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Pumped Hydro Storage in India

Getting the right plans in place to achieve a lower cost, low carbon electricity market

Five years ago, India committed to an ambitious transformational target of 275 gigawatts (GW) of renewable energy installations by 2027.

The target for new installs of 30-40GW annually puts India on track to be one of the largest developers of renewables globally, potentially second only to China.

To do this, India must continue to modernise its electricity system, developing a dynamic time of day pricing signal for producers and consumers alike. Additionally, US$10-20bn annually must continue to be invested in expanding the national grid transmission and distribution system. Flexible on-demand peaking capacity of all types also needs to be added to balance low cost but highly variable renewable energy generation.

India is on track to be one of the largest developers of renewables globally.

Storage is another key issue and IEEFA expects pumped hydro storage (PHS) to play a central role. PHS works by storing energy in water in an upper reservoir, pumped from a second reservoir at a lower elevation when there is excess power in the system. When there is demand for energy, the water in the upper reservoir is released and as it falls, it turns turbines that create the power.

This briefing note evaluates the progress and potential of PHS as a key sector in India, ideally requiring at least US$20bn of new investment in the coming decade.

India on path to becoming a world leader in pumped hydro storage

Plans have been formulated for India to become a world leader in PHS.

Some 2.6GW of PHS are already operational with another 3.1GW under construction, albeit much delayed (See Figure 1). Proposals for another 8.9GW are on the drawing board. However, given the enormous social costs and absence of a strong price and policy signal for producers and consumers, progress has been stalled for many years.

There are a number of reasons for the delay in PHS projects. Large hydro power projects in India commonly get embroiled in social and political issues mostly related to loss of significant areas of agricultural flood plains and forest lands, and forced relocation without just compensation for affected rural communities. Interstate disputes over water rights compound environmental issues such as flood safety concerns and agricultural needs.

Further, with seasonal water flows and mountainous, remote locations, hydro-electricity requires very patient capital, and engineering technology is certainly challenged.

India's enormous plans for new low-cost, deflationary, domestic renewable energy also comes with an associated, critical need to accelerate the deployment of storage,[1] and PHS is ideally suited to play a leading role.

Figure 1: List of Pumped Hydro Storage Facilities in India

Name of the Project	State	Installed Capacity (MW)	Pumping Mode operation
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	Patially Constructed
Tehri	Uttarakhand	1,000	Patially Constructed
Kadana St.I & II	Gujarat	240	Patially Constructed
Nagarjuna Sagar	Telangana	705	Patially Constructed
Total Operational		**2,612**	
Total under Construction		**3,145**	
Total including under construction		5,757	

Source: CEA, IEEFA

Recent developments look promising

India recently amended its 'hybrid wind-solar with storage' policy to clarify that any form of storage – not just batteries – could be used in hybrid projects, including PHS, compressed air and flywheels.

Then, in March 2019 India's Ministry of Power proposed electricity rule changes to incentivise electricity supply at times of peak demand, a key pricing signal needed to underpin financial bankability of storage projects.

Both government initiatives look very promising.

At the same time however, the ongoing challenges of financial viability in the thermal power sector has seen installations stall significantly faster than any expectations. Compounding this problem, several policy back-flips by the Indian government have seen the enormous growth in renewable energy installations

[1] We will address India's lithium ion battery development plans separately. The focus of this briefing note is on PHS potential.

undermined near-term (including repeated tender cancellations, the solar module import imposition, policy delays and GST confusion).

Figure 2 details the installation progress in the eleven months to February 2019 including 6.74GW of renewables versus just 0.02GW of new thermal power (net of end-of-life plant closures). New tenders for renewables are being announced weekly, and near to record low tender results are clearly still available where the right tender structures and apportioning of risks are in place and costed. In total, India tendered 35GW of new solar projects over 2018/19.

Figure 2: India's Installed Electricity Capacity (GW) to February 2019

Source	Mar-18	Feb-19	Change (GW)
Renewables	69.02	75.76	**6.74**
Large Hydro	45.29	45.40	0.11
Nuclear	6.78	6.78	0.00
Thermal	222.91	222.93	**0.02**
Total Ongrid Capacity	**344.00**	**350.87**	**6.86**

Source: CEA, IEEFA calculations

To support the targeted 7% of annual GDP growth, India needs to add 20GW of net new thermal/nuclear power capacity additions (at 60-70% capacity factors) or 40GW of renewable/hydro energy (at 20-40% capacity factors) annually, or a combination thereof. As more fast-to-build variable renewable energy is added, more fast ramping on-demand peaking generation capacity is needed.

Pumped hydro storage is well established globally

Globally, PHS is an established, proven and cost-effective technology for storing electricity at times of high generation and/or low demand, which can then be released into peak demand periods.

There is some 140GW of PHS capacity installed globally providing well over 95% of global electricity storage capacity.

PHS has a round trip efficiency of 70-80% (meaning 20-30% of electricity is lost), depending upon the distance and gradient separating upper and lower reservoirs.

PHS is designed to time-shift electricity to periods of peak demand so that power is stored when it is least expensive and then used during peak demand when prices are highest.

With its almost instantaneous start capacity, PHS is ideal for meeting evening peaks as well as providing grid frequency stabilisation services. Where and when alternative water demands allow, PHS can also provide longer duration supply – a capacity that lithium ion batteries are not well suited for.

PHS as a key facilitator of variable renewable energy in India

PHS has traditionally been built in mountainous regions using existing modified upper and lower lakes for reservoirs. IEEFA notes large scale PHS can also be undertaken on a small site using a closed or open water loop, a distinct advantage relative to more complex hydro-electricity dam complexes.

Refurbishing end-of-life dams and adding PHS to existing water storage dams could also inject significant value-add to India's existing portfolio of 45GW of hydro-electricity capacity.

In July 2017 the Central Electricity Authority (CEA) released a report focusing on the need to operationalise existing PHS plants built but yet to be commissioned, as well as prospective projects. The CEA estimated there are 96GW of PHS capacity at 63 sites across India.

The CEA concluded that a peaking power tariff is required to incentivise PHS in India. Additionally, there is significant capacity that could be added by modernising and retrofitting existing hydro-electricity capacity with PHS capacity.

India has witnessed several PHS proposals:

- In 1970 India's first PHS project commenced at Nagarjuna Sagar in Telangana with an installed capacity of 705 megawatts (MW). The hydro-electricity capacity was commissioned during 1980-85. In 2017 the CEA reported that "the project is not working in pumping mode as the tail pool dam construction took a long time and is still not functional."

- The 1,450MW Sardar Sarovar dam project in Gujarat has been massively delayed since 1961 due to technical feasibility issues as well as the enormous negative social impact due to submerging 40,000 hectares of land. In September 2017 it was finally reported as having been commissioned as a dam providing flood management, irrigation, drinking water and hydro-electricity capacity, at a financial cost of Rs16,000 crore (US$2.3bn). In 2017 the CEA reported that the final component to convert the dam into a 1,200MW PHS was under construction and due for completion in October 2018, but no confirmation has been reported since.

- In June 2017 Karnataka Power Corporation Limited announced the 2GW Sharavathy Pumped Storage Project (8 x 250MW) in the Shivamogga and Uttara Kannada districts in Karnataka, using the existing Talakalale and Gerusoppa reservoirs. The 2017 construction cost was estimated at a very low Rs2.5 crores per MW or a total of Rs4,862 crores (US$700m) given the limited civil works required, with an estimated construction time of five years.

- In February 2018 the Tamil Nadu Generation and Distribution Corporation (TANGEDCO) confirmed plans for a 500MW Kundah PHS proposal at a total cost of Rs1,831 crores (US$265m) for commissioning in 2022/23. The project finance is being sourced from the Rural Electrification Corporation (REC). Kundah's merits include a low capital cost given it leverages two existing reservoirs: the 'upper' Porthimund and the 'lower' Avalanche-Emerald. Kundah is also in an area least prone to landslides and seismic activity, a key risk in other areas of India.

- In October 2018 Odisha Hydro Power Corp (OHPC) proposed a PHS unit totalling 600MW at its existing 600MW hydropower plant at the Indravati multi-purpose reservoir in Odisha. The International Finance Corporation (IFC) is planning a US$210m tender for construction of the project with total investment estimated at Rs3,000 crore (US$430m).

- Another 1GW (4 x 250MW turbines) of PHS is proposed on Turga dam in West Bengal. In November 2018 the Japan International Corporation Agency (JICA) announced financing of US$260m for the project, which is not scheduled for completion until 2027.

The emergence of PHS as a key facilitator of variable renewable energy is critical for India. International market developments mirror this thinking.

Case studies from Australia

In Australia, low cost renewable energy projects delivering tariffs of US$25-35/MWh are now booming. In belated support of this, new PHS investment proposals worth US$6-7bn across nine projects and covering 3.05GW with a collective 358GWh of storage capacity, are under active discussion.

While the Snowy 2.0 US$5bn 2GW/350GWh PHS and associated grid expansion has been garnering the most media attention, there are many other proposals providing significant geographic diversification. These include:

- Energy Australia's 225MW / 1,770MWh seawater PHS in Cultana South Australia that is potentially on-line as early as 2021 (US$340m or US$1.5m per MW capital cost, 72% round-trip efficiency, 260 metre design head).

- Genex Power's 250MW/2GWh proposal at the end-of-life Kidston goldmine in far north Queensland that is due on line by 2022.

- Hydro Tasmania's Battery of the Nation PHS expansion stage I at 250MW (Tarraleah and Gordon), with the potential to expand this to 4.8GW in 14 sites.

- SIMEC ZEN Energy's OneSteel Iron Duchess North 90MW/390MWh PHS at a disused mine site near Whyalla, South Australia at a proposed cost of A$170m (US$120m).

- Origin Energy's PHS expansion of an additional 235MW at Shoalhaven, New South Wales at a cost of A$230m (US$160m).

- MirusWind's Walcha Energy Project which includes PHS as part of a 3.4GW wind / 0.5GW solar hybrid project near Armidale, New South Wales.

Conclusion

While hydro-electricity is fraught with social issues in India and many other non-temperate, monsoonal climates and areas of high population densities, PHS has a much smaller footprint.

PHS can play an immensely important role in facilitating India's improved energy security and transition to a lower cost, low carbon electricity market that will require flexible, dispatchable, as well as peak power capacity, especially until battery storage becomes cost competitive.

About IEEFA

The Institute for Energy Economics and Financial Analysis conducts research and analyses on financial and economic issues related to energy and the environment. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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