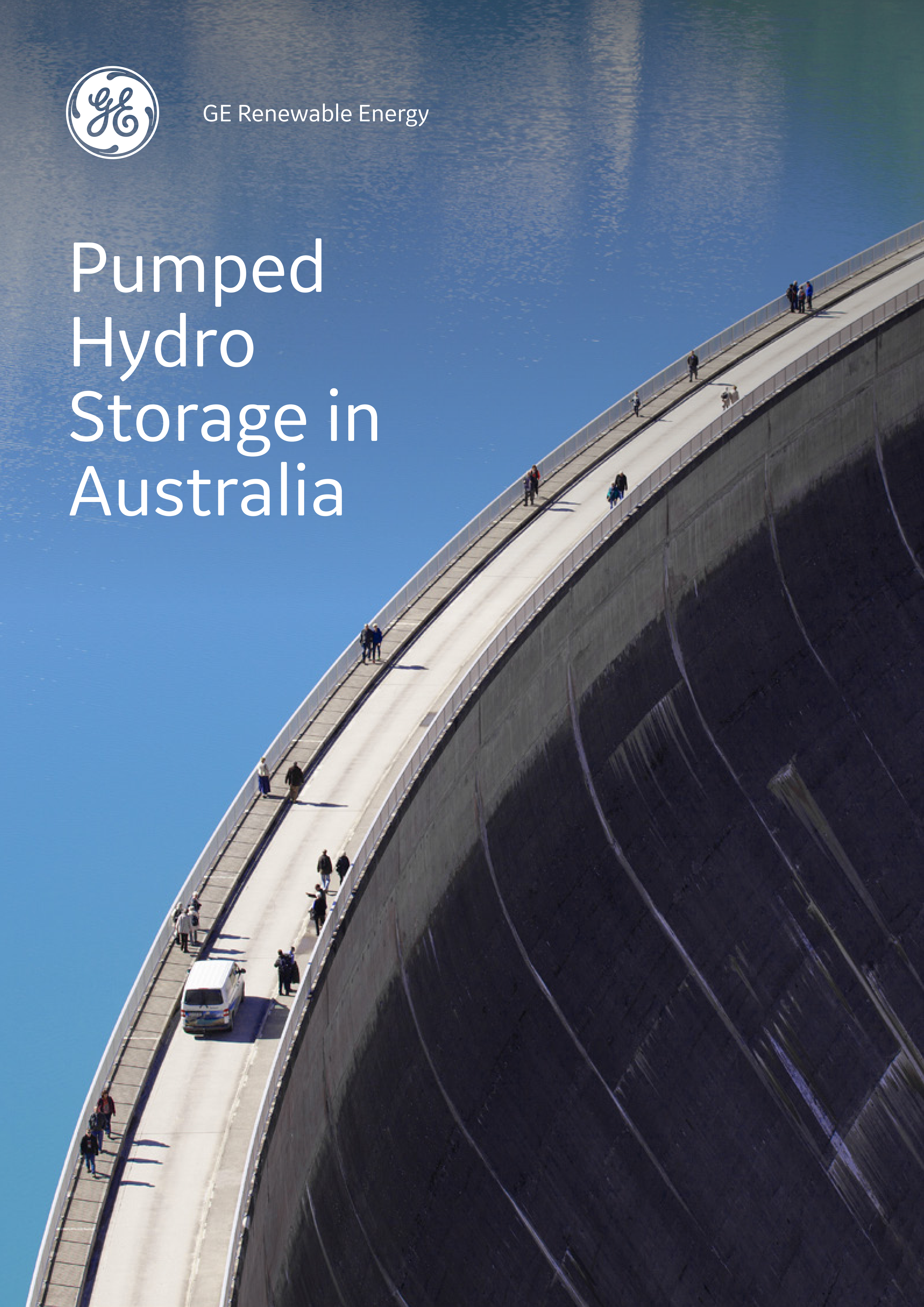
GE Renewable Energy

Pumped Hydro Storage in Australia



Contents

The Energy Transition in Australia

Australia is at the early stages of a major transition in how we generate and manage electricity. Some of the key findings in AEMO's 2020 Integrated System Plan (ISP) include:

- Almost two thirds of Australia's coal-fired generation capacity is expected to retire by 2040 (potentially much more, much sooner, depending on the forecast scenario)
- The installed capacity of distributed generation (primarily rooftop solar PV) is expected to double or even triple by 2040
- Between 26-50GW of new utility-scale renewable generation capacity (primarily wind and solar PV) will need to be built by 2040
- Between 6-19GW of new dispatchable capacity will need to be built by 2040 to manage the incremental wind and solar PV
- Billions of dollars of transmission investment will be needed to enable the connection of the new generation and storage capacity

While the ISP provides an actionable pathway for transmission investment, targets and programs at state and federal level are key drivers of investment in utility-scale generation and storage. This is a highly dynamic space, which we have endeavoured to summarise below.

Region	Renewable target	Emissions target	Key Supporting Programs
Australia – Federal Government	~23% by 2020 under RET scheme	26-28% reduction by 2030	Technology Investment Roadmap, Grid Reliability Fund
New South Wales	+12GW of wind + solar and 2GW of long-duration storage by 2030	35% reduction by 2030 Net zero by 2050	Electricity Infrastructure Roadmap, Emerging Energy Program
Victoria	25% by 2020 40% by 2025 50% by 2030	Net zero by 2050	VRET program, Renewable Energy Action Plan
Queensland	50% by 2030	30% reduction by 2030 Net zero by 2050	Renewables 400, CleanCo
South Australia	75% by 2025 100% by 2030	50% reduction by 2030 Net zero by 2050	
Western Australia	No formal target	Net zero by 2050	
Tasmania	100% by 2022 150% by 2030 200% by 2040	Net zero by 2050	TRET program, Tasmanian Renewable Energy Action Plan
Northern Territory	50% by 2030	Net zero by 2050	Roadmap to Renewables
Australian Capital Territory	100% by 2020	40% reduction by 2020 50-60% by 2025 65-75% by 2030 90-95% by 2040 Net zero by 2045	

The Benefits of Pumped Hydro in Australia

Australia already boasts a pumped hydro fleet of about 1.6GW across the Wivenhoe, Tumut 3 and Shoalhaven power stations, with an additional 2GW on the way through Snowy 2.0. We also boast some of the world's most attractive wind and solar resources, with renewable energy already delivering an average 21% of our electricity in 2019 (energy.gov.au) and significantly more in certain states and at certain times.

As this proportion of electricity coming from intermittent sources continues to increase sharply, the need to safeguard reliability and security also will rise. In addition, we increasingly will find ourselves at moments when generation output exceeds demand, leaving us no choice but to either store or waste the surplus energy.

Against this backdrop of ever accelerating change, a proactive approach by government is vital to ensure the lowest cost solution is implemented across the electricity system. In countries as diverse as China, India, Israel and Austria, governments are embracing pumped hydro technology to complement the growing penetration of wind and solar PV.

The benefits an expanded pumped hydro fleet would bring to Australia are elaborated below.

Enabling the Energy Transition with High-Capacity, Long-Duration Storage

As noted in AEMO's 2020 Integrated System Plan, Solar PV and onshore wind are already the cheapest forms of new generation in Australia and their penetration into the National Electricity Market (NEM) is expected to increase significantly in the years ahead, as aging thermal capacity is progressively retired.

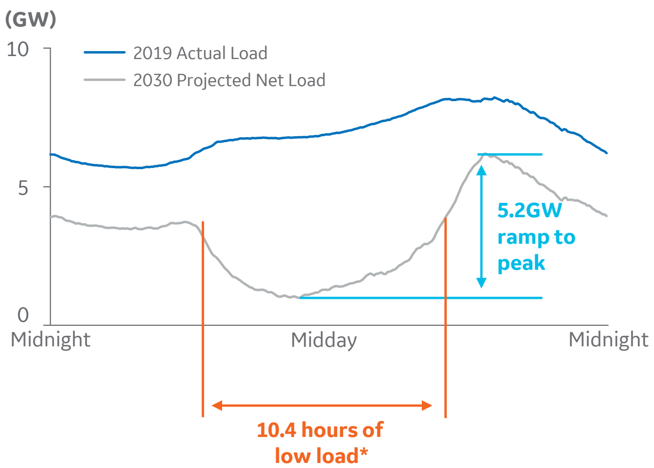
This change brings new challenges, including the need to:

- Inject power when output from wind and solar PV fails to meet demand
- Store excess power when output from wind and solar exceeds demand
- Obtain the grid reliability and security services previously provided by thermal generation, e.g. inertia, system strength, frequency control, black-start, reactive power, etc.

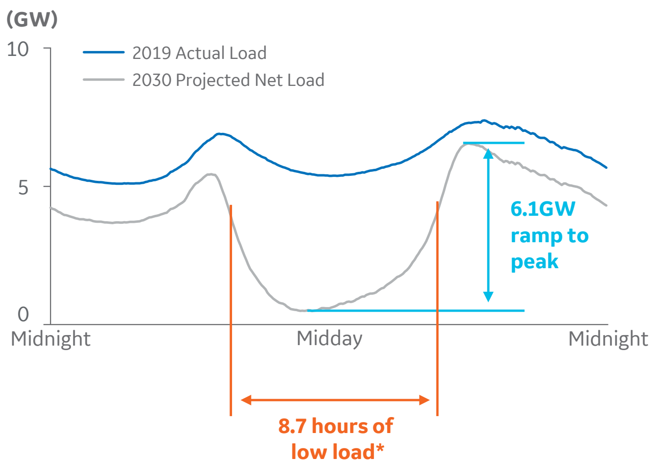
To explore this more deeply, we have modeled the 'net dispatchable load' in the various NEM states, presenting below a snapshot of our model output for QLD in 2030. In this model, 'net dispatchable load' is defined as the residual load available for dispatchable generators after wind and solar output (both utility and rooftop) have been subtracted from underlying operational demand. For the purpose of this analysis we have assumed the 50% by 2030 target is met.

Absent investment in large-scale, long-duration storage to help balance the impact of wind and solar PV, our analysis indicates prolonged periods of low net dispatchable load are likely to emerge by 2030.

QLD Summer Weekday – Net Dispatchable Load**



QLD Winter Weekday – Net Dispatchable Load**



Note: *Defined as the period during the daylight hours for which net dispatchable load is below the overnight minimum;
**Load includes Wivenhoe's pumping load, but not its generation output.

Source: Aurecon 2019 Cost & Technical Parameters Review; AEMO Market Generation & Load Data; AEMO 2020 ISP; AEMO Dispatch Data; GE Analysis

This seems consistent with the Australian Energy Market Operator's (AEMO) 2020 Electricity Statement of Opportunities (ESOO), which forecasts that minimum operational demand (i.e. without deducting utility wind and solar) will fall significantly across the NEM and could even become negative in Victoria and South Australia by 2030.

During these periods of 'excess supply', operational (or 'dispatchable') load gets pushed to very low levels, leading to one of two outcomes:

- Synchronous generation is pushed out of the market, with system strength and inertia falling to very low levels
- Synchronous generation is directed to dispatch out of merit order, leading to curtailment of wind and solar

This creates a 'lesser of two evils' situation in which energy prices (better in the first scenario) must be traded off against system security (better in the second scenario).

Pumped hydro solves this dilemma by providing a cost-effective way to store the output from wind and solar over these middle hours of the day. Not only does this stabilize the net dispatchable load, enabling more synchronous capacity to stay online, but as fixed-speed pumped hydro is a synchronous technology, it also contributes directly to inertia and system strength.

Apart from the issue of low load, our analysis shows that an ever-increasing evening ramp is likely to emerge across the various NEM regions in the coming decade. This is consistent with AEMO's findings in Stage 1 of the Renewable Integration Study (RIS), which highlights a forecast increase in the size of the evening ramp of 50% in the next five years alone.

Again, pumped hydro is well-placed to address this challenge. Because the technology can change from 100% load to 100% generation, the impact of pumped hydro is effectively double its nameplate capacity. This means that a ramp that would have required 2GW of peaking generation capacity could be met with only 1GW of pumped hydro capacity (in other words, swapping from – 1GW pumping to +1GW generating during the ramp period).

At this kind of duration and scale, pumped hydro is a highly cost-effective, long-lasting solution for utility scale energy storage. Furthermore, as a synchronous technology, fixed-speed pumped hydro can bring additional system security services that asynchronous storage technologies do not possess.

Grid Reliability and Security Services

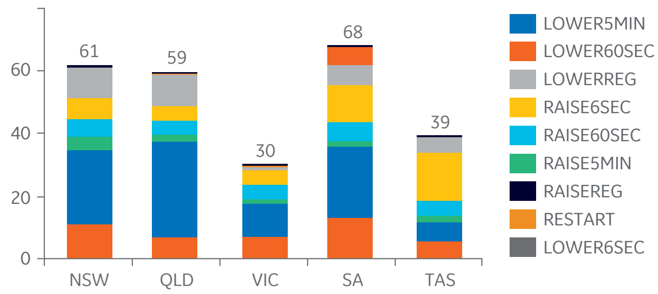
Australia spent $258 million across the 2019 calendar year on ancillary services such as Frequency Control (or FCAS), as outlined in the chart to the right.

Pumped hydro technology can provide many of these services, increasing competition in the various ancillary services markets and reducing the price at which these services are provided.

The specific ancillary services capabilities of fixed vs variable speed pumped hydro technology are summarized below for the typical modes a pumped hydro plant could be operating at when called to provide the given service.

Pumped hydro plants also are well placed to provide a range of the additional services contemplated in the Energy Security Board's 'Post 2025 Market Design' program, including system strength, operating reserve and synchronous inertia. Such services would further support the greater roll-out of intermittent technologies such as wind and solar PV.

Total Ancillary Services Payments (2019)



	FIXED SPEED				VARIABLE SPEED			
	Pump	Turbine	Condenser	Standstill	Pump	Turbine	Condenser	Standstill
Fast Raise / Lower (6 sec)	No	Yes	No	No	Yes	Yes	No	No
Slow Raise / Lower (60 sec)	No	Yes	Yes	No	Yes	Yes	Yes	No
Delayed Raise / Lower (5 min)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Black Start / Restart	Yes*	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reg Raise / Lower	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

* Plant must be designed with black start capability in mind and sufficient water must be reserved in the upper reservoir at all times to enable the plant to transition from pump to turbine mode and inject power into the grid.

Lower Electricity Prices

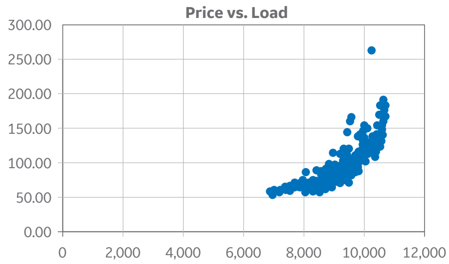
Across the NEM we observe a positive relationship between price and load, but this relationship is not linear, with each increase in load leading to ever larger increases in price. In economic terms, the NEM is typically less price elastic at low load than at high load. In practical terms, incremental generation when marketplace load is high will have a bigger downward impact on price than an equal increase in load when marketplace load is low.

As an example of this dynamic at play, observe the relationship between dispatch load and dispatch price on winter weekdays in 2019 for the three largest markets in the NEM, noting the ever-sharper slope as load increases and the ever-flatter slope as load decreases.

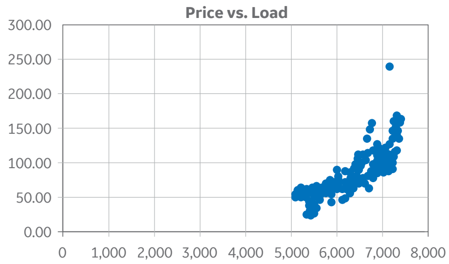
This dynamic means that the operation of pumped hydro plants when generating will tend to reduce peak prices by a much larger amount than the corresponding increase in off-peak prices when they are pumping.

This effect is shown below for an average winter weekday in 2019, based on a hypothetical 4x150MW plant located in QLD with 8 hours of storage. As shown by the grey line in the left-hand chart, our modeling suggests such a plant could deliver a reduction in total daily electricity spend of more than $600,000 across the state. Aggregated across weekdays and weekends across the four seasons of 2019, the estimated reduction in total electricity spend exceeds $140 million, as illustrated in the right-hand chart below.

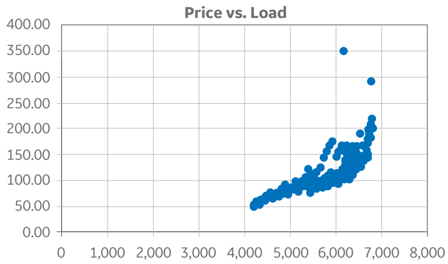
New South Wales



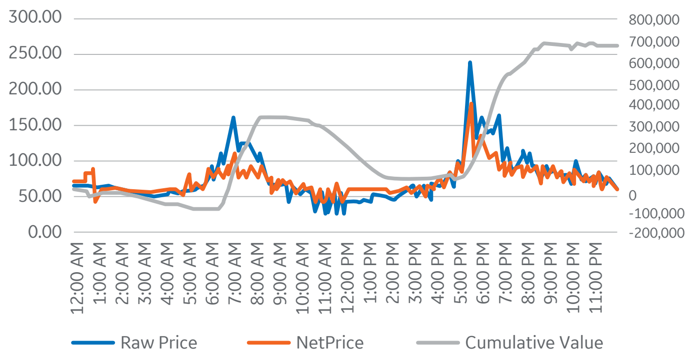
Queensland



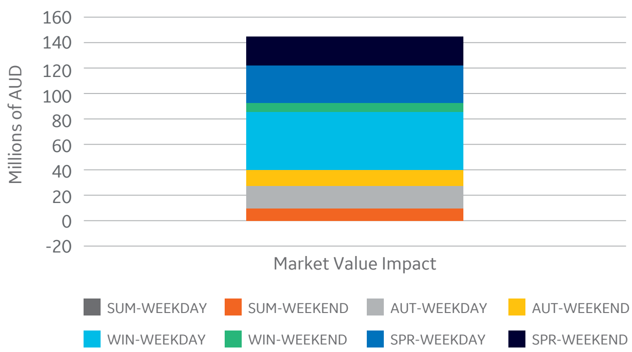
Victoria



Impact on Market Price ($/MWh)



Market Value Impact ($M)



Note: this model's scope only looked at intra-day load shifting. Consideration of the benefits of inter-day load shifting would lead to an even greater market value impact.

Jobs and Investment in Regional Areas

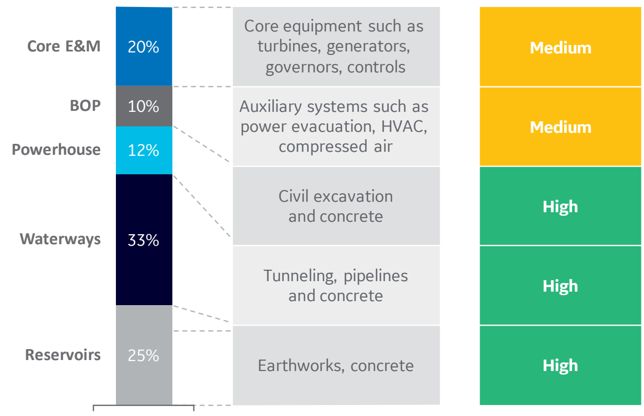
Like many energy projects, pumped hydro projects tend to be located away from urban centers bringing investment and jobs to regional communities that need them most.

Uniquely among energy technologies however, pumped hydro projects include a major civil component, often representing upwards of 70% of the total project capital expenditures (CapEx). This money flows directly into hiring workers and equipment and procuring key materials such as cement, which itself often is produced in regional centers and local communities.

If we look more deeply into the matter, the civil construction skills required to build pumped hydro plants are not dissimilar to those required in mining or road/rail tunneling projects. As such, an investment in pumped hydro would create opportunities for mining workers as well as those currently employed on the various road and rail tunneling projects around Australia.

Likewise, the mechanical and electrical skills required to install and operate the equipment in a pumped hydro plant are similar to those required in a thermal power generation plant, providing new opportunities for workers otherwise displaced by the energy transition.

Typical Capex Breakdown of Pumped Hydro **Ability to Localise**



Reduced Transmission Costs

The development of pumped hydro in strategic regional locations – for instance in the Renewable Energy Zones (REZs) identified in AEMO's Integrated System Plan (ISP) – would deliver more stable output from REZs into the NEM. This, in turn, would reduce the cost of the grid infrastructure by enabling better utilization.

Consider a hypothetical REZ, which would export nearly 100% of its generated power into the NEM. Three broad approaches to transmission could be considered:

- Size the transmission connection at 100% of total rated capacity, knowing that this level generally will not be reached
- Size it below 100% rated capacity, knowing that when output exceeds this level, power is spilled (or curtailed) that otherwise would have been used elsewhere in the NEM
- Use large-scale storage such as pumped hydro to smooth the output across the REZ, enabling high utilization rates on the transmission infrastructure, while simultaneously storing – rather than wasting – the generated power

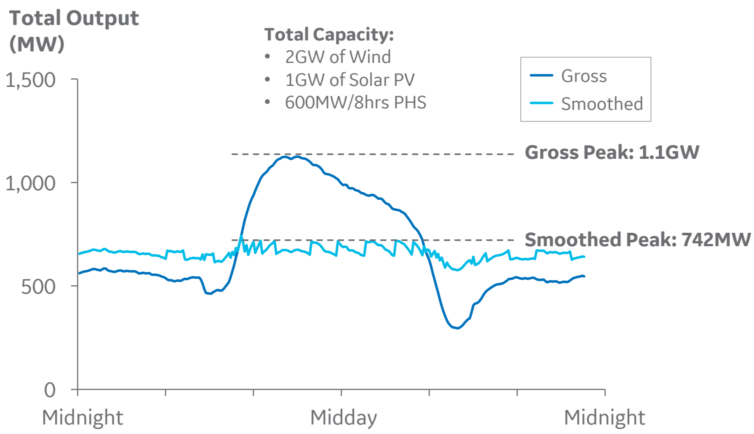
Assuming viable pumped hydro sites are available in or near a given REZ, we expect the third option generally will be preferable.

To demonstrate this effect in action, we have modeled a hypothetical REZ in QLD comprising 1GW of solar PV, 2GW of wind and 600MW for 8 hours of pumped hydro storage (PHS). As outlined below, the addition of pumped hydro to this hypothetical REZ significantly reduces the volatility of output, translating to a significantly smaller, cheaper, and better utilized transmission infrastructure.

In addition, the local system strength and inertia the pumped hydro could bring potentially can greatly reduce the cost of securing these same services through transmission investment in, for instance additional lines or synchronous condensers.

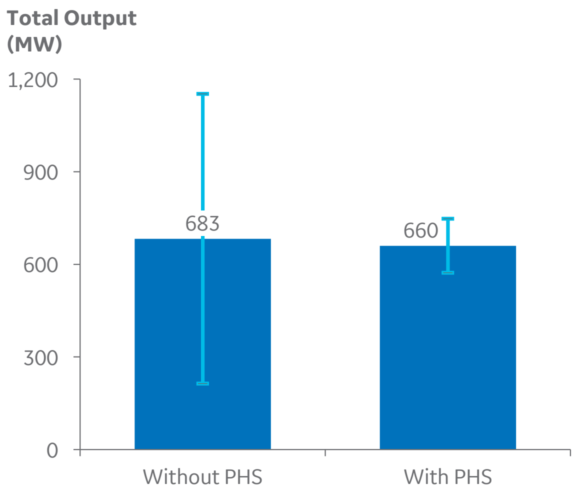
Consideration of the state-level benefits of lower prices, the regional benefits of improved reliability and security and the community benefits of regional jobs and investment would further strengthen the case for inclusion of pumped hydro sites in as many REZs as possible.

Winter Weekday Output for a Hypothetical QLD REZ*



Potential to replace a 1.1GW line at ~60% utilisation with a 742MW line at ~90% utilisation

95% Confidence Interval For Average REZ Output*



Lower Environmental Impact

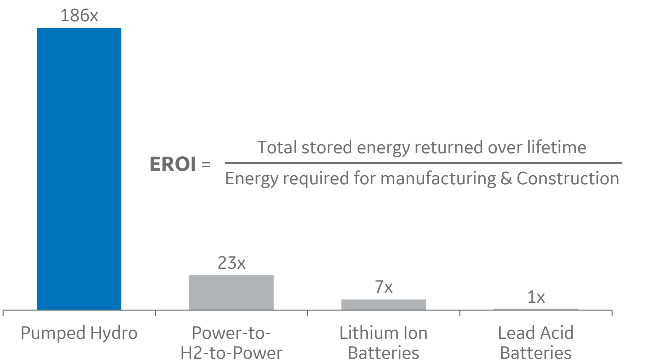
A recent study by Swiss Federal Institute of Technology (ETH) analyzed the "Energy Returned on Energy Invested" of a broad range of power generation and storage technologies.

This metric measures the energy stored or generated over the life of power generation assets in terms of the energy embedded in their manufacture and construction.

Pumped Hydro achieves the highest ratio of the technologies assessed, returning 186 times the energy required for its construction across its operating lifetime.

As such, pumped hydro offers a way to 'firm' the intermittency of renewables, that is itself renewable.

Energy Returned on Energy Invested (EROI)



Source: study by ETH Swiss Federal Institute of Technology Zurich, for SATW (Swiss Academy of Engineering Sciences) on energy performance of power generation technologies in Switzerland

Furthermore, the long operating lives of pumped hydro plants mean that the investments we make today will continue to provide renewable power and grid stability services for generations to come.

A Highly Cost-Effective Solution

As noted in the Technology Investment Roadmap discussion paper, delivering the equivalent amount of storage that the Snowy 2.0 station produces (at a cost of $5.1 billion) would cost hundreds of billions of dollars using Li-Ion batteries. While Snowy 2.0 boasts an unusually long storage duration of 175 hours, pumped hydro remains a highly cost-effective option at far shorter durations than this.

This relates to the fundamental cost structure of pumped hydro: while the MW power capacity drives the cost of the equipment, waterway and powerhouse; incremental duration increases only the size of the reservoirs. This 'economy of duration' is illustrated below for a hypothetical 600 MW project.

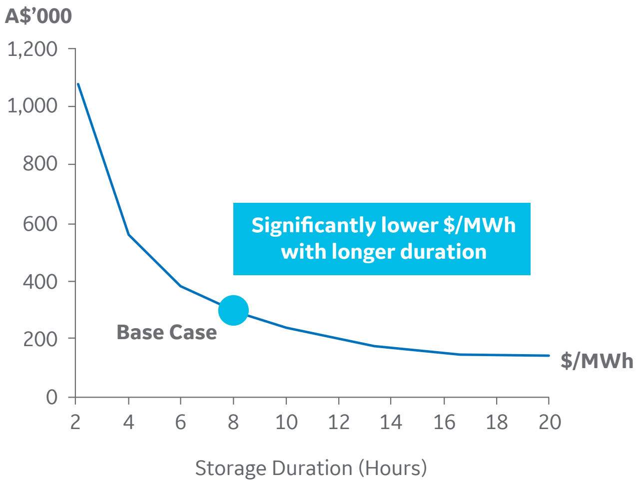
Because of this phenomenon, pumped hydro is naturally very competitive at longer durations compared with other storage technologies, for which capex scales with duration in a more linear manner.

Note that the above analysis considers a hypothetical site with moderate head and waterway length. Higher head and/or a shorter waterway would shift the entire curve downwards, reducing cost per MWh across all durations.

Key Project Characteristics

Capacity	4 x 150 MW
Duration	8 hours (Base Case)
Head	250 m
Waterway	1,250 m
Upper Reservoir	Turkey Nest
Lower Reservoir	Existing Reservoir

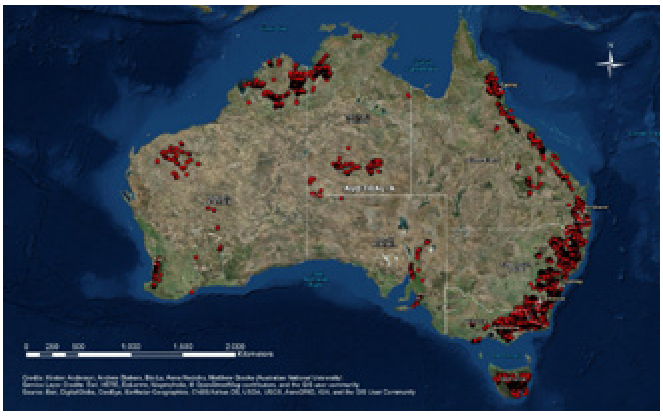
QLD Winter Weekday – Net Dispatchable Load**



Challenges and Opportunities

Positioning Australia as a Clean Energy Superpower

Australia's abundance of high-quality wind and solar resources is now widely acknowledged and greatly exceeds the amount required to meet domestic electricity demand. Industry experts and analysts increasingly are discussing about the opportunity this presents for Australia to position itself as a "clean energy superpower", as the world transitions to a lower carbon future and wind and solar PV continue to come down steep cost curves.



However, if we are to build up (or in some cases build back) our strength in energy intensive industries such as steel and aluminum production, we need electricity that is reliable and secure as well as cheap, which is where technologies such as pumped hydro come to the fore.

While Australia's endowment of pumped hydro resources is not as widely understood as wind and solar, it is no less impressive, with researchers at the Australian National University (ANU) identifying more than 22,000 potential pumped hydro locations across Australia, or roughly 1,000 times the storage capacity needed to enable a 100% renewable electricity system meeting 100% of domestic electricity demand. The map on the left summarizes their findings.

Properly supported, pumped hydro could form the backbone of a reliable, greener electricity system that delivers power at globally competitive prices and enables a renaissance of energy intensive Australian industry and exports.

In effect, pumped hydro offers Australia the opportunity to use the fundamental features of our landform to build a competitive advantage that will serve our country for generations.

Challenges to Overcome

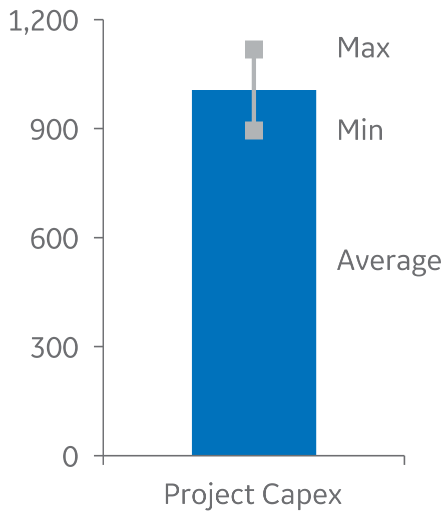
Misalignment of Costs and Benefits

If we return to our hypothetical 600MW x 8-hour project in QLD and assume the site characteristics outlined in the table below left, our modeling indicates an estimated CapEx of $900 million-$1.1 billion.

Key Project Characteristics

Capacity	4 x 150 MW
Duration	8 hours (Base Case)
Head	250 m
Waterway	1,250 m
Upper Reservoir	Turkey Nest
Lower Reservoir	Existing Reservoir

Estimated Capex ($M)



Under a private investment model, this CapEx would be paid entirely by the asset developer/owner over the course of the construction period. In developing their business cases, our customers have advised us they typically consider income from electricity arbitrage and the sale of cap contracts. As such, we have modeled the trading profit (electricity arbitrage + cap revenue) a plant such as this could expect to have earned if it had operated throughout 2019. As shown in the left-hand chart below, we estimate an annual trading profit of $28 million. As shown in the right-hand chart, this is dwarfed by the market value created through lower electricity prices across the market due to the operation of the pumped hydro plant.

Note: We have excluded ancillary services from this analysis as customers advised they are typically less than 10% of the revenue stack and are not considered "bankable".

Under private ownership, most of the value created by the project would be a positive externality – benefiting electricity consumers across the marketplace but providing no cashflow to the developer. In this situation, only the $28 million trading profit would be considered in the business case, leading to a simple payback period in excess of 35 years.

While this is well below the typical design life of a pumped hydro plant, it is far beyond the investment horizons of most private sector investors.

Under public ownership, the full economic benefit of $173 million per year would be considered against the CapEx of about $1 billion, leading to a simple payback period of just below 6 years. In fact, this analysis is conservative, as it considers only the trading profit and the market value associated with lower electricity prices. Quantification of the other benefits of pumped hydro (such as reduced transmission investment) would further improve the overall economic payback period.

Long Timeframes

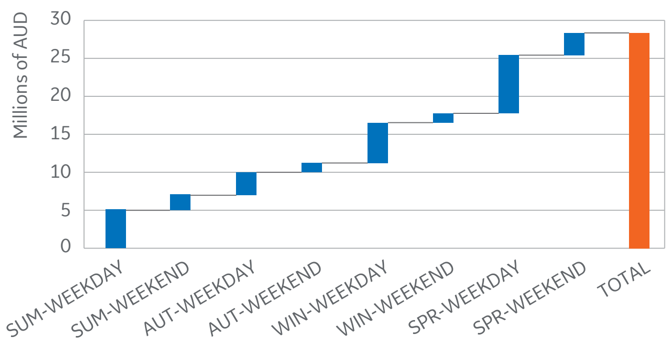
Investment in pumped hydro is a long-term proposition, with most of the sites under development in Australia expected to take at least 3-4 years to build. However, the typical design life of a pumped hydro plant is at least 50 years, with an operating life that greatly exceeds this in practice. This is significantly greater than the operating life of every other generation or storage technology currently available.

Importantly, the operating life of a pumped hydro plant is relatively unaffected by the number of daily cycles it completes. This is not the case for chemical storage technologies, whose operating life is measured in charge-discharge cycles. Hence these solutions decline rapidly as the number of daily cycles increases (a likely scenario as renewable penetration continues to rise).

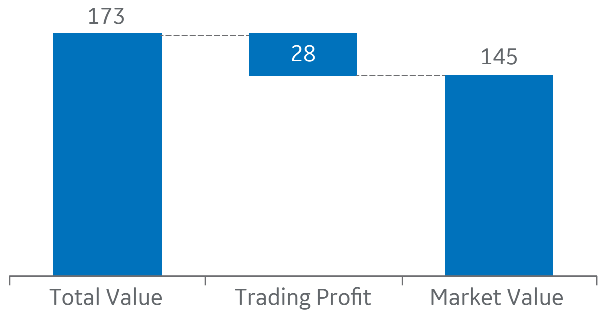
Despite these advantages, the discounted cashflow methodology used by private sector investors places far greater weight on near-term cashflows than on long-term ones, amplifying the costs incurred during the long construction cycle while discounting the revenues and benefits created during the long operating life.

This dynamic exacerbates the cost-benefit misalignment outlined above and makes it harder still for pumped hydro development to occur without meaningful government involvement to help better align the benefits of pumped hydro with the costs. This government involvement can take many forms, from direct underwriting of revenue to capital grants to the creation of new markets that allow developers to monetize more of the benefits their projects create.

Annual Trading Profit by Season & Day



Trading Profit vs. Market Value



Note: We have excluded ancillary services from this analysis as customers advised they are typically less than 10% of the revenue stack and are not considered "bankable".

Successful Pumped Storage Models Around the Globe

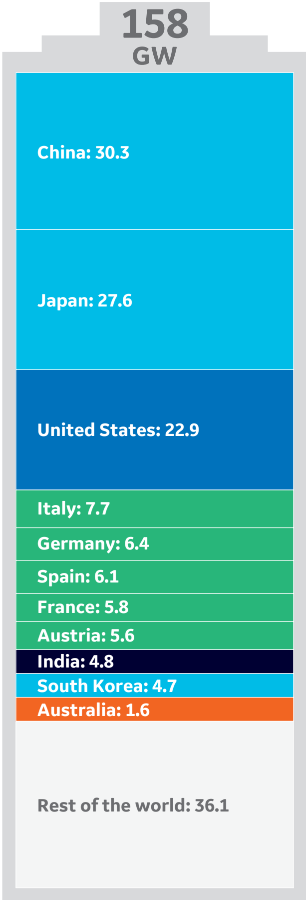
Overview of pumped hydro Development Worldwide

According to the International Hydropower Association (IHA), total installed pumped hydro capacity was estimated at approximately 158 GW in 2019 and can store globally up to 9,000 GWh.

Several studies have identified vast potential for the development of pumped storage sites worldwide, and there is also a strong potential for retrofitting disused mines, underground caverns, non-powered dams and conventional hydro plants. With more than 100 projects in the pipeline, IHA estimates that pumped hydropower storage capacity is expected to increase by almost 50% – to about 240 GW by 2030.
In terms of energy storage capacity, IRENA estimates that pumped hydro storage capacity will increase by 1,560-2,340 GWh above 2017 levels by 2030. In the longer term, IRENA forecasts that pumped hydro would need to double, reaching 325 GW by 2050 to accompany the global energy transition.

Recent developments globally were mainly driven by China. Approximately 80% of new pumped hydro plants currently under construction are located in China. Other projects have recently been commissioned or are still under construction in Europe, Asia, Israel, Australia, Morocco, or United Arab Emirates.

Pumped hydro assets involve both generation and transmission, making the business models more complex. Long term policies, regulatory simplification and increased visibility can help utilities and investors better understand the benefits—and their value—that pumped hydro storage provides. A variety of market designs and revenue schemes have been implemented successfully globally. Summarized below are some of the different approaches we have seen.



Source: IHA 2020 Hydropower Status Report

China: Managing pumped storage as a Grid Asset

To address a growing need for energy while ensuring the "energy revolution" towards more renewable sources, China has been investing massively in clean power solutions.

To accommodate its increasing share of wind and solar sources, as well as to support its significant coal and nuclear power fleet, China has planned in the 13th Five Year Plan to add 17 GW of pumped hydro storage capacity by 2020, bringing the overall capacity to 40 GW (and even targeting 90 GW by 2025). This will provide the grid with power for peak demand, supplemental power for periods of reduced production, and energy storage for emergency power standby and frequency regulation.

In China, storage assets are considered as grid assets and therefore are largely managed by state-owned grid companies that benefit from clear business model as those costs are included in the grid operating expenses.

Several regimes have been adopted over time to allow asset owners to cover project's operating costs plus an agreed (with the regulator) rate of return on the project's capital costs. The latest evolution is based on a two-part tariff scheme, which consists of a capacity payment and energy tariff. On the one-hand, the capacity fee is regulated and settled for each individual project together with the local power grid company. The capacity fee rewards the availability of the pumped hydro plant and the support services that it provides to the grid (power system reserve, frequency and voltage regulation, black start). On the other hand, the energy tariff compensates the variable operating costs such as pumping charges and generation losses. Compared with previous mechanisms that were solely based on capacity payment, this two-part tariff regime does not only provide fixed guaranteed revenues but also additional payments depending on utilization, thus contributing to the optimization of those resources.

	Generation-based tariff regime	Capacity-based tariff regime	Generation- and capacity-based two-part tariff regime
Payment basis	Energy generated (i.e. per kWh)	Installed capacity (i.e. per kW)	Energy generated and installed capacity
Value reflected	Generation value	Capacity value	Capacity value and generation value
Revenue Certainty	Revenues depend on the utilization of PSH plant by the grid company	Revenues are guaranteed by the grid company	Revenues are ensured by the grid company and additional payment depending on utilization
Assessment	**Simple, but not attractive to investors**	**Tariff sharing policy is crucial**	**Attractive to investors**

Source: Institutional and pricing reforms for pumped storage hydroelectricity in China (2015)

Israel: Private Investment Thanks to 20-Year PPA For Availability

Israel is another example of how hydro storage can support a nation's energy plan. Operating on a stand-alone independent grid that requires stability and high flexibility, Israel decided to balance increasing solar and wind production by building pumped hydro storage power plants. The Israeli Electricity Authority have fixed a target of 800 MW of pumped hydro, accounting for 5% of the 18 GW total installed capacity. One project has already been commissioned (Gilboa 300 MW) and another one is under construction (Kokhav Hayarden 344 MW).

The plants are under the control of the Israel Electric Corporation (IEC) which is in charge of power generation assets, sub-stations, as well as transmission and distribution networks in the country. The plant performance has to comply with Public Utilities Authority (PUA) regulation for pumped storage plants, and with all relevant Israeli laws and IEC standards.

A 20-year Power Purchase Agreement (PPA) was signed with Independent Power Producers that are building power plants to cover the costs of investment, Operation & Maintenance, and return on equity. Revenues comprise three kinds of payments: basic availability payment, energy payment and performance payment. Indeed, extra revenues can be awarded for additional benefits provided to the IEC and are mainly based on the performance of the plant in terms of flexibility such as start-up time and transition times.

For Gilboa and Kokhav Hayarden, GE Renewable Energy will cover the full day-to-day operation and maintenance for 18 and 20 years respectively, keeping performance up and reducing operational risks. This guarantees tariff-setting performance to GE's customers and is a concrete example of how GE can work with its customers all along the value chain.

India: Firming Renewables through Combined Auctions

India has set up very ambitious renewable energy targets, as the country aims to reach 175GW of installed renewables by 2022, meaning it has to connect 30 to 40 GW of renewable capacity annually. It is also targeting to reach 450 GW of renewables installed base by 2030, including Hydropower.

This additional capacity will have to be balanced with flexible storage power assets. Pumped Storage can play a critical role to enable a smooth energy transition through the provision of flexible peak power capacity. India currently has 2.6 GW of Pumped Storage that are already operational and another 3.1 GW under construction. Additionally, about 90 GW of Pumped Storage potential has been identified across 63 sites and recognized in national energy policies for their valuable grid services.

Name of the Project	State	Installed Capacity (MW)	Status
Kadamparai	Tamil Nadu	400	Operational
Bhira	Maharashtra	150	Operational
Srisailam	Andhra Pradesh	900	Operational
Ghatgar	Maharashtra	250	Operational
Purlia	West Bengal	900	Operational
Poithan (Jayakwadi Dam)	Maharashtra	12	Operational
Sardar Sarovar	Gujarat	1,200	Partially Constructed
Tehri	Uttarakhand	1,000	Partially Constructed
Kadana St. I & II	Gujarat	240	Partially Constructed
Nagarjuna Sagar	Telangana	705	Partially Constructed
Total Operational		**2,612**	
Total Under Construction		**3,145**	
Total Including Under Construction		**5,757**	

Source: CEA, IEEFA

Therefore, the government has taken a series of decisions to favor the development of hydropower and Pumped Storage. In 2019, hydropower has been reclassified as renewable power and new policy rules have been adopted to incentivize electricity supply during peak hours, better recognizing the value of flexible and dispatchable power solutions such as hydropower and Pumped Storage.

In this context, GE will supply four 125 MW fixed speed pumped storage turbines for the new Kundah Pumped Storage plant that will be operated by the state government utility Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO). This greenfield project is part of the initiatives supported by the central government of India to significantly increase storage capacity/hydropower resources locally to support better renewables integration in the overall Energy Mix. The policies are intended to ensure sustainable and flexible energy production during peak demand periods and consequently reinforcing grid stability in the country.

Besides, India also amended its 'hybrid wind-solar with storage' policy, allowing Pumped Storage to participate in auctions together with Wind and Solar projects. Thus, the country launched in 2019 the World's first gigawatt-scale renewables plus storage tender. Solar Energy Corporation of India (SECI) issued a tender for 1.2 GW of renewable projects, combined with 600 MW of storage capacity during 6 peak hours. Auctions including Pumped Storage were the most competitive and will benefit from a 25 year PPA (Power Purchase Agreement) based on a two-part tariff (auctioned Peak Tariff and settled Off-Peak Tariff). There are another 3-4 GW RTC (Round The Clock) Green Power tenders expected to be floated by SECI in the next 2-3 years time frame. Also the Ministry of Power (Government of India, GOI) has been advocating building Integrated, Schedulable Renewables, instead of standalone, wherever possible.

Austria: The Alpine Battery of Europe

Hydropower accounts for more than 50% of total installed power generating capacity of the country. With a target of a 100% power from renewable energy in 2030, further balancing capacity and flexibility will be needed for grid stability. Austria's 2017 Power Grid Development Plan identifies hydropower as a key enabler of the energy transition and the related projected increase of wind and solar. Further development of Hydropower will also support the increasing electricity demand and energy security objectives.

Most of the energy utilities are partially owned by the federal and state governments (up to 51%) which can therefore support the development of new projects. The Austrian government has decided to expand hydropower generation with several new greenfield plants and expansion and retrofitting projects. For example, the 360 MW Obervermuntwerk II pumped storage plant which has been designed in parallel to the existing Obervermuntwerk plant, was commissioned in 2019. This is one of the biggest horizontal units in the world and is equipped with GE's motor generator technology. Besides, GE is currently in charge of retrofitting the two units of the motor generator for the pumped storage power plant Malta Upper Stage. The works consist in the upgrade of the motor-generator to a fully fed variable speed pump storage motor-generator, providing more flexibility.

Additional projects under development/construction are listed here below:

Project	Power (MW)	Energy (GWh)	Grid synchronization	Technology
Kaprun Oberstufe (refurbishment)	48	10	2021	Conversion from ternary to fully fed varspeed
Malta Oberstufe (refurbishment)	40	2	2021	Conversion from ternary to fully fed varspeed
Malta Hauptstufe (refurbishment)	150		2022	Conversion from ternary to fully fed varspeed
Reißeck II (extension)	42		2022	New fully fed (extension to existing power station)
Tauernmoos	170	16	2025	New fully fed
Limberg III (extension)	480		2025	Double fed varspeed (as planned today)
Ebensee	170		2020	
Kaunertal (extension)	900	557	2034	
Kühtai	130	216	2026	New fully fed
Obervermuntwerk II (extension)	360		2019	Ternary
Riedl energy store	150		Completed	

Source: based on Oesterreichs Energie – Association of Austrian Electricity Companies – List of projects (https://oesterreichsenergie.at/kraftwerksliste.html)

On top of this domestic context, Austria is strategically located at the center of Europe and its electricity network is highly interconnected with neighboring countries, especially Germany, Switzerland, the Czech Republic and Slovenia. Bottlenecks in the European transmission network get more and more regular and Austria is particularly affected by north-south electricity flows, and has to balance volatility by absorbing and transporting huge volumes of electricity generation from solar and wind power. This is a key opportunity for Austria to position as the European electricity hub and battery.

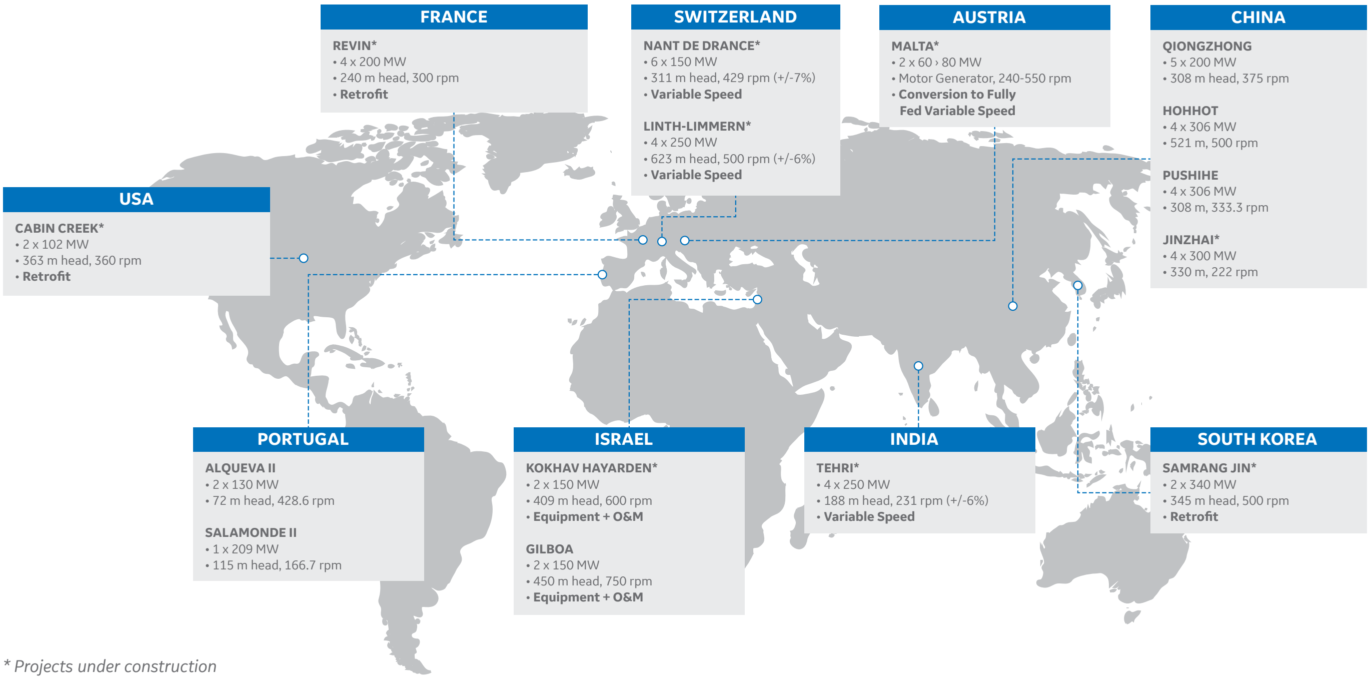
To support those challenges in Europe's energy system infrastructure, the European Union has put in place public funding mechanisms such as the Projects of Common Interests (PCI). The Kaunertal pumped hydro storage project will benefit from this mechanism. ENTSO-E (the European Network of Transmission System Operators) highlighted in a report that this new PSH project is one of the most effective means to solve deficits of the region, as it is designed for integration of renewables generation, ancillary service provision in all time frames as well as all flexibility products, such as voltage stabilization, black start capability and islanding operation on transmission system level.

Middle East and North Africa: Securing a Cleaner Energy Mix

Several countries in the Middle East and North Africa have started the decarbonization of their power fleet. They are leveraging the solar resources which offer great potential in the region as well as wind power in some cases. Besides, several countries such as the United Arab Emirates, Egypt or Turkey also plan to install their first nuclear power plants. Both the integration of higher shares of renewable energy together with the development of nuclear power capacity have led those countries to develop pumped hydro plants. Thus, in UAE, the Dubai Energy and Water Authority (DEWA) has launched the construction of a 250 MW pumped hydro storage plant.

GE's Pumped Storage Experience and Expertise

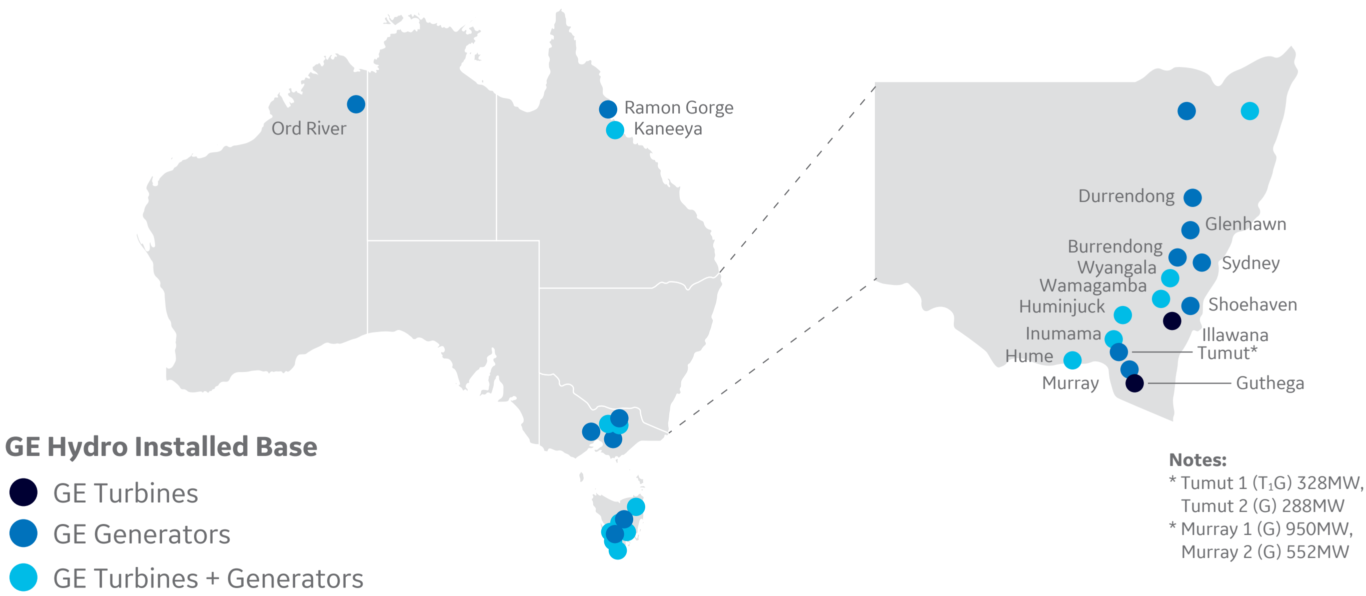
GE is a major global player in both conventional and pumped hydro, with an installed base exceeding 320 GW in total and 45 GW in pumped hydro specifically. Backed by more than 50 years of pumped hydro plant experience, our reference book covers everything from 4 MW to 400 MW units at head heights ranging from 25 meters to 1112 meters. Current and recent projects around the world are outlined below.



** Projects under construction*

Across Australia, GE boasts a 3.9GW installed base of hydro turbines and generators that power almost half the hydro capacity in Australia. We also maintain an in-country service team, based out of our office in Hobart, supporting customers across the NEM and helping to ensure Australia's more than 8GW fleet of hydro generation plants continues to operate smoothly.

GE Hydro Australian Installed Base



GE Renewable Energy offers integrated solutions for both fixed and variable speed pumped hydro plants. Together with our customers and partners, we help minimize cost, maximize energy output and provide optimal grid support and responsiveness. Our offering across both new equipment and service is summarized below.

New Projects & Equipment

- From standardized small and micro solutions to customized large solutions
- Design and supply of all key equipment pump turbine, motor-generator, control system, hydro mechanical equipment, full Balance of Plant
- Supervision of installation, training, testing, commissioning
- Selective early-stage project development support

O&M Service & Retrofit

- Planned and unplanned outage
- Plant support
- Retrofit
- Service agreement
- Asset management
- Full O&M capability – 65 units under management globally

Through constant investment in engineering and R&D, we are able to offer solutions delivering high levels of efficiency, rapid transition times and wide operating ranges without ever compromising on hydraulic stability, noise or vibration levels.

Should you wish to explore our offering (or your project) further with us, then please contact Martin Kennedy (martin.kennedy@ge.com) to arrange a meeting.

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