Mitsubishi Corporation

GRID SCALE ENERGY STORAGE

University of Auckland Business School
Summer School in Energy Economics

Presenter: Mark Booth, Mitsubishi New Zealand Ltd.

Approach to this presentation

- What's in and what's out for this presentation.
- What we historically mean by energy storage in New Zealand.
- What's happening next door in Australia.
- The role and opportunity for grid scale batteries around the world.
- What's happening now in New Zealand.
- A personal view of what might develop in future in NZ.

Disclosure: *The author is an employee of Mitsubishi Corporation, which has interests in grid scale energy storage both as an investor and as a promoter of energy storage solutions in certain markets including Australia and New Zealand. Specifically these storage products include the 'Advancion' brand developed by the AES Corporation and now marketed via the company Fluence, itself a joint company of AES-Energy Storage and Siemens Energy Storage. The views in this presentation are solely those of the author.*

What kind of energy storage will this presentation cover?

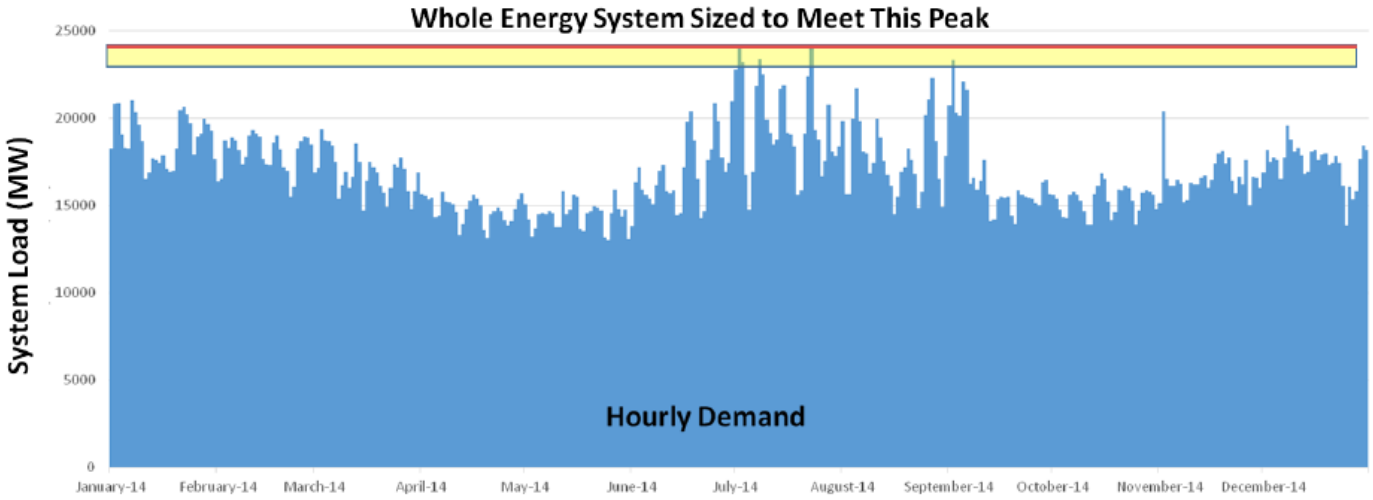
The application of energy storage at the level of commercial, industrial, transmission and distribution and utility levels.

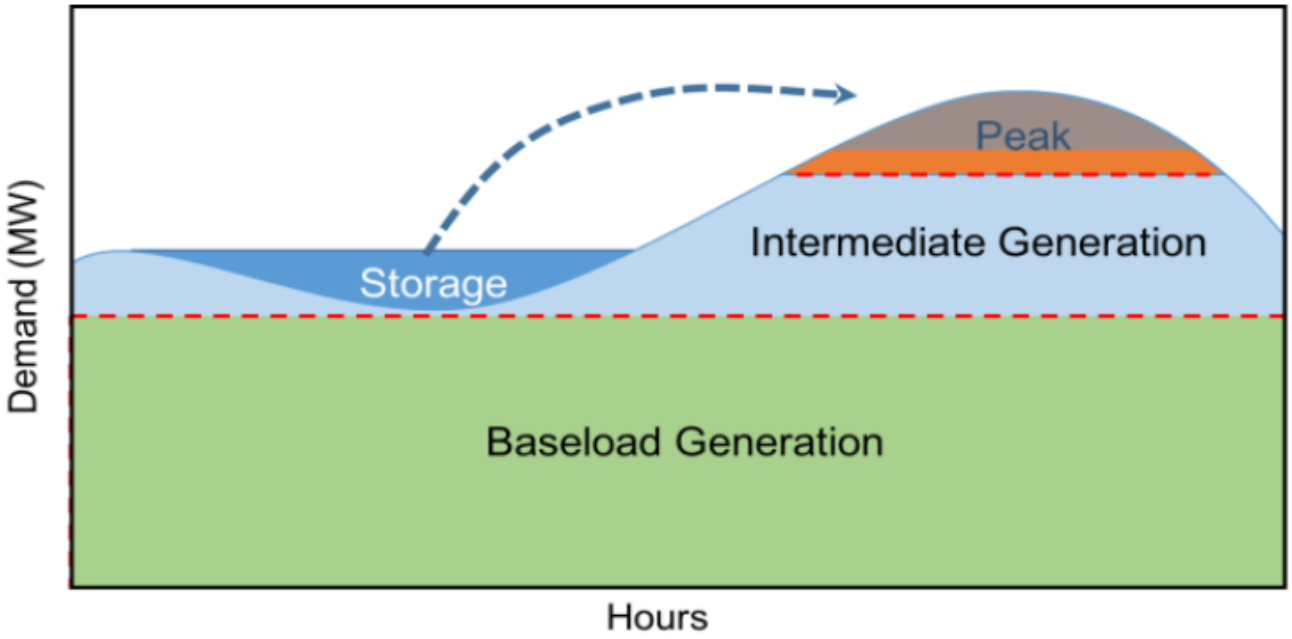
"Grid scale"

It will not cover the use of energy storage at the domestic level, in conjunction with PV or electric vehicles, though both are worthy subjects.

"Behind-the-meter"

Why is energy storage valuable? – in general.

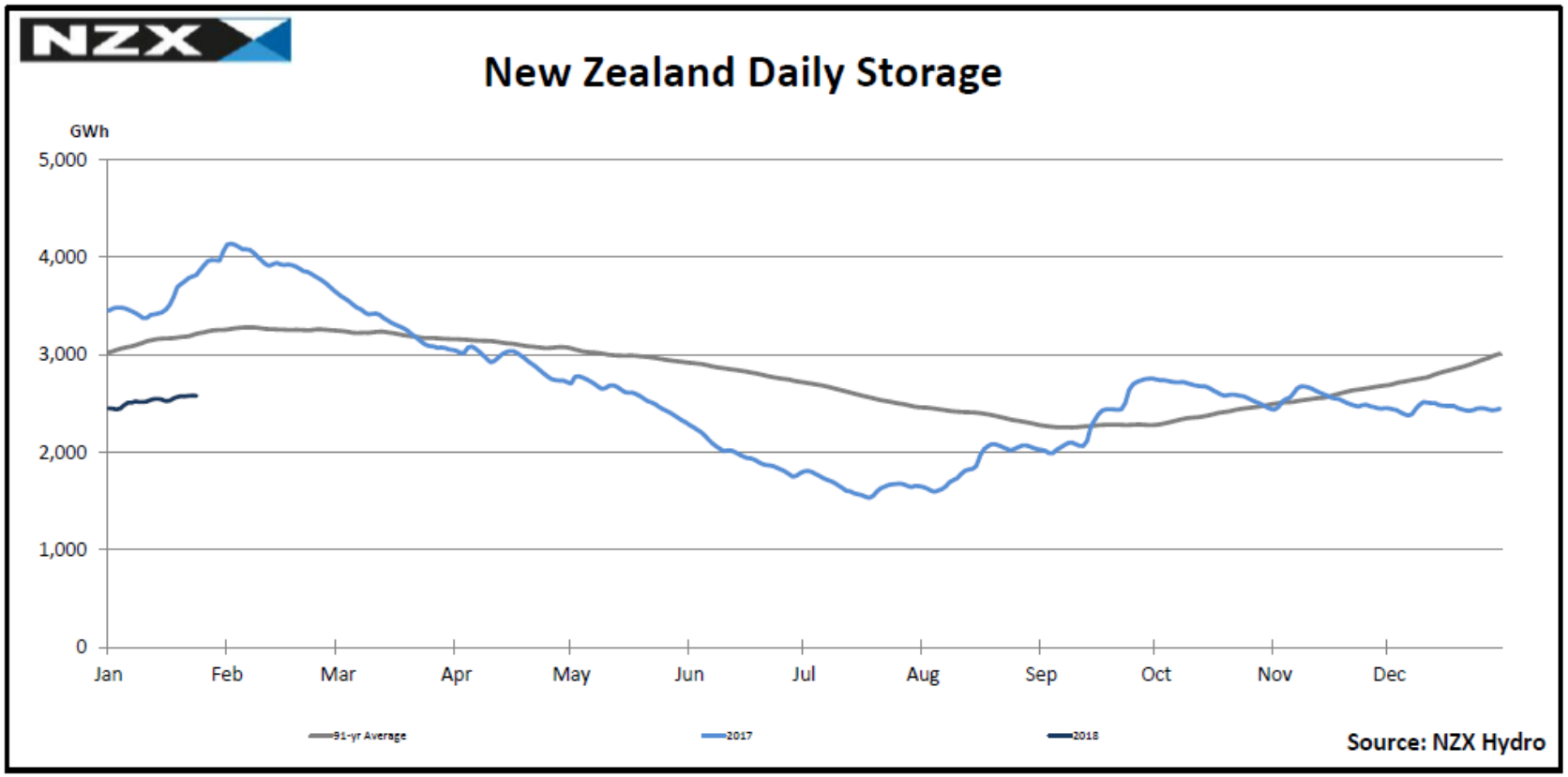




Massachusetts Energy Storage Initiative Study

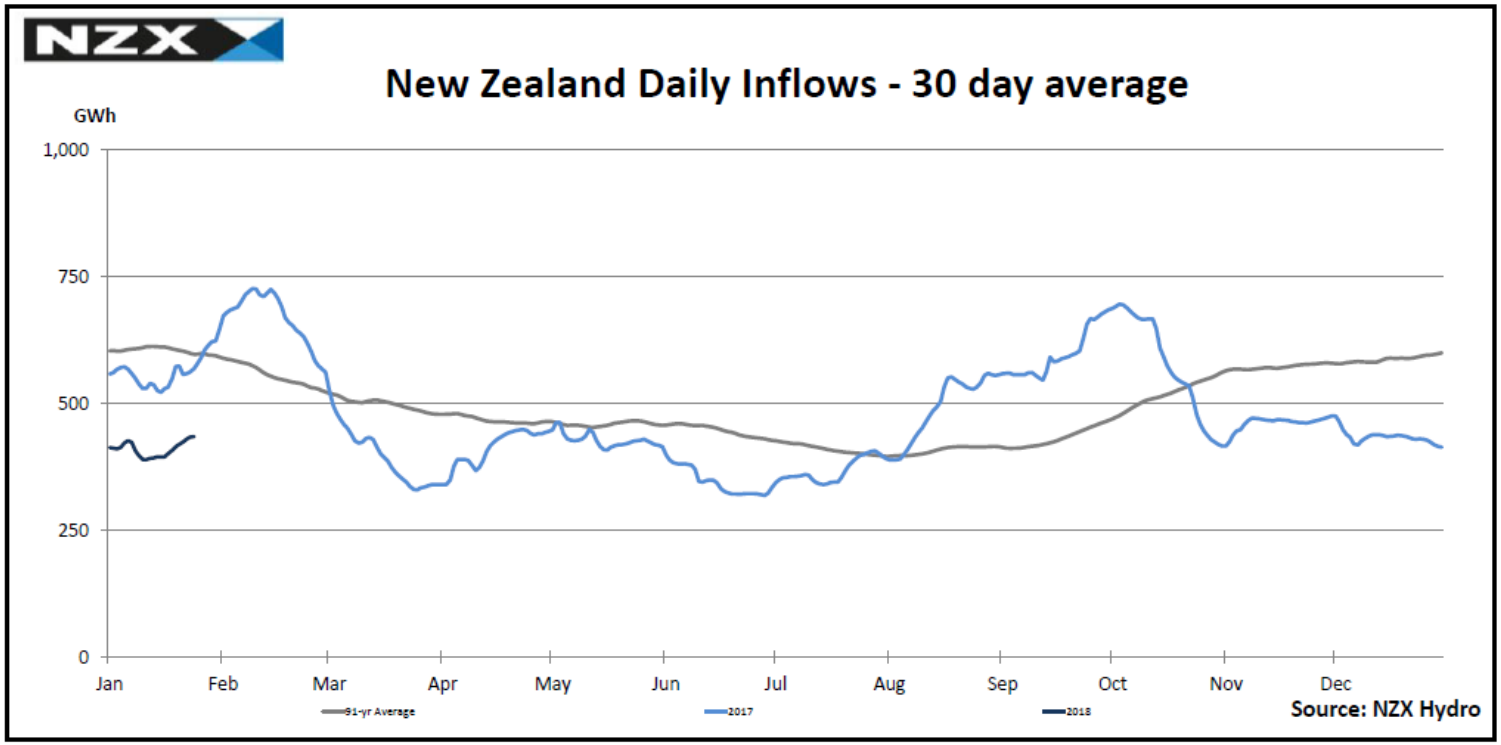
What we historically mean by energy storage in New Zealand.

Around 70% of the electricity in New Zealand is sourced from hydro generation, coming from river flow systems and water stored in natural or man-made lakes. Inflows and careful lake management are crucial to New Zealand's electricity supply - graphs showing current storage and inflow situations are displayed below. The New Zealand daily storage graph will be updated on a daily basis. If you are interested in receiving this graph plus additional hydrological information on a daily basis (Monday - Friday) you should contact energy.data@nzx.com to subscribe to the daily hydrological summary. The monthly cost of subscribing to this publication is $437 plus GST. The New Zealand weekly inflows chart is also updated daily.



Source: NZX Daily Hydrology Report, 29th January 2018.

….and like a battery, the hydro storage also needs to be recharged. NZ has only 60 typical days or 38 peak demand days of storage.



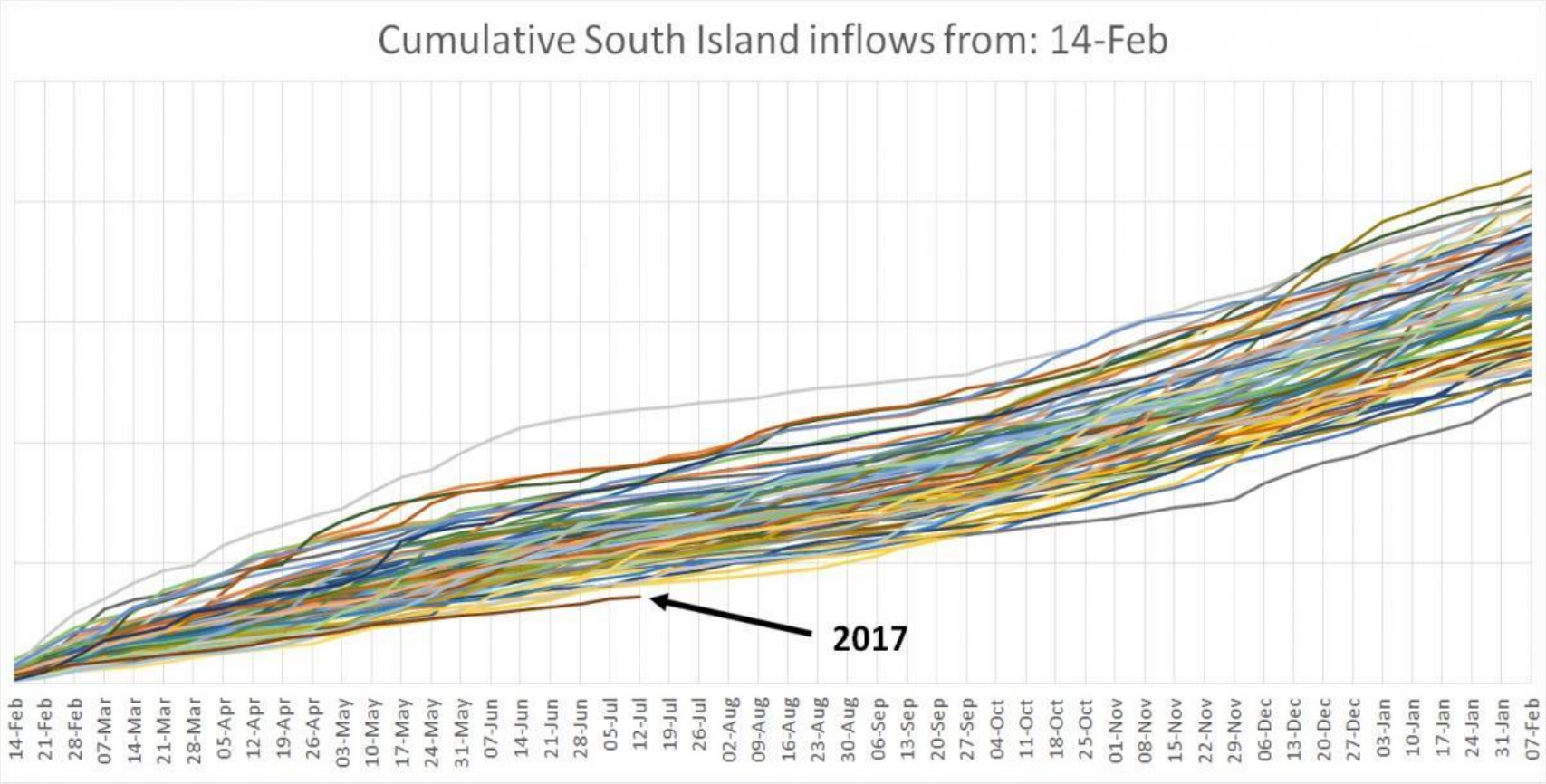
Inflows into the hydro lakes vary dramatically depending on seasonal rainfall and snowmelt. South Island inflows commonly occur during springtime, while the major North Island inflows typically occur in Winter.

For further information about hydrology or information regarding Subscription to the hydro datasets, please contact Monday to Friday **PM@nzx.com** or call NZX on +64 4 498 0012.

To view the NIWA National Climate Centre's hydro-climate forecasts for the next three months go to www.niwa.co.nz/climate/nzcu.

Long term trends and (critical) South Island inflows.

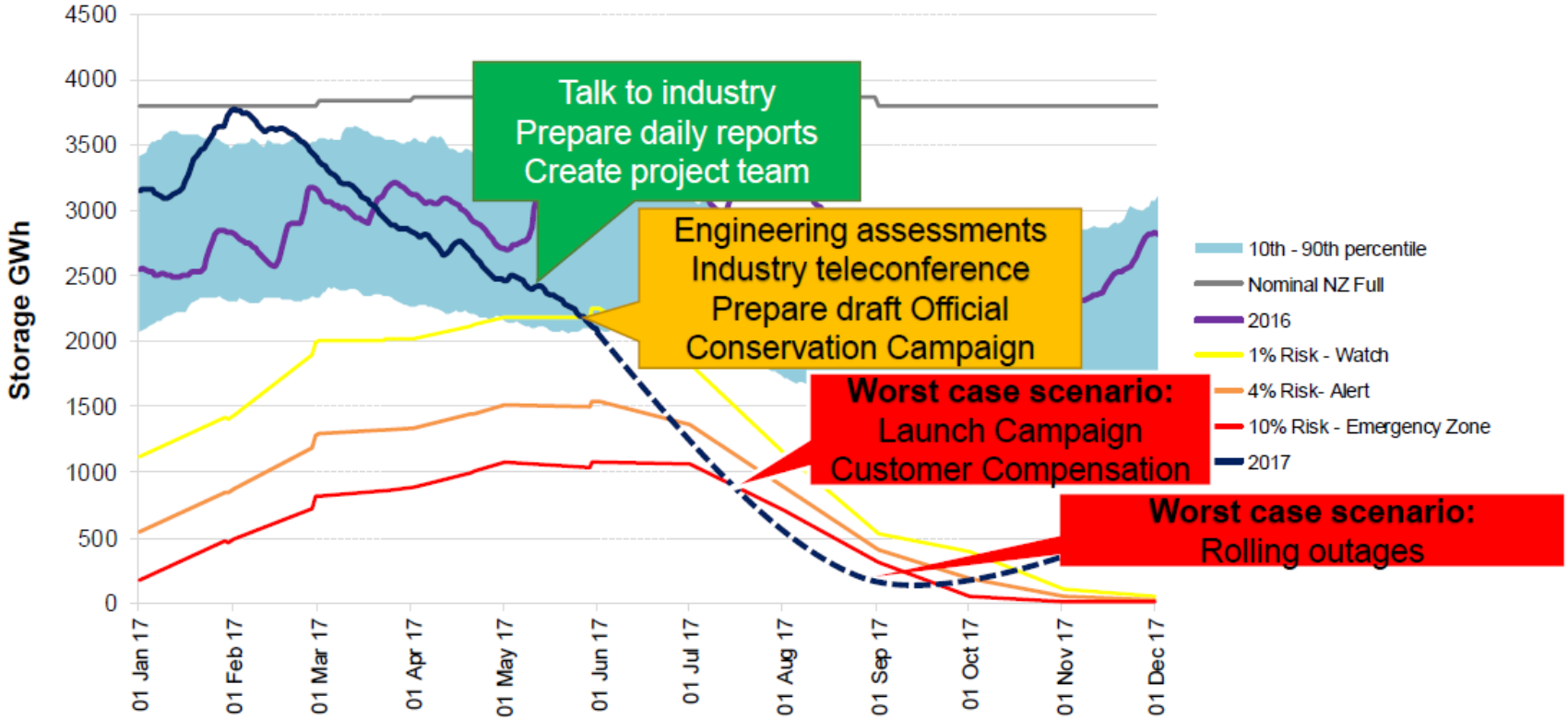
"There is a 20 year trend showing in the South Island with inflows being lower in February-March and wetter in May-June-July relative to the first 66 years of data we have access to. These two trends haven't produced an overall change in the average annual inflow, just a change in their timing."*



* Greg Size, Energy Link – 19th July 2017.

Illustration: The management role of Transpower as system operator, in response to falling hydro storage capacity. The Hydro Risk Curve.

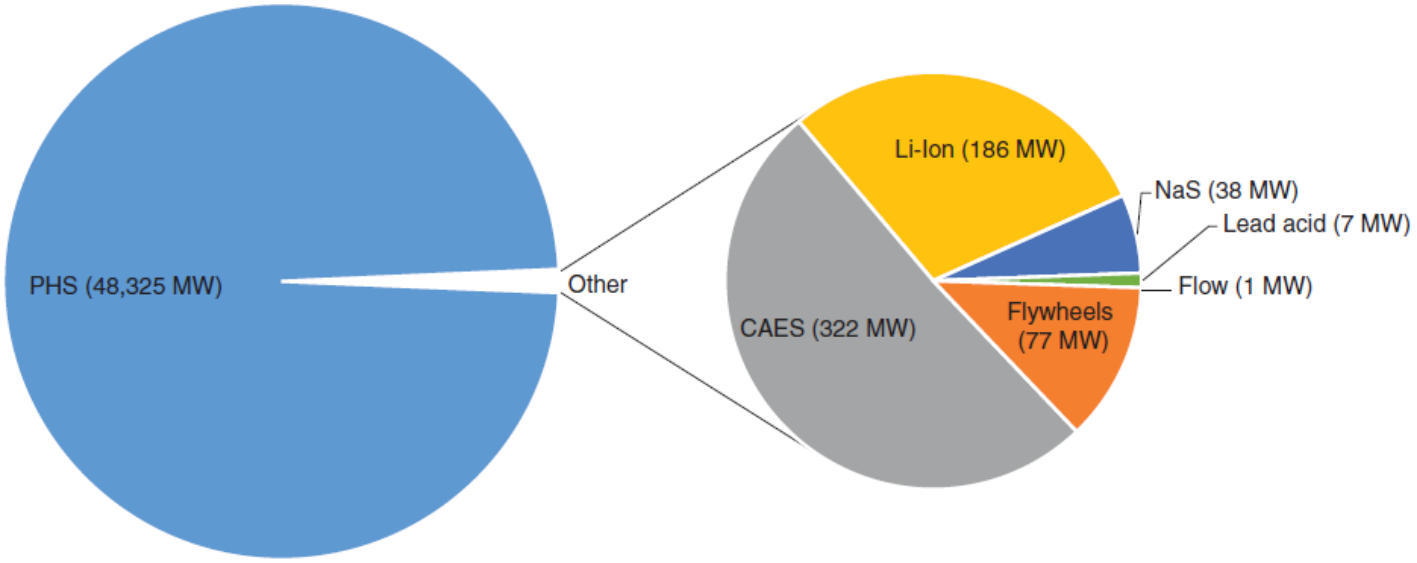
In 2018 South Island hydro lakes are 73% of seasonal average. Genesis thermal generation up 66% in 2017 4Q to offset low hydro inflows. In January Meridian said huge Waitaki storage system was 81% of average and 30% below same time last year. In February 2018 Contact Energy stated Clutha storage was 41% of seasonal average, December inflows 50% of average.



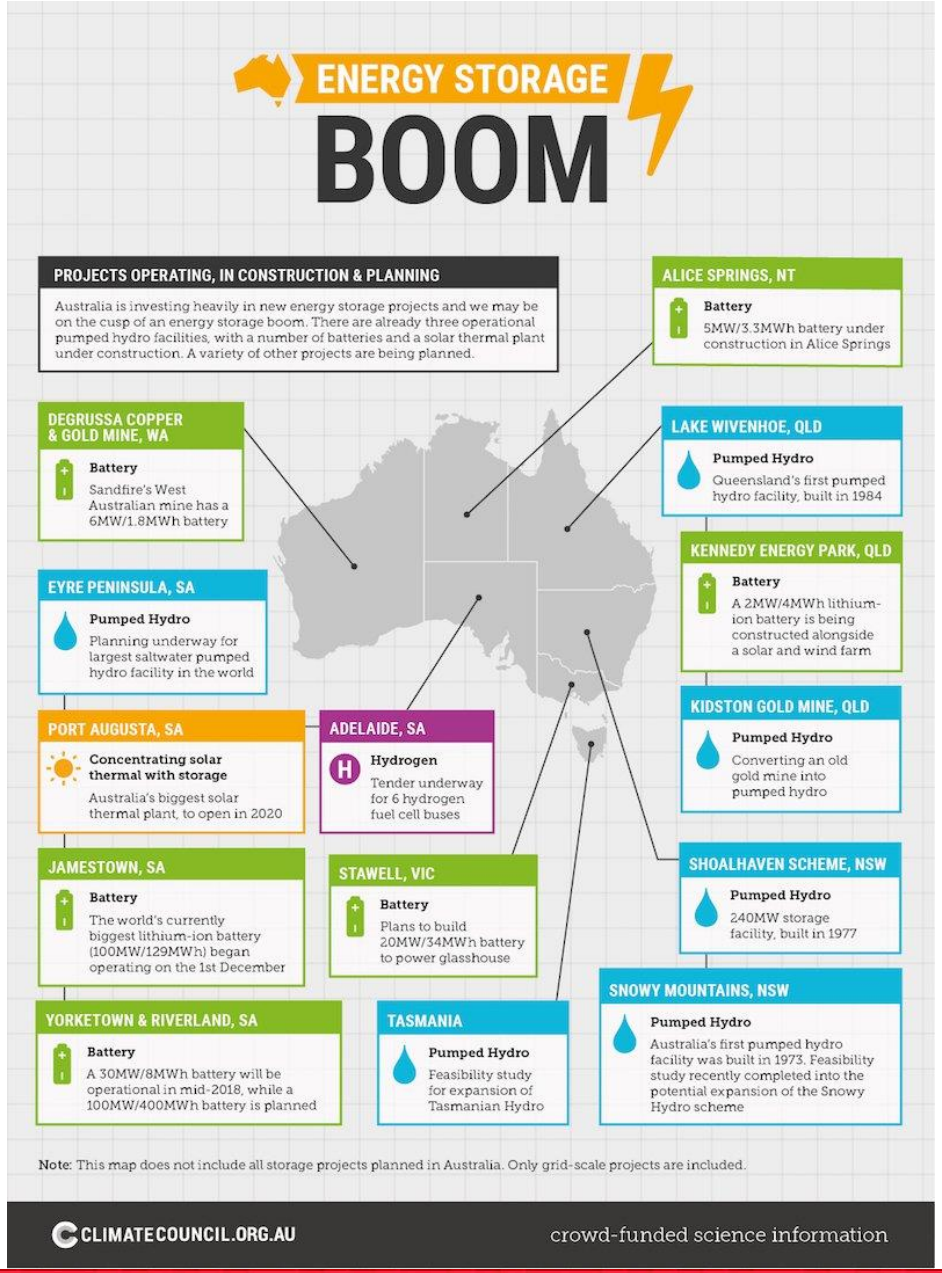
Source: Transpower, Emily Calvert ‘Security of Supply Winter 2017’.

Illustration: What ‘energy storage’ means in Europe (2016 data).

PHS = Pumped Hydro Storage – water is pumped back into the hydro dam using lower cost off-peak power, using the same turbine/generator but as a pump/motor. (Not applied at all in New Zealand).
CAES = Compressed Air Energy Storage – also using off-peak power, air is compressed, usually underground, to be re-released to spin turbines at peak times.



European Academies Science Advisory Council, ‘Valuing Energy Storage in European Grids’ – May 2017.

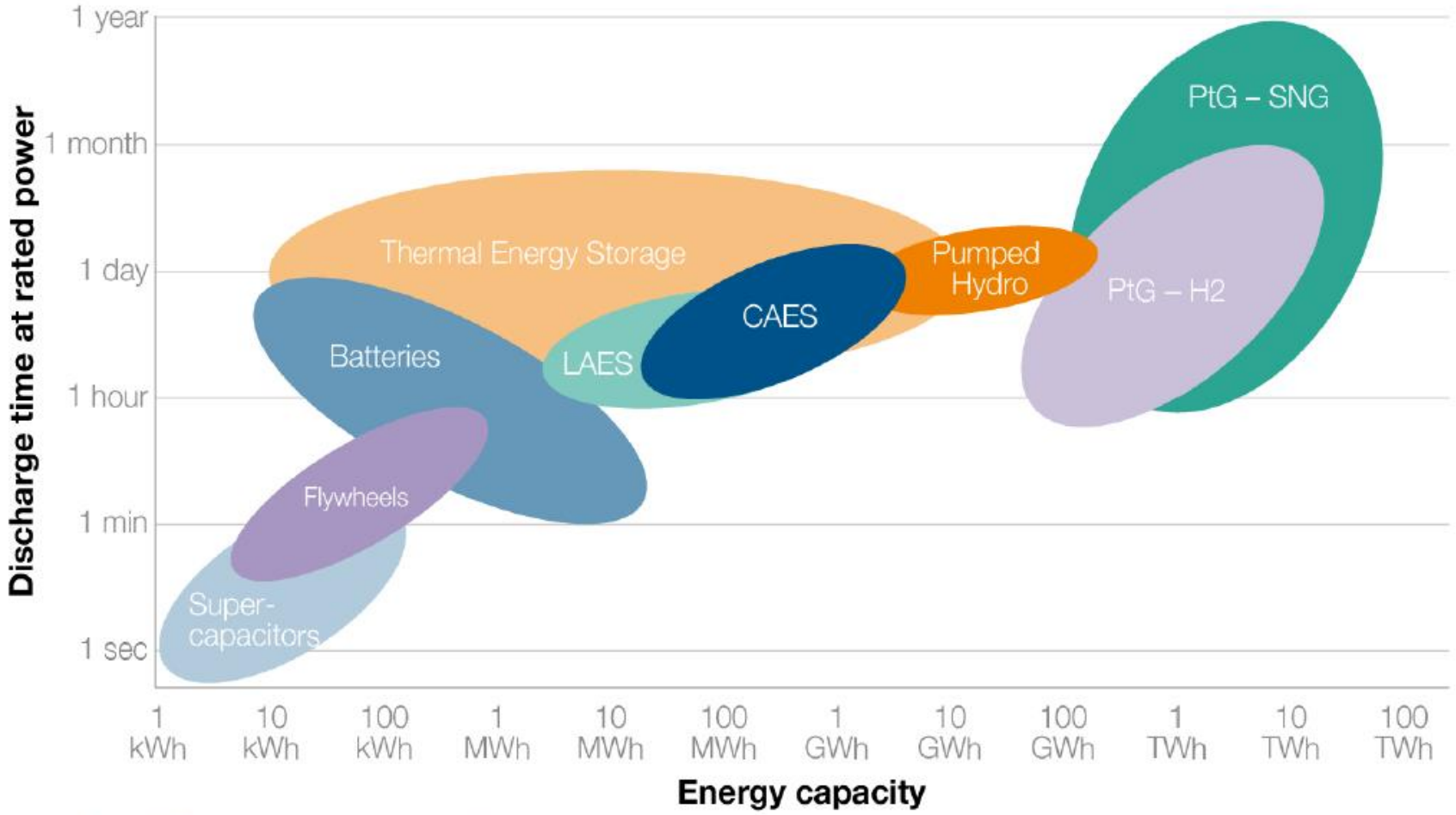


Australia……(2018 data).

Key parameters of various kinds of energy storage:

Energy Storage System Attributes	Lead Acid	Li –Ion	NaS	Flow Batteries	Flywheel	CAES	Pumped Hydro
Round Trip Energy Efficiency (DC-DC)	70-85%	85-95%	70-80%	60-75%	60-80%	50-65%	70-80%
Range of Discharge Duration	2-6 Hours	.25–4+ Hours	6-8 Hours	4-12 Hours	.25-4 Hours	4-10 Hours	6-20 Hours
C Rate	C2 – C6	4C – C6	C6-C8	C4-C12	4C-C4	N.A.	N.A.
Cost range per energy available in each full discharge ($/kWh)	100-300	400-1000	400-600	500-1000	1000-4000	>150	50-150
Development & Construction Period	6 months - 1 year	6 months - 1 year	6 months - 1.5 year	6 months - 1 year	1-2 years	3-10 years	5-15 years
Operating Cost	High	Low	Moderate	Moderate	Low	Moderate	Low
Estimated Space Required	Large	Small	Moderate	Moderate	Small	Moderate	Large
Cycle life: # of discharges of stored energy	500-2000	2000 -6000+	3000-5000	5000 - 8000+	100,000	10,000+	10,000+
Maturity of Technology	Mature	Commercial	Commercial	Early - moderate	Early - moderate	Moderate	Mature

Considerations of capacity and duration. Battery cover is getting larger….



Source: PwC, 2015, following Sterner et al. 2014

Lithium ion energy storage has rapidly gained cost advantage.

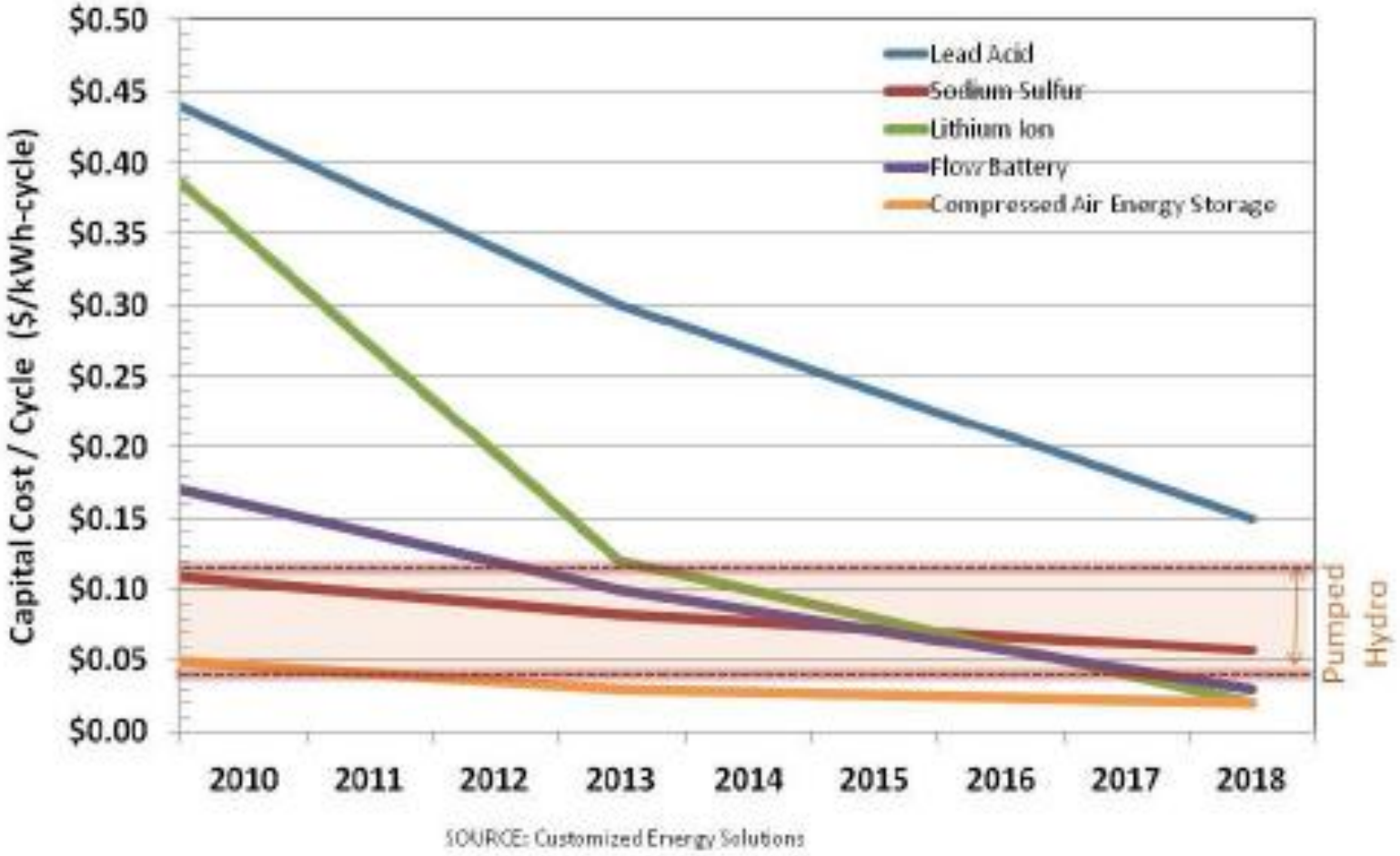
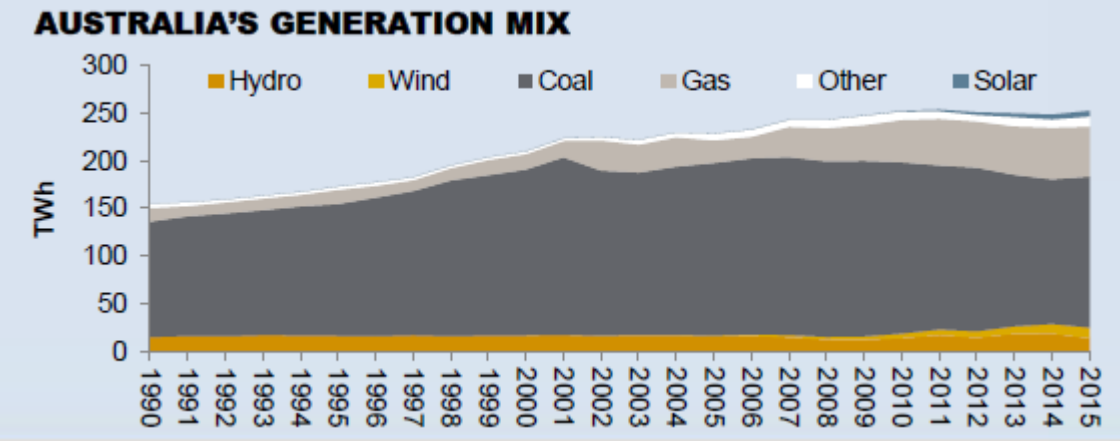


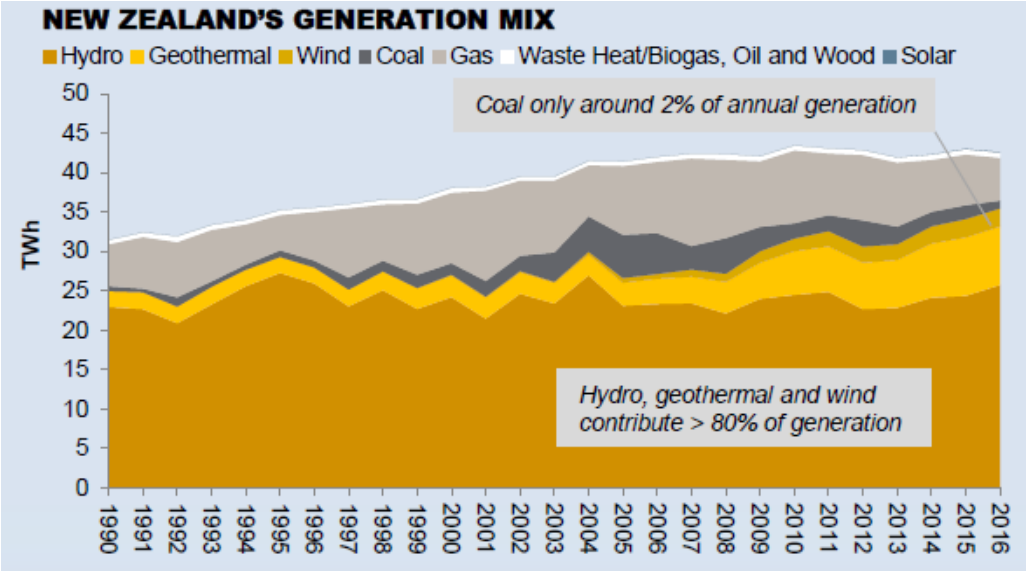
Figure 1-3: Forecast of Estimated Capital Costs by Storage Technology and Type[16]

What's happening in Australia?

Australian generation is dominated by ageing coal plant some of which is being retired. Gas fuelled power is indexed to international LNG fuel prices. Meanwhile there is also a high transmission and distribution component in retail electricity costs (it's a big country!). In SA, their wind-dominated generation suffered system collapse.

Grid scale battery energy storage makes sense to enable distributed wind and photo-voltaic generation, both on and off-grid.





Source for charts and text: Mercury investor roadshow, 15th November 2017.

Project developers and independent power producers are leading the development of distributed wind and solar photovoltaic projects quickly to market. Increasingly these are coupled with lithium-ion battery storage to provide system stability and synthetic inertia.

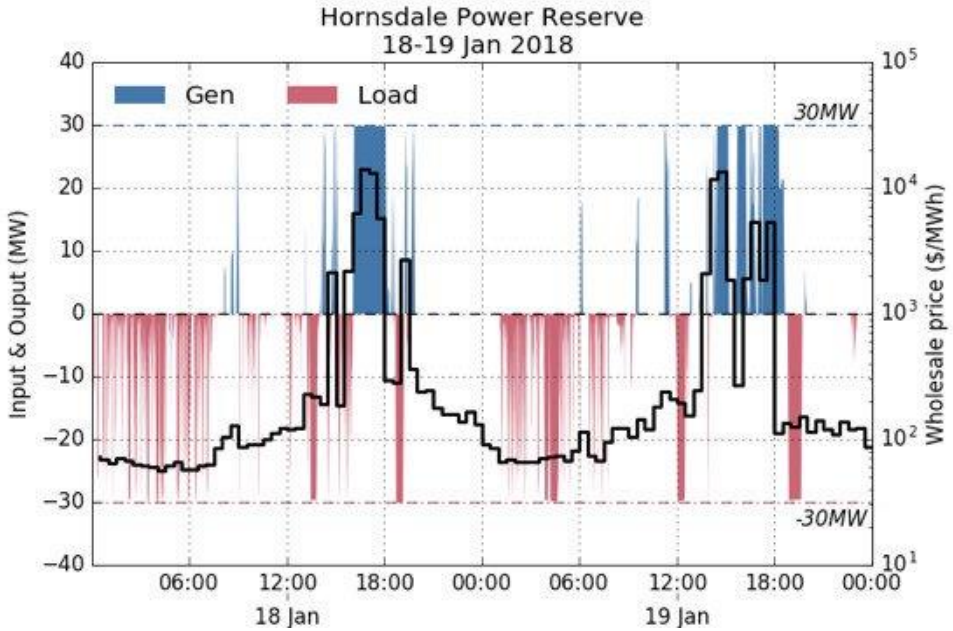
The Australian Clean Energy Regulator (CER) confirms the 33,000 GWh Renewable Energy Target will be met ahead well ahead of the 2020 timeframe due to strong growth in large-scale solar PV projects particularly in QLD and other eastern states. In 2017, the CER indicated some 1,054 MW of new capacity was accredited and expects around 2,600MW in 2018 and a further 2,700MW in 2019 based on current announcements.

Example: Territory Generation – Alice Springs
Battery capacity – 5MW / 3.3MWh
EPC contract by Vector Australia. (NZ parent).
Batteries by LG Chem (Korea).
Inverters by Siemens (Germany).
Control system by Yokogawa (Japan).

Mission: To support 12MW of PV in Alice Springs – 40% of demand, and growing. Provide increased system stability and allow displacement of expensive and polluting gas/diesel generation.

SA wind integration – Tesla's largest battery.

- The SA Government called tenders for battery storage to integrate wind energy and provide fast-response system support.
- Over 90 bidders responded! Final bids due June 2017. Tesla founder Elon Musk famously bet on delivery in 100 days, or no charge ($50m+ bet).
- In due course 100MW was awarded to the Neoen/Tesla partnership which proposed a 100 MW / 129 MWh system connected to the 100 MW Hornsdale wind farm. Tesla made good on their bet in less than 100 days.



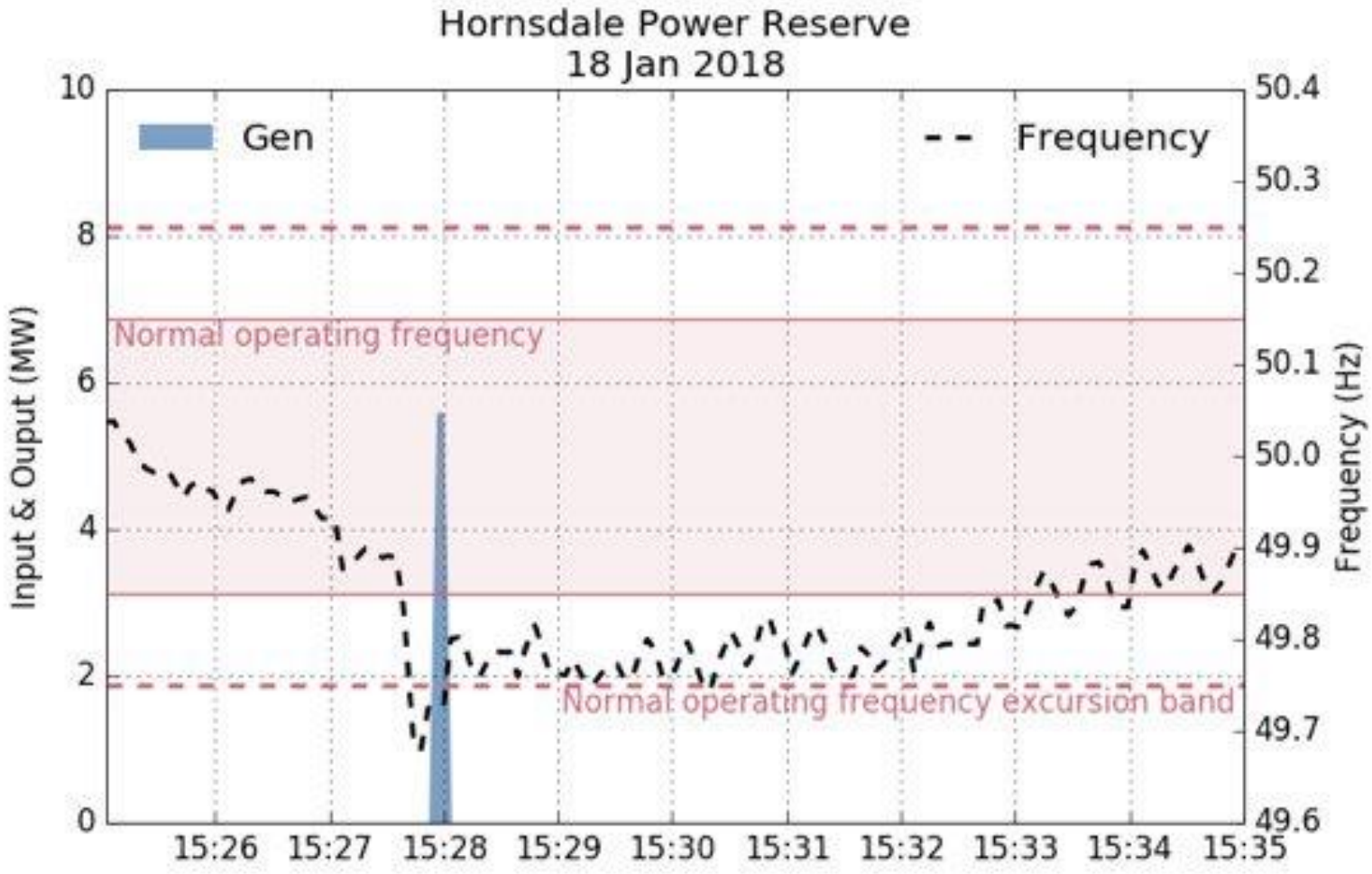
30MW/90MWh capacity used in the wholesale market as a form of price arbitrage, balancing wind output from the neighbouring Hornsdale wind farms taking advantage of spikes and dips, generating when supply gets tight, and making micro adjustments to supply and demand.

"It's hard to be sure, but it might have made around $1 million over the two days from the wholesale market."*

*Chart and quotation from Giles Parkinson, Renew Economy, 23rd January 2018.

Tesla SA grid-scale battery integrated with wind farm.

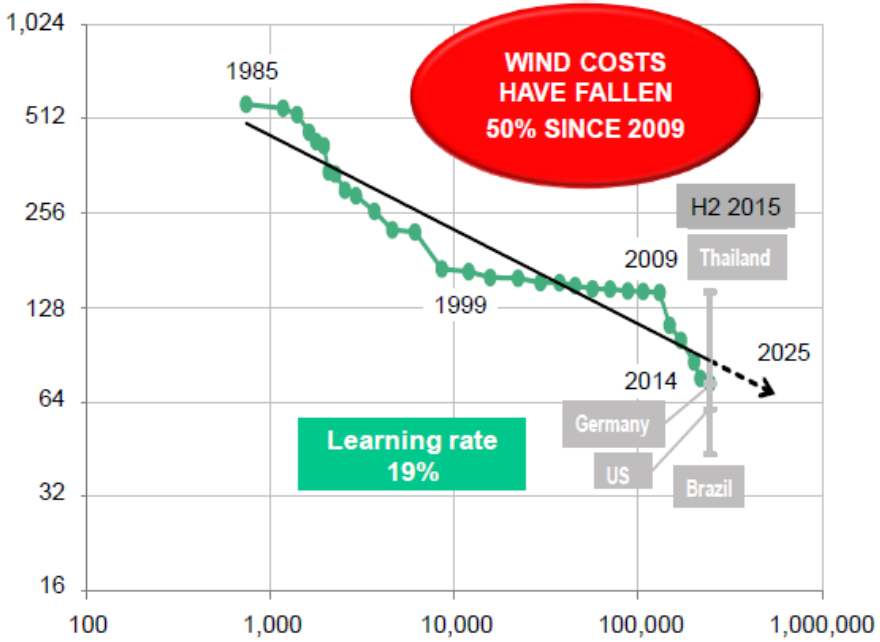
Taking advantage of the high performance that lithium-ion batteries provide (e.g. 0-100MW in 140 milliseconds) the rest of the battery capacity – around 70MW, 39MWh – is contracted by the South Australia government specifically to deliver network services, such as frequency control (FCAS) at time of system faults and problems. **Jan'2018: first ever participation by wind energy (via battery) to FCAS market**.



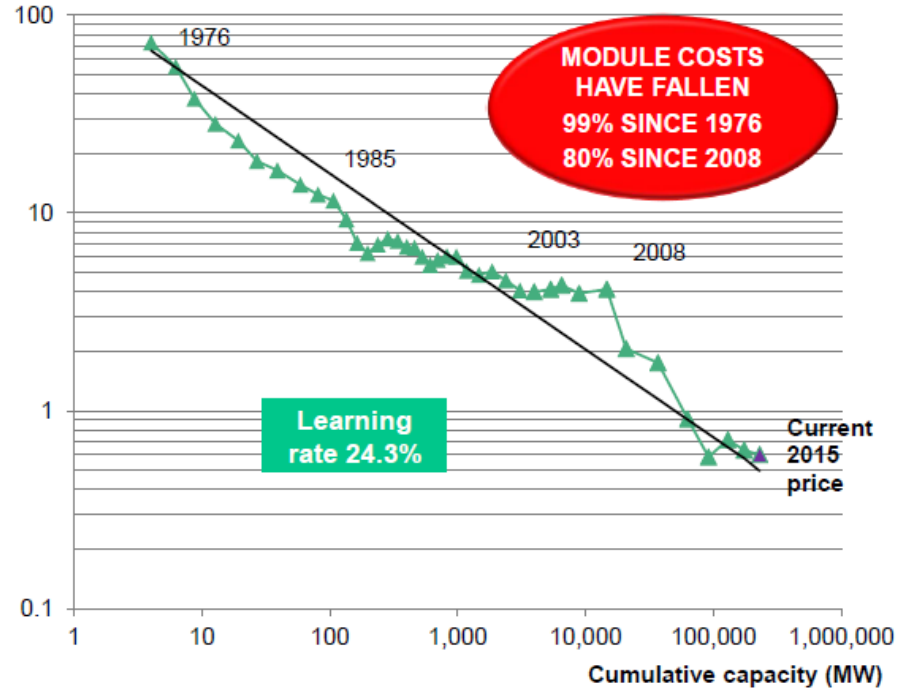
Giles Parkinson, Renew Economy, 23rd January 2018.

The drivers of Australian distributed generation + storage:

ONSHORE WIND LEVELISED COST ($/MWh)



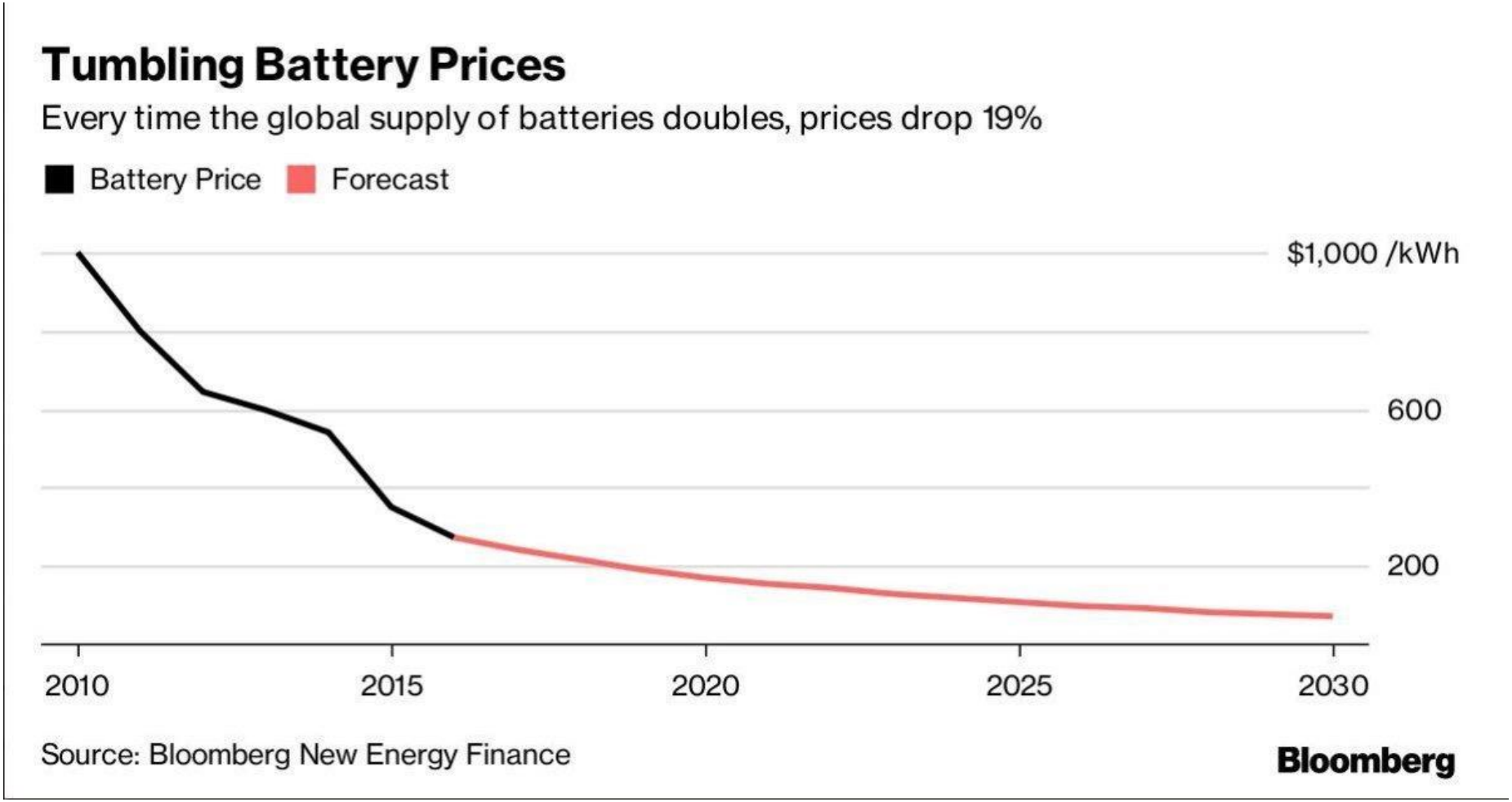
SOLAR PV MODULE COST ($/W)



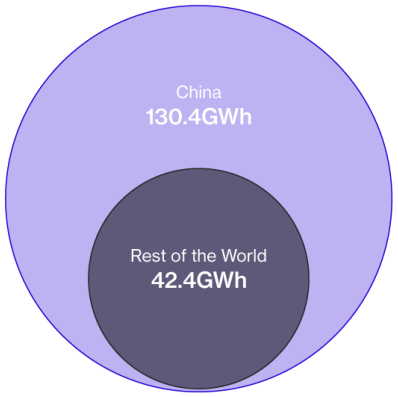
Couple distributed renewables with the low price, high performance and speed of deployment of lithium ion batteries, and the result is compelling in Australia.

Source: Bloomberg New Energy Finance, 5th April 2016 New York Summit.

Lithium ion used in EV's and many other applications. Economy of scale is driving cost down relentlessly.



Set to Dominate
China's pipeline of planned battery plants is about triple the rest of the world combined

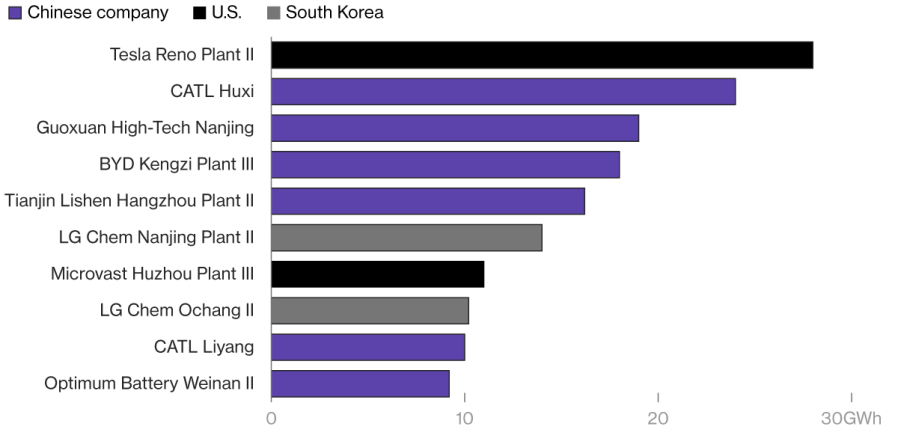


Source: Bloomberg New Energy Finance

Bloomberg

….and the global production of lithium-ion storage batteries is yet to hit it's peak. The pipeline in China is triple the pipeline in the rest of the world combined……Tesla's Reno 'Gigafactory II' is still huge, but not the only one on such scale.

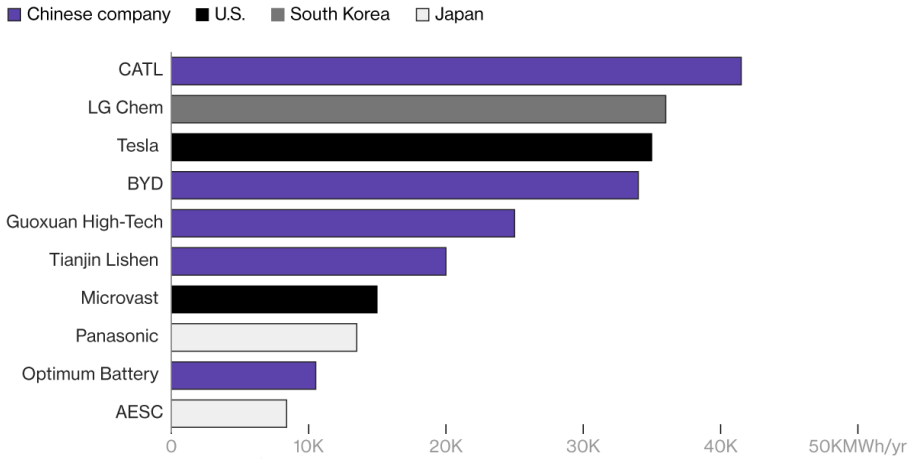
Beyond the Gigafactory
CATL's planned Huxi battery cell plant will be the world's second-largest by capacity



Source: Bloomberg New Energy Finance, company filings

Bloomberg

Aiming to Lead
CATL aims to use a $2 billion IPO to expand and become the No. 1 battery cell maker

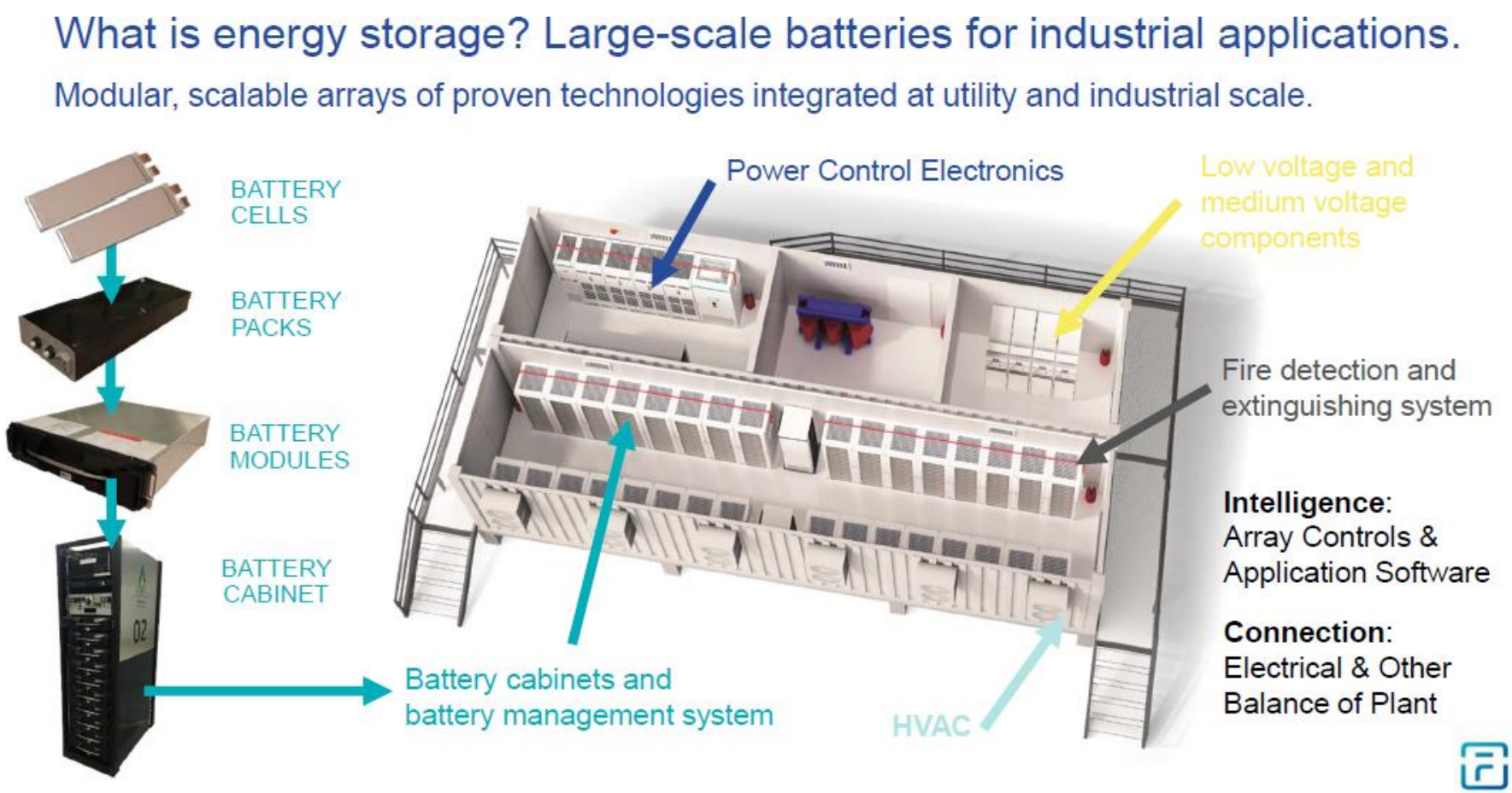


Source: Bloomberg New Energy Finance, company filings

Bloomberg

So what does a grid-scale battery look like?

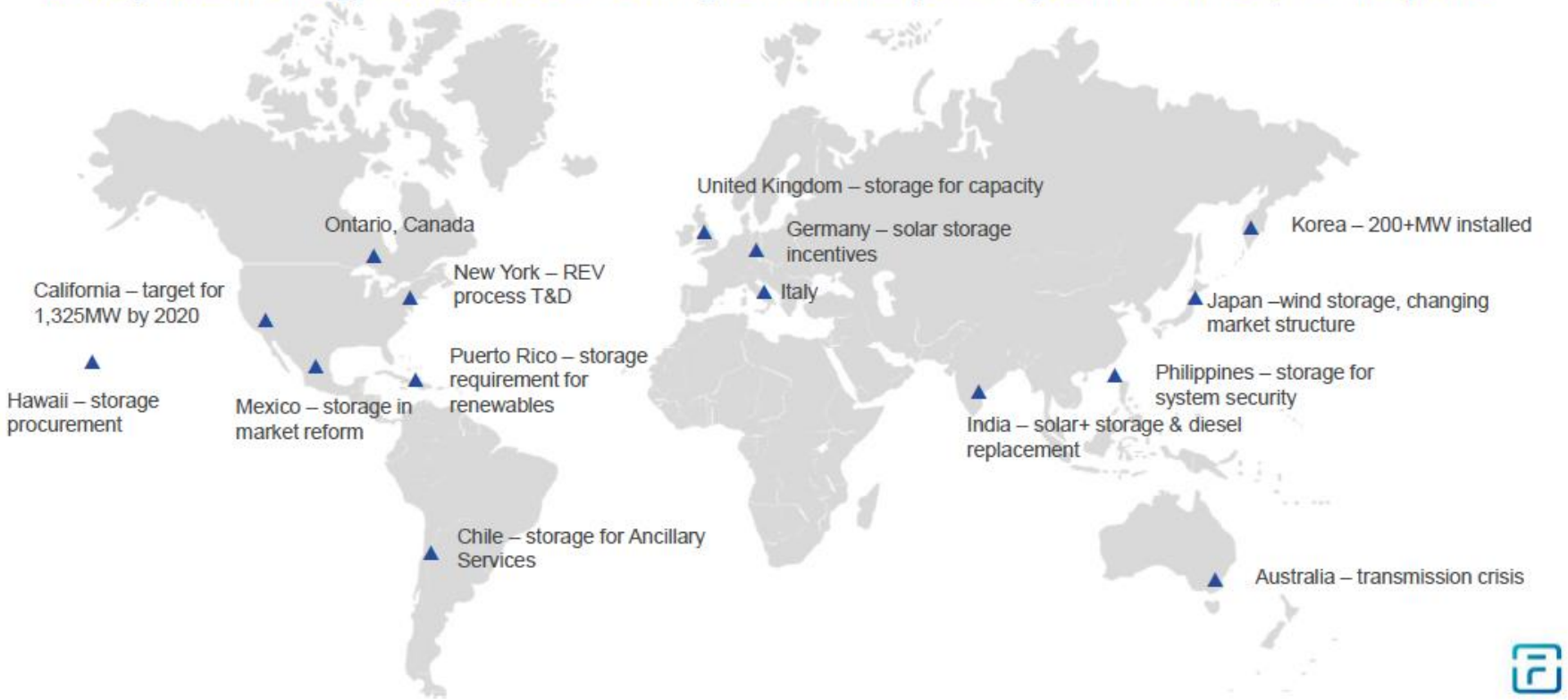
Unobtrusive, no emissions to air or water, little noise, relatively easy to consent and quick to assemble and commission.



The role and opportunity for grid scale lithium ion battery storage around the world.

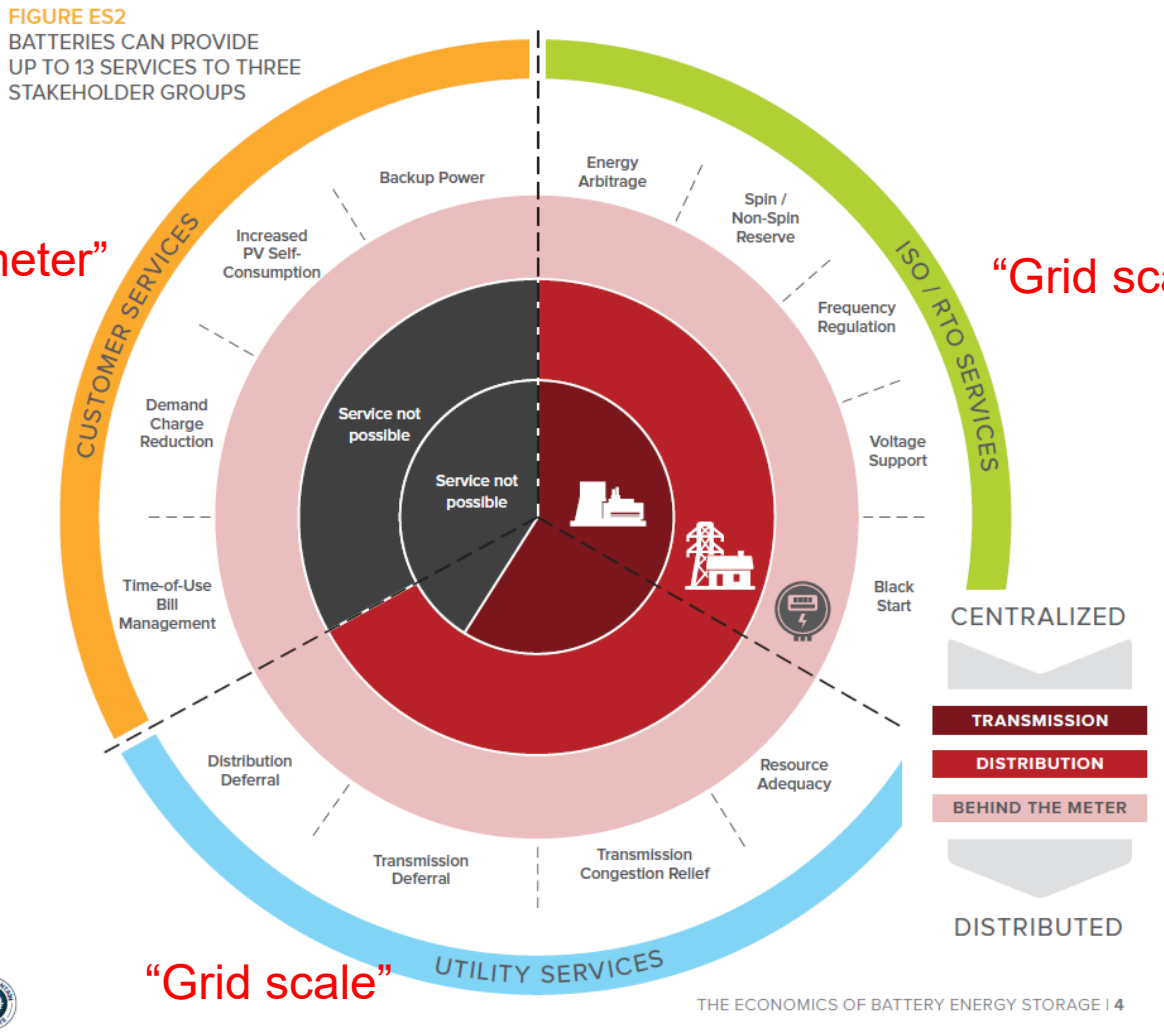
Energy storage continues to gain momentum worldwide

Battery-based energy storage assets serving constrained power systems with fast, flexible power



Source: Fluence

Rocky Mountain Institute Battery Services Diagram.



"Behind-the-meter"

"Grid scale"

"Grid scale"

Grid scale batteries in New Zealand in 2018.

Alpine Energy - Timaru	Counties Power / Genesis - Tuakau	Vector - Glen Innes	Dominion Salt – Lake Grasmere	Mercury - Southdown
2016	2017	2016	2017	2018
36kw/143kwh	250kw/500kwh	1 / 2.3MWh	250kw/570kwh	1MW/2MWh
Demand response, R&D.	Demand response, power quality, R&D.	Distribution asset deferral, demand response.	Wind energy integration	Arbitrage, ancillary services, R&D
EMC/Carnegie	S&C Electric	Tesla	Tesla	Tesla

The 2017 Transpower review : assumptions in the New Zealand context

(1 of 2).

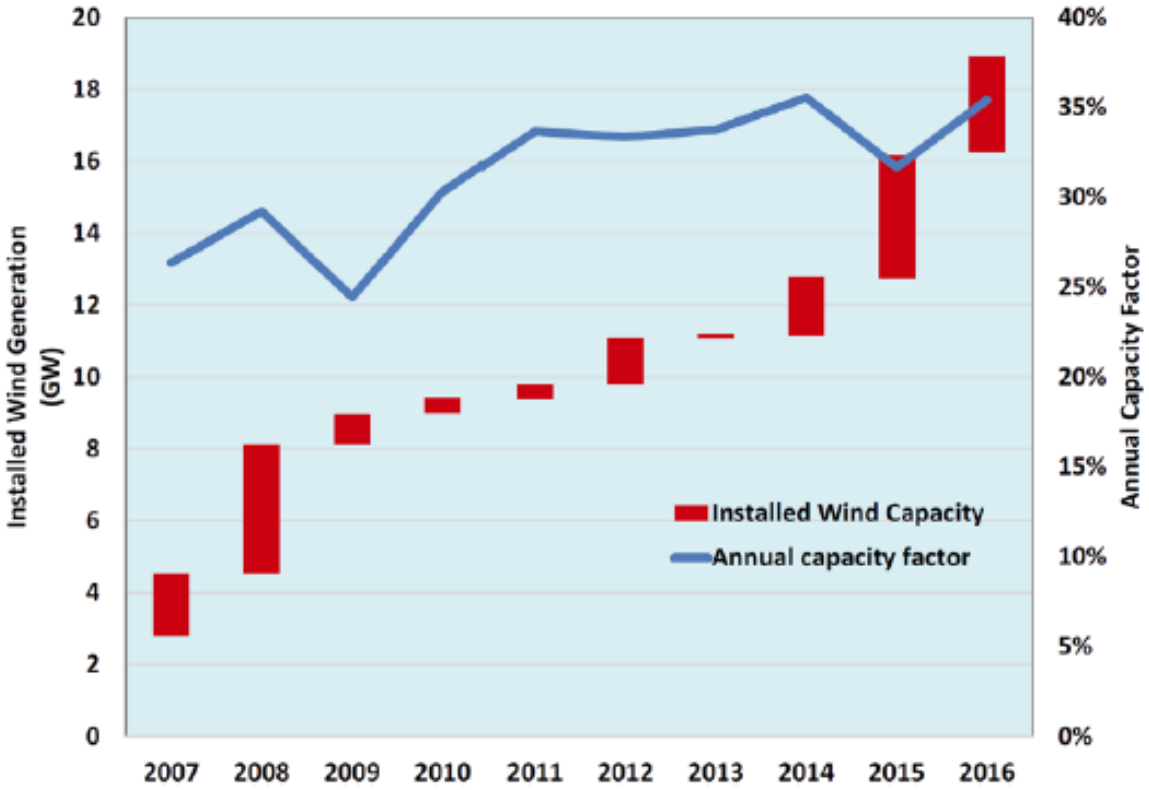
SERVICES	ASSUMPTIONS
Energy arbitrage	We analysed daily spot price data over a seven-year period (to account for hydrological variations) to calculate an average daily "off-peak" to "peak" market price for each major transmission network region. This difference ranges from ~$15-20/MWh in the South Island to ~$30/MWh in the North Island. We used these values in the case studies for batteries located at generation and transmission network sites; in the commercial/industrial sector we used a typical TOU tariff to determine arbitrage values.
Spin/non-spin reserves	We based our assumptions on 2016-17 year-to-date trends, because our procurement costs have significantly reduced since the upgrades to our HVDC and the introduction of a national Reserves market and multi Frequency Keeping in 2016. The reserve cost is assumed at approximately ~$6/MWh in the North Island and ~$3/MWh in the South Island.
Frequency regulation	We based our assumption on the 2016 average of ~$12/MWh in the North Island and $14/MWh in the South Island. This service is capped at 15MW per Island.
Voltage support	We based this value on equivalent Statcom carry costs of ~$40k/KVA/pa, assuming dynamic reactive support is required. This can be considered an upper bound, acknowledging that voltage support can also be provided from other potentially lower cost options such as capacitors and synchronous condensers.
Black start	We consider that there are limited opportunities for batteries to receive revenue for black start services. The total cost for this service each year is ~ $600k, currently spread across four providers, so we assume $50k pa fixed at generation site only.
Resource adequacy	In a capacity market, this is typically valued as the annual carrying cost of an open cycle gas turbine (OCGT) plus fixed O&M costs.[2] However, given that batteries do not provide the same sustained energy as an OCGT, this is discounted to ~$100/kW/pa to take a conservative approach. We acknowledge there an expected additional upside to battery storage, from the faster response and lower operational cost (avoided start-up and low load running).

SERVICES	ASSUMPTIONS
Transmission deferral (transmission congestion relief)	The cost of transmission deferral covers a range from both short to long term. We used our Demand Response Programme[3] trial payments as an estimate for short-term substitute for transmission deferral. For long term deferral we used a significant proportion of the capital component of the HVAC interconnection charge. We have therefore assumed a LRMC value for transmission deferral for this report to be in the range $30-$80/kW/pa. If transmission upgrades can be deferred or avoided by a battery, then it is assumed the owner will receive payments of similar value via either the Demand Response Programme or a contract with the Grid Owner, but not both.
Distribution deferral	Network costs range from $100/kW/pa[4] to greater than $200/kW/pa, depending on the nature of the network. Australia (LV) ranges from $100-150/kW/pa. The analysis is based on a mid-point of $150/kW/pa for distribution network expansion costs.
Time-of-Use bill management	Indicative TOU tariff for large commercial customers, including Wellington Electricity's variable lines charges.
Increased PV self-consumption	We assumed that the battery is fully charged with excess solar during the day and discharged over the evening peak, with the avoided costs derived from an average feed-in tariff of 8c/kWh. No allowance has been made for changes to network injection costs.
Demand charge reduction	We used the Wellington Electricity pricing schedule[5] for 300-1500KVA ICPs, at ~$150/kW/pa.
Reliability/Backup power	There are many factors that go into determining the Value of lost load (Voll) for each customer classification and geographical location. Our assumption in this report is based on the 2013 EA Voll Survey[6] Table 1. Refer to Appendix for a break-down by customer classification. For grid-connected assets, the simple average value of $25,300/MWh is used to value reliability.

The future for grid-scale energy storage in New Zealand?

- Unlike in Australia, the ‘demand-pull’ to displace central station thermal with distributed renewable isn’t compelling in an economic sense. NZ tends to integrate wind energy with hydro to effectively provide storage.
- The conclusion of the RMI and Transpower is that the greater value for grid scale energy storage lies further down the electricity supply chain.
- Vector’s Glenn Innes substation (and others pending?) is a tangible example of this. CEO Simon Mackenzie stated that their 1MW/2.3MWh would cost 70% of the alternative substation cost. This is an ‘distribution asset investment deferral’ play.
- Now the Labour/Green government policy is to plan the transition to a 100% renewable electricity system by 2035. This may offer a fresh opportunity for grid scale battery storage to allow a greater penetration of intermittent wind energy than would otherwise be the case, and allow wind to participate in ancillary market services (frequency and voltage support, 6s reserves, demand reduction).
- If the NZ wholesale market moves to a 5 minute ‘gate’ this will also assist battery storage and wind to become more dispatchable.
- Some large commercial and industrial power users may be able to stack value in energy storage enough to make it ‘bankable’ by reducing network peak demand charges which otherwise set the bar for pricing. If this is integrated with rooftop PV and participation in demand reduction and possibly voltage support, data centre UPS, the value starts to add up…
- Site-specific wind applications: island locations or micro-grids – battery smooths ramp-up and down, enables intermittent wind and PV to displace diesel. (Stewart Island?).

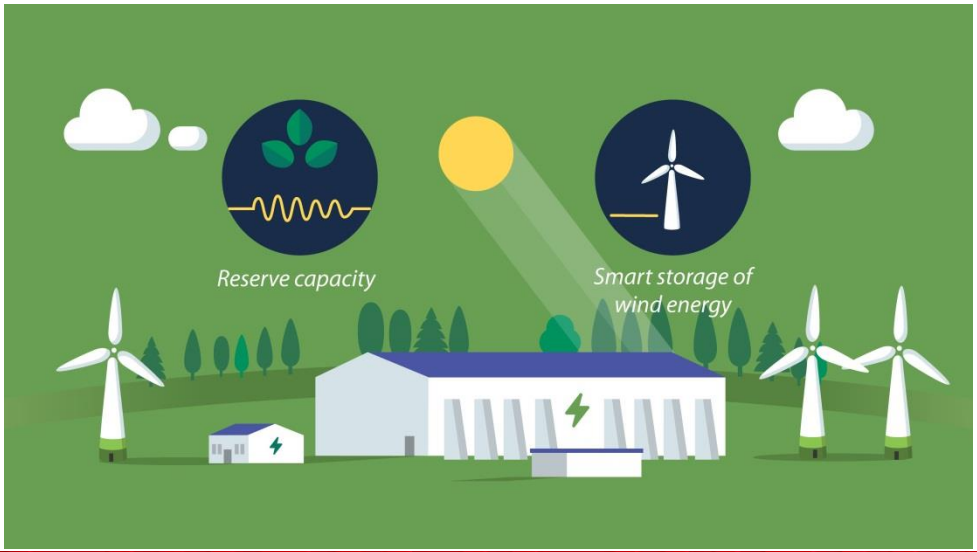
Challenge for New Zealand wind industry: how to integrate larger quantities of intermittent wind energy without compromising stability or calling on fast-start thermals?



Data: Texas (ERCOT) – Peter Cramton, U. of Maryland, Feb'2018.

Appendix: Mitsubishi Corporation and grid scale energy storage as a business investment.

2017 April 6th: “EnspireME”, 48MW - the largest battery system in Europe. This battery system will be located in Germany and enable Eneco and Mitsubishi Corporation to supply sustainable reserve capacity to the European electricity grid.



2018 January 23rd: Delhi, India - AES India, Mitsubishi Corporation and Tata Power-DDL India’s first grid-scale battery-based energy storage system 10 MW

(Image below of Masinloc, Philippines, similar design, also 10MW, for reference).