Solving Queensland's trilemma

(and legacy benefits of commercialising clean tech and storage)

Introduction.

The Council Of Australian Governments (COAG) have accepted 49 of the 50 recommendations made in the final report of the *Finkel Review into Australia's National Energy Market (NEM)*, including the need for battery storage of electrical energy, to ensure integrity of the grid network.

In the weeks that followed publication of these recommendations, federal minister for energy and environment Hon Josh Frydenberg MP frequently referred to key energy security challenges as a "trilemma" where policymakers must have regard to ensuring: energy security; downward pressure on electricity prices; and Paris Accord carbon dioxide emissions targets. One would be excused for assuming these are competing factors. The public's general impression is of a *choice*, for example between cheap and reliable[1] coal fired electricity on one hand, *or* greenhouse gas reduction on the other. Or the electricity supply certainty provided by pumped hydro, *weighed against* the CO_2 emissions caused by pumping gigalitres of water uphill into 'reset' the generator.

All governments agree on the need to maintain dispatchable electricity[2] supply. In the developed world, it is primarily required for:

1. **Load matching**. This refers to the changing need for power throughout the day since generally far less electricity is needed at night than during the day. Load matching plants can vary their output slowly over hours to meet the general trend in this.
2. **Peak matching.** Peak matching is done by power plants to meet the highest electricity use during the day. Demand typically peaks for power grids at a relatively predictable time, depending on culture, weather and geographic location.
3. **Covering lead-in times.** A lead-in time is the amount of time that a power plant takes to get to its desired output. Many of the common power plants take some time to achieve this. Therefore, it is important for power generation that can be deployed quickly to ensure the supply meets the electricity demand during these times.
4. **Covering intermittent sources.** Intermittent electricity sources such as solar and wind not stored in batteries, do not produce consistent electricity, therefore their power output cannot be controlled. Although they provide valuable electricity, they do not provide guaranteed electricity, therefore dispatchable sources are required when they are not meeting their production demands.
5. **Load shifting (or "peak shaving").** This is where cheap "off peak" energy is downloaded from an energy grid into a utility scale battery storage facility and then delivered back to the grid at peak demand times when the system strains to match demands placed on it.[3]

The fact that batteries can perform, or support, all of the abovementioned functions make them vitally important to solving the "trilemma" (of reliable supply, affordable power, and greater reliance on renewables in the energy "mix").

This paper is to aid the Queensland government's internal discussion about its future reliance on battery storage technology *vis a vis* (and connected to) other sources of dispatchable electricity, and in deciding which battery technology to adopt. It also offers suggestions to retain maximum value

[1] Notwithstanding evidence to challenge assumptions about both reliability and value of fossil fuels: http://reneweconomy.com.au/far-right-hijacked-australias-energy-policy-11836/
[2] In an electrical power system, sources such as power plants can be turned on or off; in other words they can adjust their power output supplied to the electrical grid on demand.
[3] The use of large scale batteries is explored in the FC Power Solutions review of Renewable Embedded Generation proposed for the fringe of grid in NSW. Tesla CEO Elon Musk indicated the Tesla battery might be employed to fulfil this function once it is installed in South Australia.

for the Queensland economy, further to the functional benefits of securing battery storage infrastructure.

Comparing battery storage options

1. Vanadium Flow (Redox) Batteries (VRB)

In July 2017, a senior policy officer from DEWS attended the University of NSW and met with HydroSun's corporate affairs manager, and officers of the University of NSW Energy Institute, UNSW Mechanical and Manufacturing Engineering schools, and the university's Vanadium Redox Battery research team. She observed a 130kWh vanadium flow battery in operation at the Tyree Energy Technologies Building, and led discussion on the relative merits of lithium ion, vanadium flow, lead acid, and silicon battery technologies for dispatchable power storage. VRB technology holds several advantages over Lithium-Ion batteries:

- VRB has a levelized cost of storage between a quarter and a half of the cost of the lithium ion alternative
- they offer easy scalability (into large MWh scale solutions – by increasing the size of the tank and therefore its electrolyte to increase the energy stored)
- a lifespan of 20+ years
- no capacity loss over time
- immediate energy release
- excellent charge retention (energy stored in electrolyte tanks represents up to 80% of total stored energy that has indefinite capacity retention)
- the ability to discharge 100% with no damage
- the state of charge of the battery is measured by monitoring one body of liquid (in two electrolyte tanks) rather than in multiple cells. With an upscaled lithium ion battery there will likely be thousands of cells connected, with the entire infrastructure working or failing at any given time due to one faulty cell.
- end of life value is retained in the vanadium electrolyte which can be re-used or sold. Since the value is maintained, there is scope for Queensland to establish a vanadium electrolyte leasing industry.[4]

A vanadium flow battery connected to a wind farm in Hokkaido (Japan) was recharged over 200,000 times without incident, and membrane components now last more than 10 years before they need replacing. So confident are the Chinese in this Australian invention, an 800MWh battery facility was announced there in 2016 and is currently under construction in Dalian City.

In 2012, the US Department of Energy noted;

> *"The redox flow battery is well-suited for storing intermittent, renewable energy on the electricity grid. The technology can help balance supply and demand, prevent disruptions and meet the grid's varying load requirements… Redox flow batteries can also help utilities during times of peak demand on the grid, providing additional power when it is needed. Successful commercialization of DOE-sponsored technology development, such as this, is vital for creating the grid of the future, and sustaining U.S. leadership in advanced technology."*

The only downside might be that vanadium flow batteries need a larger amount of space of storage size compared to that required by a lithium ion battery of equivalent capacity. SEE ATTACHED

[4] https://www.thebushveldperspective.com/vanitec-2nd-energy-storage-meeting-part-1/

COMPETITIVE ANALYSIS. For utility scale battery infrastructure storing hundred or more megawatt hours, the size of storage containment is an irrelevance in most cases in regional Australia.

The superiority of flow batteries over lithium ion batteries is well known to readers of clean tech niche media[5], and in the chemical and electrical engineering community.

The original UNSW vanadium battery patents expired in 2006 and since then, many companies around the world have been commercially exploiting the technology. The UNSW team have however continued to refine the technology and have filed several improvement patents in recent years. Many companies (including Rongke Power, manufacturer of the 800MWh battery being built in China) continue to use UNSW's original electrolyte composition. (UET's advanced electrolyte chemistry is patent protected, and not available to other VFB manufacturers, although Rongke Power stacks are used for both chemistries)

2. Lithium Ion Batteries

Lithium is the lightest known metal and consequently it has excellent applicability for transportable devices (such as motor vehicles, telephones and watches). As any mobile telephone user would know, these batteries have a finite life span, and less effectively hold a charge with each recharge cycle. Moreover, if the device is completely discharged then recharged this considerably shortens a lithium ion battery life span.

There is a potential ulterior motive for Premier Weatherill to pay more than double what he should for a 129MWh battery, and why it might make sense for Tesla CEO Elon Musk to risk delivering it free-of-charge (if he fails to meet the agreed 100-day deadline). South Australia is seeking to replace the lost manufacturing employment that will occur when Holden finally closes its manufacturing plant in October 2017[6]. Tesla has publicly cited the shortage of lithium battery supply as a key reason for falling short on its recent deliveries of motor vehicles to market.[7] It remains to be seen what will happen to the assembly plant announced for SA once it fills the 129MWh order for the state's energy grid, however it would seem less of a waste of taxpayer funds if it emerges it was part of a long term 'play' for a slice of the electric car manufacturing market. That market is expected to take off after 2023 when analysts[8] predict electric motor vehicles will be cheaper than petroleum fuelled cars. It is expected that many countries will follow the UK's lead in banning petroleum fuelled cars after 2040.[9]

The world's two largest lithium mines are both in Western Australia. At the most recent state election, Pauline Hanson's One Nation Party articulated that the state is missing out by "digging and shipping" its lithium to China and reimporting transformed manufactures, thereby losing value chain benefits like jobs creation. Governments that use taxpayer funds to invest in purchasing Elaborately Transformed Manufactures (ETM) should consider whether they might also retain benefit from the value chain. In the absence of a lithium minerals exploration and extraction capacity, Queensland's investment in a lithium ion battery, and even establishment of a Li-Ion battery assembly plant, would ultimately drive mining royalty benefit for WA.

Standards Australia has released a "draft voluntary standard, DR AS/NZS 5139:201X Electrical installations – safety of battery systems for use with power conversion equipment". It is open for public comment until 15th August 2017. The Minister for Energy and Water Services should note the

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[5] https://cleantechnica.com/2015/06/21/flow-battery-vs-tesla-battery-smackdown-looming/
[6] http://www.abc.net.au/news/2017-01-13/holden-announces-october-closure-date/8181144
[7] https://www.businessinsider.com.au/tesla-car-deliveries-for-the-second-quarter-2017-7?r=US&IR=T
[8] https://www.youtube.com/watch?v=mRRzDaX7ZVs&feature=em-share_video_user
[9] http://www.abc.net.au/news/2017-07-26/uk-to-ban-sales-of-petrol-diesel-fuelled-cars-from-2040-reports/8744076

recommendations when they are made. While Standards Australia states; "the use of all Australian Standards is voluntary and governments may choose to reference Australian Standards and other documents in regulation", DEWS would know Australia has ratified the International Risk Management Standard. Since the legal matter of Telstra Vs Hornsby Shire, the precautionary principle[10] now has an Australian domestic precedent. Consequently, DEWS should advise its minister to take sufficient steps to protect the public from injury, and to safeguard infrastructure.

Where governments purchase battery storage to guarantee energy supply, it should consider best taxpayer value, it should note the cost to business of power outages[11]. In the event of a potential future failure of battery storage made or installed in Queensland, it is likely that legal action might seek damages from government for people and property affected[12]. Thus, not only is it an obligation, it is a sensible that government undertakes *formal risk assessment* – including risk identification, risk analysis and risk evaluation[13].

Throughout its term in office, the Palaszczuk government has encouraged thoroughgoing inquiry of contentious public policy issues. This has fostered confidence in government decision making, aligned with the key principle of the Office of Best Practice Regulation (legislation and regulations should be "sensible, workable and evidence-based"). While DEWS and the Minister awaits outcomes of the review by Standards Australia, the department might independently engage those with expertise in:

- OH&S (including the Queensland Electrical Trades Union, and WorkCover, noting the loss of life and the political fallout from the federal government's pink batts scheme);
- asset procurement quality control (for example the major manufacturers of lithium ion batteries now x-ray every single cell as part of automated quality control. Software used in the manufacturing process examines anomalies such as bent tabs or crushed jelly rolls. Uneven separators can also trigger cell failure. Poor conductivity due to dry areas increases the resistance, which can generate local heat spots that weaken the integrity of the separator;
- government asset management (ensuring battery device is situated away from flammable materials and placed on a non-combustible surface outdoors since it might become necessary for it to be left to burn out);
- insurance and reinsurance (to avoid a potential dispute about proper system maintenance, the proper recording and repairing accidental damage, and possible voiding of warranty); and
- fire emergency response (metropolitan and rural fire services, to ensure appropriate tools are at hand to extinguish a fire, and that training is provided in responding to "thermal runaway").

Cadex[14] likens managing the catastrophic failure of battery cells to ensuring the integrity of built water infrastructure, something well understood by DEWS, DPC, and those involved in Queensland politics since 1974.

> *"The real problem lies when on rare occasions an electrical short develops inside the cell. The external protection peripherals are ineffective to stop a thermal runaway once in progress.*

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[10] https://www.claytonutz.com/knowledge/2006/july/getting-connected-with-the-precautionary-principle
[11] http://www.abc.net.au/news/2016-12-09/sa-blackout-costs-could-have-been-worse-business-sa-says/8106600
[12] At the time of writing, Gilbert and Tobin lawyers continue with their class action for damage done to property as a result of the Queensland floods.
[13] Noting expert witness statement by D Stark to the Royal Commission into the Home Insulation Program (Pink Batts Scheme).
[14] http://batteryuniversity.com/learn/article/safety_concerns_with_li_ion

The batteries recalled in 2006 had passed the UL safety requirements — yet they failed under normal use with appropriate protection circuits…

A mild short will only cause elevated self-discharge and the heat build-up is minimal because the discharging power is very low. If enough microscopic metallic particles converge on one spot, a sizable current begins to flow between the electrodes of the cell, and the spot heats up and weakens. As a small water leak in a faulty hydro dam can develop into a torrent and take a structure down, so too can heat build-up damage the insulation layer in a cell and cause an electrical short. The temperature can quickly reach 500 ℃ (932 ℉), at which point the cell catches fire or it explodes. This thermal runaway that occurs is known as "venting with flame." "Rapid disassembly" is the preferred term by the battery industry."

To conclude, the key *disadvantages* of Li-Ion are:

- A levelized cost of storage is more than double that of Vanadium Flow (see detailed breakdown of business input costs)
- They are not practical as large-scale MW infrastructure, despite the SA project that will connect multiple small units[15]
- A short lifespan (7,000 recharge cycles, which amounts to less than 10 years, and sooner if there are multiple charges each day)[16]
- Capacity loss over time (battery less effectively holds a charge with each cycle)
- The ability to only discharge battery 70% with no damage (as opposed to 100% with VRB)
- Overheating, and combustion, and the inability of fire services to extinguish a fire once started until infrastructure is destroyed.
- The conjoining of multiple cells which must be tested individually makes the state of charge difficult to manage (faulty or under-performing cells will impact the entire system)
- End of life disposal is an issue with lithium, whereas vanadium can be re-used and retains its value.

Lead Acid Batteries

The lead-acid battery was invented in the mid 1800's and is the oldest type of rechargeable battery – though readily in use today. Thus, it is technology that is familiar and one that provides a good reference point for comparison.

As a system built on a heavy metal, it has a very low energy-to-weight ratio and a low energy-to-volume ratio. However, it supplies a high surge current (cells have a relatively large power-to-weight ratio). These features, along with their low cost, makes lead acid batteries to provide the high current required by automobile starter motors (though their weight makes them impractical as a car's main energy source).

As they are inexpensive compared to newer technologies, lead-acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. Large-

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[15] The Tesla Powerwall 85kWh has 16modules of 444 cells for a total of 7,104 cells which all need to be monitored. Larger utility scale systems will also require cell voltage balancing, because when cells are in series, the performance of the overall system can be limited by the performance of the weakest cell. In grid scale applications, when cells are in series, performance of the whole system can be limited by the performance of the weakest cell.

[16] The amount of energy available and how long the batteries last is closely related to the quality of the materials used. Higher quality, purer (uniform consistency) materials and customised formulations lead to longer battery life and better battery performance.

format lead-acid designs are widely used for storage in backup power supplies in mobile phone towers, high-availability settings like hospitals, and stand-alone power systems (emergency back-up power for off-grid residential, for short periods). For these roles, modified versions of the standard cell may be used to improve storage times and reduce maintenance requirements. *Gel-cells* and *absorbed glass-mat* batteries are common in these roles, collectively known as VRLA (valve-regulated lead-acid) batteries.

Lead acid batteries account for around 40% of the total value in world sales, and their availability provides for their low cost.

They are not a practical option for consideration as large-scale MW energy storage systems for several key reasons:

- They have a low depth of discharge (40% compared to 70% for lithium ion and 100% for vanadium flow batteries)
- A very short life cycle (1000 compared to 7,000 for lithium ion and 25,000+ for vanadium flow)
- They retain no residual value once spent (whereas lithium ion batteries hold *negative value*, as distinct from a 25% value of flow battery componentry – which allows for recycling)
- Whereas vanadium flow batteries do not degrade at all, and lithium ion batteries degrade by only 3.13% per annum, lead acid batteries degrade by almost 30% each year)

3. Silicon Batteries

South Australian firm 1414 Degrees has announced a mid-2017 Initial Public Offering (IPO) to float the business[17].

While the company has made some impressive claims about its silicon battery, it has yet to make public all information around the Levelized Cost of Storage claimed.

When researching different battery storage technologies for a Market Led Proposal for Queensland, HydroSun discounted these batteries for several reasons:

- The system generates a significant amount of heat as 'by–product'. This renders the battery economically unviable in a 'hot country' like Australia, however it may be ideal for those countries in which central heating used (such as Scandinavia, Holland and Belgium).
- There appears to be no plan to establish an assembly or manufacturing presence in Queensland
- There appears to be no plan to source manufacturing inputs from Queensland to derive vertical integration benefits for the state

The company appears to be attempting to sell its heat output issue as a positive, arguing it can deliver heat energy for hydroponic farms (an outcome that is simply impractical for Queensland)

[17] http://www.afr.com/business/energy/hydro-energy/silicon-battery-firm-1414-degrees-ignores-teslasnowy-hydro-blitz-for-ipo-20170316-gv04rz

Levelized Cost Of Storage (LCOS) data

Levelized Cost of Storage, or LCOS is a means of comparing energy storage technologies, by considering the cost of the storing energy out over its lifetime. Simply put it is the lifetime sum of all the costs; construction, maintenance, divided by the amount of electricity storage during its lifetime

The following table covers the LCOS of three key technologies Vanadium Flow, Lithium-ion and Lead acid. This is based on current market price assumptions of reliable quality products and their performance specifications. The comparison is based on a 5-hour duration system which is the optimal energy duration for energy storage coupled with solar generation to provide low cost base load solar power.

The table below shows the clear benefits of Vanadium Flow batteries over Lithium Ion and Lead Acid batteries. VRBs are 50% cheaper than Lithium-ion and 25% the cost of Lead acid over its lifetime. This cost analysis does not also include the cost of disposal for Lithium Ion and Lead Acid technologies which is a large environmental problem. Vanadium flow batteries are fully reusable, the only technology resource in the energy sector which is not a consumable and doesn't create pollution and waste.

	Vanadium	Lithium Ion	Lead Acid Battery
Duration (hours)	5.0	5.0	5.0
Capital Cost (USD$/kWh)	$425	$450	$250
Roundtrip Efficiency (%)	75%	88%	80%
Depth of Discharge (% of Capacity)	100%	70%	40%
Cycle Life	25,000	7,000	1,000
Remaining Capacity (%)	100%	70%	60%
LCOE 10 Year (US$/kWh)	0.12	0.21	0.45
LCOE 25 Year (US$/kWh)	0.11	0.19	0.41

Recommended manufacturers of large scale Vanadium Flow machines

RedT energy storage plc is one of the oldest Vanadium Flow companies in the world, having developed its technology over 17 years. RedT in 2016 launched the world's lowest cost vanadium flow machine into Europe and Africa, later 2017 it plans to launch its product range into Australia. RedT has manufacturing floor space of 3.4 million square metres across the world - six times that of Tesla's gigafactory. RedT uses the original simple UNSW formulation for VRB technologies. RedT has a proven track record of success with systems deployed with Europe's leading energy companies. RedT is prepared to establish a permanent manufacturing presence in Queensland, after the initial assembly of its first machine in Australia. RedT is also considering manufacturing its proprietary vanadium electrolyte utilising access to local Vanadium resources to create a local downstream supply chain setup in Australia.

Auspac Energy Technologies Ltd is the Australian sister company of UET, which has a proven track record in manufacturing and delivering world-class batteries, with over 150MWh of projects to date. Advanced engineered UET systems assist utilities, independent power producers, microgrids, the military and a wide range of commercial and industrial applications in the US, China and Europe with the transition to a smarter grid. UET is in business partnership with Rongke Power, which is currently building the world's largest battery: a 200MW/800MWh Storage Plant in Dalian City, China. Like redT, AET/UET are prepared to establish a permanent manufacturing presence in Queensland, using locally-sourced vanadium, following local assembly of an industrial scale VRB. Further information on AET/UET accompanies this document.

Options for consideration

1. Market Led Proposal (MLP) under consideration by Cairns Regional Council

Australian renewable energy business, HydroSun, has welcomed comments by Queensland Premier Anastacia Palaszczuk that the state will push for a “battery factory in Queensland, with incentives and a new training program potentially on offer to entice such a business to the state”.[18]

Since November 2016, HydroSun has been preparing a Market Led Proposal (MLP) that involves kick starting new industries in north Queensland in renewable energy, battery storage, and related supply. HydroSun proposes a 40MW floating solar farm, with energy generated there stored in a 200MWh battery. This is scaled to provide clean energy to service Cairns’ projected growth (18,000 new homes are planned for the region). The battery would also be deployed to load shift energy from the grid.

An integrated floating solar farm and vanadium flow battery of this size would sufficiently warrant a Public Private Partnership (PPP) to pursue the Queensland domestic production of:

- Vanadium flow batteries[19] (redT or UET working with UNSW);
- Vanadium mineral extraction supply chain (Australian Vanadium Limited)
- Vanadium electrolyte production (Australian Vanadium Limited)
- Components for next generation floating solar units (HydroSun, with an Environmental Impact Study delivered by James Cook University and the Mulloon Institute[20])
- (Potentially) next generation solar PV panels (QUT and Sumitomo Electrical).[21]

HydroSun has been in communication with the Department of Energy and Water Services (DEWS) since 19 April 2017 about the work of the *Queensland Expert Panel on Renewable Energy*. And since agreement was reached at COAG on 49 of the 50 recommendations of the *Finkel Review of the National Energy Market*, HydroSun has been in regular communication with DEWS about:

- the Powering Queensland Plan[22]
- the reverse auction for 400MW of new renewables including 100 MW of storage[23]

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[18] http://www.couriermail.com.au/news/queensland/premier-wants-teslastyle-battery-factory-for-queensland/news-story/0d35ad2a6817862ae9cd234a612e0144

[19] Solar farms are now situated on lakes, dams and reservoirs in China, India, Japan and the UK. In a speech in Townsville Queensland Opposition Leader Hon Tim Nicholls referred to the UK floating solar farm as the sort of Market Led Proposal the LNP would back if elected. Vanadium Redox Batteries are now in operation in Washington (USA), California (USA), Hokkaido (Japan), Utah (USA), St. Petersburg (Florida) Gelderland (The Netherlands), Sumba Island (Indonesia), Gongju (South Korea), Évora (Portugal), Cornwall (UK) Liaoning (China), Yokohama (Japan), Kolarovo (Slovakia) and Koblenz (Germany). redT, the proposed PPP stakeholder recommended in this paper for consideration by the Queensland government built the battery installed in Cornwall: http://www.redtenergy.com/blog/redt-largest-cornwall-project

[20] A UN Sustainable Development Goals partner agency

[21] A project announced by Premier Palaszczuk that partners QUT with Japanese firm Sumitomo Electrical, which has experience with both VRB technology, and with next generation solar PV cells. Academics from QUT currently working with Sumitomo have worked previously with UNSW Professor Maria Skyllas-Kazacos, the Australian inventor of VRB.

[22] https://www.dews.qld.gov.au/electricity/powering-queensland-plan

[23] https://www.dews.qld.gov.au/__data/assets/pdf_file/0006/1253832/transitioning-to-low-carbon-energy-sector.pdf

- the Queensland Advanced Manufacturing Roadmap[24]
- the potential to source next generation solar panels (noting Premier Palaszczuk announced a R&D partnership between QUT and Japanese firm Sumitomo Electrical Industries).[25]

The 40MW floating solar farm that HydroSun proposes for Cairns matches the generative capacity of the world's largest[26], and would provide clean energy to 18,000 homes planned for the Cairns region. The (Australian) inventor of floating solar, Soren Lunoe, offers his latest improved design, secured by an international design patent in May 2016, with several improvements over his early design now in operation worldwide. The storage capacity is one quarter of the 800MWh capacity announced already in China[27]. In preparing its MLP for Cairns, HydroSun is aligned with Premier Palaszczuk's objectives to:

- **provide job opportunities for people with a range of skill sets.** HydroSun's proposal focuses on the regional development benefits of economic diversification, and the economic principle of "value capture" (as articulated in the Australian Infrastructure Plan). Consequently, its MLP has the written third-party endorsement of business groups including Advance Cairns and Cape York Sustainable Futures. HydroSun has long established a Corporate Social Investment commitment[28] of allocating 20% of its pre-tax profits to philanthropic causes. As such HydroSun has engaged Job Network service provider Impact Employment to fill roles including a quota reserved for Yidinji and Yarrabah people in the seats of Cook and Barron River. HydroSun also intends to work with Migrant Talent and Refugee Talent (agencies to recruit skilled migrants and refugees).
- **drive support training in schools.** HydroSun has proposed that if its project is announced during the forthcoming election campaign it can establish factories for both floating solar and vanadium flow batteries, hire workers, and deliver infrastructure all in good time to allow the government to switch on the infrastructure more than a year out from the subsequent election. During years 3-4 (while the Mulloon Institute and James Cook University provide an independent assessment of the environmental benefits of the infrastructure package), HydroSun proposes that all workers hired for the project will be retained and provided ongoing formal training through TAFE and universities. This is to allow the government *the option of* announcing further infrastructure project work in floating solar and vanadium flow batteries in the subsequent election.
- **offer incentives to private enterprise to attract such a new business to the state.** HydroSun notes One Nation has a policy of offering a payroll tax free holiday for new businesses. HydroSun feels notes Queensland already has the lowest payroll tax rate in Australia (established by the Beattie government and maintained by Labor and LNP governments since). Of more benefit to renewable energy businesses would be (revenue neutral) incentives for electric motor vehicles borne by drivers of petroleum fuelled cars[29]
- **Undertake a co-operative arrangement.** HydroSun commends the Queensland government's approach to this project, and has since 2016 been pursuing an arrangement

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[24] This document articulates a vision "for Queensland's advanced manufacturing sector to test and deploy innovations such as composites for wind turbines, cooling tower design for solar thermal generators, as well as the next generation materials for solar panels and batteries."

[25] http://statements.qld.gov.au/Statement/2016/11/15/premier-hails-renewable-energy-trial-between-qut-and-japanese-company

[26] https://phys.org/news/2017-06-solar-farm-china-energy-ambitions.html

[27] See excerpt from the presentation by Prof Huamin Zhang from Rongke Power at the recent International Flow Battery Forum in Manchester, attached.

[28] https://www.hydrosun.com.au/philanthropy

[29] See page 2 HydroSun's MLP for Cairns; "While some state governments are actively considering how best to transition to electric motor vehicles is too early to project the rate at which this will be achieved. State Government can influence this, however, through measures such as waiving metropolitan road tolls on electric cars (with a concomitant increase payable by petroleum fuelled cars), and waiving stamp duty on new electric or hybrid motor vehicles".

whereby a range of businesses seen as market leaders can coalesce to establish new enterprise in Queensland, maximise jobs and growth, and establish the most valuable vertical integration (from minerals extraction, to assembly, manufacturing, and ultimately export growth for Queensland manufactures).

The 'reverse auction' being planned by DEWS

HydroSun's proposal before Cairns Regional Council (described above) includes generation and storage in a specific 1:5 ratio (being 40MW floating solar[30] farm and 200MWh vanadium flow battery[31] storage facility).

Since the publication of the Finkel Review and Queensland Expert Panel on Renewable Energy reports, the Queensland government has announced a reverse auction[32] for 400MW of new renewables and 100 MW of storage (a ratio of 4:1)

HydroSun can design a new project (either for Cairns as planned or another Queensland location) to establish

- 400MW of floating solar generation including 100MW vanadium flow storage; or
- 20MW of floating solar generation including 100MW vanadium flow storage (maintaining the optimum ratio in order not to waste renewable energy generated and allow the battery storage to arbitrage the NEM.

Vanadium minerals extraction and electrolyte production

HydroSun and UNSW recommend a Public Private Partnership that includes Australian Vanadium Ltd.

The company is set to produce vanadium electrolyte to supply batteries within Australia and internationally. AVL has installed a vanadium electrolyte pilot plant at the University of Western Australia, where the company has successfully produced battery grade vanadium electrolyte. The company has signalled it "will either produce the electrolyte at a mine-attached facility, or on the east coast if the market dictates that makes more economic sense".

Australian Vanadium Limited looks forward to working with the Queensland government to establish not only vanadium minerals extraction capacity in Queensland, but also electrolyte production and recycling. This is to derive maximum value for the Queensland economy – beyond the already lowest cost of storage of safe storage systems.

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[30] https://en.wikipedia.org/wiki/Floating_solar
[31] https://en.wikipedia.org/wiki/Vanadium_redox_battery
[32] https://www.dews.qld.gov.au/__data/assets/pdf_file/0006/1253832/transitioning-to-low-carbon-energy-sector.pdf