CSTEP's analysis on

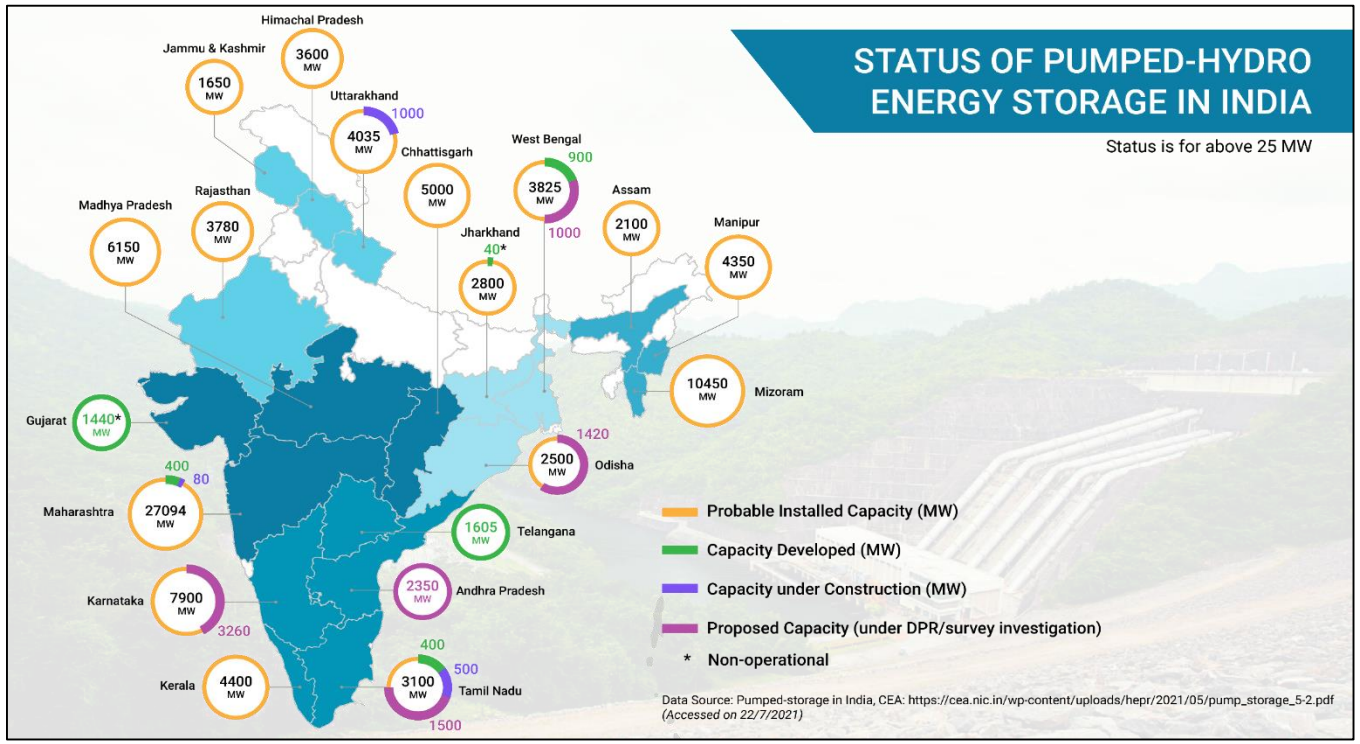
Pricing Mechanism of Pumped-hydro storage in India

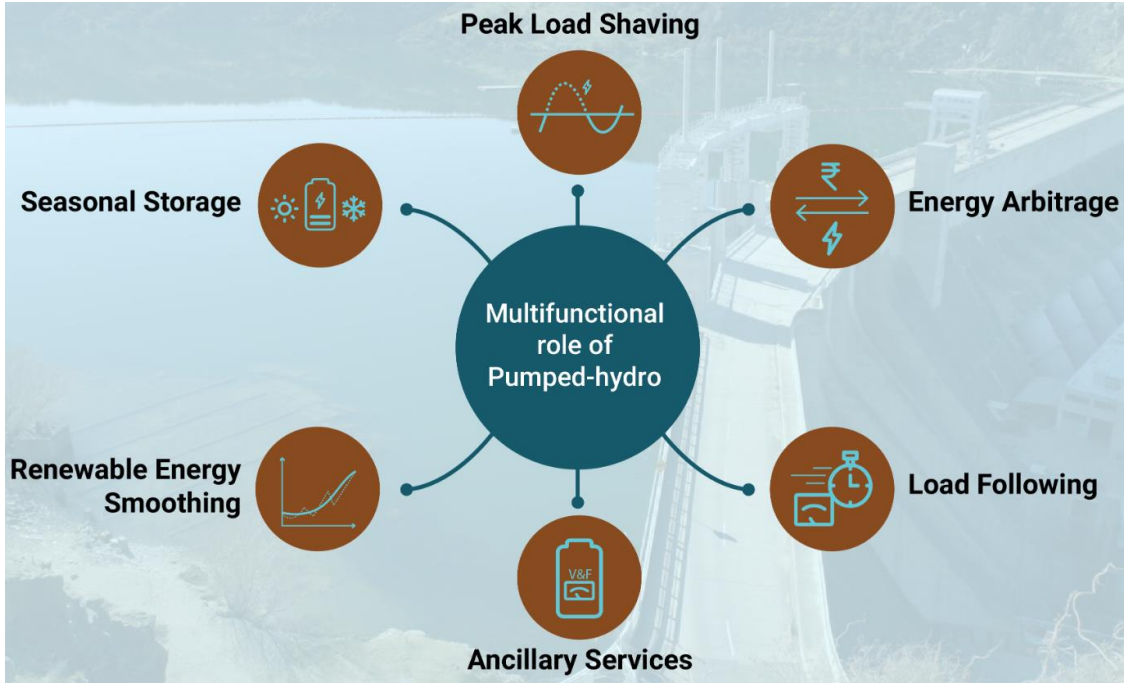
Introduction

- India plans to install 450 GW of renewables by 2030.
  - Pumped hydro energy storage (PHES) is an available and mature energy storage technology
  - The probable capacity of PHES in India is 96.5 GW

Status of Pumped storage plant in India (GW)			
Operational	Non-operational	Under Construction	Proposal development
3.3	1.48	1.58	8.38

Operational PHES in India	Type
Nagarjuna Sagar, Telangana	705 MW, Open loop
Srisailam, Telangana	900 MW, open-loop
Ghatghar, Maharashtra	250 MW, open-loop
Bhira, Maharastra	150 MW, open-loop
Kadamparai Tamil Nadu	400 MW, open-loop
Purulia, West Bengal	900 MW. Closed loop

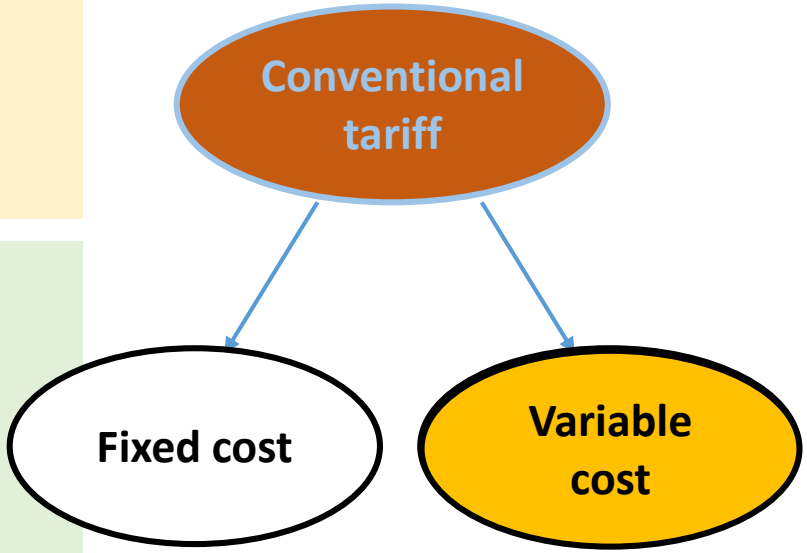




Motivation & Objective

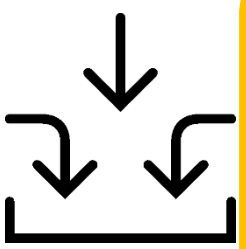
- Motivation
  - The pace of development of PHES in India has been tepid
  - Due to high initial investment, environment clearance issues, and low recovery from current pricing mechanism
  - Current tariff system based on the amount of energy generation from PHES
    - Do not take into account the grid flexibility aspects of PHES

- Objective
  - Develop a pricing mechanism for PHES in India with high penetration of renewables
  - Revenue to be based on variable cost
  - Mechanism to be developed for specific use-cases:
    - Peaking operation
    - Renewable Smoothing



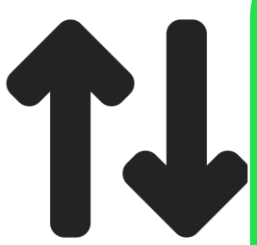
Tariff computation for peak load shaving

- PHES utilization as a market asset
- Use-cases: Peak Shaving / Energy arbitrage / Load following asset



Inputs

- Short-term market prices
- Market Volume
- Regional load profile
- Details on the PHES operation



Dispatch Strategy

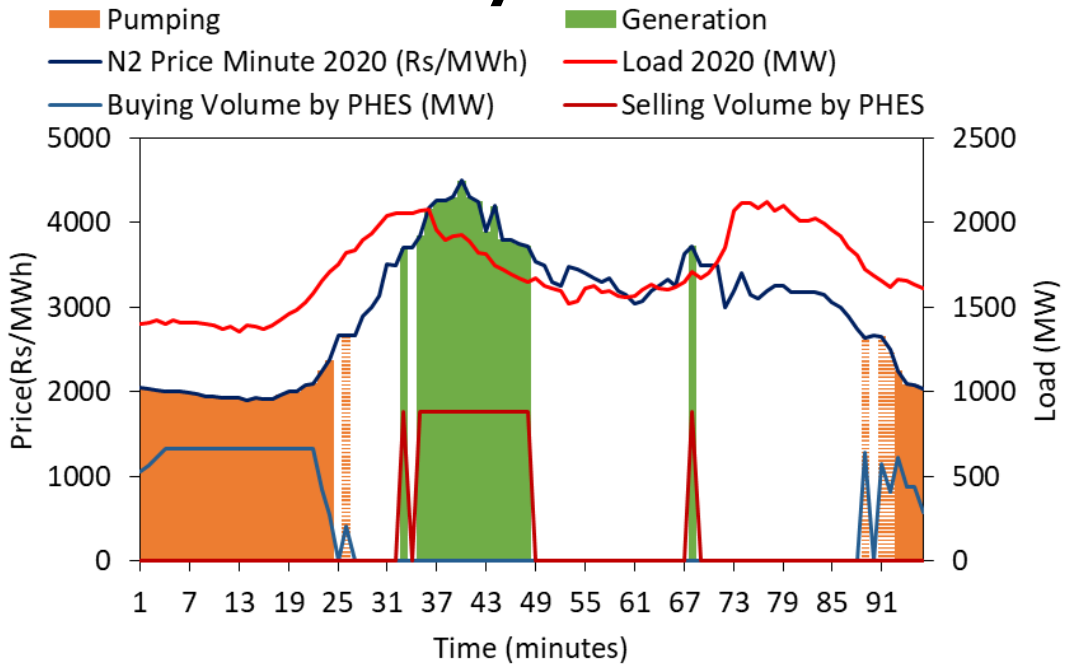
- Charging during low prices and discharge during high prices
- Charging during low prices and discharge during peak load

Pricing Mechanism

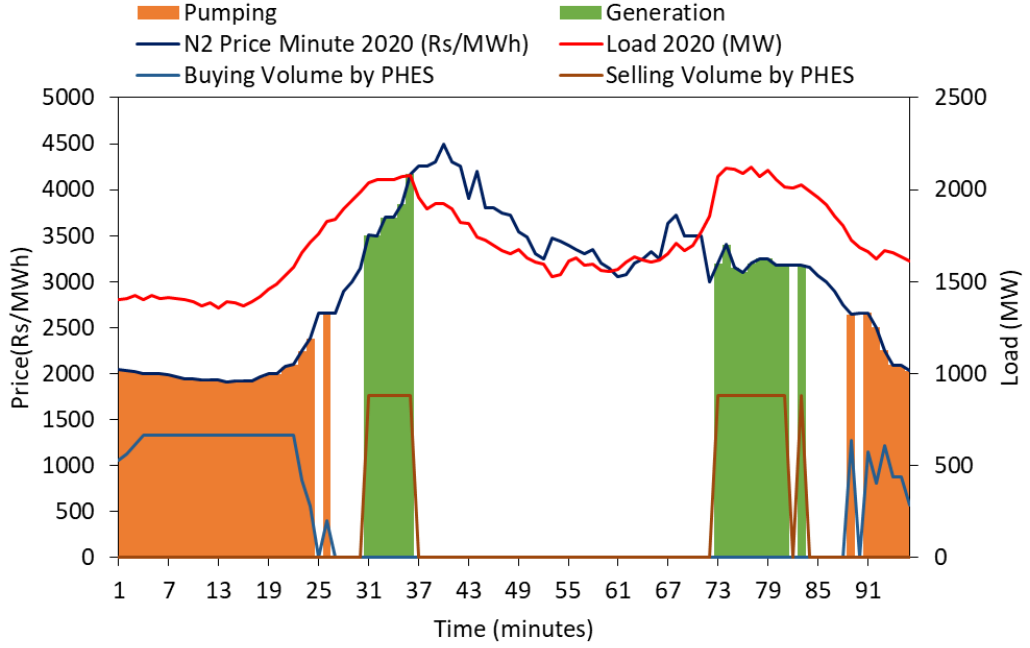
- PHES trading in IEX market
  - Peak and off-peak pricing based on the market clearing prices for different time periods
  - Compute profit as the difference between peak tariff and energy charges

Case Study: Uttarakhand

Maximizing the Profit

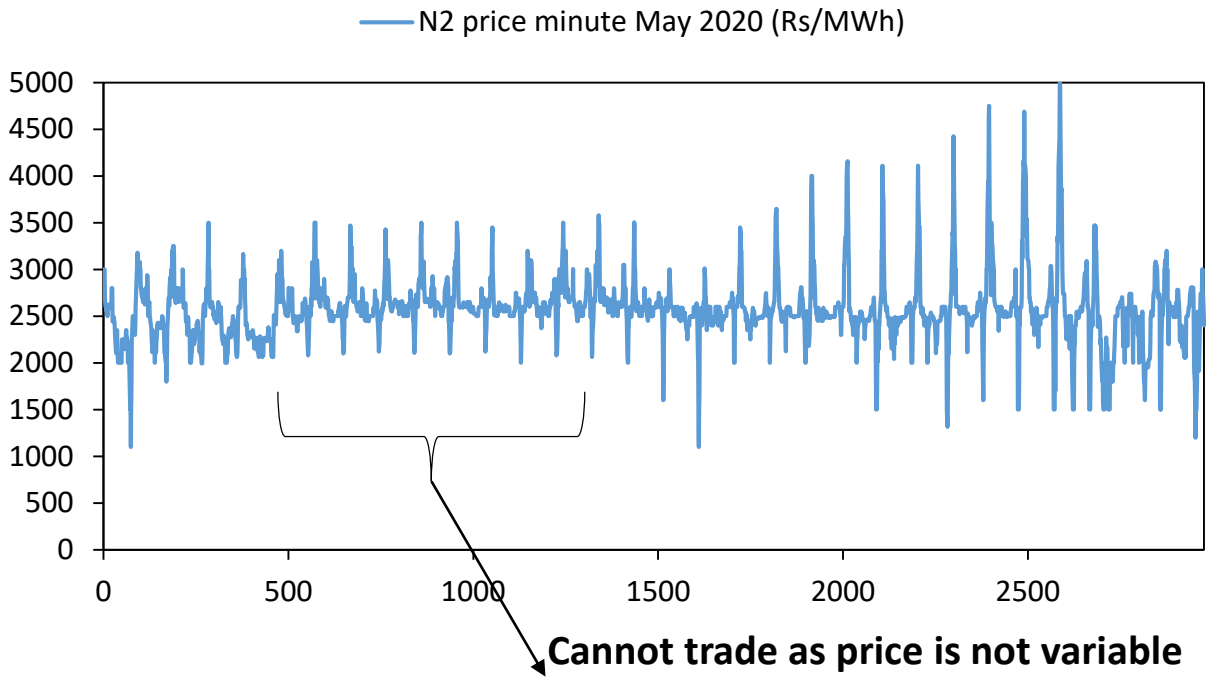


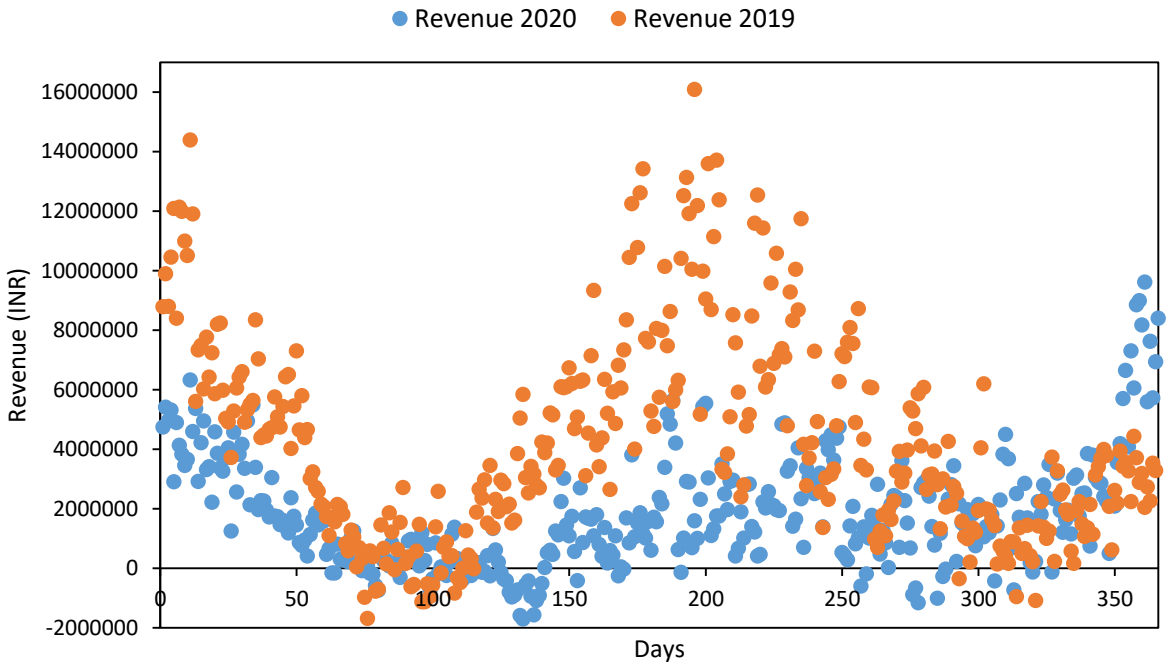
Peaking operation



Particulars		Maximizing the profit	Peaking Operation
Consumption cost (Buying from IEX) (Rs)		96,29,168.68	96,29,168.68
Selling cost from IEX (Rs)		1,41,58,222.3	1,19,67,113.87
Profit/Loss with POC & IEX charges		38,25,323.22	16,34,214.74
With POC charges	Avg. Peak tariff (Rs/kWh)	3.94	3.32
	Avg. Off-Peak tariff (Rs/kWh)	2.15	2.15

Pricing variability across years



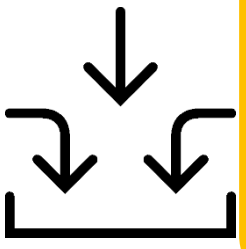


- If there is no saving potential then no need to bid in market
- For the Uttarakhand case study
  - Price averaged for the highest 16 minute time blocks for a day for 2019 & 2020
  - Price averaged for the lowest 28 minute time blocks for a day for 2019 & 2020

Results	2019	2020
No profit generation days	21	53
Ratio of average peak price to off-peak price to generate profit	1.35	1.33
Max profit generated for a day (Rs) Avg. peak price (Rs/kWh) Off-peak price (Rs/kWh)	1,60, 82,247 (15-Jul) 7.5 2.25	96,14,821 (26-Dec) 5.3 1.95
Net profit for the year (INR crores)	157	70
% fixed cost recovery	16	7

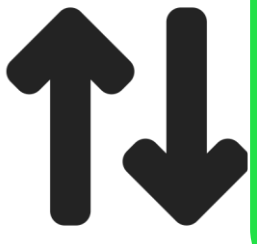
Tariff Computation for RE smoothing

- PHES utilization as a grid asset
- Use-cases: Round-the-clock support / RE smoothing



Inputs

- Load
- RE profile (solar + wind)
- Inputs related to market and incentives



Dispatch Strategy

- Charging using peak RE production and discharge during low RE and peak load/high price

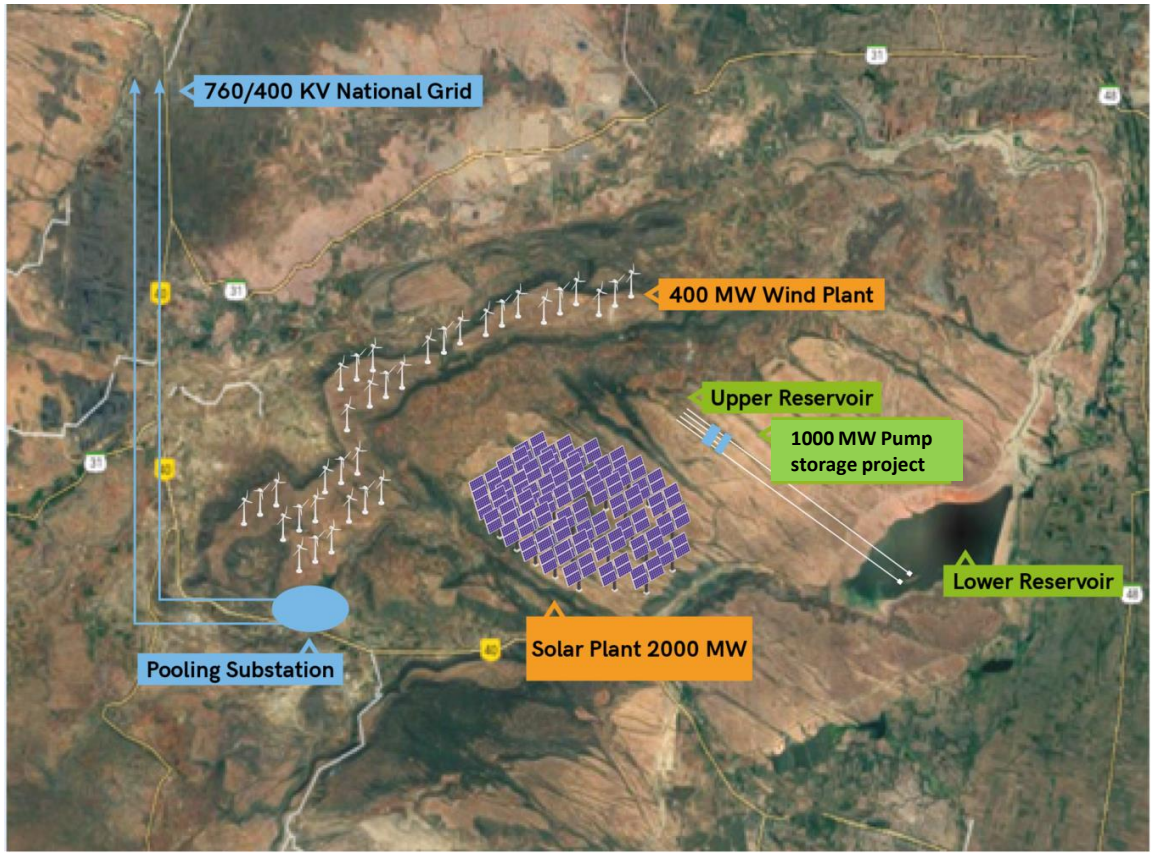
Pricing Mechanism

- PHES trading in long-term market (PPA/bilateral trade)
  - To meet RPO obligations
  - To reduce RE curtailment
  - To provide dispatchable power

Case Study: Pinnapuram PHES, Andhra Pradesh

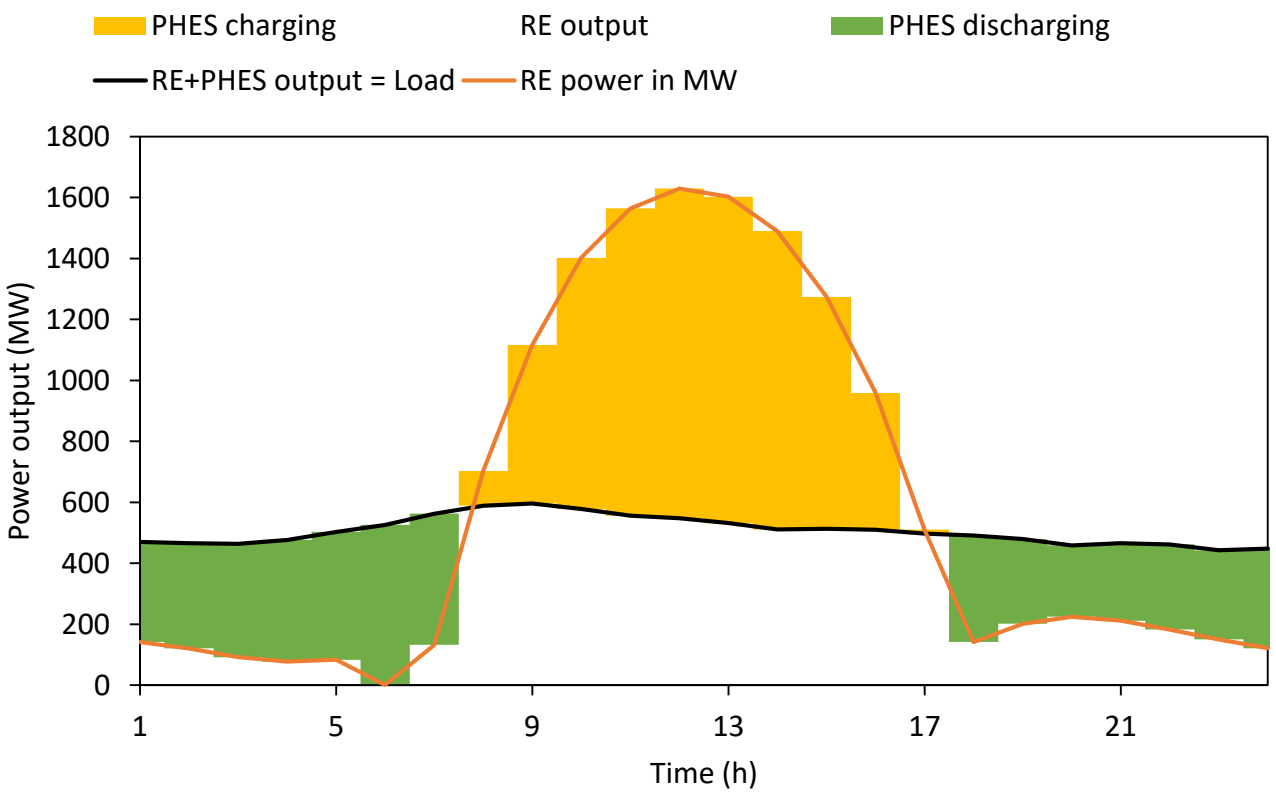
- Co-located PHES plants/Grid-connected PHES plants
- Case study: Pinnapuram integrated renewable energy storage plant

Pinnapuram PHES details	
Solar plant (MW)	2000
Wind plant (MW)	400
PHES (MW)	1000
Annual Generation (GWh)	2774
Annual consumption (GWh)	3645
Generation duration (h)	8
Pumping duration (h)	9.22
Turbine & Pump	6 units (3 fixed & 3 variable speed)
Efficiency	76%



Case study – Dispatch Strategy & Pricing Mechanism

- Diurnal variation of RE can be levelled using PHES



PHES pumping energy for the day (MWh)	6819
Pumping hours(h)	10 (< 1083 MW)
PHES generation energy (MWh)	4833
Generation hours (h)	14 (<950 W)
Efficiency for the day	70.8%

Pricing Mechanism	
Pumping price (P)	RE cost + interconnection charges
Generation Price (G)	P+ **X**
X	RE curtailment penalty **and/or** avoided cost from high priced purchase of thermal or gas **and/or** incentive for providing grid flexibility **and/or** Generation based incentive

Case Study – Pricing Mechanism

		Minimum scenario	Intermediate scenario 1	Intermediate scenario 2	Intermediate scenario 3	Maximum scenario
Pumping cost (Rs/kWh)	**RE cost (Rs/kWh)**	2	2	2.5	2	3
	Interconnection charges	1	1	1	1	1
Compensation (Rs/kWh)	**RE curtailment penalty**	0	0.5	0.875	1	1.5
	Avoided cost from high priced gas / thermal plants (from AP tariff order)	0.37	0.37	0.37	0.91	0.91
	Grid flexibility incentive	0	0	0.5	0.5	1
	Generation based incentive (GBI)	0	0.5	0.5	0.5	1
Generation cost (Rs/kWh)		3.37	4.37	5.745	5.91	8.41
Profit/Loss (Rs/kWh)		**0.37**	**0.87**	**2.245**	**2.91**	**4.41**

Our Recommendations

- A differential pricing mechanism with different pumping and generation prices instead of having only generation based energy charges.
- The profit generation to be used for fixed cost recovery.
- Pricing mechanism for PHES should be based on specific use-cases.

❑For energy arbitrage/peak load shaving/load following use-case
- ▪Operate PHES in market
- ▪As for Tehri PHES, there is a fixed-cost recovery of 16% or 7% depending upon the MCP's

❑For round-the-clock support/RE smoothing use-case
- PHES is used as grid asset
- Incentives - Compensation for avoiding RE curtailment, avoided cost from high-priced purchase of thermal or gas plants, grid flexibility incentive, generation-based incentive
- As for Pinnapuram PHES, profit can be in the range of INR 0.37 to INR 4.41 per unit

Our Recommendations

- Alternative funding mechanism for PHES
  - An expense distribution model with multiple stakeholders involved reduces the risk
    - Utilization of open-pit coal mines as well as beneficiary owned lands will further reduce the fixed cost
  - Budgetary subsidy on viability gap funding
  - Foreign direct investment for pumped-hydro project
- On high commissioning cost/environmental concerns of PHES
  - Smaller distributed PHES plants
    - Flexible operation
    - Mitigate delays /cost overruns/legal hurdles/protests due to environmental clearances

Thank you

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