INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

8th International R&D Conference on
Global Trends in Water Resources, Power & RE Sectors
Feb 08 – 09, 2024

Net-Zero Goal- Hydro and PSP

Feb 08, 2024

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Future Trends for Energy Use

The future of global energy is dominated by four trends:

- Declining role for hydrocarbons,
- Rapid expansion in renewables,
- Increasing electrification,
- Growing use of low-carbon hydrogen

McKinsey Global Perspective 2023

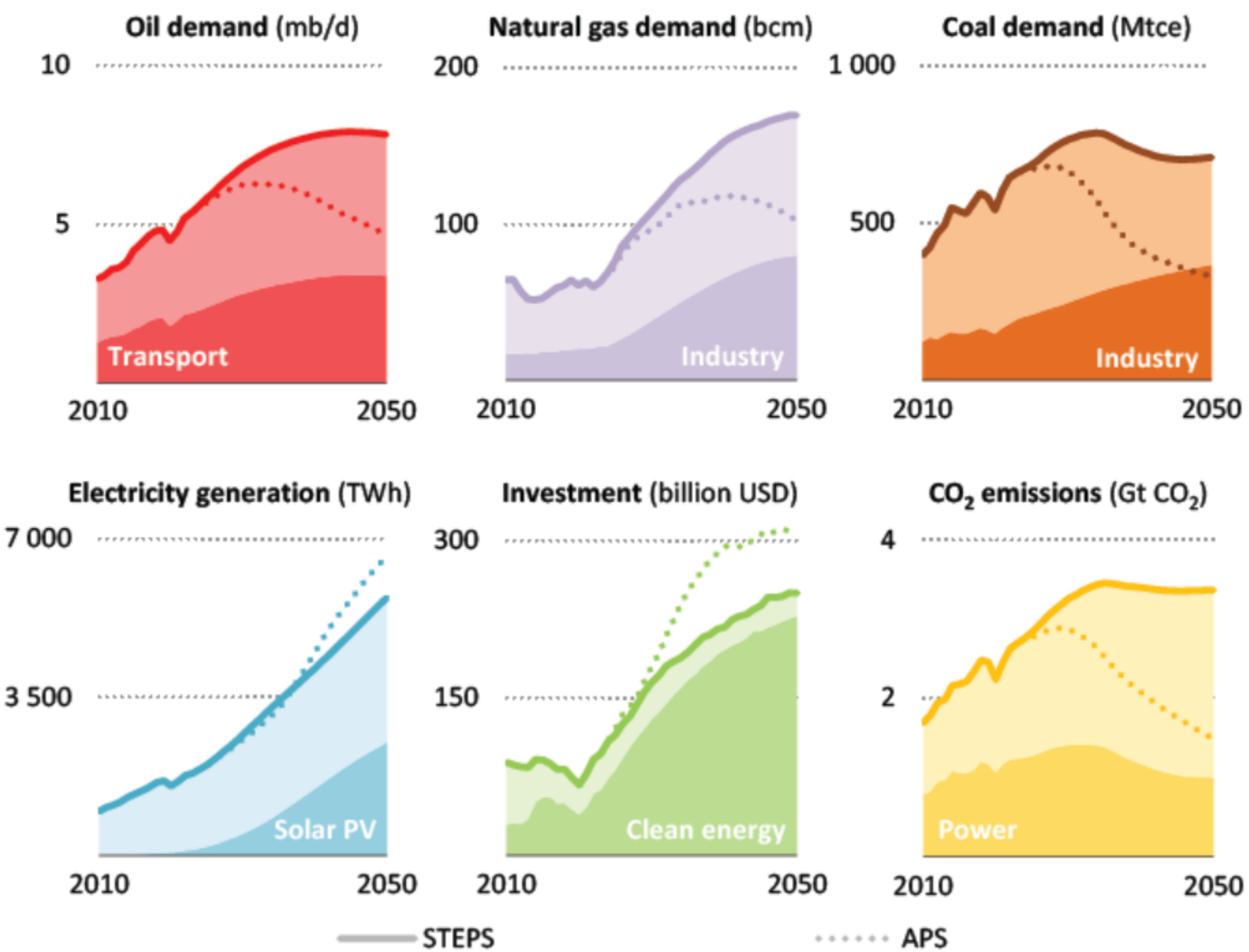
- Uptake of low-carbon technologies continued to grow
- a persistent demand in fossils fuels and increase in emissions
- Faster transition scenarios show stronger energy-efficiency gains and a faster uptake of electrification and low-carbon fuels
- Fossil fuel demand is projected to peak soon, but the outlook remains uncertain

Drop in demand by 2050 for Oil by 48% and coal 85%

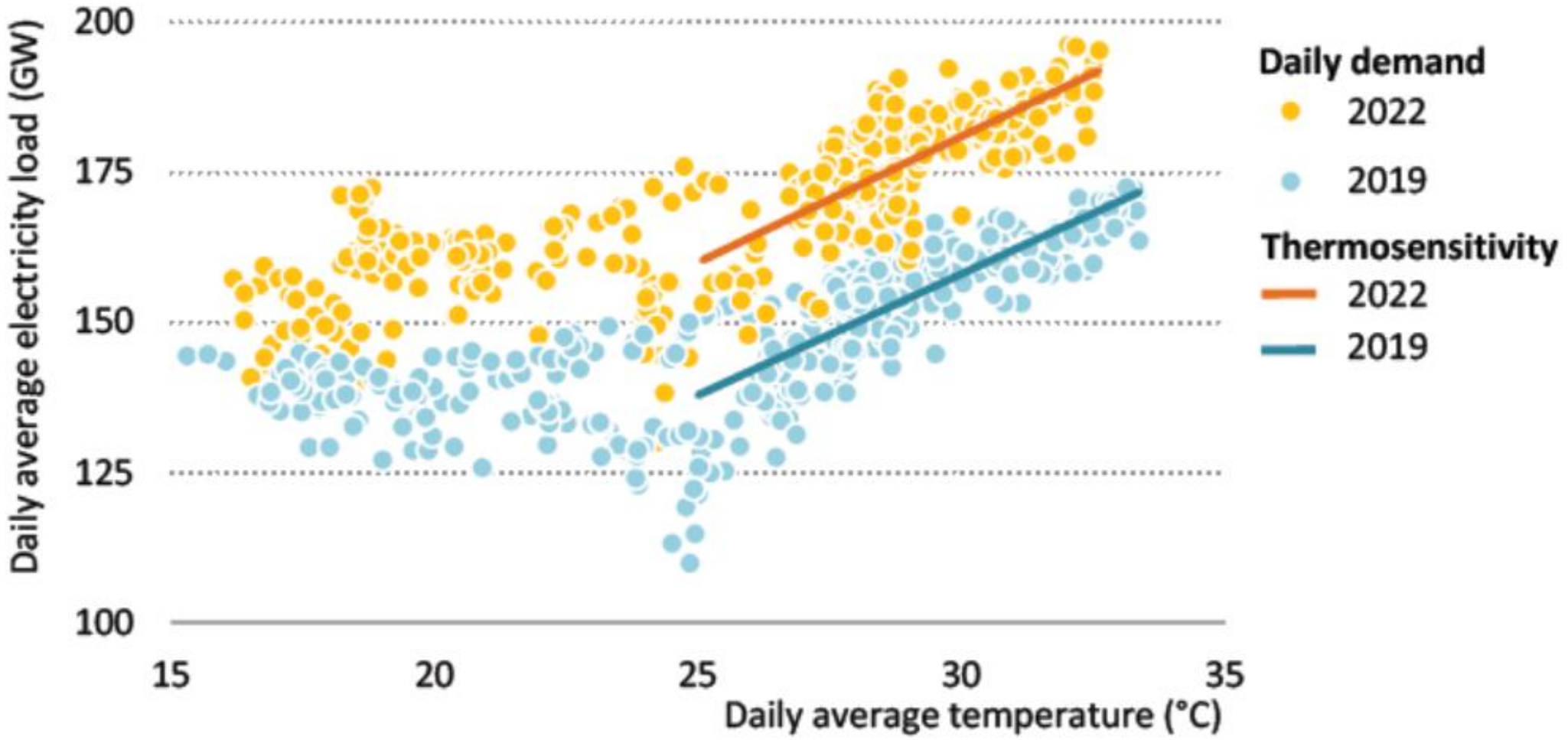
Key trends in India 2010-2050

STEPS: Stated Policies Scenario

APS: Announced Pledges Scenario



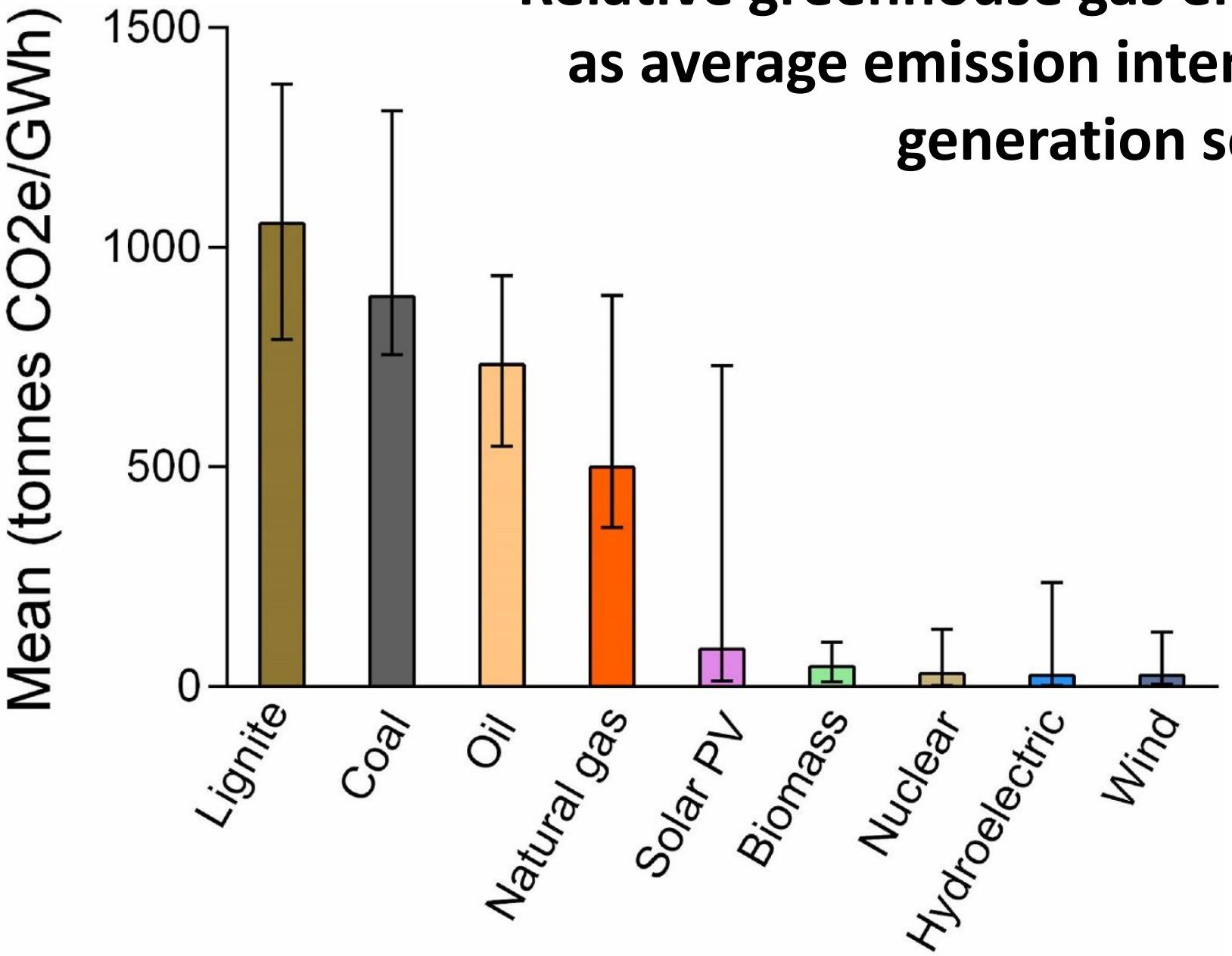
Daily average electricity load versus daily temperature in India, 2019 and 2022



Electricity demand rises sharply with temperatures above 25°C

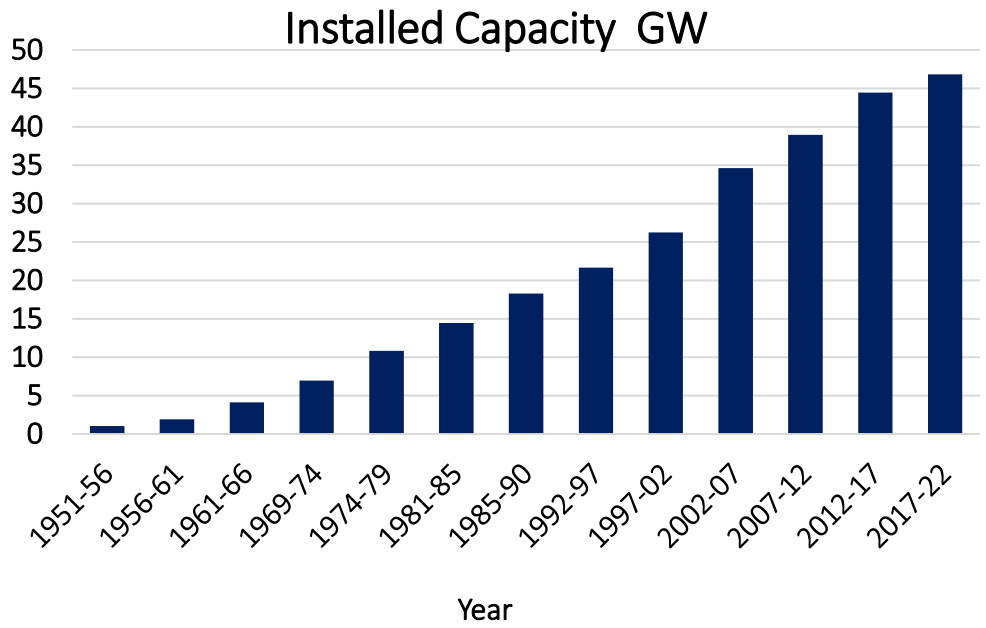
use of more space cooling appliances is pushing electricity demand up

Relative greenhouse gas emissions (CO_2/GWh) as average emission intensity by electricity generation source



India Power and Drivers for boosting RE including Hydropower

- Third largest electricity consumer 1300-1500 TWh.
- Capacity - 425 GW (238 GW thermal, 179 GW RE including 52 GW Hydro and 7.5 GW nuclear) today.
- 179 GW of RE – 29% hydro power, 24% wind and 47% solar today.
- Per capita electricity consumption: 1,255 kWh during 2021-22
- India has aligned its domestic policies to meet the commitments made on international stage COP 26 Glasgow by Indian PM
- Non Fossil electricity capacity of 500 GW by 2030
- Carbon intensity reduction of 45 % from the 2005 levels till 2030
- Net zero by 2070



First Hydro plant in 1897

India's Hydro potential – 145 GW

Harnessed – 46.85 GW, Small Hydro – 5 GW

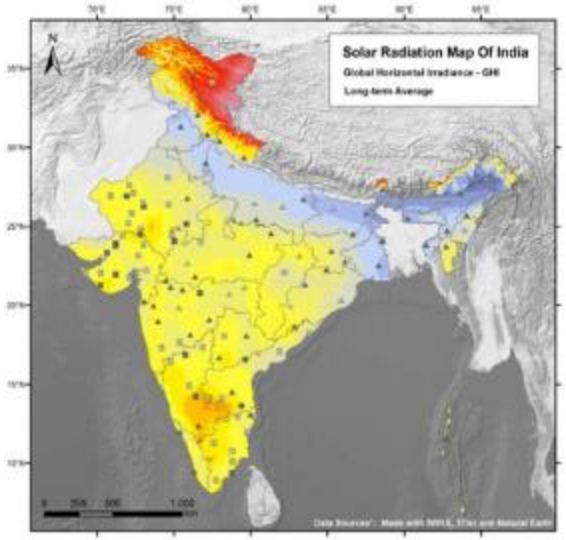
Federal 33%, state: 60%, Private: 7 %

15.5 GW under construction,
20 GW cleared,
21 GW under survey

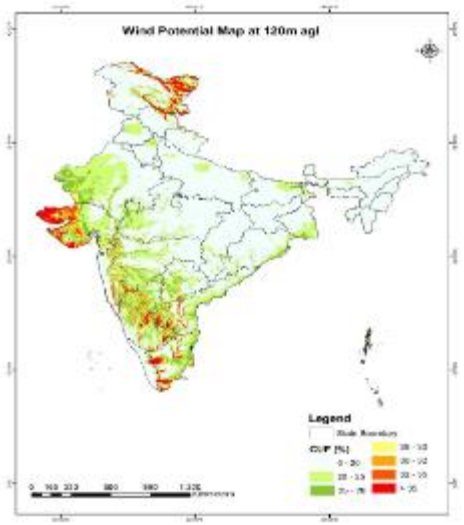
PSP
- 4.7 GW in operation till 2022
- 2.7 GW Under Construction – 2024

Clean Energy Transition Underway in India

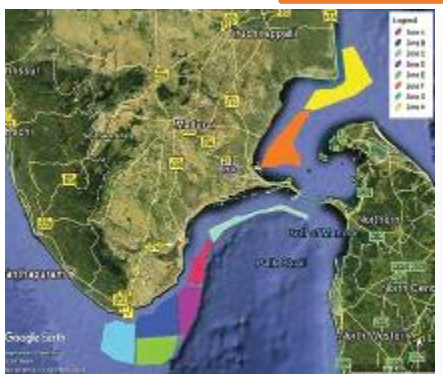
Solar Radiation Atlas



Wind Atlas



Offshore Wind



Solar and wind dominated India's power generation capacity growth in 2022, accounting for 92% of total capacity additions. Coal accounted for only 5%.

Source: ग्रिड-इंडिया GRID-INDIA

Present Total Installed Capacity ~416 GW

Present Renewable Installed Capacity ~ 172 GW

Present Solar + Wind Installed Capacity ~109 GW

Solar Potential ~ 750 GW,

Wind Potential @ 120 mtr agl ~ 700 GW

Off-shore wind potential ~ 70 GW (coast of Gujarat & Tamil Nadu)

RE PENETRATION			
Region/State (FY 2023-23)	Annual VRE Penetration (Energy Terms) (%)	Maximum Daily VRE* Penetration (Energy Terms) (%)	Maximum Instantaneous VRE Penetration (MW Terms) (%)
Rajasthan	14.57	35.81	56.00
Northern Region	10.56	18.36	46.75
Gujarat	15.44	35.80	55.80
Madhya Pradesh	11.01	32.40	53.90
Maharashtra	10.10	23.00	37.21
Western Region	11.03	23.10	35.13
Karnataka	27.52	65.38	132.00
Andhra Pradesh	20.50	58.59	81.00
Tamil Nadu	18.42	50.08	77.00
Telangana	12.17	17.63	49.00
Southern Region	16.91	36.32	61.00
All India	11.01	20.40	31.80

*VRE:Wind and Solar only

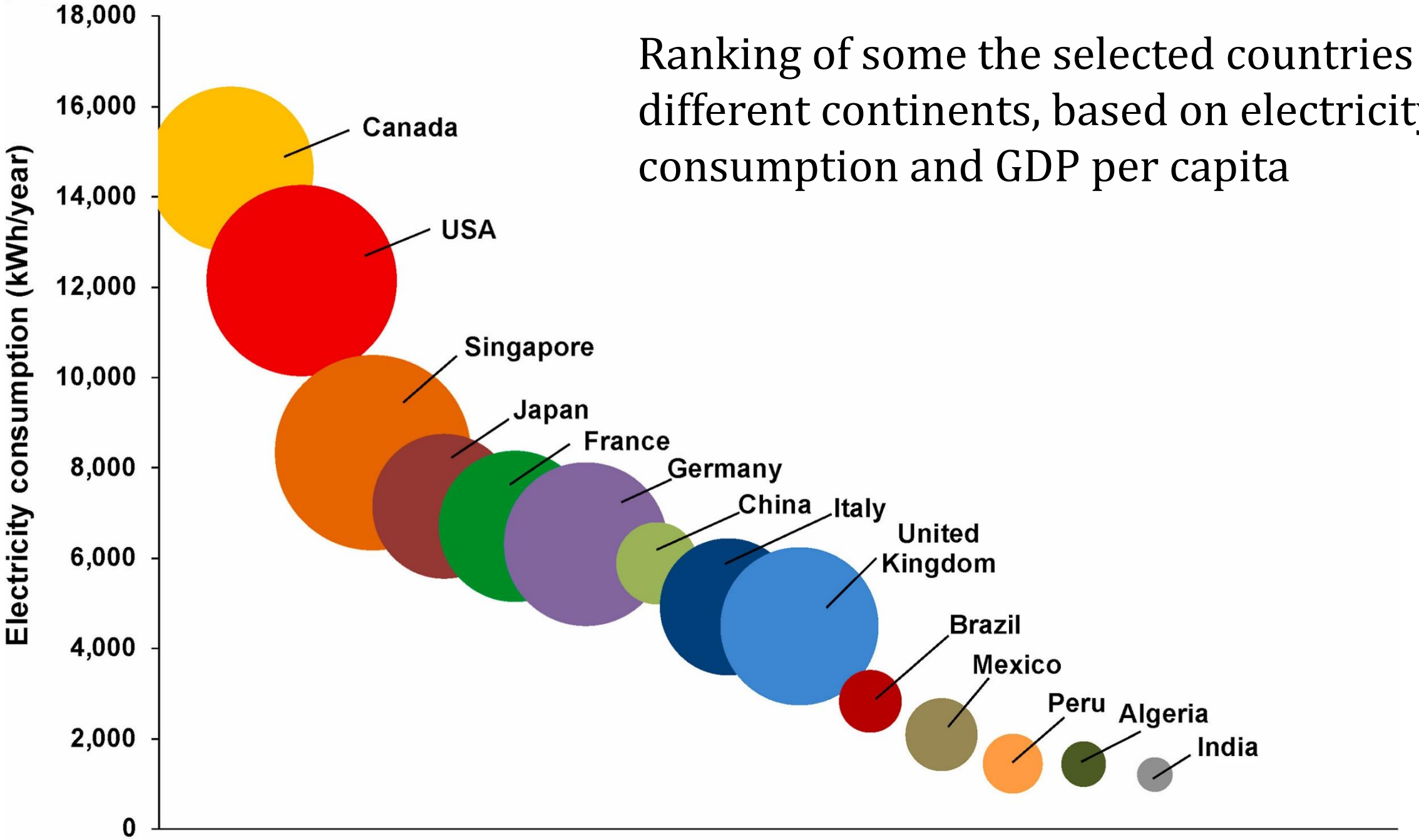
Key Policy Initiatives in India

Policy	Description
Production Linked Incentives	• Provide subsidies towards the creation of new manufacturing capacity of solar PV modules and modern batteries.
National Green Hydrogen Mission	• Targets low-emissions hydrogen production capacity of 5 Mt per year (with an associated renewable energy capacity addition of 125 GW). This is to be accompanied by policies to generate demand for low-emissions hydrogen, particularly from industry.
Carbon Market	• Passed a law in 2022 that sets the stage for the creation of the Indian Carbon Market, a carbon credit trading scheme

Key Policy Initiatives in India contd.....

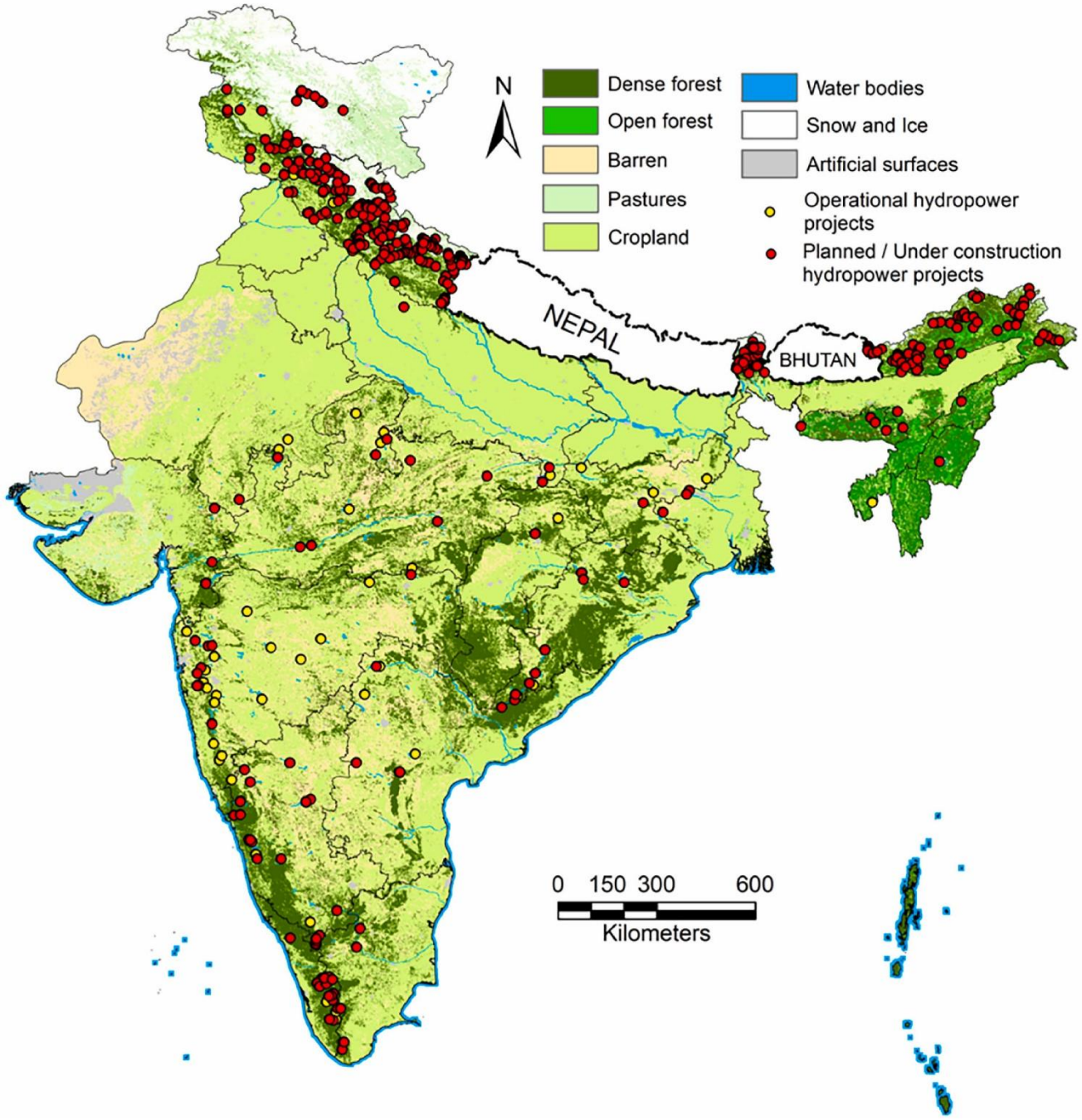
Policy	Description
Net Zero Emissions by 2070	• India announced the ambition to reach net zero emissions by 2070 in 2021. It was formally adopted as a part of its updated Nationally Determined Contribution in 2022.
Renewable energy and transmission targets	• Aims to have 50% of power generation capacity fuelled by non-fossil sources by 2030, compared to 41% in 2022. It has also set a target of 500 GW of non-fossil capacity by 2030. • The Green Energy Corridor project aims to create transmission capacity to integrate a rising share of variable renewable power. Its transmission plan targets the integration of 500 GW of renewable capacity by 2030.

Ranking of some the selected countries in different continents, based on electricity consumption and GDP per capita



Hydropower Hydropower Special Market Report- IEA 2021

- A key role in the transition to clean energy – not only high density but also unmatched capabilities for providing flexibility and storage.
- This makes sustainable hydropower an attractive foundation for integrating greater amounts of wind and solar power,
- Requires a range of strong policy actions from governments to address the major challenges that are hampering faster deployment of hydropower
- Providing long-term visibility to ensure hydropower projects are economically viable and sufficiently attractive to investors, while still ensuring robust sustainability standards.
- can make it a natural enabler of secure transitions in many countries as they shift to higher and higher shares of solar and wind – provided that hydropower projects are developed in a sustainable and climate-resilient way."
- Often face long lead times, lengthy permitting processes, high costs and risks from environmental assessments, and opposition from local communities.
- result in higher investment risks and financing costs compared with other power generation and storage technologies, thereby discouraging investors.



hydropower projects across India

7 priority areas for governments to accelerate hydropower growth

Hydropower Special Market Report- IEA 2021

1. Move hydropower up the energy and climate policy agenda
2. Enforce robust sustainability standards for all hydropower development with streamlined rules and regulations
3. Recognise the critical role of hydropower for electricity security and reflect its value through remuneration mechanisms
4. Maximise the flexibility capabilities of existing hydropower plants through measures to incentivise their modernisation
5. Support the expansion of pumped storage hydropower
6. Mobilise affordable financing for sustainable hydropower development in developing economies
7. Take steps to ensure to price in the value of the multiple public benefits provided by hydropower plants

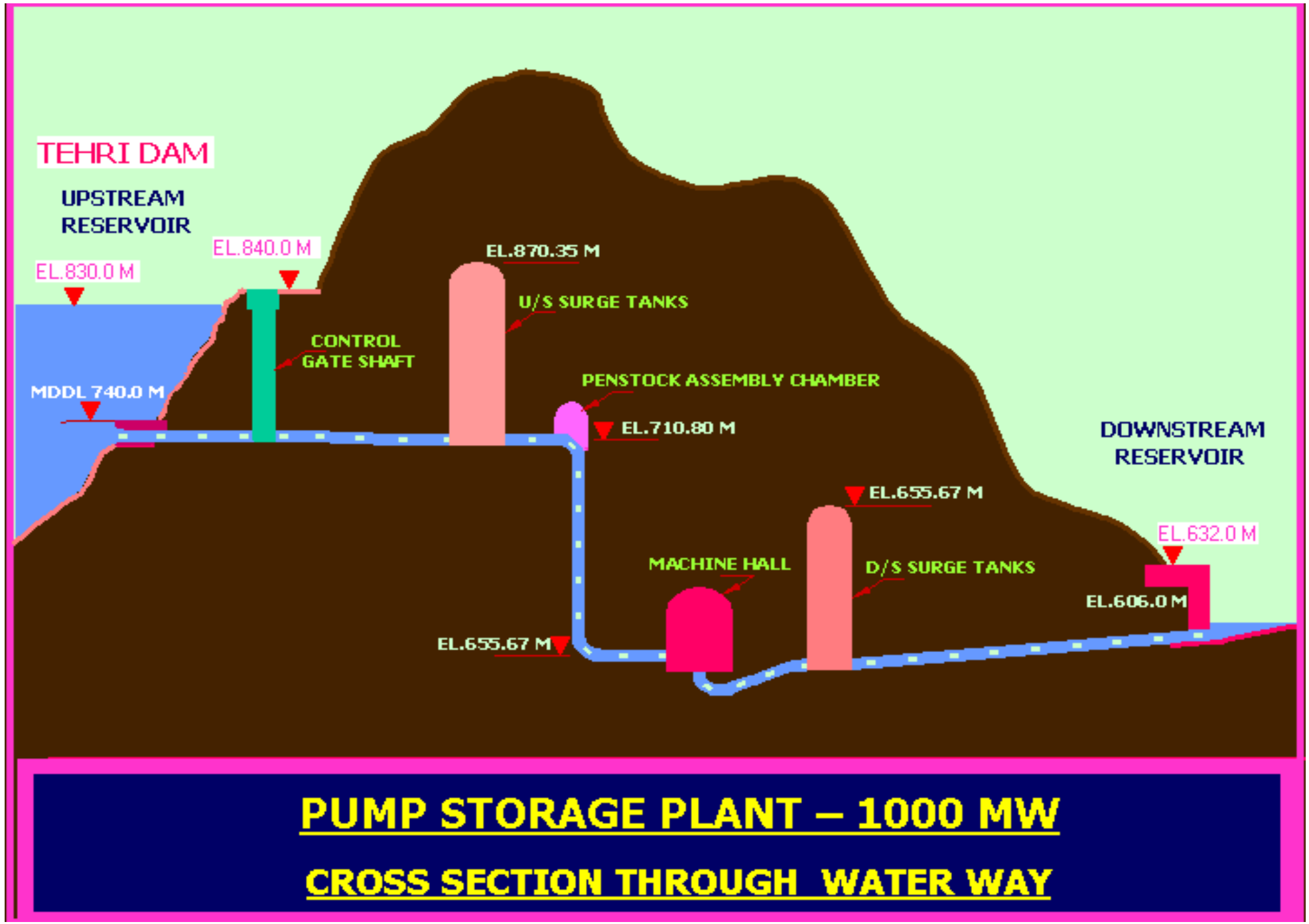
Pumped Storage

- Central Electricity Authority projects 19 GW/128 GWh PSP for 2029-30
- Current PSP capacity is 5 GW and about 40 GW of projects are under different stage of development
- Capital cost is Rs. 3.5 to Rs. 5.5 crore/MW for off river project; LCOS is roughly Rs. 7.5/unit
- Major cost is of civil works, largely available in India
- Currently, India imports some of the key electrical equipment Electrical steel laminations, Forgings, Thick steel plates > 160 mm, PLC and Converters for DFIGs
- Enabling Policies announced as guidelines in April 2023
- High potential and favorable geology in central and Southern India
- Standard units including possibility of standard tunnel size

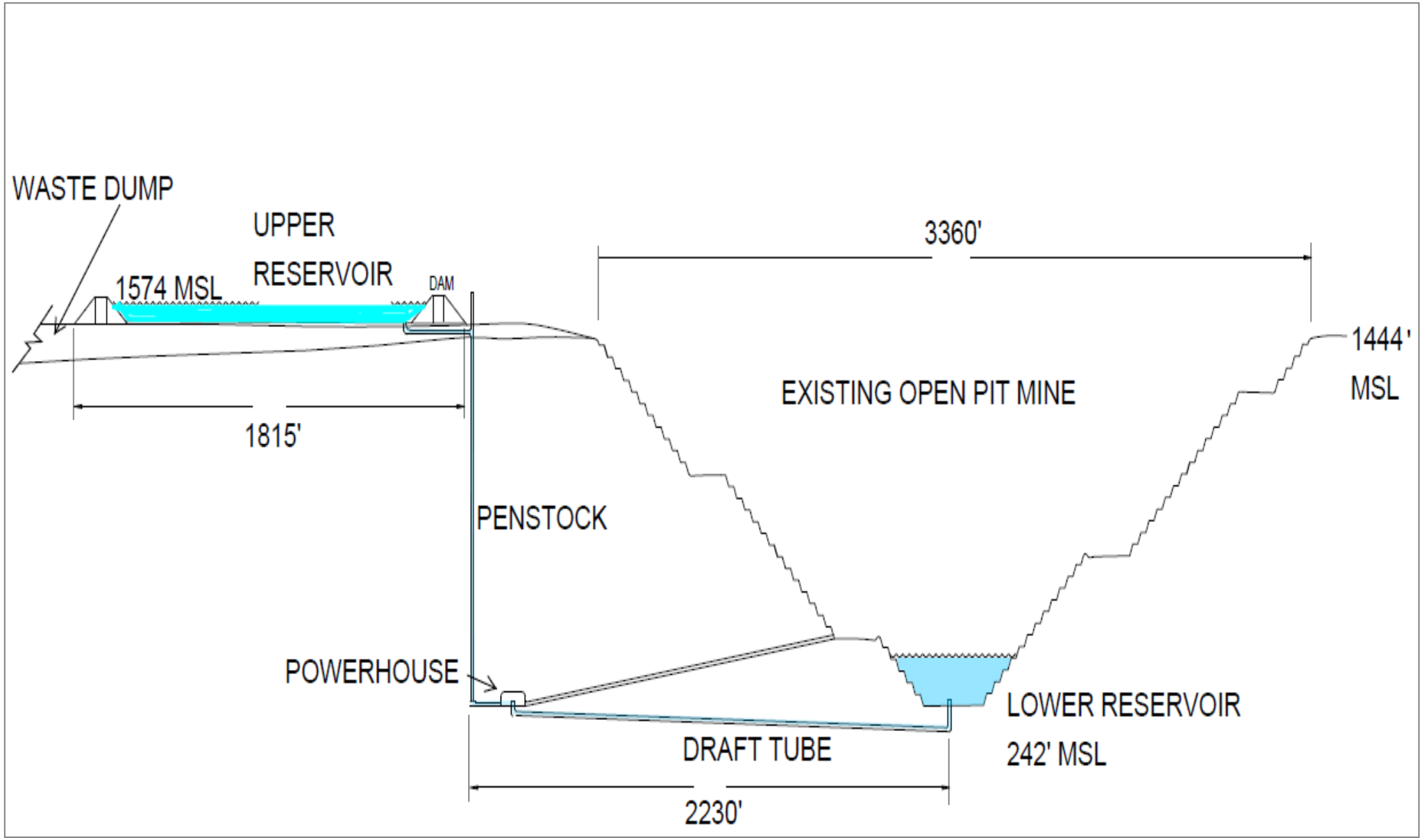
Erzhausen – Pumped Storage, Germany

Outside the Leine River system

Goldisthal pumped-storage power plant, Germany (1053 MW)

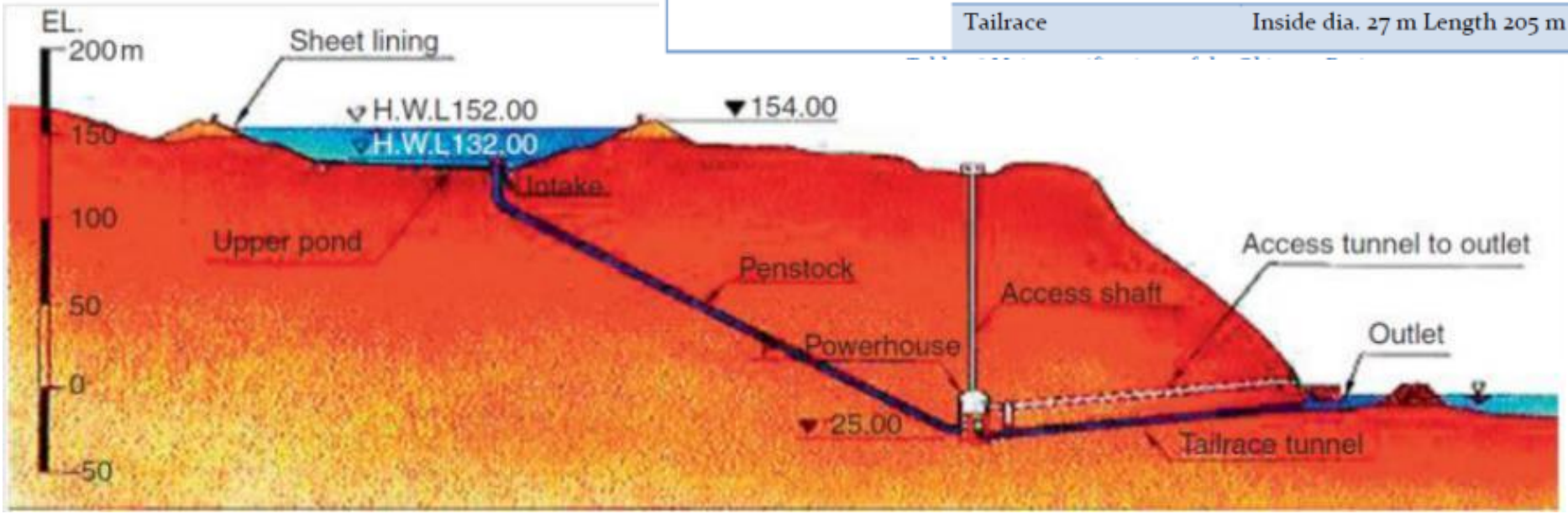

TEHRI DAM
UPSTREAM
RESERVOIR
EL.840.0 M
EL.830.0 M
EL.870.35 M
U/S SURGE TANKS
CONTROL
GATE SHAFT
MDDL 740.0 M
PENSTOCK ASSEMBLY CHAMBER
EL.710.80 M
DOWNSTREAM
RESERVOIR
EL.655.67 M
EL.632.0 M
MACHINE HALL
D/S SURGE TANKS
EL.606.0 M
EL.655.67 M
PUMP STORAGE PLANT – 1000 MW
CROSS SECTION THROUGH WATER WAY

PSH in Discarded Mine Sites

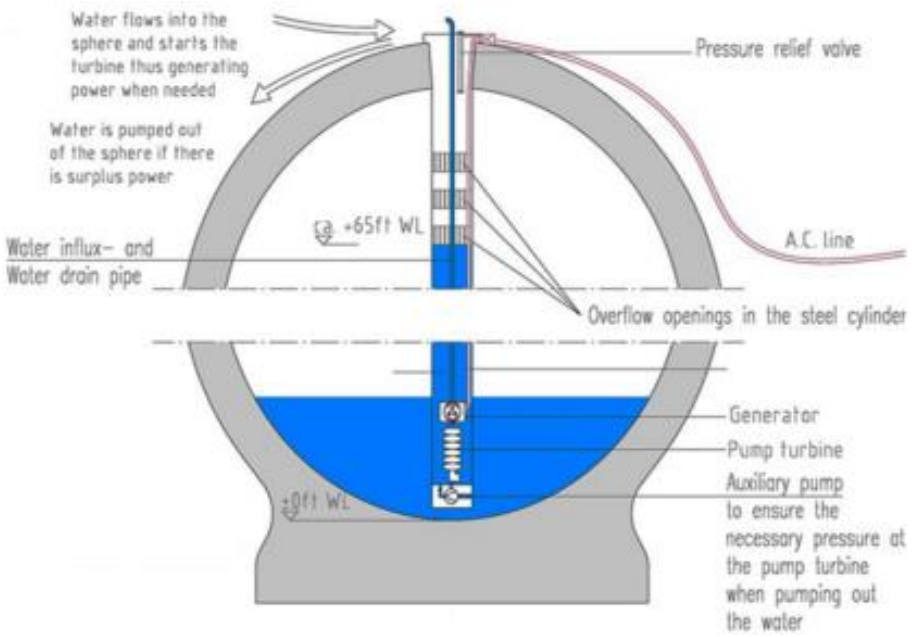


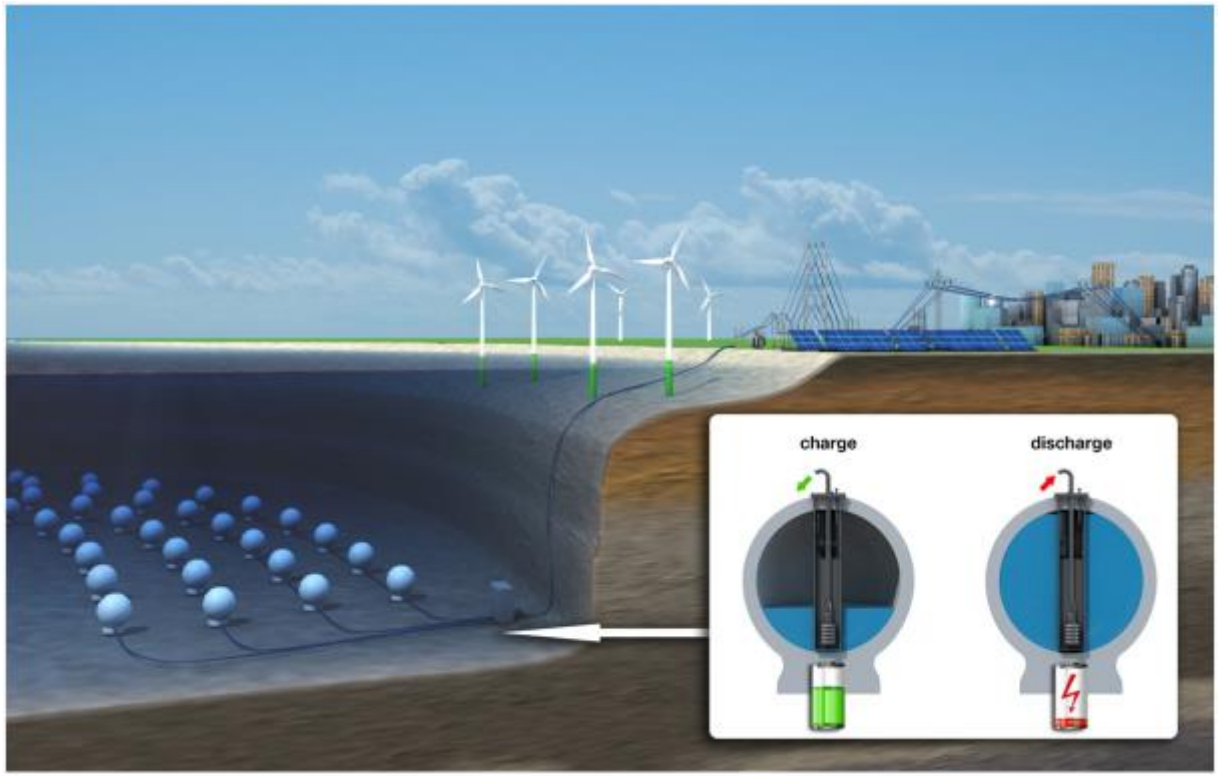
Okinawa Seawater Based PSP, Japan

Okinawa Yanbaru Power Plant		Specification
Power plant	Max. Output	30 MW
	Max. Discharge	26 m^3/s
	Effective head	136 m
Upper regulating pond	Type	Excavated type, Rubber sheet-lined
	Max. embarkment height	25 m
	Crest circumference	848 m
	Max. Width	251.5 m
	Total storage capacity	0.59x106 m^3
	Max. depth	22.8 m
Waterway	Penstock	Inside dia. 24 m Length 314 m
	Tailrace	Inside dia. 27 m Length 205 m



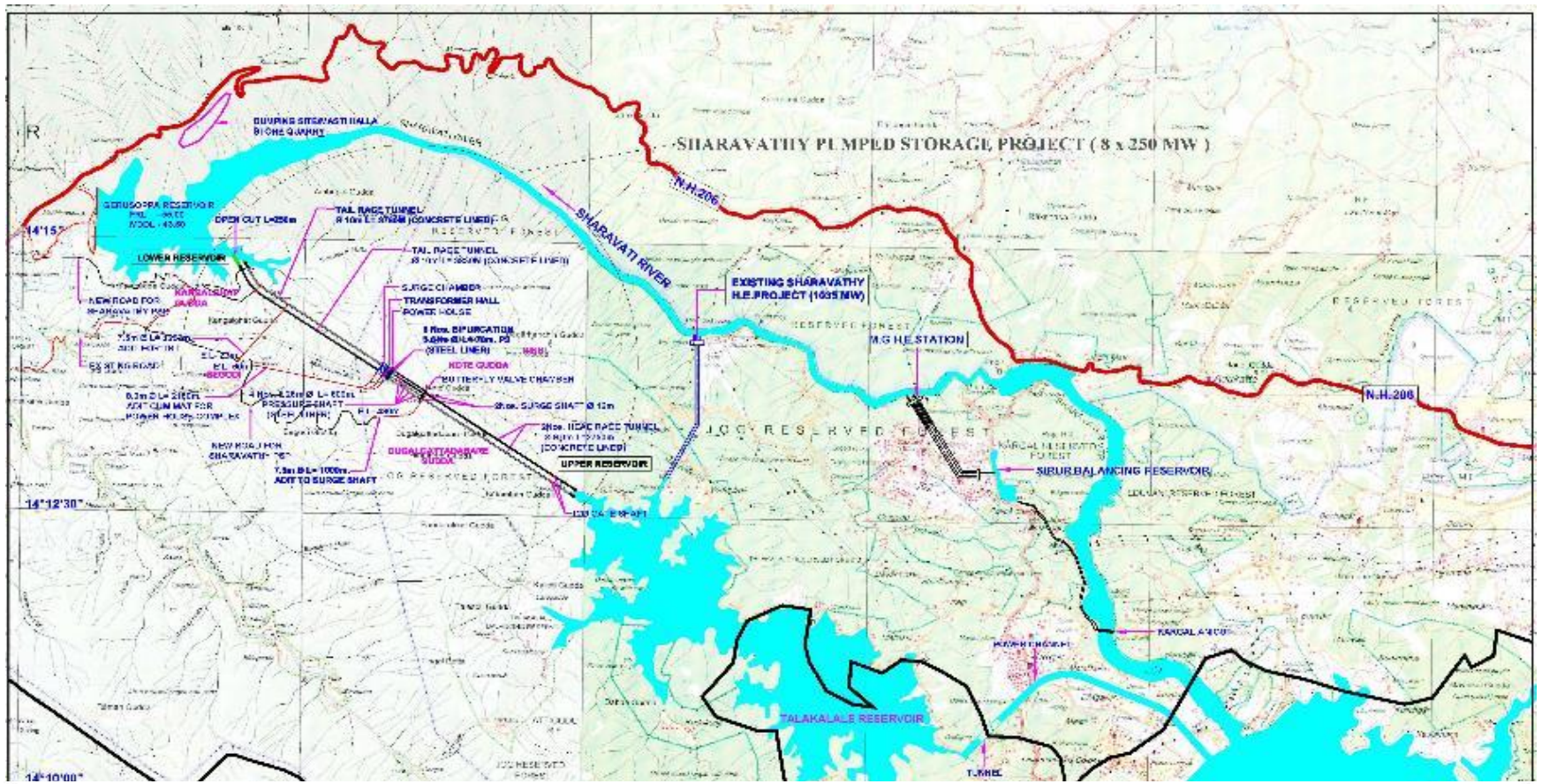
Underwater PHS (Stensea project)

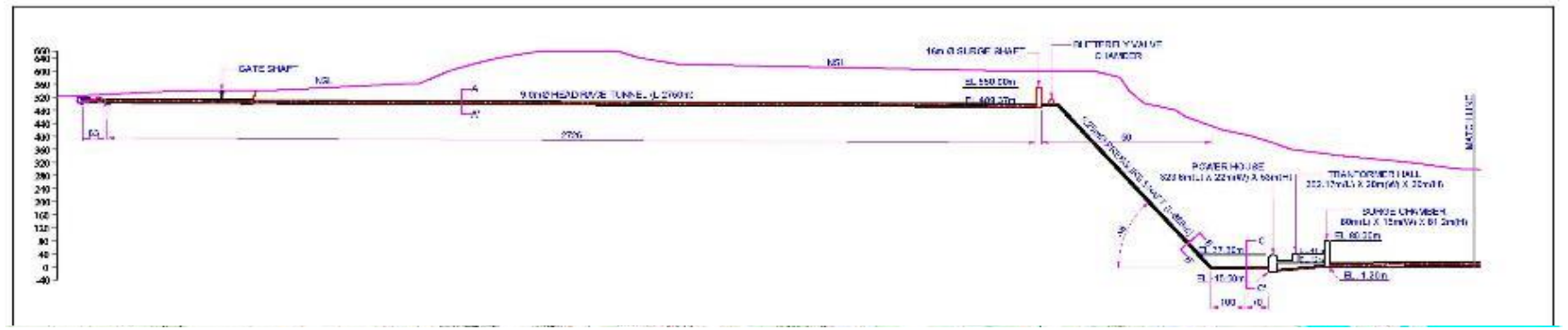




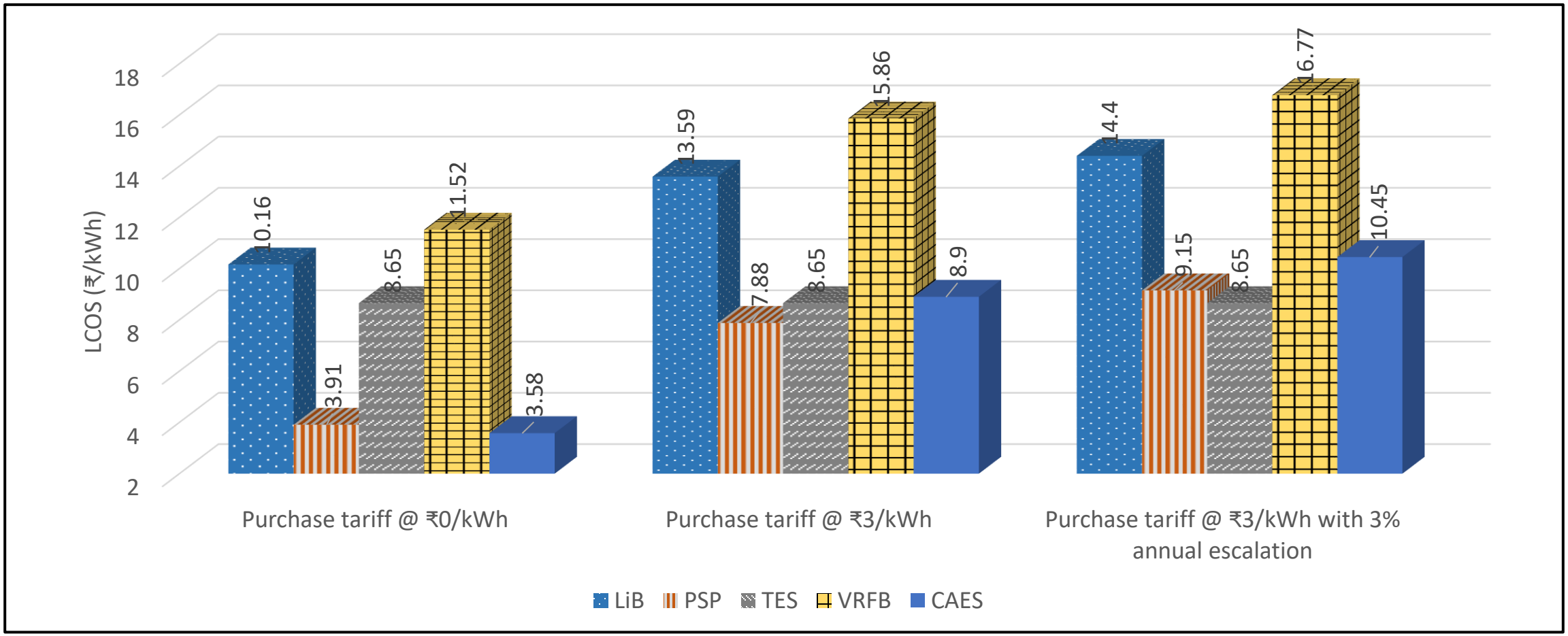
Pumps water into 30-meter diameter spheres anchored at the seabed, which can store up to 20 MWh each. Another sea-based alternative solution was proposed in Belgium.

Sharavathi Pumped Storage Scheme

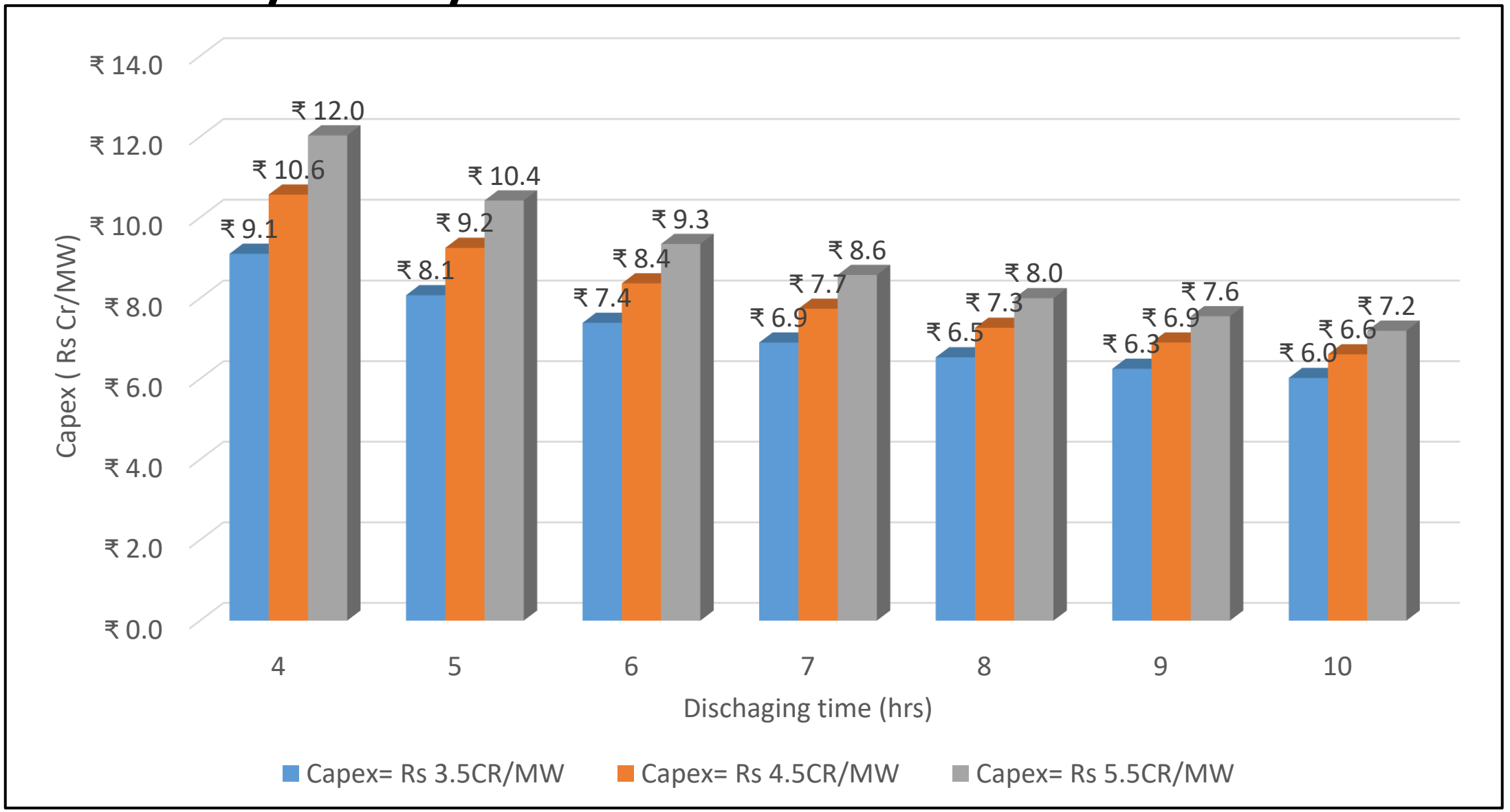




Life cycle cost of storage (LCOS)

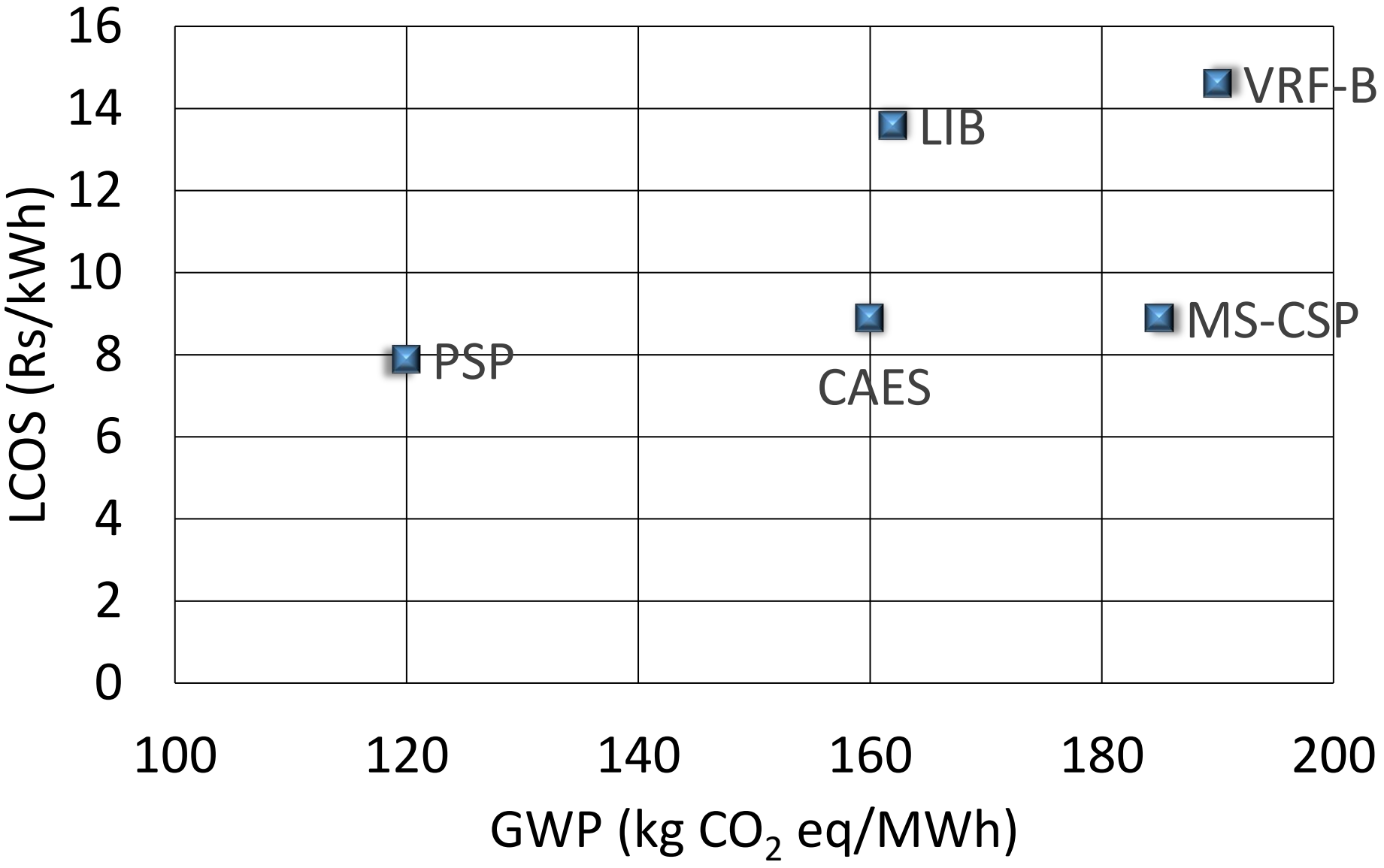


Sensitivity analysis of LCOS for PSP with CAPEX



Input Electricity Cost Rs. 3 per unit

Levelised Cost of Storage vs Global Warming Potential



Take away -PSP

- Availability of the pre-feasibility report, detailed S&I, DPRs etc.,
- Location outside or more than 10 km of protected area boundary,
- Market for energy cost stored and value of flexibility from by PSH,
- PSH projects that could be implemented within next 3-4 yr,
- PSH projects with some existing structures/hydro projects
- Grid connectivity at interstate and super grid level
- Geomembrane lining systems in addition to concrete linings
- Standard tunneling diameter for TBMs to reduce the construction time
- Standard unit size and capacity for speedy availability

Other Measures taken Recently

- Energy transition where PSPs a natural enabler for integrating greater RE Utilization of CPSUs capabilities
- Energy Storage Obligation (ESO) for solar and wind generation and Discoms
- National Framework for promoting Energy Storage Systems announced
- Guidelines for reducing incidence of Time & Cost Overrun issued
- Monetization of Intangible Hydro Benefits
    - Spinning Reserve
    - Ramping Support
    - Reactive Power Support
    - Black Start Capability
    - Peaking supply/ Avoiding RE curtailment, and
    - Emission Reduction etc.
- A single window system for clearances, thereby reducing the time

Other R&D Initiatives to Support Development of PSP

R&D Hydro Turbine Laboratory of International level at HRED- IIT Roorkee

- research & development
- turbine-model testing,
- human resource development (HRD)
- generation of design data
- design validation through CFD analysis
- Third party evaluation

First independent facility in the region

- Head 15-60 m and discharge 1000 lps
- Building 15x24 m height +13.5 to – 6.5 m
- Water storage 600 cubic m

- Laboratory inaugurated in April 2018
- Turbine Manufacturers and project developers may take benefit.

Independent Hydraulic Turbine R&D Laboratory

Turbine Model Testing of New / Refurbished Projects

- **Francis Turbine**
- **Kaplan Turbine**
- **Pelton Turbine**
- **Reversible Pump Storage Turbine**

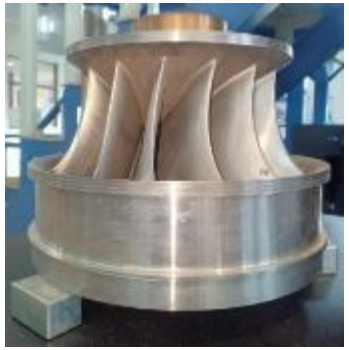
SCADA based Control

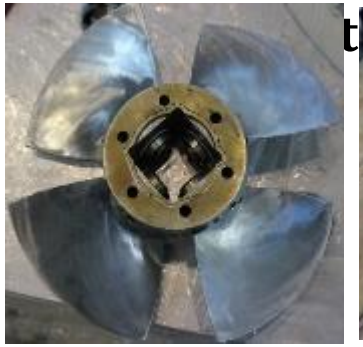
Overall uncertainty of ±0.25 % , Repeatability ±0.15 %

Main Hydraulic Performance & Additional Performance Test

Design Validation through CFD Analysis

Third Party Witness





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Thank You