Submission No 24

INQUIRY INTO DEVELOPMENT OF A HYDROGEN INDUSTRY IN NEW SOUTH WALES

Organisation: Star Scientific Limited

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Development of a Hydrogen Industry in New South Wales

Submission to the Legislative Council Standing Committee on State Development

"Taking Energy Off the Table"
By Star Scientific Ltd

February 2021

Please note: Where this submission refers to hydrogen, it is green hydrogen – sourced from sustainable energy, unless specifically referred to as blue or brown hydrogen.

About Star Scientific

Star Scientific is a private research and development company located on the Central Coast, north of Sydney, Australia. Founded by Andrew Horvath in 1997, it is governed by a Board of Directors of which Mr Horvath is Chair.

The core business of Star Scientific for two decades was research into muon-catalysed fusion. During its research, it discovered an anomaly which it soon realised was a profound discovery - and named it the Hydrogen Energy Release Optimiser, or HERO®.

HERO® has captured global attention with Star Scientific winning the *Emerging Technology* Award at the S&P Platts Global Energy Awards and signing Memorandums of Understanding (MoU) with the Department of Energy of the Republic of the Philippines, as well as multiple entities such as, private sector utilities, manufacturers, and service providers.

The commercial roll-out of HERO® will be facilitated by two subsidiaries, Planet Power Systems, which will lease and maintain the HERO® units and Zurich-based Planet Power Finance, which will finance Star Scientific's investments in its vertically integrated development of the green hydrogen chain. In Europe, Star Scientific is by represented Star Scientific Europe, also based in Zurich.

Introducing HERO®

HERO® is unique, it has been patented globally and has no competitor.

It is a catalyst that can allow hydrogen to achieve its full potential and become the world's pre-eminent sustainable energy source. HERO® will be the catalyst of a new, clean, industrial revolution.

When hydrogen and oxygen are introduced to the HERO® catalyst, it can generate temperatures of up to 800 degrees Celsius, without combustion. The catalyst is not used up in the catalytic process and once the feed gases are removed it quickly reverts to its inert state with zero combustion.

Contemporary thinking limits the application of hydrogen for industrial purposes to combustion, blending with other gases and combusted, via fuel cell technology or as a feedstock in the form of ammonia. All have their limitations for large-scale, continuous, scalable application.

HERO® changes this.
HERO® is the missing link in the hydrogen supply chain, turning hydrogen into continuous industrial heat without combustion.

While heat exchangers have been in use for many decades, they are usually passive devices that exchange heat between two media (one hot, the other cold). The HERO® technology requires a design that can be described as an 'active side' heat exchanger. In HERO® the heat source is a reaction on the catalytic surface and this heat is then conductively transferred to the cool medium (for example water to make steam). This is extremely unusual, if not unique, as far as heat exchanger design is concerned.

In terms of using HERO® to generate steam, the situation is very similar. A typical (non-HERO®) boiler design for steam generation involves the use of multiple stages, including header tanks. Based primarily on conductive heat transfer as described above, HERO® can deliver saturated steam in a single stage. Star Scientific has already successfully demonstrated this on a small scale (sustaining tens of kilos per hour). That is, water goes in and high-quality steam comes out.

This is another example of where the existing body of knowledge relating to steam engineering lacks direct application to the HERO® technology. The development of HERO® systems is contributing to a source of new knowledge.

Commercial Pathways

In Australia, Star Scientific has conducted a study, through our consultant Arup, with one of Australia's major energy utilities on retrofitting one of its key coal-fired power stations to hydrogen via HERO®.

The results demonstrate that the application of HERO® provides the power station with a new lease on life in a post-fossil fuel environment, and that the retirement of coal-injection

infrastructure, pollution control infrastructure and reclamation of parasitic energy provides significant capital savings to the owners of the facility.

The retrofitting of existing fossil-fuelled infrastructure to green hydrogen is therefore a key commercial pathway. Cambridge Econometrics has valued the worth of potentially stranded fossil-fuel assets as up to US $4 trillion globally.

Having said that, HERO® is not restricted to large scale power generation. Any industrial process that requires heat can use a HERO® system. Star Scientific sees a particular application to desalination processes and large industrial applications.

The beauty of HERO® is its scalability. When mated with technology such as the new generation of super-critical $_sCO_2$ turbines, HERO® can be utilised for small-scale, off-the-grid power generation purposes, particularly in regional and remote locations. It can also be scaled up to develop stand-alone smart grids of up to 400MW, taking large industrial users off the main grid. For example, this will ameliorate the strain placed on the main grid from the rise of 5G wireless networks and the Internet of Things (IOT), which will use over three times the energy of the current 4G network. Data centres and other IOT infrastructure can be taken off the grid.

Star Scientific and New South Wales

Although Star Scientific is global in scope, and is in discussions with most Australian States, Star Scientific remains deeply embedded in its home State of New South Wales.

While the company is open on the location of its manufacturing facilities both here in Australia and globally, the plan is for its Research and Development headquarters to remain in New South Wales and specifically in the region spanning the Central Coast, Lake Macquarie, and the Hunter. Star Scientific enjoys a particularly close relationship with the University of Newcastle and most of its research and engineering staff live in the region.

The hydrogen opportunity

Before addressing the specific terms of reference, Star Scientific would like to take this opportunity to focus on what we see as unique opportunities and, in doing so, introduce a perspective that may challenge hydrogen "orthodoxies".

New South Wales needs a greater sense of urgency when it comes to hydrogen.

The pace of the hydrogen revolution is rapidly accelerating both globally and here in Australia. Globally, investors are looking for a sustainable energy source that has the capacity to provide reliable, continuous dispatchable energy and industrial heat.

Hydrogen has emerged as the leading candidate across the world, with advanced economies such as Japan, Germany, Korea, and France leading the way and with the United States entering the race following the election of the Biden administration.

Investment markets are hungry for green hydrogen at present and early-mover states and companies will stand to benefit. In Australia, West Australia, South Australia, Queensland, and Tasmania have robust hydrogen strategies and several projects currently in development and consequently, they stand to benefit from an inflow of investment.

New South Wales has, in our view, been slower to grasp the opportunities, notwithstanding that it holds a number of the basic but critical building blocks required to build a hydrogen economy. We hope that this Inquiry kick-starts the State's entry into the hydrogen race in a substantial way.

The primary product is heat.

Star Scientific is not in the business of selling energy. Rather, we are in the business of heat as a service.

Heat is the key input into most human endeavours, whether it be for real products such as construction materials, plastics, foodstuffs, chemicals, transport, textiles, water, household heating, tools, or services supplied using digital infrastructure powered by grid-derived energy.

Therefore, from our perspective, the key question is "*how do we provide carbon-free heat?*" and work back from there. It is our view that too much emphasis in the public discourse is placed on the supply-side challenges of green hydrogen.

From our point of view, if there is a demand for "green heat", then the market will arrange itself through Research and Development (R&D), innovation, investment and entrepreneurial activity to meet that demand at an acceptable price. We are confident that New South Wales, which is home to many of the lead institutions in hydrogen R&D, such as the University of Newcastle and University of NSW and arguably, the national headquarters of competitive and entrepreneurial financial markets, will rapidly take advantage of any government lead in hydrogen industry development.

This is not just about climate change.

The hydrogen revolution is much broader, and more profound than a "climate change measure". There is no doubt that the development of the global hydrogen economy will have an historic impact on human development.

The capacity to harness an inexhaustible, continuous, clean source of energy will lift hundreds of millions of people out of poverty, particularly in the developing world. The distinction between energy "haves" and "have nots" will be removed, and with it the source of much geo-political tension.

Take, for example, the Republic of the Philippines. In January 2021, Star Scientific signed a Memorandum of Understanding (MoU) with the Department of Energy of the Republic of the Philippines to assist them in developing their hydrogen economy.[1] The Philippines is an energy "have not" and that, combined with its geographic profile, has been a brake on its economic development.

Over 30% of the population of the Philippines is under 15 years of age and half the population is under 25, most of whom have a relatively high standard of education. The Philippines has recognised, there is now an opportunity to change its underdeveloped status.

The Government has bold plans to develop the economy and to cater for a rapidly emerging young consumer class that will demand products and services that are ecologically sustainable, slavery free and recyclable. The brake on these plans has been energy. Green hydrogen will release that brake.

Of course, one of the added benefits of the development of a green hydrogen economy - and a significant one at that - will be a massive reduction in carbon outputs. Yet the socio-economic benefits will be so much more, and profound. At Star Scientific, our mission is to "take energy off the table" as a global issue, freeing the world up to invest our human endeavour in other seemingly intractable problems.

Australia's approach to hydrogen is too small and based on incorrect assumptions.
Even the best hydrogen policy in Australia (arguably, Tasmania's) is orders of magnitude too small in its thinking. In order to be "fair dinkum" about a hydrogen economy, we need to vastly lift our aspirations for hydrogen production and use. Recently, Star Scientific, through its consultants Arup, concluded a theoretical study into retrofitting a coal-fired power station in New South Wales to hydrogen via a HERO® system.

The conclusion was that while it is easily done and will provide substantial capital and recurrent savings to the power station, it would necessitate the production of two million tonnes of green hydrogen annually.

This brings us to the first of the two major errors in the orthodox thinking impacting hydrogen policy in Australia.

[1] See attached media release.

The first centres around the debates on climate change or sustainable energy, and much of the government policy thinking - including in New South Wales - that is based on a false premise of an either/or approach, or rather a zero-sum game in relation to sustainable energy infrastructure versus fossil fuel powered systems.

The orthodox thinking is that the former must replace the latter and the policy challenge we need to confront is to have in place base-load energy from sustainable energy sources before the power stations close.

It is our contention that power stations need not close.

If the answer to reliable, sustainable baseload power is spinning mass via turbines (and it is), then the question needs to be asked; why do we need to dispose of those assets including the transmission systems to which they are attached and render them "stranded"? If the issue is the fuel source, then why not simply change the fuel and keep the turbines spinning?

Hydrogen, and HERO® provide us with that alternate fuel source – and it is inexhaustible, continuous, and does not produce emissions. Now is the time to explore this as a viable solution for a zero-emissions energy source.

The second, is the blind faith that electrons generated by wind, solar and pumped hydro injected straight into the grid is the preferred, and seemingly only viable model for energy supply. As recent reports have found, the problems of intermittency and over-supply at certain times are yet to be addressed, creating actual stability issues for the grid and uncertainty in energy markets.

Hydrogen addresses this in two ways.

Firstly, green hydrogen is, in one respect, a "better battery" than the lithium-ion subset, with problems of longevity, rarity of core components and carbon debt in their production. In the last two decades there had been a "gold rush" in the sustainable energy sector, and many wind and solar assets have been rushed to the market, with poor business models, and are now under financial distress.

Hydrogen offers a better business model for these assets, allowing them to turn their spilled electrons to the production of green hydrogen, regardless of the time of day and the weather conditions.

The second way that hydrogen obviates this issue is that, as a better battery, hydrogen when matched with emerging technologies such as super-critical $_sCO_2$ turbines, is scalable. It is therefore able to be applied to industrial and domestic uses off the grid. Thus, the supposed risks of sustainable energy sources to the grid are significantly reduced or removed.

Another argument holding back our thinking and policy approach to hydrogen in Australia (if not globally) is that we are ascribing too much weight to the problems of supply-side issues; the efficiency of electrolysers, environmental issues assigned to wind turbines and issues around transportation and storage. Indeed, our national target – hydrogen costed at $2 per kilogram – is the ultimate supply-side target.

Star Scientific is of the view that this false "groupthink" fixating on the supply-side and perceived problems of hydrogen stems from an unconscious bias against it from traditional thinkers and vested interests in the energy sector.

Star Scientific has scoured the globe for technological innovations that address these supply-side challenges. We are happy to submit that the pace of innovation is faster than forecast by private and public sector entities even as recent as a year ago. Smarter electrolysers, double-headed floating wind turbines and subterranean storage systems are to name but a few that we are studying and are preparing to invest in.

It is our strong view that public sector policy and private sector investment need to generate the *demand* for hydrogen, and, as in simple economic theory, supply side challenges will be addressed by innovators and investors.

Good policy is what we need from government.

Governments' investment of taxpayers' dollars is welcome where it advances our understanding of hydrogen and its applications. We understand that government funding programs are important in raising the profile of hydrogen and government's commitment to the sector.

Much of the good policy work being done by governments, however, is far more mundane and not particularly noteworthy in a political sense. Nevertheless, it is critical. For example, in late 2019 the COAG Energy Ministers' meeting agreed to a national program on definitions and standards for the handling of hydrogen. This is to be applauded as it is crucial to the sustainable adaption of the hydrogen economy.

However, more radical thinking needs to be applied to stimulating demand for hydrogen, and some critical policy opportunities have been missed. For example, in 2020, the Federal Government announced that it was prepared to intervene in the electricity market by

building a gas fired power station in the Hunter Valley. This announcement was criticised for a range of reasons, including that the plant would be a stranded asset as renewables "took over".

However, if the power station had been mandated to run on a blend of 10% green hydrogen, moving over time to 100%, it would have a massive boost for green hydrogen investment and research and development, not to mention removing a major plank of the criticism.

Star Scientific welcomes this Inquiry into the development of the hydrogen industry in New South Wales. The State has been a late comer to the hydrogen party, and yet, alongside Victoria and possibly Central Queensland, it stands to gain the most from the hydrogen economy.

As we argue below, a detailed hydrogen economy audit of assets and gaps across the whole hydrogen chain is a critical first step.

Response to Terms of Reference

Please note: In our comments below we have restricted ourselves to the direct experience of Star Scientific and its subsidiaries.

Topic 1 - The size of the economic and employment opportunity created by the development of a hydrogen industry in NSW, in particular those opportunities for regional NSW.

The response to this question depends on several variables;

- How rapidly is the public and private sector prepared to commit to the development of the hydrogen economy?
- What are the employment consequences of the existing transition from fossil fuel energy to sustainable energy and what is the potential net impact of hydrogen investment?

From Star Scientific's perspective, the employment opportunities are best a broken down into the individual components of the supply chain, and then the uses of hydrogen.

The hydrogen supply chain

- Research and Development

In its early stages this will be the key driver in employment. Star Scientific employs fifteen staff members in its research and development facility at Berkeley Vale, NSW.

The plan is to treble this over the short term and Star Scientific is actively sourcing a site for a purpose-built facility that will accommodate at least 200 employees. We expect the construction of this facility and associated infrastructure will generate significant employment.

In terms of indirect employment benefits, Star Scientific manufactures approximately 95% of its engineering needs on-site and have a local purchase preference policy and this includes site consumables including office supplies and uniforms. Additionally, Star Scientific engages a range of consultants across several functions.

- Green Hydrogen Production - renewable energy sources

As noted above Star Scientific believes that for Australia to fully participate in the hydrogen economy, we need to lift our aspirations for production of green hydrogen by orders of magnitude. We have yet to conduct a definitive study, however it is our view that even if all the states' existing wind and solar resources were turned over to the production of green hydrogen it would still be far from enough.

Therefore, New South Wales would need to encourage significantly higher investment in the resources to produce green hydrogen, the deployment of which would generate significant employment.

The important point here is that this is not a "wind or solar vs hydrogen" discussion. The development of a green hydrogen economy will provide a more efficient business model for existing solar and wind stock and encourage further investment.

Star Scientific is actively investigating the new generation of double-headed, offshore floating wind turbines for investment and development. We see an opportunity for them to be manufactured in and exported from Australia.

- Green Hydrogen Production – electrolysis

There can be no green hydrogen "revolution" without electrolysis. The supply of electrolysers and their cost (and therefore the cost of green hydrogen) is one of the challenges oft-cited as supply-side issue for green hydrogen.

As noted above Star Scientific is actively investigating and may invest in a new generation of super-efficient electrolysers which have the added benefit of being scalable and thus easily transportable.

As with the floating wind turbines referenced above, Star Scientific believes these can be manufactured in Australia for both domestic use and for export.

- Transportation and storage

As noted above on electrolysis, there have been rapid technological advances in the transportation and storage of hydrogen – both in its form (liquid, gas, ammonia and other forms) and in infrastructure.

Star Scientific is investigating several cost-effective, safe options for subterranean storage.

- Deployment

The deployment end of the hydrogen chain also offers major employment opportunities. Star Scientific plans to manufacture its patented HERO® units here in Australia for domestic use and export.

We are also exploring offshore manufacturing sites.

Star Scientific also sees manufacturing opportunities in Australia for the new generation of super-critical $_sCO_2$ referenced above.

Uses of hydrogen

If the hydrogen delivery chain promises to deliver considerable levels of new economic activity and employment, it is in the uses of hydrogen that the most exciting potential lies. This area can be broken down into three subclasses: export, domestic industrial, and domestic residential uses.

One of the most exciting potential benefits is for regional economic development.

- Export

The production and export of green hydrogen is rightly being cited as a large economic opportunity for Australia. Various studies have pointed to Australia's comparative advantages combining an abundance of wind, solar and hydro with established supply infrastructure including rail, gas pipelines and ports. New South Wales is potentially particularly well placed in this regard.

While the potential markets of industrial nations such as Germany, Japan and South Korea have been well documented, Star Scientific believes that some of the most exciting markets for Australia are developing nations in our region, including the Philippines, Indonesia and even India.

This is because the deployment characteristics of hydrogen are far more flexible and therefore complementary with the characteristics of developing nations, particularly those not linked by electricity grids.

There are two additional comments that we would like to make about the export potential for hydrogen:

1. The first is that we believe there are some geo-political limitations to the potential of the hydrogen export market (and the electron export market as well). It is our view that many of our potential markets in developing countries wish to develop energy sovereignty, and that green hydrogen gives them this very opportunity. For those reasons and because of advances in electrolyser and wind technologies, we believe that in the medium term, hydrogen will be produced domestically by these markets.

2. The second is that Australia (and New South Wales) should not limit thinking to the export of the raw material. Australia is currently a global leader in green hydrogen R&D, and we should be targeting the export of manufactured components of the supply chain, and expertise in research, engineering, technology, and finance.

- Domestic Industrial use

As noted above, green hydrogen, using HERO® systems, can be deployed to existing fossil fuel infrastructure including power generation but also for any other industrial process which requires heat.

For example, Star Scientific believes that HERO® and green hydrogen can be deployed for the desalination of water, using superior heat-driven systems that remove the heavy carbon load of traditional desalination plants and wasteful outputs of salts and heavy metals.

Star Scientific notes that US President Joe Biden has flagged the merging of climate and trade policies, for example “green tariffs” on steel imports, and that other jurisdictions are considering these measures. If this is to be the case, then to *protect* Australian jobs and, in particular, the heavy industrial centres of the Hunter and the Illawarra, then rapid commitment to the green hydrogen economy is essential.

- Domestic Residential Use

Star Scientific notes several products and projects to drive personal consumption of hydrogen fuel via fuel cell technology for household energy supplies and personal transport.

We remain agnostic in this area as our mission is to "green the grid", that is to retrofit the existing energy transmission infrastructure to hydrogen, therefore decarbonising existing household energy supply systems and making electric vehicles genuinely carbon-free.

That is not to say we are opposed to residential and individual uses of hydrogen, particularly for long haul vehicles.

If the use of electric vehicles (EVs) is to rapidly increase in Australia then we need to confront the reality that they need to draw their power from green sources, and from our point of view that means a grid that is powered by spinning mass created from green hydrogen and HERO®.

Where we *do* see a key domestic use for green hydrogen is for off-the grid heat and energy uses, particularly in regional centres.

Regional Development

One of the key benefits of green hydrogen mated to a HERO® system and technologies such as super-critical $_sCO_2$ turbines is its scalability. This means we can provide bespoke energy or heating systems for off-the-grid industrial and domestic purposes.

For example, in the last decade a group of entrepreneurs outlined a vision for a series of regional cities developed in New South Wales linked to Melbourne and Sydney via a fast rail system. Star Scientific is not involved with that consortium; however, we would contend that with the employment of HERO®, bespoke local energy systems could be developed that do not require linkages to the existing grid.

The other stark application for green hydrogen via HERO® systems is with identified ore bodies that have been uneconomical to mine because of remoteness from energy sources. Local energy systems based on green hydrogen may make these ore bodies economical for development.

In summary, the promise of a well-developed green hydrogen ecosystem for economic development and employment in New South Wales is profound. The initial opportunities will stem from the development of the hydrogen supply chain for export and domestic uses, and subsequently from the use of hydrogen for industrial and residential energy needs, with benefits accruing to regional development that may have previously been held back by the provision of energy infrastructure.

Topic 2 - The State's existing hydrogen capabilities

Star Scientific regards New South Wales as a world leader in research and development into the production and use of hydrogen. The company alone has invested over $100 million dollars into hydrogen research and is preparing to scale up to invest significantly more. New South Wales and in particular the Hunter/Central Coast region produces world-class scientists and a skilled and inventive engineering workforce. The quality of living in the region is an important lure for our workforce.

A key part of our success is a close association with the University of Newcastle (UON), and its School of Chemistry and the National Institute for Energy and Resources.

To be situated in a region so well served by a skilled industrial and research workforce, backed by an excellent tertiary research institution in UON, and an entrepreneurial and innovate private sector and workforce that is "up" for the energy transition makes the region an ideal base for Star Scientific's global research and development programs. It is also why, in our view, the region should be a leading candidate for the Federal Government's proposed Hydrogen Hub.

In 2019 the COAG Energy Minister's Council released that National Hydrogen Strategy. The technical paper supporting the Strategy was the National Hydrogen Hubs Study, conducted by Arup. Among 30 potential *export* hubs around Australia, Arup identified Newcastle (Kooragang Island), Port Botany / Kurnell and Port Kembla. While the Arup study is a good start, its focus was largely on export.

Star Scientific contends that if New South Wales is to be serious about developing a hydrogen economy then it needs a detailed, granular study into the infrastructure, workforce, and regulatory and investment requirements. The report should envision a multi-faceted hydrogen ecosystem which includes export, industrial domestic use, residential domestic use and research and development.

Star Scientific regards this as the most important potential recommendation of this Inquiry and is prepared to participate in and contribute to this study.

This study will form the basis of an investor prospectus, which we refer to below.

We also believe that the development of this study and the implementation of its recommendations requires high levels of political leadership. As noted above we believe that the economic benefits of the development of a hydrogen economy in New South Wales are potentially profound, and for that reason we strongly recommend the commissioning of a Parliamentary Secretary for Hydrogen.

The Parliamentary Secretary should be supported by a dedicated Office of Hydrogen within the Department of Climate Change and Energy. A key role of this leader would be to be engage with potential investors, of whom Star Scientific believes will be several.

We note the precedent for this has already been set by the Queensland Government, which has a Minister for Hydrogen, a Parliamentary Secretary and dedicated MP "champions".

Topic 3 - The capacity of and barriers to NSW becoming a major production, storage and export hub for hydrogen.

Star Scientific believes that New South Wales, and in particular the Hunter Valley, has significant capacity to develop a self-sustaining hydrogen ecosystem, for both export and domestic use.

The fact that the Hunter has skilled manufacturing, research and development, and energy supply as part of its DNA makes it highly prospective for innovators and investors in the hydrogen chain.

Around the country, Central Queensland and a bubble encompassing northern Tasmania (Bell Bay) and Geelong in Victoria[2] are the prime competitors where these conditions are already *in situ*. This is not to say there are exciting greenfield developments in South Australia, The Pilbara and potentially the Northern Territory.

Specifically:

(a) Star Scientific believes that, by the example of its own investments and its relationship with the University of Newcastle, New South Wales and specifically the Hunter/Central Coast is positioned to make a pre-eminent contribution to Australian and global research and development in green hydrogen.

(b) As noted above, the State, and especially the Hunter and the Illawarra, by dint of their industrial heritage and industrial ports, are well positioned to be major centres of manufacture and export of hydrogen componentry.

[2] The John Curtin Research Centre have published a report giving a good insight into Victoria's thinking on hydrogen: https://static1.squarespace.com/static/587e1296579fb39e3199b6e9/t/5fa21168ca5f3f6309e415de/1604456864601/power+state

(c) Similarly, advances in technology for the storage and transportation of hydrogen will, in our view, lead to a manufacturing boom, not the least for hydrogen transportation infrastructure. We see no reason why this cannot occur in the Hunter and Illawarra, powered by green hydrogen and therefore creating a virtuous cycle.

(d) This is a key aspect of the study we have called for above. To develop a green hydrogen ecosystem in the Hunter and/or Illawarra will require the annual production of millions of tonnes of hydrogen. Mapping of the available land and sea resources, including their reservation for hydrogen production is essential, along with the hydrogen delivery systems such as road, rail, and gas pipelines. Also, of importance will be community "buy in" along environmental and social-economic equity grounds.

(e) While hydrogen for transport is not a primary area of expertise for Star Scientific, if green hydrogen is produced in the volumes envisioned above, then hydrogen supply should not be an impediment to the use of hydrogen for transport.

(f) As noted above, Star Scientific believes these are the primary, and most exciting applications for hydrogen. Any process which requires heat can be served by hydrogen using Star's Scientific's HERO® systems, continuously and without emissions.

(g) As noted above, Star Scientific has conducted a theoretical study on the retrofitting of a major coal-fired power station using our HERO® technology. Preliminary findings are that it is a relatively simple process, and the facility will make significant capital and recurrent savings as a result.

(h) As noted above, Star Scientific believes the safety and safeguarding of hydrogen utilisation is amongst the most important work that the COAG Energy Ministers committed to at their meeting in November 2019, which adopted the National Hydrogen Strategy. For the hydrogen industry to emerge and bloom, safety and standards are critical for community confidence and social license. Star Scientific serves on several technical committees and have committed to achieving ISO 14001 certification.

Critical to this work will be the education of regulatory officials in industry, as well as the three levels of government. One of the most concerning potential barriers to the hydrogen sector is it being slowed down by gaps in the hydrogen regulatory regime and a lack of awareness of the existing regulations.

Topic 4 - The economics of hydrogen's use in different sectors of the economy, including emerging opportunities to use hydrogen in industrial processes and as a feedstock.

A significant number of studies have examined this topic globally, and most of them boil down to the following conclusion:

"hydrogen energy is relatively expensive, however with growing levels of demand, economies of scale and technical innovation it will be competitive sometime by 2030-2050"[3].

While the fundamentals of this statement are correct, as we state above, we believe too much focus is placed on supply-side challenges. Star Scientific believes that a hydrogen revolution will occur significantly quicker than these reports predict, and the company is prepared to back its judgment by investing hundreds of millions of dollars in New South Wales and elsewhere.

Topic 5 - The infrastructure, technology, skills, workforce capabilities and other things needed to realise the economic opportunities of hydrogen as and when it becomes commercial in different sectors of the economy.

If New South Wales is to take advantage of the global hydrogen revolution, it needs to attract private sector investment against the backdrop of some highly vigorous competition, both here in Australia and globally.

It needs to develop a prospectus outlining the State's existing hydrogen assets as well as any existing gaps. A good example the recent materials developed by the Tasmanian Government to support their Strategy.

This prospectus will be drawn from the detailed study we recommend above into the existing infrastructure, and skills base and gaps that need to be filled, with specific reference to the Hunter and Illawarra.

Star Scientific suggests that the Federal Government's investigation into its first Hydrogen Hub might be the target of such a study.

[3] See, for example, https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf,

Topic 6 - The actions needed of the public and private sectors, to support the development of a hydrogen industry in NSW and to realise the associated economic opportunities, including actions to manage any safety risks in the hydrogen industry.

As noted earlier the two most important actions of government (in cooperation with industry) are:

- The study and prospectus referred to in Topic 5.

- Continued work on standards, regulation, and safety of the hydrogen chain, alongside community education programs to raise awareness of hydrogen.

Topic 7 - The potential for jobs in New South Wales, both directly in the hydrogen industry and in other industries powered by hydrogen

We have answered this in several places above as part of Topic 1.

MEDIA RELEASE **28 January 2021**

How Star Scientific Limited's cutting-edge hydrogen innovation will help drive Philippines sustainable economic development

The Department of Energy of the Republic of the Philippines to utilise award-winning Australian green hydrogen technology to drive the abundant clean energy and desalinated water foundations of its economic growth.

(Sydney, Australia) Leading hydrogen research, development and deployment company, Star Scientific Limited, has signed a Memorandum of Understanding (MoU) with the Department of Energy of the Republic of the Philippines to help drive the country's energy self-sufficiency and economic development through green hydrogen as a fuel source.

At the heart of the MOU is Star Scientific Limited's breakthrough technology, the Hydrogen Energy Release Optimiser or HERO®. The S&P Platts award-winning HERO® technology is a true catalyst that converts hydrogen and oxygen into heat and water, without degrading the catalyst. There is no combustion, and the only outputs are heat and pure water. The HERO® catalyst can generate temperatures beyond 700 degrees Celsius in just over three minutes, and it is being used as the heat source in the HERO® heat exchanger system.

For the Philippines, which is largely reliant on imported fossil fuels, HERO® heralds the hydrogen revolution and provides an opportunity for energy as well as water security and self-sufficiency in an environmentally sustainable and responsible way.

The objectives of the MoU will see Star Scientific Limited and the Department of Energy of the Republic of the Philippines to study retro-fitting existing coal-fired power plants to run on the HERO® system powered by green hydrogen. They will also work together to explore the utilization of green hydrogen production in the Philippines using an abundance of offshore wind resources.

Additionally, the parties will investigate decentralised scalable power systems for all of the Philippines' inhabited islands utilising green hydrogen, HERO® and the new breed of supercritical CO_2 turbines. The parties also aim to use the HERO® system for decentralised desalination of ocean water. The aim of the working relationship is to bring abundant clean energy and desalinated water to the people of the Philippines. Additionally, the Philippines will have the opportunity to offer global companies zero emissions manufacturing capability.

As part of the MoU, the Star Group will assist the Philippine Department of Energy with the development and implementation of funding models to attract global financing for the different aspects of all the projects as they develop.

Global Group Chairman of Star Scientific Limited, Andrew Horvath, said he was proud that an Australian innovation had captured the attention of a national government that wanted to drive its

economic development through an environmentally sustainable energy source for power generation and water desalination.

“This agreement with the Department of Energy of the Republic of the Philippines represents a significant milestone in the development of the global hydrogen economy. Thanks to this bold and visionary step by the Philippines, we can begin to see the reality of whole economies turning over to hydrogen and a rapid acceleration to sustainable energy on a global scale. This is just the start,” Mr Horvath said.

“This will represent the largest single boost to Australia’s role in developing the global hydrogen economy, heralding a new era of research, development and deployment in the manufacture and installation of all parts of the hydrogen supply chain. We are particularly grateful and excited to be part of the next phase of the Philippines’ economic growth.”

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About Star Scientific Limited

Star Scientific Limited is a leading hydrogen research, development and deployment company based in Australia, with a global reach and scope.

Star Scientific Limited discovered and developed a breakthrough technology for converting hydrogen into heat without combustion – the Hydrogen Energy Release Optimiser, or HERO®.

HERO® is unique. It has been patented globally and has no competitor. While hydrogen - particularly green hydrogen - is enjoying significant global attention at present, there is a gap in its deployment for industrial purposes. Star Scientific Limited believes this is where HERO® will allow hydrogen to achieve its full potential, whilst simultaneously enabling supercritical CO_2 turbines to also achieve their full potential.

HERO®, which won the S&P Platts Global Energy Award for Emerging Technology of the Year 2020, has been designed to begin its commercial deployment through retrofitting coal-fired power stations, which will ensure the ongoing life of the industrial infrastructure associated with power generation whilst making it zero emissions. HERO® will be deployable for decentralised small-scale power solutions in remote locations or for large scale legacy power generation and industrial heat production. HERO® will also be deployable for highly efficient decentralised ocean water desalination at a large or small-scale.