their attempted commercialisation of their 25 metre large thermal solar dish energy project.

John Zeni (Abergeldie)– Technical Advisor

John has been a technical adviser to Abergeldie on all its mine infrastructure projects since 2010, after Abergeldie's 2007 acquisition of Ardent Underground Pty Ltd, of which John had been a partner with Abergeldie's managing director, Mick Boyle. John's experience includes 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 coal and other mineral mines in the USA, Papua New Guinea, France and Australia.

- Occupational Health and Safety Certification in Australia as a crane operator with "Open" classification (unlimited tonnage).
- Certified mine site supervisor for coal mines in Queensland, Australia, classifications S1, S2 and S3.
- MSHA certified hoisting operator
- Charter member of Institute of Shaft Drilling Technology
- Authored technical papers for the Australasian Institute of Mining and Metallurgy, Society of Mining Engineers, World Rock Boring Association and the Rapid Excavation and Tunnelling Conference.

Kalirajan Urkalan (ITP Thermal)– Engineer

Kalirajan is an Energy Engineer with more than 14+ years of experience in design and engineering of multidisciplinary energy projects. He has previously worked for Manufacturing and EPC companies implementing small- and large-scale projects in India, Sri Lanka. He is currently working as a Design Engineer in ITP Thermal. Kalirajan is a Chartered Professional Engineer with Engineers Australia.

He has worked in the previous REIF funded project (Advancing Solar Energy Storage with Ammonia). The research project led to the progress of high-pressure underground storage system which can be utilised for hydrogen storage. He has worked in prefeasibility study of large-scale grid connected CSP project in Australia and has knowledge of industrial design codes such as ASME, API and TEMA. The project includes performance modelling and determining optimum storage size for CSP operation in the NEM. Other projects include renewable energy options for Australian industrial gas users and feasibility study for implementing solar heating systems in Food and Carpet manufacturing units.

David Bentley (Abergeldie) -Business Development

David Bentley is the General Manger of Abergeldie Energy with more than 30 years' experience in the energy industry focused on efficiency and integration of plant wide solutions. Before joining Abergeldie, David was involved in many power generation projects and cogeneration systems both in Australia and abroad. Able to identify process waste and opportunities to improve efficiency David has delivered many innovative solutions that reduce GHG emissions and save energy.

Gian Marco Gentilini (ITP Thermal)– Engineer

Gian Marco is an Engineer with ITP Thermal. He has four years of experience in the design of energy and chemical systems. In Europe, he has worked with an EPC company on projects in Italy and Turkey, with a particular focus on implementing cogeneration solutions and developing innovative renewable power systems. In Australia, before joining ITP Thermal he worked with an PV system technology developer, taking care of the design, procurement and testing of the technology. He received a MSc in Energy Engineering at Polytechnic of Milan, Italy.