Online Training on

Renewable Energy Grid Integration through Hydro Pumped Storage

Reinvigorating Hydropower

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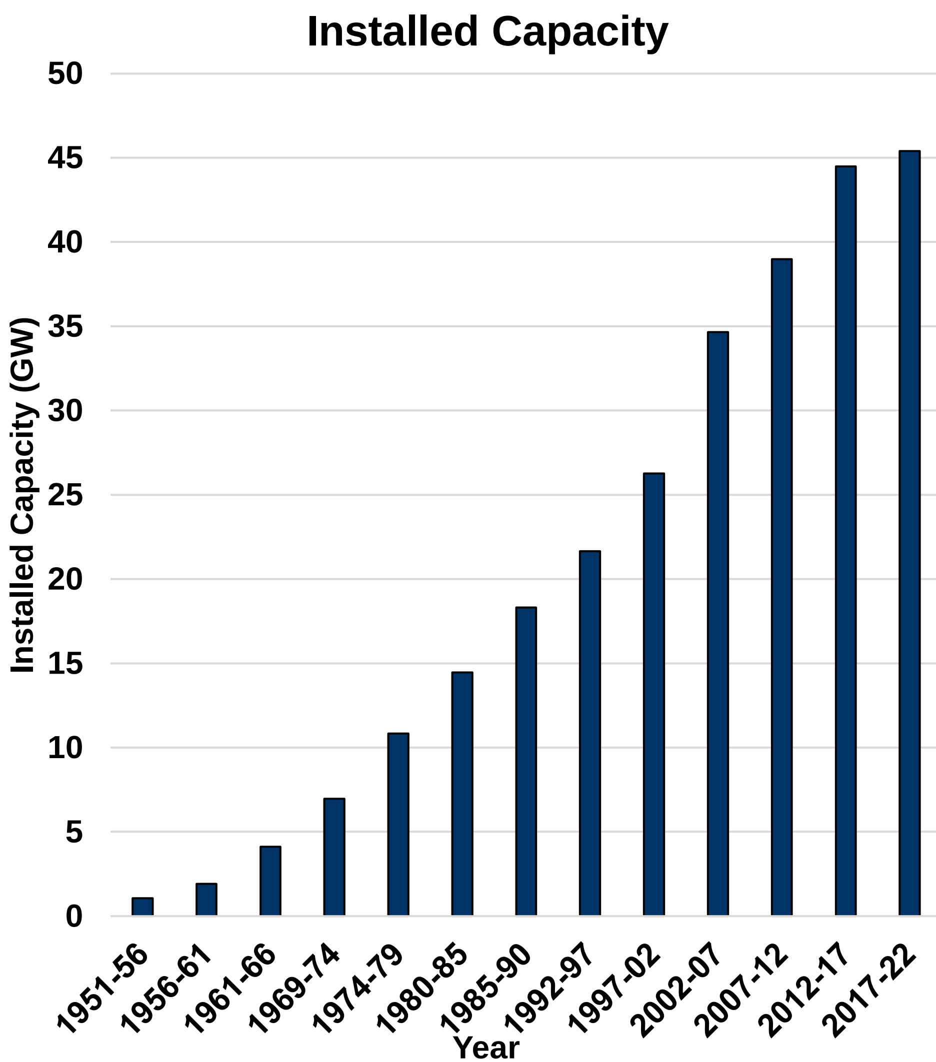
Journey of Hydropower Development



+ Small Hydro 4.5 GW

First Hydro plant in 1847

India's potential – 145 GW
Harnessed – 45 GW

204 Power Stations, 710 units
Including 9 Pumped Storage

36 projects of 12 GW under construction

Multipurpose Storage - 30%
storage only for power , 20%
ROR with Pondage - 40%,
ROR without Pondage- 10%

Surface Powerhouses - 62%, underground 38%

Hydro: federal 33%, state: 60%, Private: 7 %

Value of Hydropower

- Special value of hydropower due to its inherent characteristics of peak power, ancillary and support service and economic development
- Primary values of hydropower:

  (a) Electricity sale,

  (b) environmental (Carbon emission reduction)

  (c) social benefits (infusion of money in local economy, jobs)
- Unfortunately environmental and economic part have not been emphasized and strengthened by the government, legal, regulators, manufacturer, developers and media unlike solar and wind sector.
- combination of power markets, environmental markets, and project economics to create the sustainable revenue

Hydropower a strategic partner with wind and solar

- for environmental and social goals and grid optimization.
- Requires Significant public policy changes to avoid risks of losing hydropower capacity and associated grid benefits.

Policy measures to promote hydropower

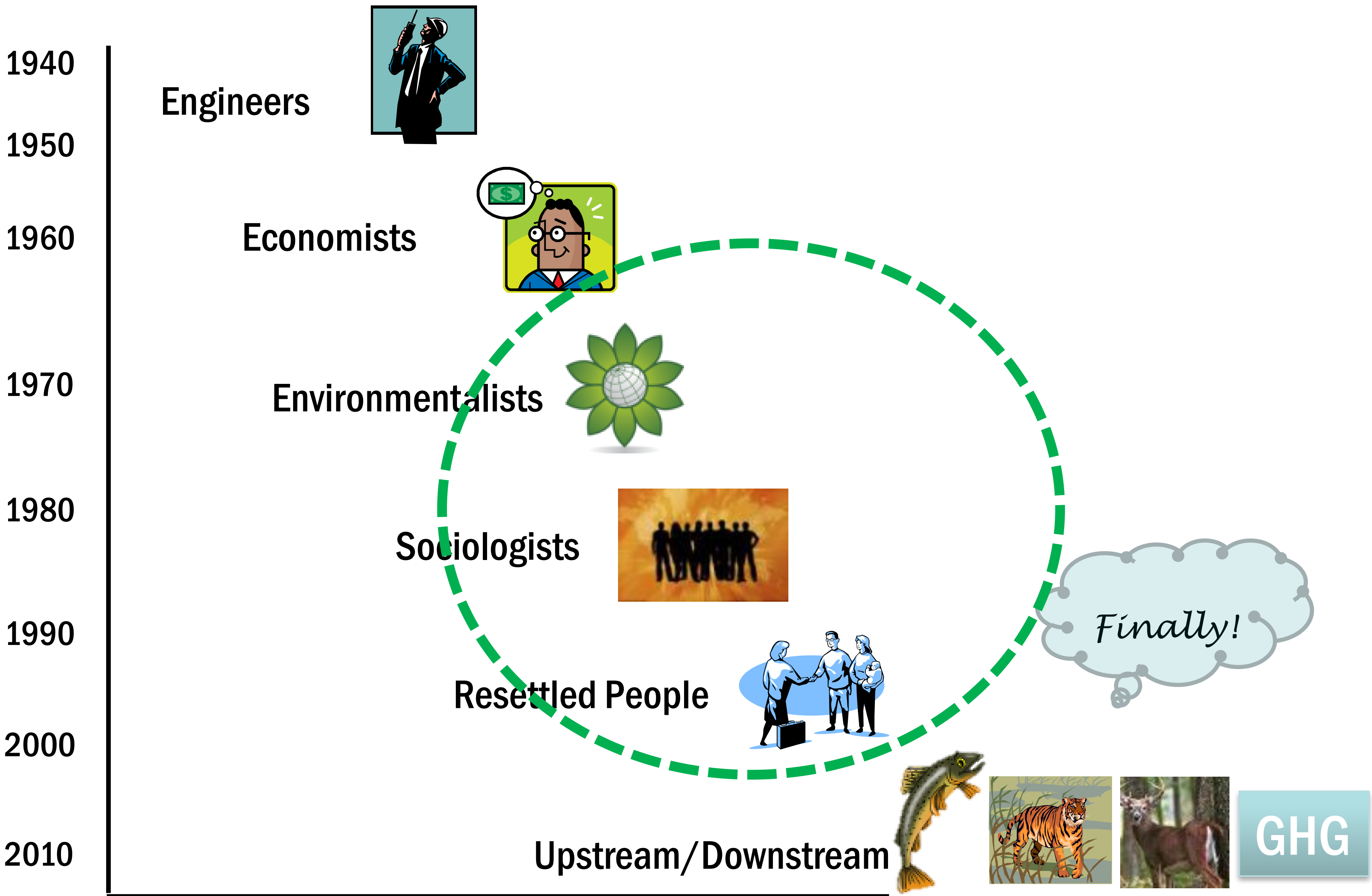
Existing measures (Hydro policy 2008 and Tariff 2016)

- Regulated tariff (exemption from competitive bidding)
- 12% free power to Home State and 2% for Local Area Development
- Rigorous Environment Impact Assessment & Management
- Right to Fair Compensation in Land Acquisition, Resettlement & Rehabilitation
- Cumulative Carrying Capacity and Basin Studies completed

Introduced in March 2019

- Large Hydropower projects to be treated as Renewable energy Source
- Hydropower purchase obligation (For new projects)
- Grant for Enabling Infrastructure (on case to case basis)
- Flexibility in Tariff Determination
- Grant for Flood Moderation (on case to case basis)
- Policy to promote Cross Border Trade

Evolution of Thinking



Adapted from Pablo Cardinale, IFC

Socio economic benefits

Primary Methods	Secondary Methods/ Benefit transfer techniques
• Irrigation	• Flood moderation
• Water supply	• Hydro Tourism
• Impact on local economy in terms of increased income and employment (contactors, labour, material, transportation, hotels, residences, local business)	• water security resulting in high value products
• Wildlife quality	• White water rafting, boating
	• Low water consumption for energy production

Socio-economic Environment

During construction stage

- There is an impact of infusion of money in local socio-economic system in and around project area from the investment on the hydropower projects (assumed @ 10% of project investment on highly conservative way).
- These impacts will be cumulative in as much as the economies of areas affected by HPs are interdependent and grow or decline in tandem.

After construction of project during the project life time

- The impact after commissioning is much wider and recurring in nature. As per Government of India Hydropower Policy 2008, a revenue equivalent of 2% of electricity generated (1% from project owner and 1% from state royalty if applicable) is available every year till the life time of the project as local area development assistance (LADA).
- Expenditure on maintenance and operation is largely shared with and inducted in the local economy. About 25% of O&M expenses with percentage varying from 5% to 4% of the project cost. SHP projects have smaller overall socio-economic impact, they bring higher percentage of the investment and O&M expenses in to the local area, have a higher involvement of the local people in the project and thus relatively their impact is more intense.

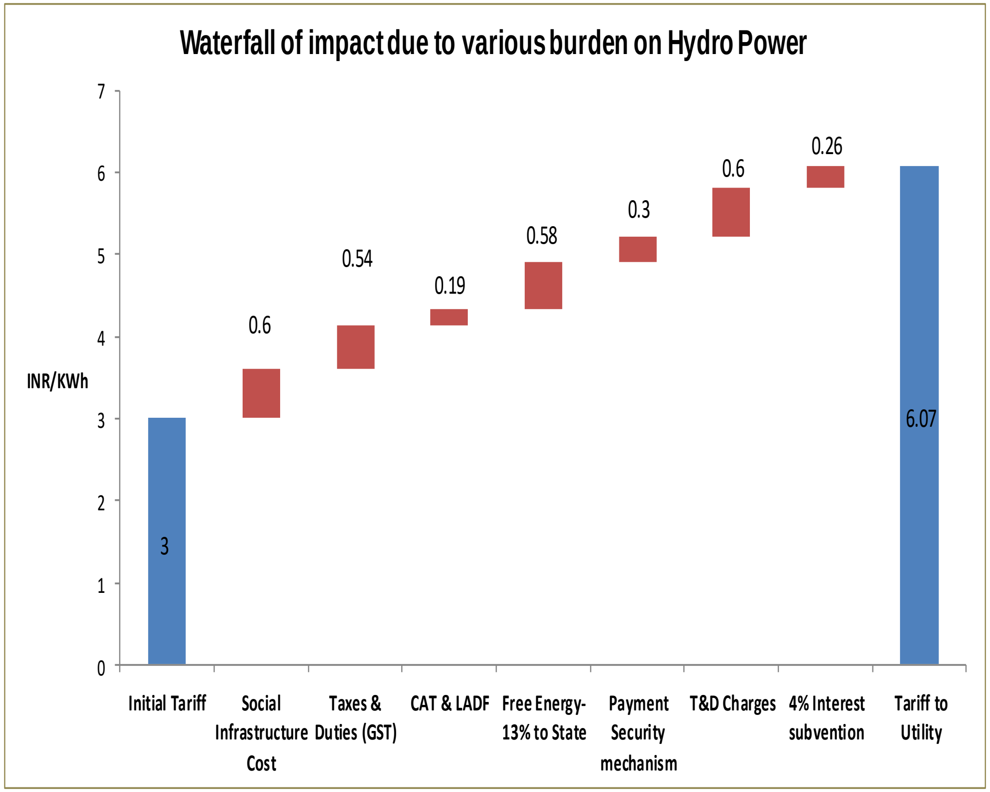
Start-up/Shut-down cost

- According to USBR report (June 2014, Page:16) each start-up/shut-down reduces about 10-15 hours of the generator winding and turbine runner life.

Comparison of Hydro development with Solar per MW

Description	Hydro	Solar
Capital Cost /MW	Rs 9-10 Cr.	Rs 3.5-4 Cr.
Employment Generation During Construction	184 jobs	30 Jobs
Employment generation during operation	18 Jobs	5 Jobs
LADF during construction	1% of project cost	Nil
Free power to state and LADF	13% of project cost	Nil
Catchment area treatment plan,	2.5% of project cost	Nil
Building cess / labour cess	2% of project cost	Nil
GST contribution	18% of project cost	5%
Return on equity	Less than 5%	More than 15%
Wheeling and transmission charges (open excess Charges)	Rs. 0.45- Rs 1.43 per kWh	Nil
Salvage value and value of Land	10% only and project transfer at Zero Value	Land appreciates after life of project
Manufacturing	Indigenous/Make in India	Partially Imported
Rural infrastructure development	Road, Bridges, Ropeway	Nil
GHG emissions (gCO2 – eq/kWh) Source: IPCC/2014/IHA 2018	18.5	48

HYDRO-COST ANALYSIS (source: Assocham, 2017)



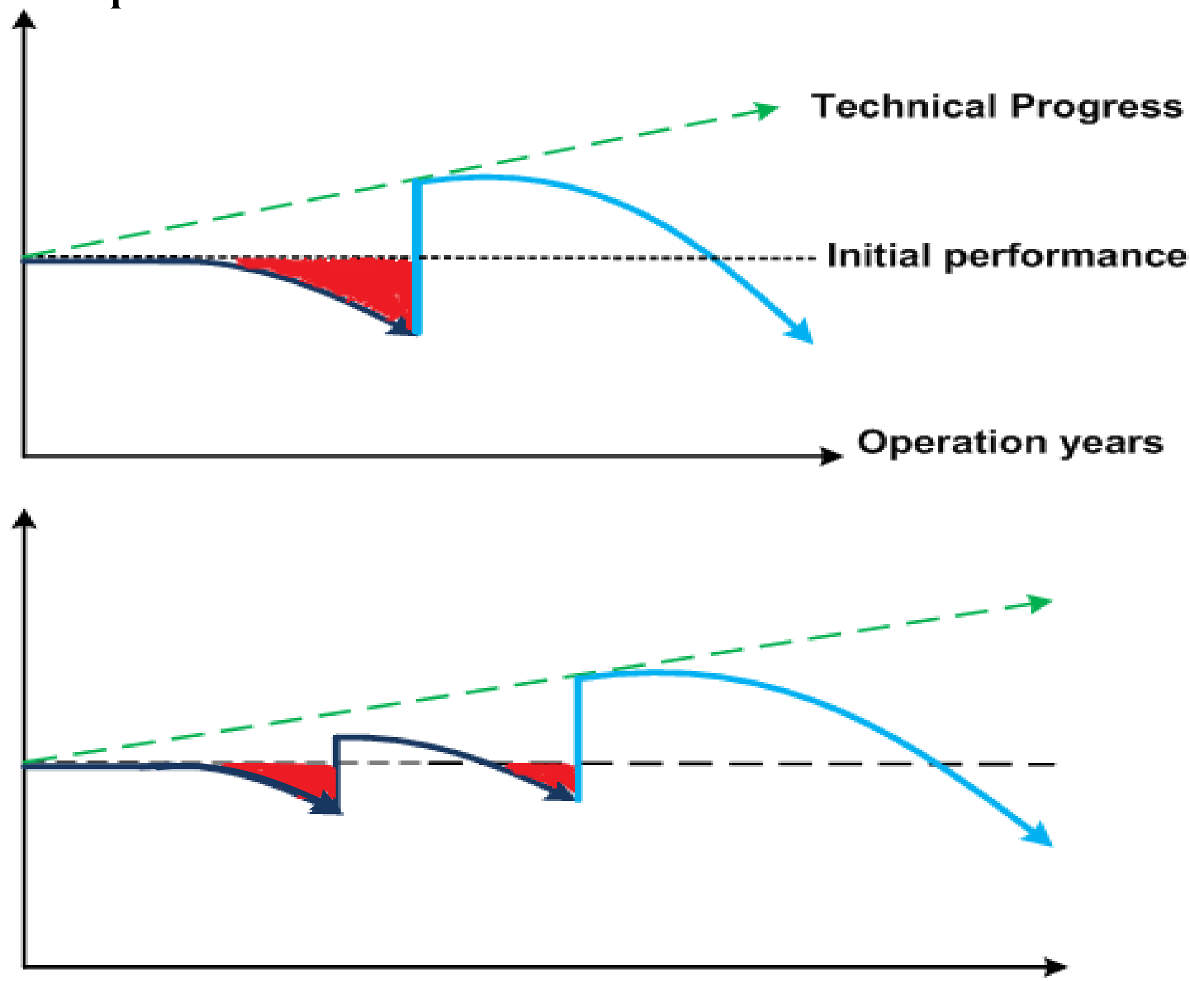
Particulars	Solar	Hydro
Tariff	2.50	3.00
Social Infra. Cost	0	0.60
GST	0.15 (5%)	0.54 (18%)
CAT & LADF	0	0.19 4.5%)
Free Energy	0	0.58 (13%)
T&D Charges	0	0.60
Payment Security Mechanism	0	0.30
Interest subvention	0	0.26
Total Tariff to Utility	**2.65**	**6.07**

Above tariff are considered at P90 for Hydro and P50 for Solar/ Wind

- **Hydro Could Supplement As Balancing Renewable And Can Serve As Base Load**
- **Life Cycle Is 60 Years With Refurbishment After 25 Years And Is 100% Make In India**

Wait to Get Renovation for Upgrading Performance

- Higher efficiency, reliability and longevity using CFD design
- Advance manufacturing process, new materials
- Provide upgrade or renovate solutions with fast lead time implementation



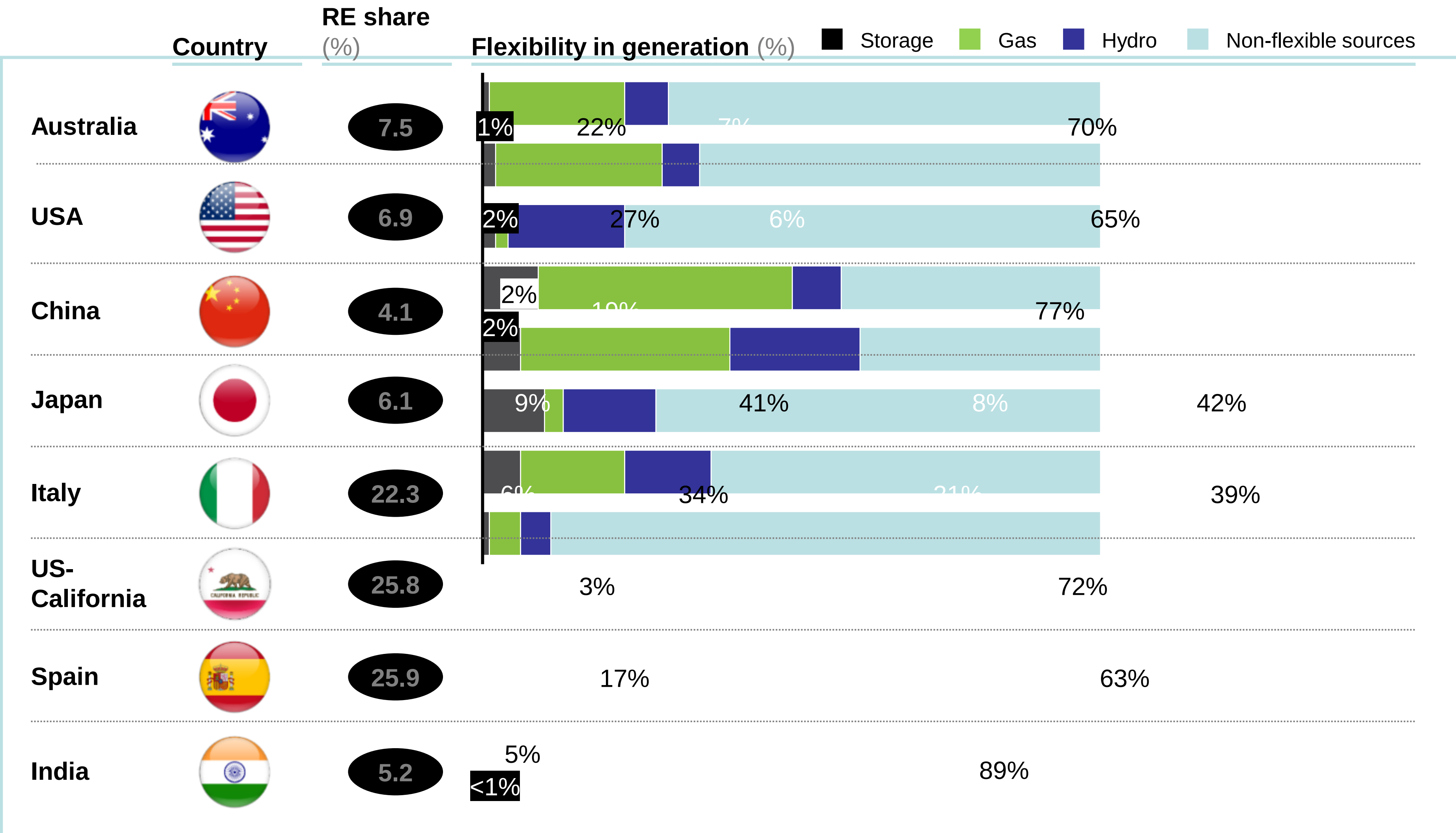
Usual approach

New approach

Adapted from Verone et al. 2016

India has limited flexible generation

The total reserves and its segregation into primary, secondary and tertiary reserves is extremely important in the context of balancing. Currently the reserves are insufficient to respond to grid fluctuations and 175 GW of RE would require reserve capacity



Source: Greenko Group

Technology Trends

	Lead Acid	Li –Ion	NaS	Flow Batteries	Flywheel	Compressed Air	Pumped Hydro
Efficiency (%)	70 - 85	85 - 95	70 - 80	60 – 75	60 - 80	50 – 65	70 - 80
Cost range ($/kWh)	100 - 300	150 - 250	400 - 600	500 - 1000	1000 - 2500	>150	100-150
Construction Period (Years)	0.5 - 1	0.5 - 1	0.5 – 1.5	0.5 - 1	1-2	3 – 10	5-15
Space Required	Large	Small	Moderate	Moderate	Large	Moderate	Large
Life (cycles)	500-2000	2000 - 10,000+	3000-5000	5000-10,000+	100,000+	10,000+	10,000+
Maturity	Commercial	Commercial	Commercial	Early Commercial	Demonstration	Demonstration	Commercial

Source: IESA

Need for PSP

- There is a paradigm change in Power System operation now with the Large Scale Variable RE
- In the Past, fully controllable Power Generation was following non-controllable load demand.
- Now with Renewable Energy Sources, Power Generation is no longer fully controllable.
- Pumped Storage hydro projects are System Operator's Tool and Renewable Energy's Best Partner
- Carbon friendly and partner to National commitment for non fossil power

Hydropower a strategic partner with wind and solar for environmental and social goals and grid optimization

Projected Energy Mix by 2030
Source: CEA
http://cea.nic.in/reports/others/planning/irp/Optimal_generation_mix_report.pdf

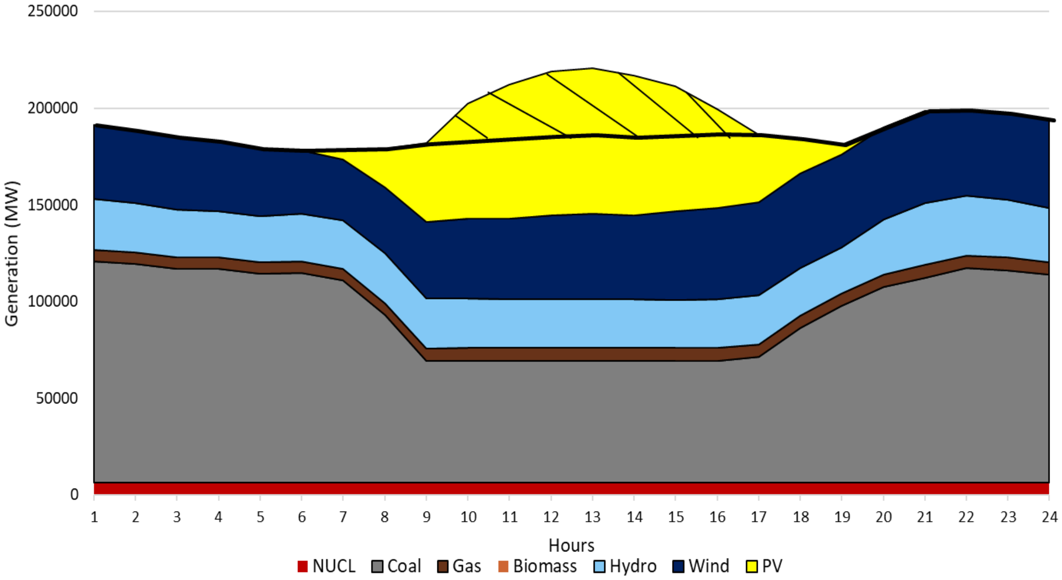
	Source	Capacity (GW)
1.	Solar	300
2.	Wind	140
3.	Thermal	267
4.	Gas	24
5.	Hydro	74
6.	Nuclear	17
7.	Biomass	10
	Total	832
	Storage	34 GW (136GWh)

PSP under planning

Sl. No.	Name of project	Sate	Installed capacity (MW)	Agency	Present Status
Projects planned on existing hydro projects					
1	Humbarli	Maharashtra	400	NPCIL & THDC	Commitment from GoM awaited.
2	Varahi	Karnataka	700	KPCL	DPR likely by 2022.
3	Idukki	Kerala	300	KSEB Ltd.	Yet to be taken up.
4	Pallivasal	Kerala	600	KSEB Ltd	Yet to be taken up.
5	Upper Indravati	Odisha	600	OHPC	DPR to be prepared by WAPCOS.
6	Ghatghar Stage – II	Maharashtra	125	GoMWRD	
7	Sharavathy	Karnataka	2000	KPCL	TOR for CIA study from MOEF received. DPR under preparation.
8	Sillahalla	Tamil Nadu	2000	TANGEDCO	Survey under progress.
		Sub total	6,725		
New Pumped Storage Projects					
9	Malshej Ghat	Maharashtra	700	NPCIL & THDC	TOR for EIA expired. Commitment from GoM awaited.
10	Mutkhel	Maharashtra	110	GoMWRD	Preliminary investigation
11	Warasgaon	Maharashtra	1200	GoMWRD	NHPC explored and found attractive. No Forest land. Commitment from GoM awaited.
12	Atvan	Maharashtra	1200	GoMWRD	NHPC explored and found attractive. Under wild life.
13	Koyna st-VI	Maharashtra	400	GoMWRD	NHPC explored and found attractive. Under wild life.
14	Bandhu	West Bengal	900	WBSEDCL	DPR by 2019.
15	Kulbera	West Bengal	1110	WBSEDCL	Preliminary studies. Likely after Bhandhu.
16	Lugupahar	Jharkhand	2800	DVC	PFR under progress.
		Sub total	8,420		
		Total	15,145		

Potential for PSP

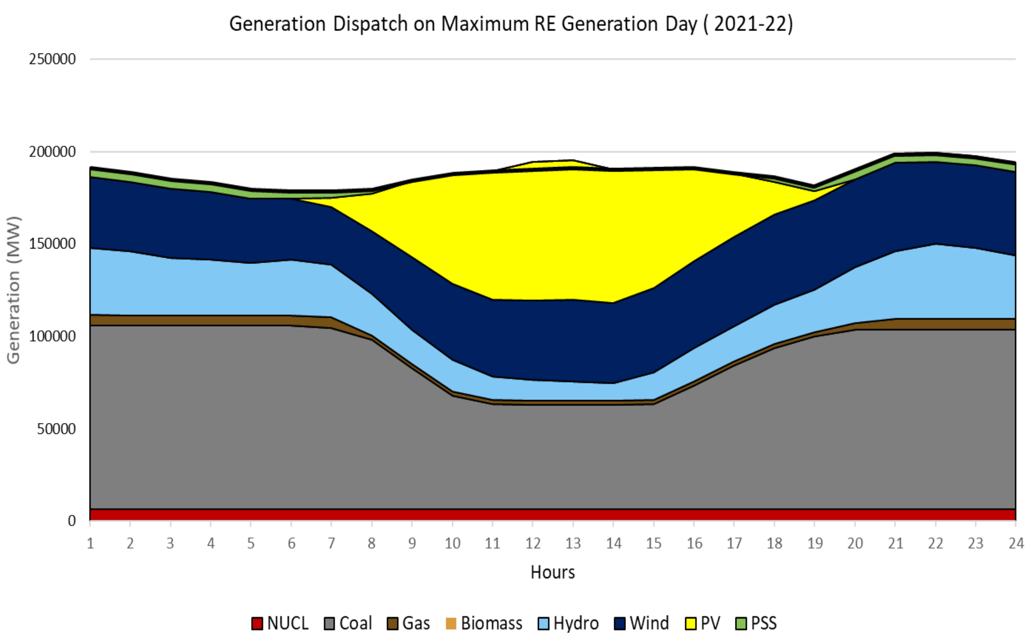
State	No. of sites	Capacity (MW)
Himachal Pradesh	2	3,300
Uttar Pradesh	1	1,935
Rajasthan	2	3,915
Uttarakhand	2	1,005
Andhra Pradesh	1	1,950
Bihar	5	5,370
Madhya Pradesh	4	6,150
Chhattisgarh	3	5,000
Gujarat	2	1,440
Manipur	2	2,000
Assam	1	2,100
Mizoram	7	7,200
Maharashtra	31	35,925
Odisha	4	3,820
Telangana	3	2,575
Karnataka	7	11,600
Kerala	17	11,505
Tamil Nadu	7	6,900
West Bengal	7	5,040
	108	118,730



Comparison

RE curtailment without storage

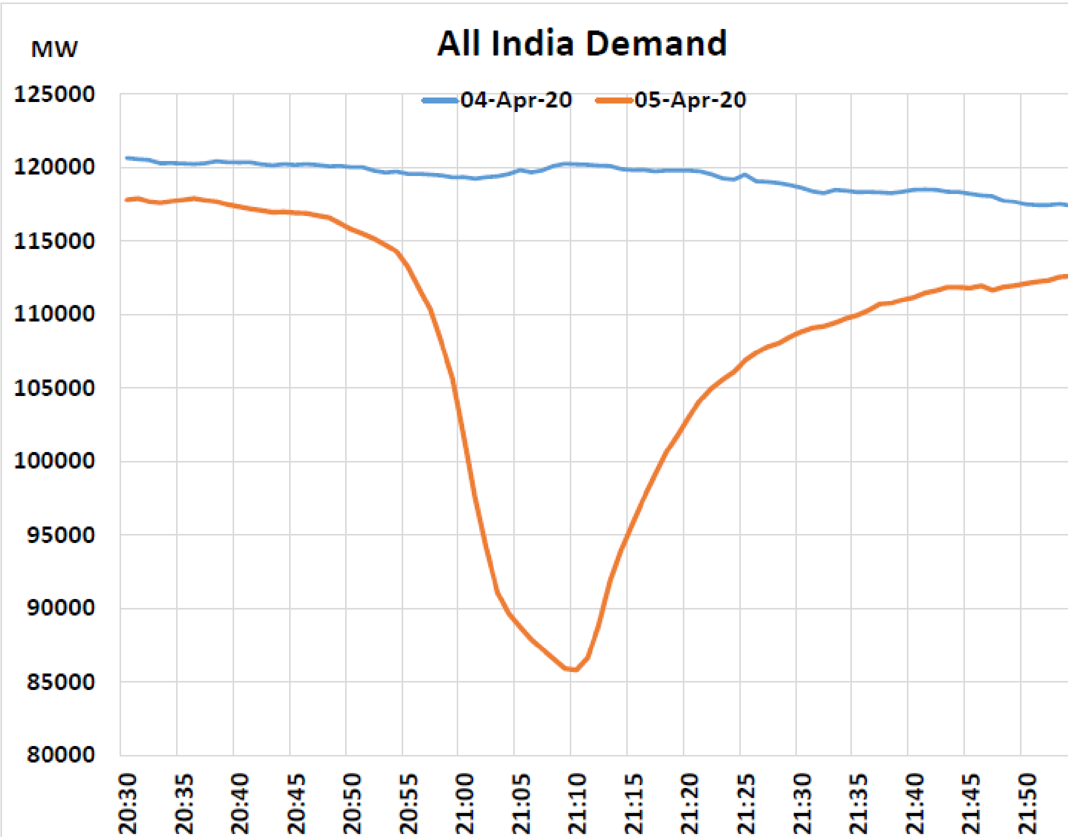
- 34 GW of storage envisaged 2030
- No RE curtailment with storage
- As RE is on constant increase
- Agriculture load may be shifted from night to day
- Based load plants shall become more and more expensive
- Storage from PSP shall be helpful and may become financially justifiable



Source: CEA Study

http://cea.nic.in/reports/others/planning/irp/Optimal_generation_mix_report.pdf

Hydro storage – support on April 05, 2020 for 31 GW drop and ramping

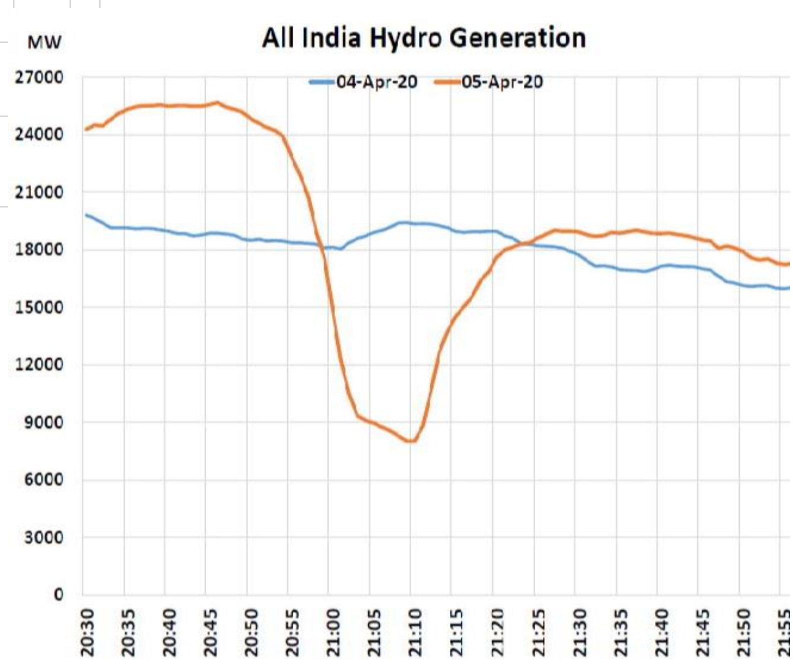


POSOCO

Residential lighting load to go off suddenly at 9:00 pm and come back at 9:09 pm as per PM call

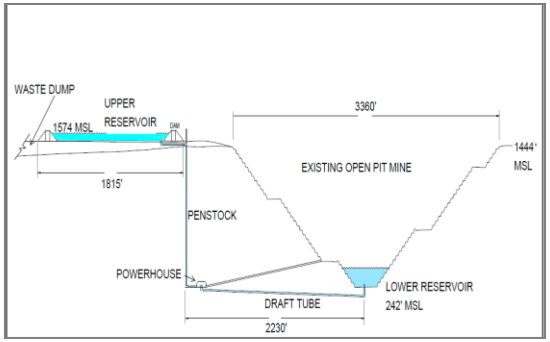
Hydro alone supported a reduction of 18 GW (20:45- 2110) out 31 GW reduction

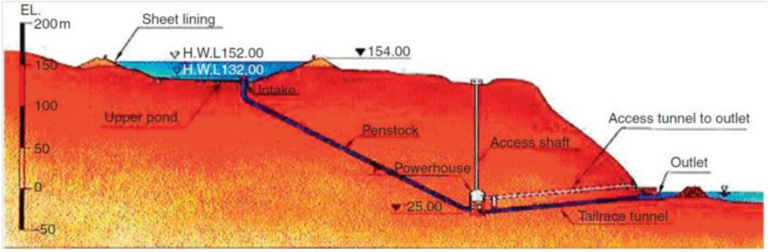
Ramped up by 11 GW (21:10-21:27) to meet rising power demand



Identification of Non- Traditional PSP Sites

- Strong need of identification, carrying out surveys and investigations, preparing detailed project reports, obtaining the clearances,
- Several new ways for PSH- Discarded mines, open pit or underground mines,
- Use of sea water where sea acts as lower reservoir is another option for PSH.
- India has over 5,264 large dams -excellent opportunity for PHES between two large dams in cascade or one dam with second reservoir on the hill top





Reduction in Evaporation

- Floating Photo voltaic (FPV) systems on water surface bodies like pumped storage have the potential of 1%, 5% and 10% area of total available water surface area can have the 404 GW, 2022 GW and 4044 GW
- Among various potential benefits, evaporation reduction is important features of FPV systems
- As per different research, 25 to 45 % of reduction in Evaporation
- Water saved by the FPV systems – to improve economic feasibilities and life cycle cost
- India has over 5264 large dams – to reduce water loss as most dams are in water deficit area

World bank report 2019)

Apathy for PSP

- ISGF has published a report on energy storage (http://www.indiasmartgrid.org/reports/ISGFESSReportFinal10Oct2019.pdf) omitting the pump storage with the argument

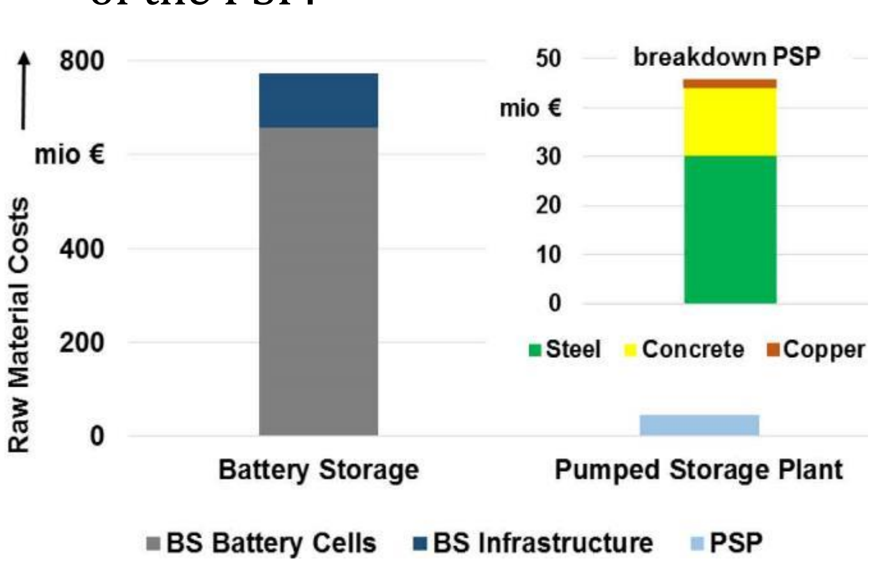
  Few PHS plants in India (cumulative capacity: 5.7GW) have been identified long time back, but these projects have not made any progress in the past two decades owing to variety of issues. Hence, the PHS plants are not considered in this report.

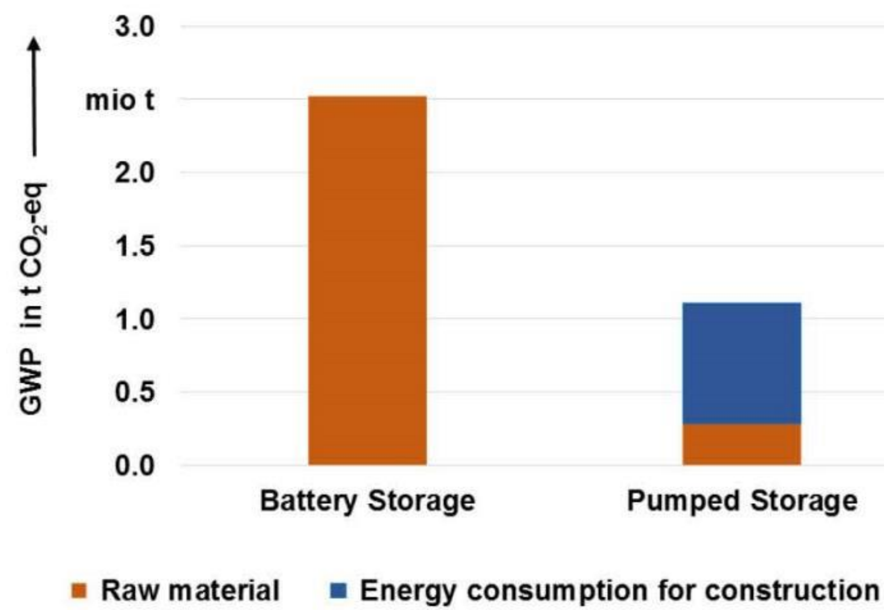
- Such omission of a proven utility scale storage technology (pumped storage) from a energy storage road map for India is not good.

- Such documents are normally referred by the policy makers and it is high time we should flag this issue with the decision makers.

Balancing comparision

- A comparative study of Li-ion battery system (BS) and PSP (Kruger et. al 2018) showed that in terms of raw material costs for the initial installation, the BS scaled to the same power and energy storage capacity is about 17 times higher compared to the PSP for the initial installation. The capital investment and operating costs of the BS are 18 times higher than for the PSP.
- Due to the high greenhouse gas potential of certain raw materials of the battery cells, the carbon footprint of the BS turns out to be double the footprint of the PSP.

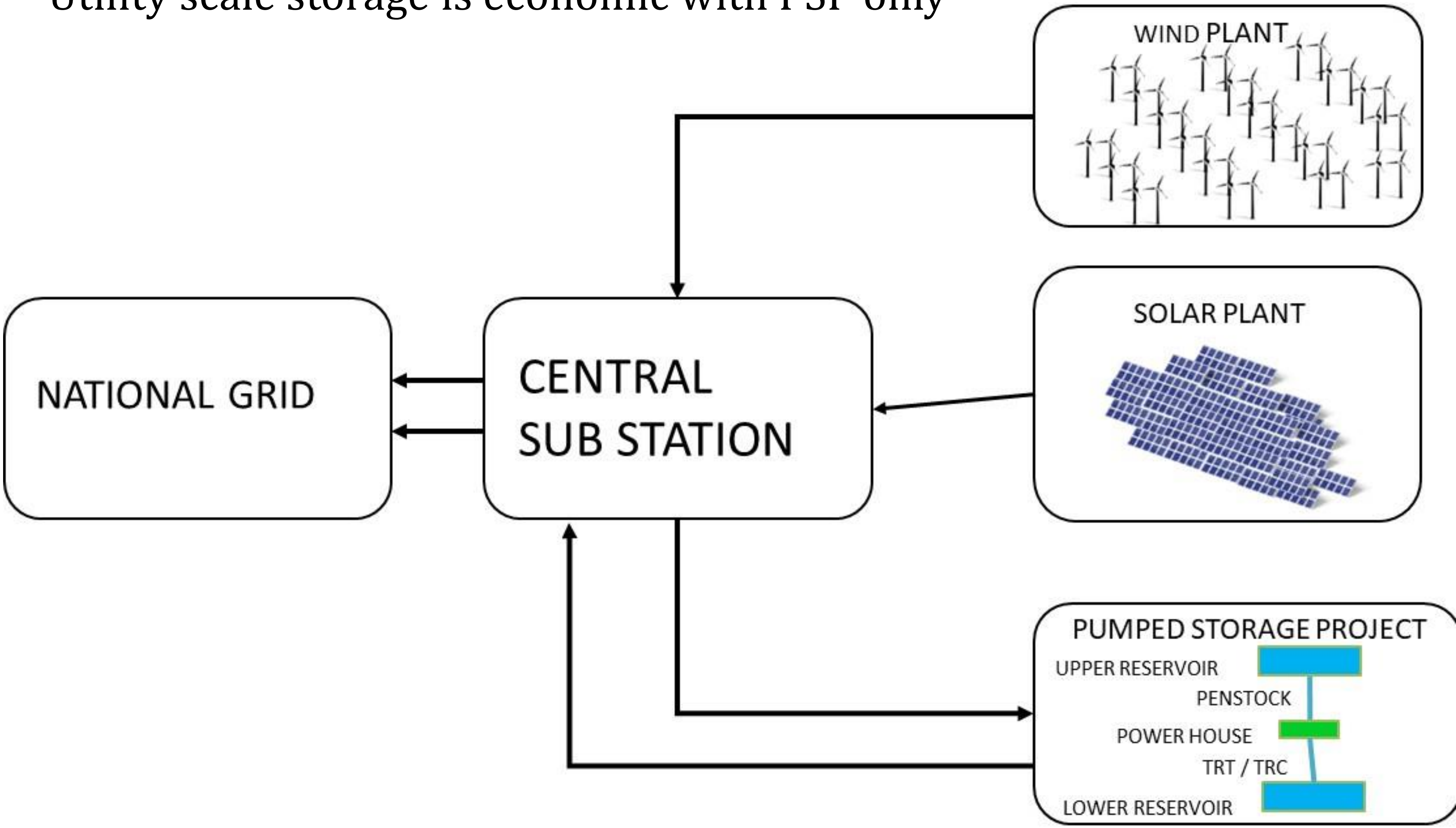




(**Krueger et. al.,** Accepted and presented paper for the Seventh International Conference and Exhibition on Water Resources and Renewable Energy Development in Asia, Ariyana Convention Centre (ACC), Danang, Vietnam, 13-15 March 2018)

To give 24 hours, integrated approach with PSP

- Bids are happening to give 24 hours supply with solar and wind using PSP and battery
- Utility scale storage is economic with PSP only



Andhra Pradesh IRESP: Layout

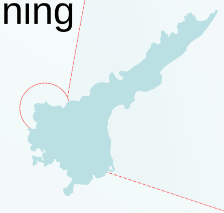
Project details and illustrative site layout (Andhra Pradesh)

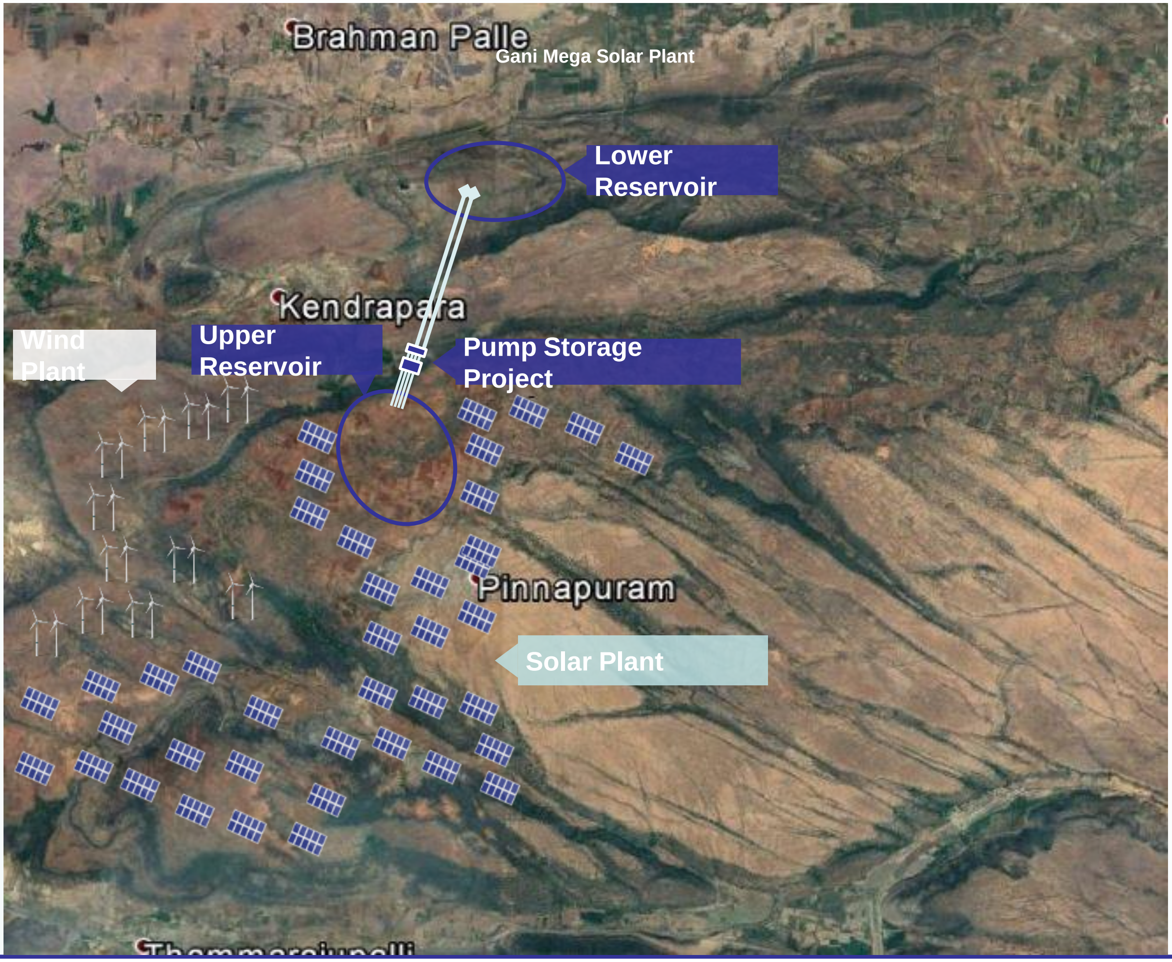
Location

1200 MW PSP in near Kurnool, Andhra Pradesh

Details for Round the clock (RTC) project

- Solar + Wind: 3500MW
- Storage: 1200 MW
- Key Features:
  - Caters to RTC, Fixed and Peak Power requirements
  - Commissioning by 2022

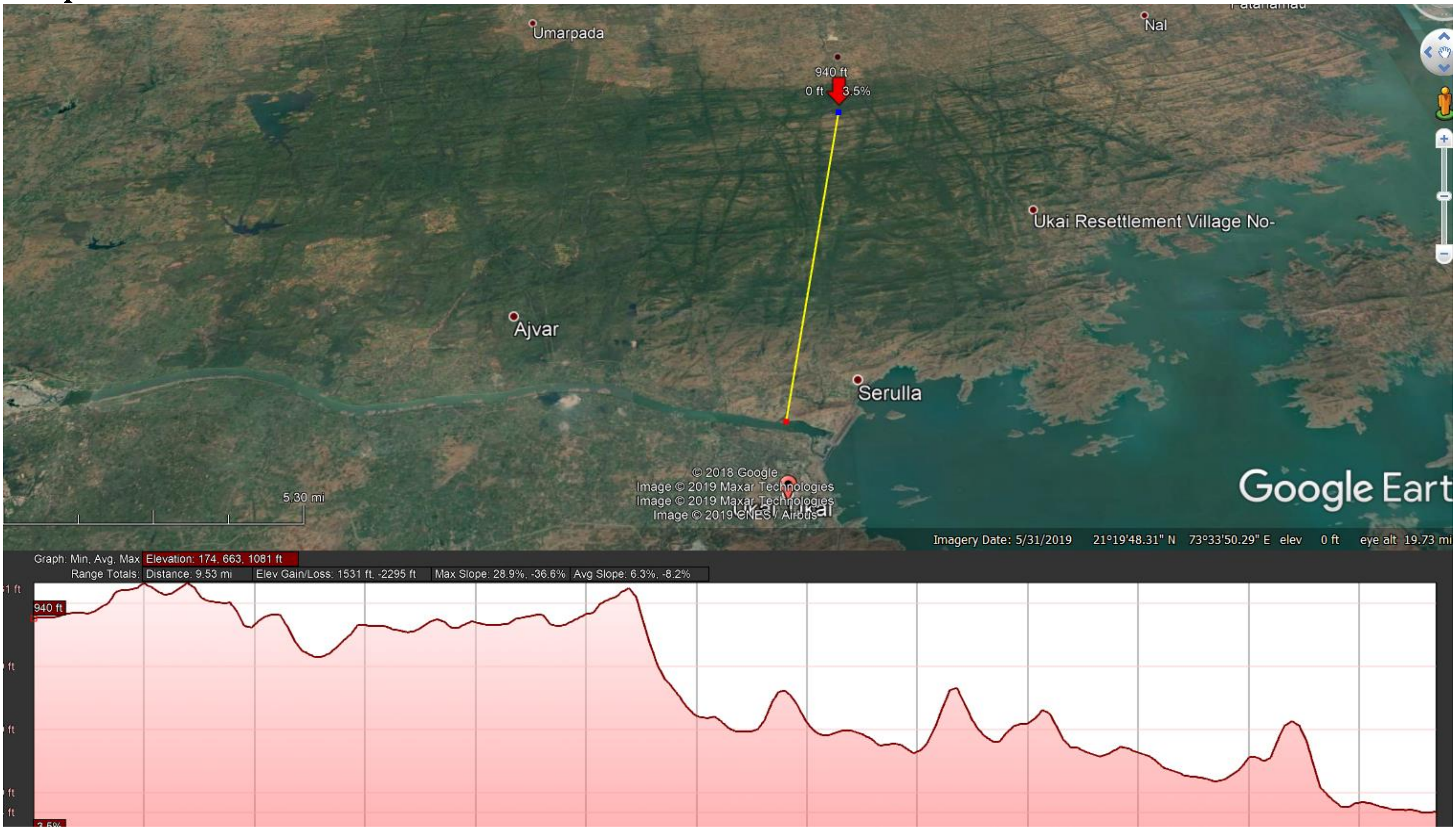




Source: Greenco

New Thinking- Off River- A Preliminary Study

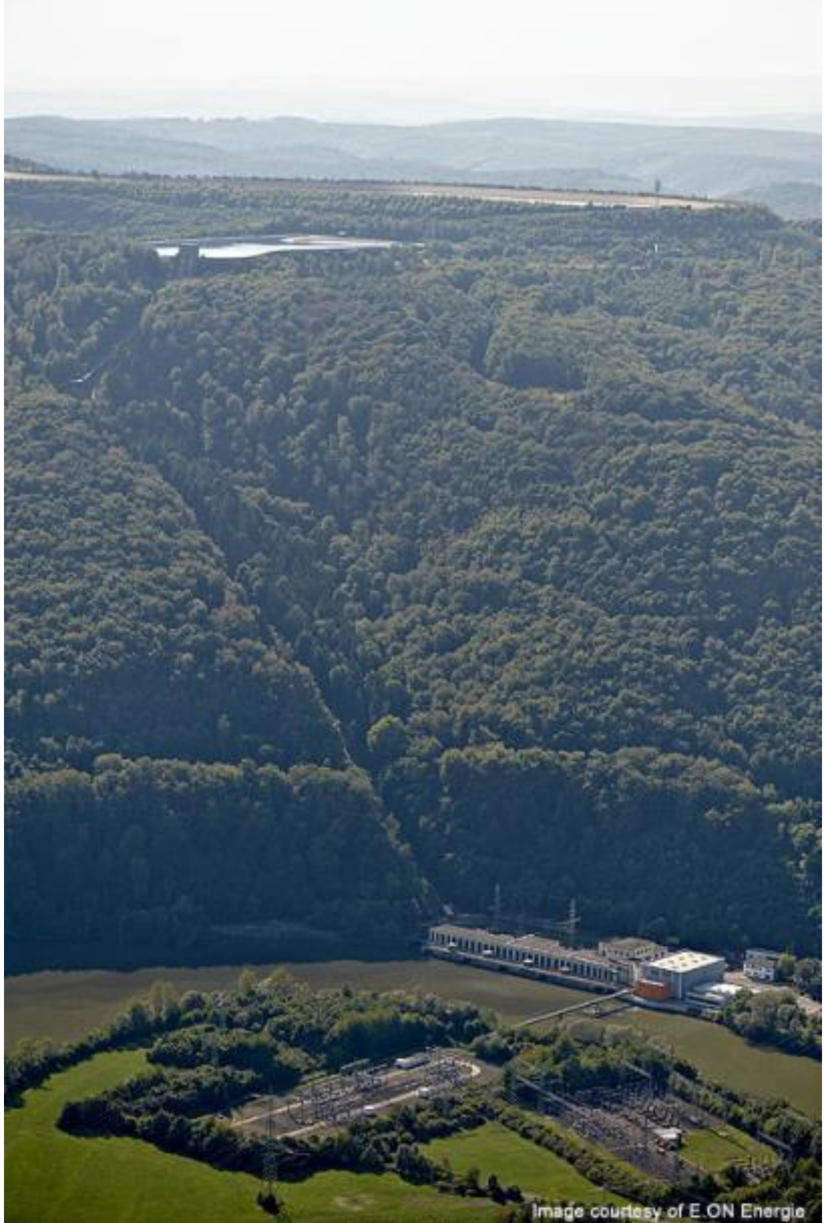
- River reach from Ukai dam Gujarat to Kakrapar weir -36 BCM live storage.
- PSP of 1200 capacity for 6 hours of operation and to 600 MW for 12 hours of operation



Erzhausen – Pumped Storage, Germany

Outside the Leine River system

Waldeck Pumped Storage Hydroelectric, Germany (920 MW)



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

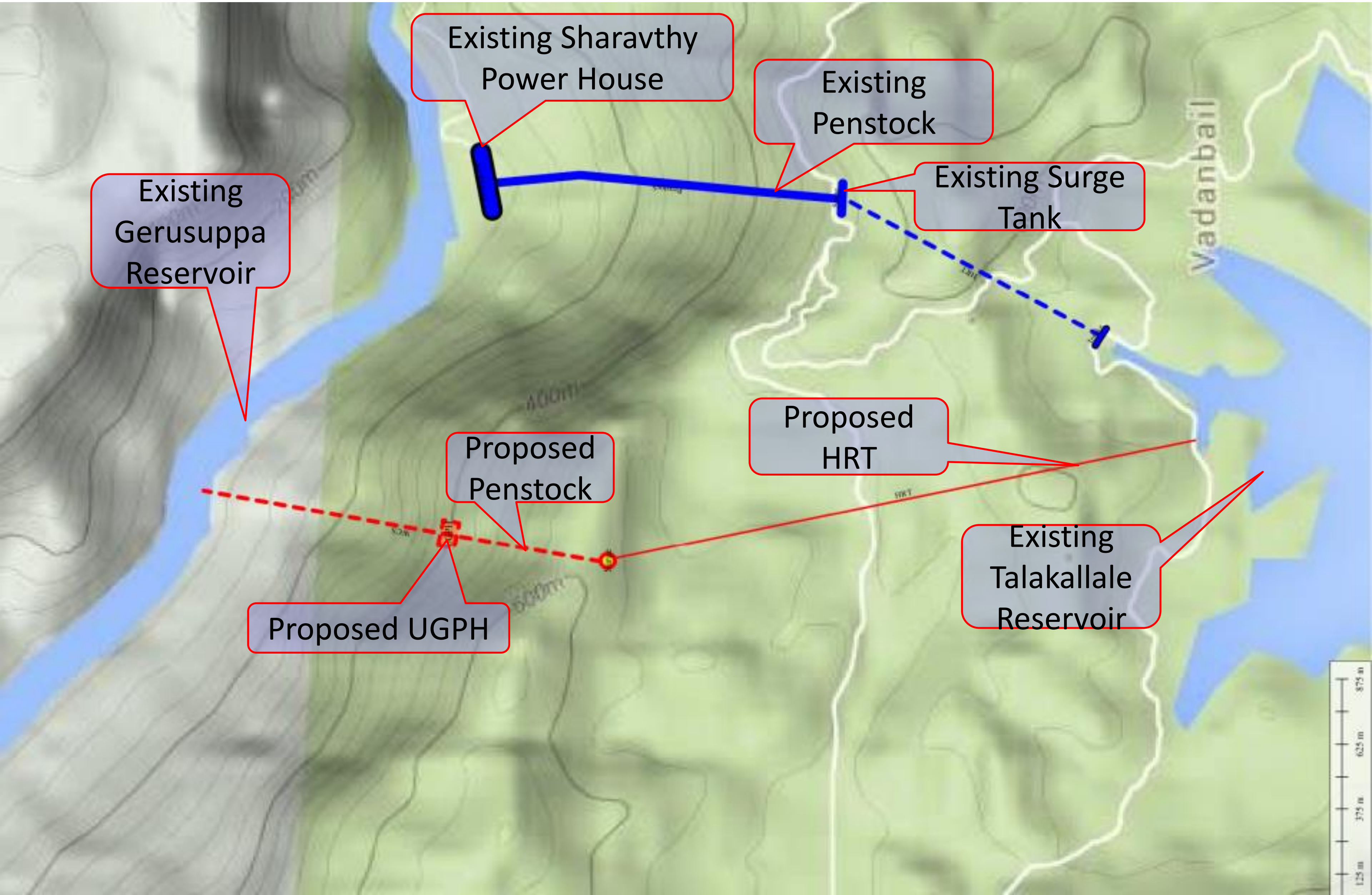
The Porąbka-Żar pumped-storage power plant, Poland

The upper reservoir - 250 m x 650 m.

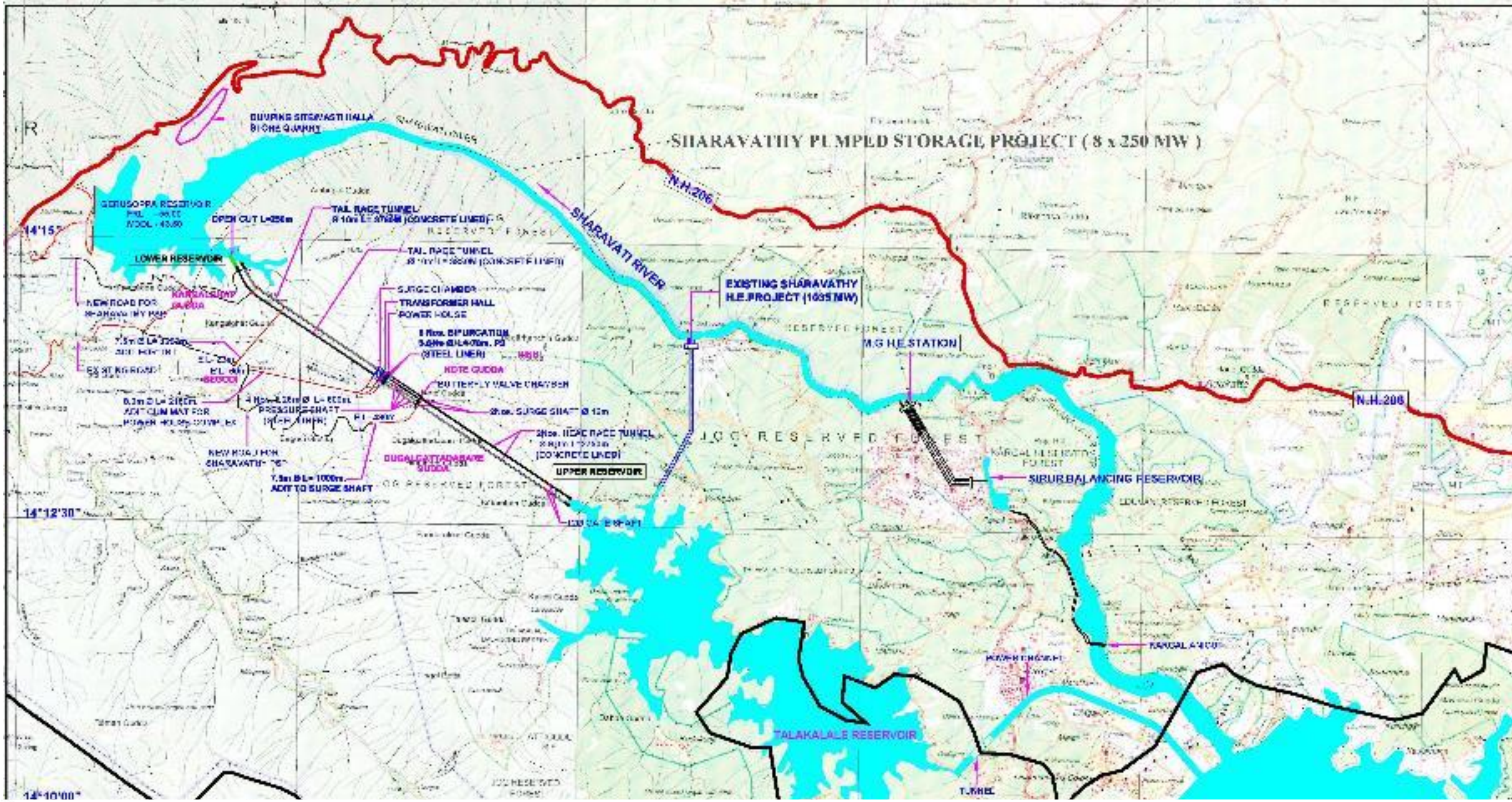
The total volume of the reservoir is 2.3 million m3.

Taum Sauk, 450 MW PSP, Missouri, USA Started in 1963

Proposed Sharavathi Pumped Storage Scheme (Option 02)

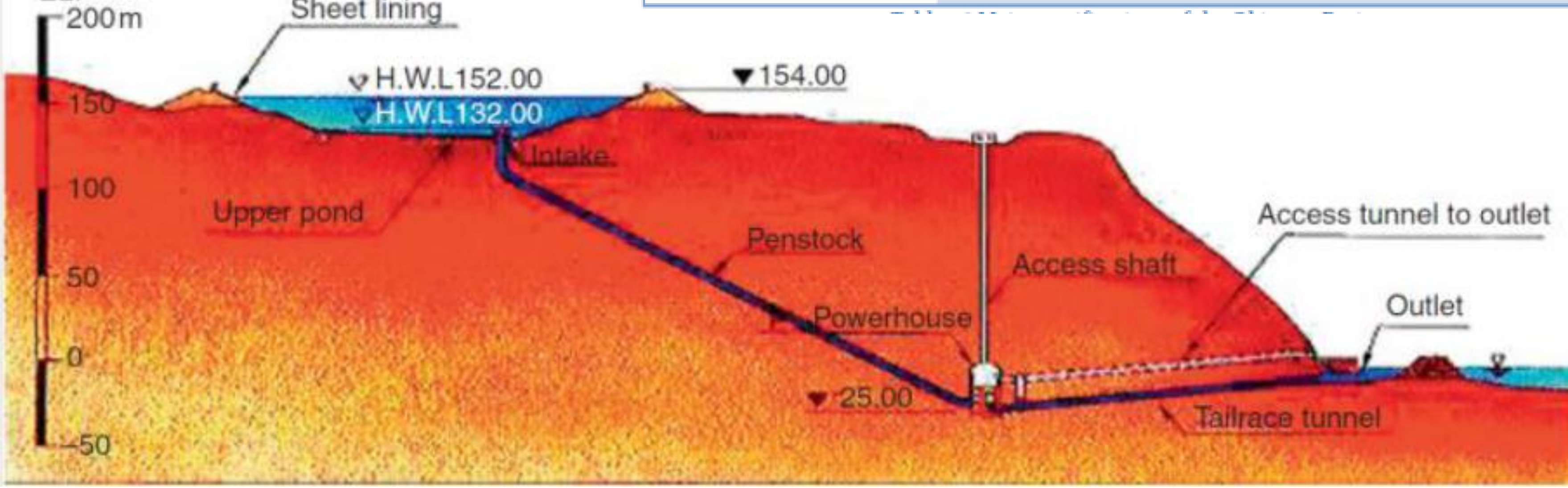


Sharavathi Pumped Storage Scheme

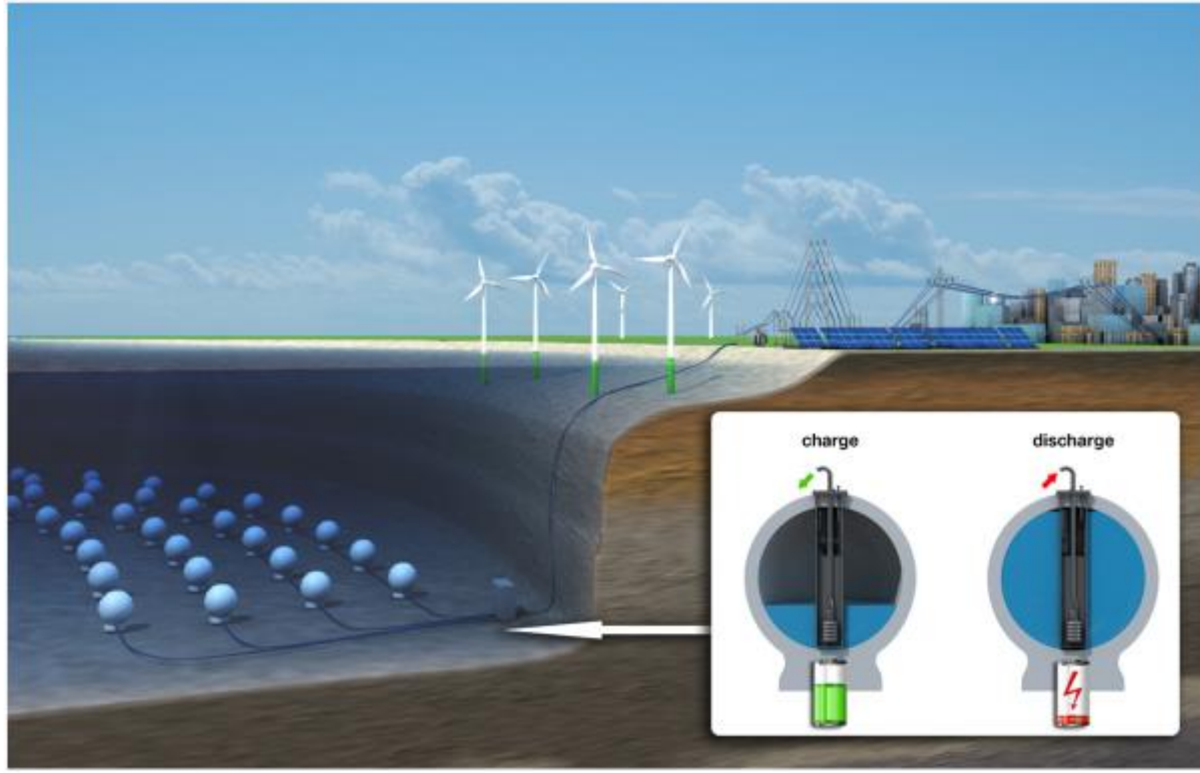


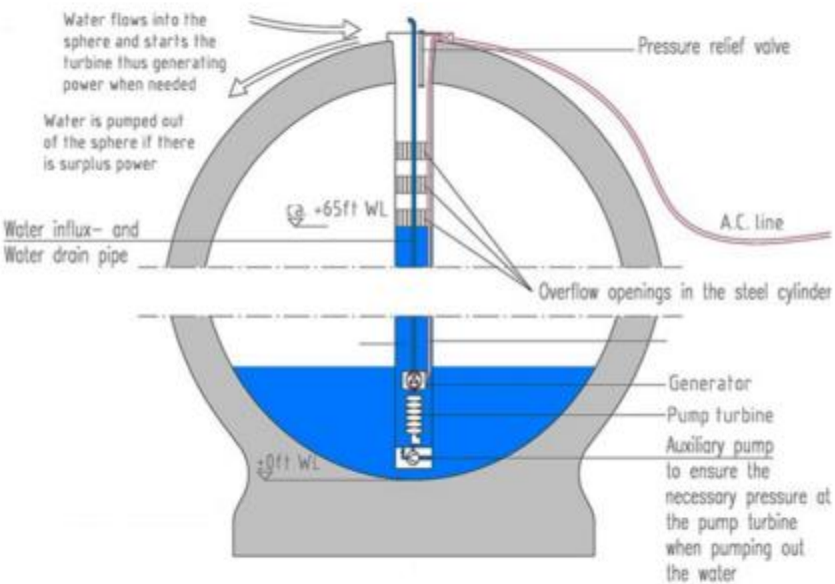
Okinawa Seawater Based PSP, Japan

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



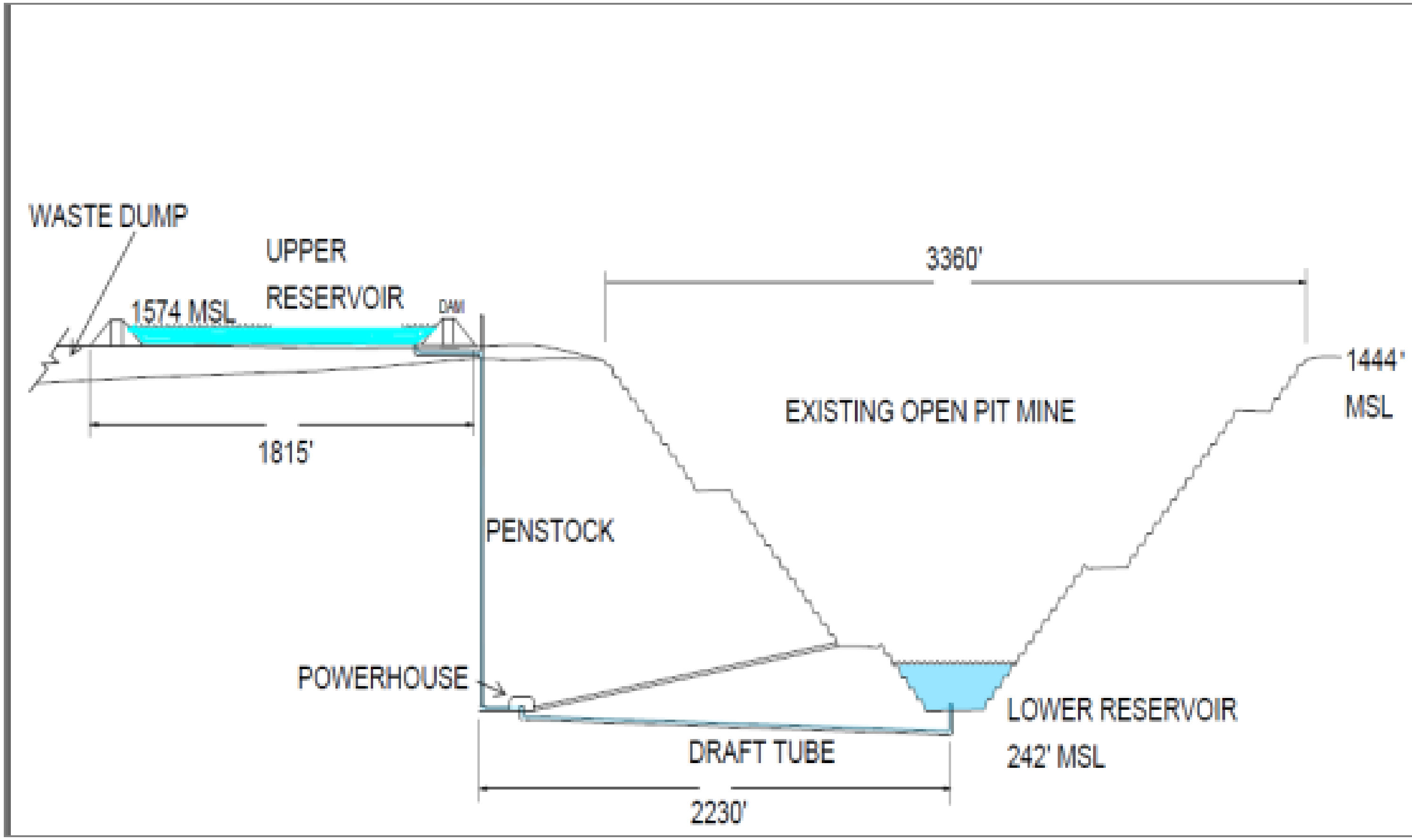
Underwater PHS (Stensea project)



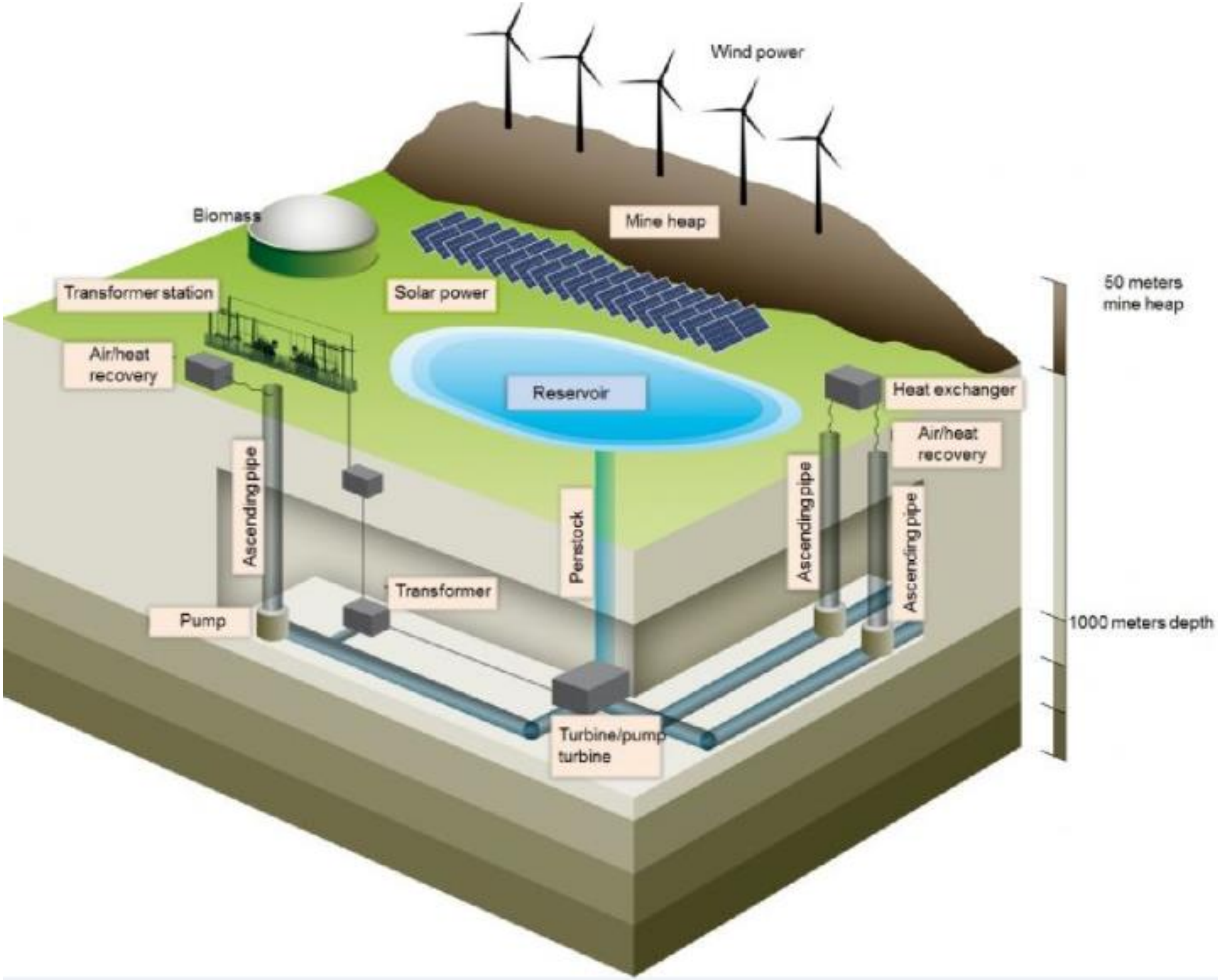


Pumps water into 30-meter diameter spheres anchored at the seabed, which can store up to 20 MWh each. Another sea-based alternative solution was proposed in Belgium.

PSH IN DISCARDED MINE SITES



The state of North-Rhine Westphalia (Germany) – Prosper-Haniel hard coal mine (600 m deep) 200 MW.



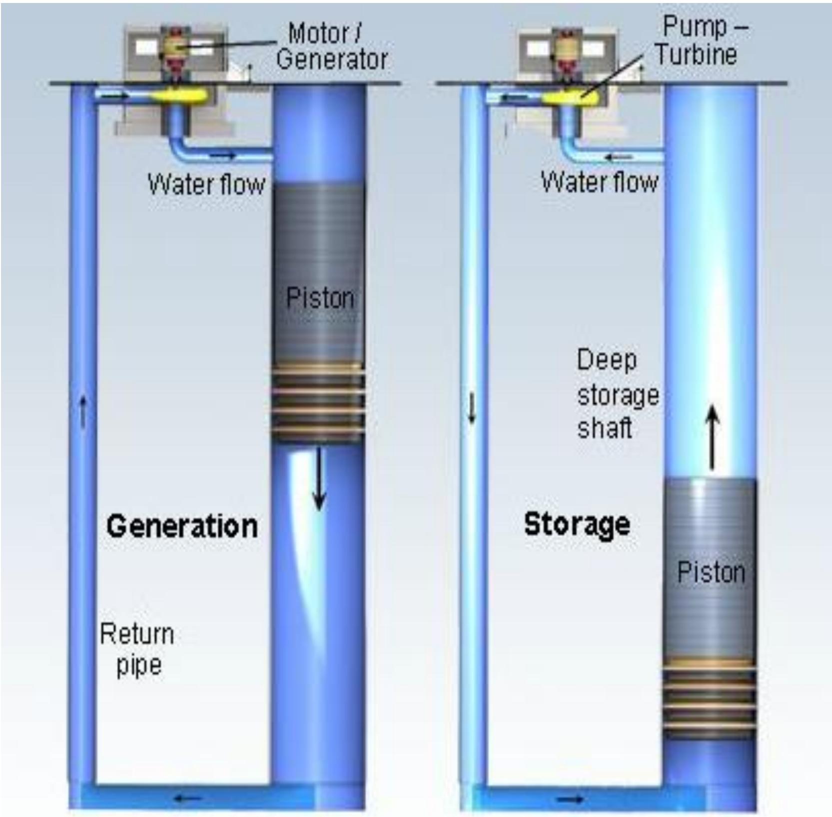
GROUND WATER SITE - GRAVITY POWER MODULE

- Gravity power module (GPM) is the latest technical advancement which is in current development for exploitation of the widely available sites based on PSH
- Suspended large piston made from iron and concrete
- Deep shaft filled with water
- The energy stored by using grid power to force water down and lifting the piston.
- To produce electricity, the piston drops to force water through the turbine, and drives the generator
- The shaft is filled with water once, at the start of operations, but is then sealed and no additional water is required.

Typical GPM Parameters

- 30-100 m diameter storage shaft
- 3-6 m diameter return pipe
- 500-1000 m deep
- 3 acre surface footprint

Advantages: high efficiency; flexible siting; use of existing technology, environmental compatibility, short time from project start to revenue, long lifetime, low cost per megawatt-hour and rapid construction.



(Source: Anthony DA. New energy storage option. Gravity Power 2011)

Patent: Gravity Power

Flexibility Value!!

- In theory, the market value of flexibility- related products should reflect the value providing to the electricity system. Unfortunately today these services are not fully recognized nor adequately remunerated in markets.
- The value of flexibility to the power system and the users of electricity is difficult to quantify.
- Analyses and assessments is required for
  - Optimizing market mechanisms to ensure that hydropower and other technologies contribute to sufficient flexibility at the right scale and the right time
  - The rising value of flexibility, understanding the frequency and magnitude of extremes and the impact on power prices in different markets
- Studies are needed urgently to analyse, assess, quantify and monetise the services from storage hydro

Value of Hydropower

- Changes and trends in the electric sector call for a fresh look at the future role for hydropower.
- Increasing penetrations of variable renewable generation, such as solar and wind – will lead to greater demand for grid flexibility and balancing services
- This is going to change the way the grid is operated and there is an urgent need to view the way hydropower is being developed, scrutinised, delayed at all level but not compensated.

Needed to be done for Hydropower

- To increase hydropower's competitiveness shall be requiring
  - continued improvement in mitigating adverse effects,
  - protection of biodiversity
  - increased public awareness of progress made.
- Requires
  - continued technical innovation and R&D,
  - measurable and implementable environmental sustainability metrics and practices,
  - increased planning at the basin or watershed scale,
  - access and application to new science and assessment tools.

To be acted upon

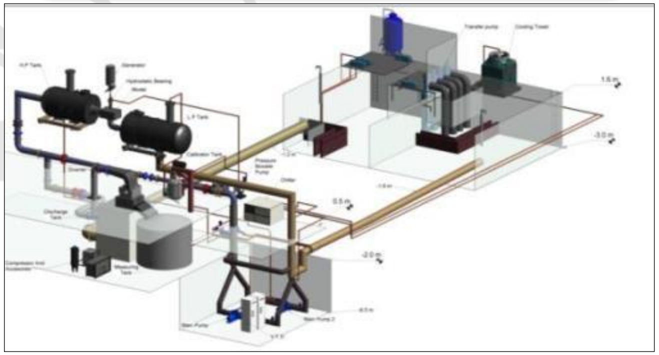
- National Hybrid Policy allowing technology agnostic storage + RE Hybrid projects as eligible hybrid projects for RTC/ flexible hours supply bids
- Design markets that value hydropower grid services and ancillary services utilizing PSP storage
- PSPs cost not be charged fully to DISCOMs but VRE, for creating variability in Grid, be also charged for supporting frequency and Voltage control services, system stability services and other operation benefits.
- Utility scale Off river PSP integrated with Renewable power be treated as "Renewable Project" and all incentives and easy clearances available to Renewable projects be granted
- Separate guidelines for Off river PSP for concurrence from CEA to make it short & expeditious, easy clearance from MOEFCC as linear land requirement case
- Have technology neutral policies for meeting societal goals for carbon reduction and levelise incentives
- Identify the off river and non traditional sites for cost reduction and reduced gestation period

R&D HYDRAULIC TURBINE LAB at HRED

- NABL accredited
- 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

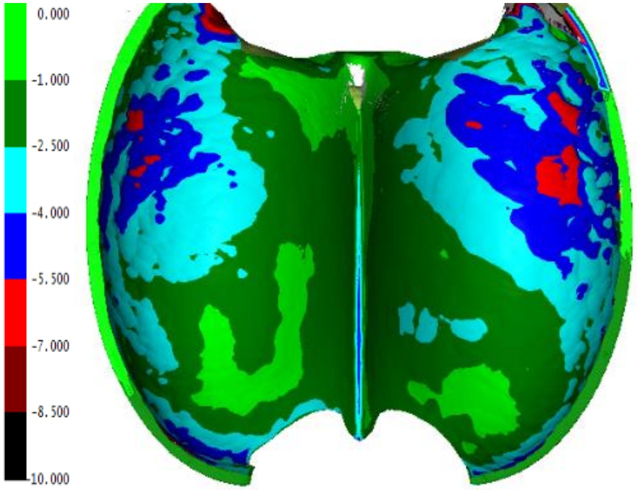
- Head 15-60 m and discharge upto 950 lps
- Building 15 x 24 m height +13.5 to – 6.5 m
- Water storage 300 cubic m



- Laboratory was inaugurated in April 2018
- Turbine Manufacturers and project developers may take benefit of the lab.

Sediment Monitoring and Impact Analysis Laboratory

- Laboratory for sediment monitoring and impact analysis studies in hydropower plant is under establishment.
- to be a depository of silt data and online monitoring of silt flow for all hydropower stations experience gained by different power utilities and manufacturers
  - Online Turbidity Sensor and Suspended Solids
  - Laser Diffraction sediment sensor,
  - Acoustic based sediment measurement,
  - Digitizer for quantifying shape and size
  - High speed camera system



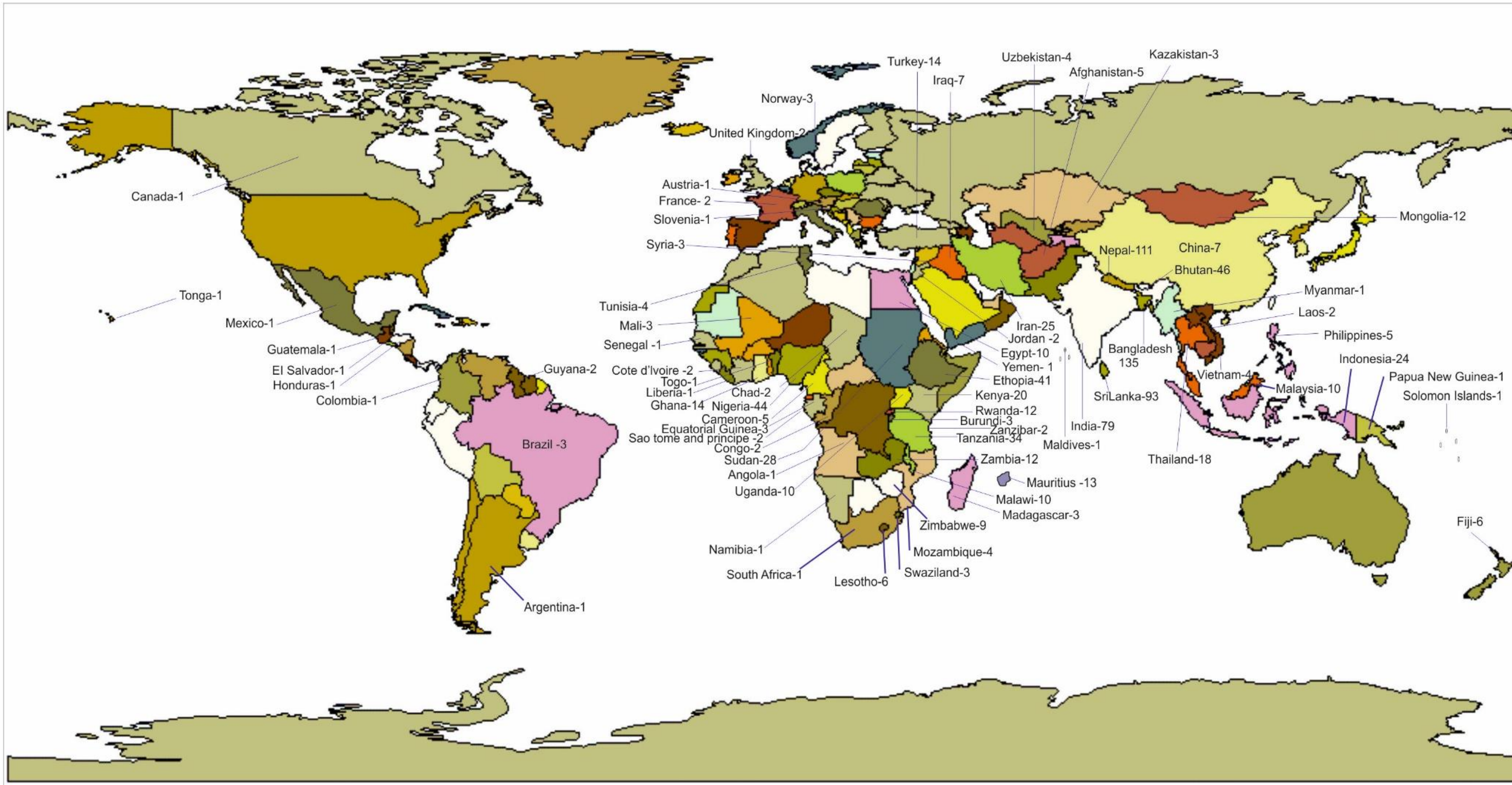
Real-Time Digital Simulator (RTDS) for Hydropower Plant

Department of Hydro and Renewable Energy

Commissioned in 2007

Number of Participants attended the International Training Courses on SHP Development Organised by AHEC,IIT Roorkee

1999 Onwards

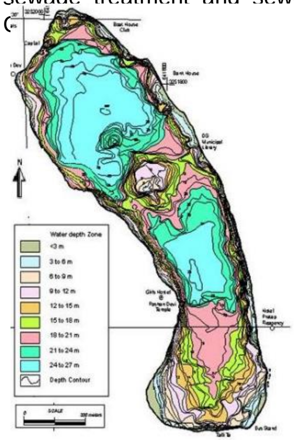


AHEC/Oct. 2018

ENVIRONMENTAL MANAGEMENT OF RIVERS AND LAKES

MAJOR ADVISORY SUPPORT PROVIDED IN UTTARAKHAND

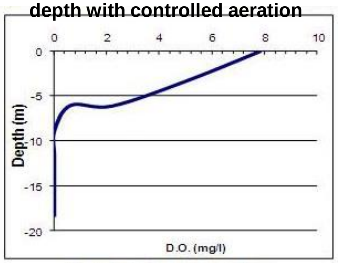
- Conservation and Management Plan for Nainital Lake, Bhimtal, Naukuchia Tal, Sat Tal and Khurpa Tal in Nainital District.
- Conservation Measures: Planned and designed, vetted
- Plan and Design of Artificial Lake at Champawat
- Status Paper on River Ganga: State of Environment and Water Quality
- Review of proposals for River Pollution abatement through sewage treatment and sewer network of Muni ki Reti and



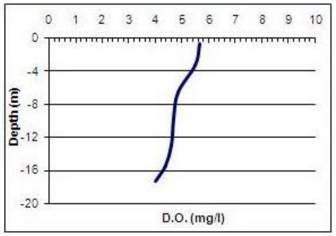
NAINITAL LAKE 2011

NAINITAL LAKE 2007

Variation in dissolve Oxygen with depth with controlled aeration



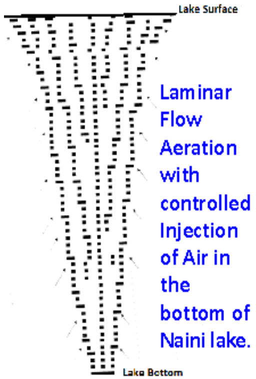
2007 Before Aeration

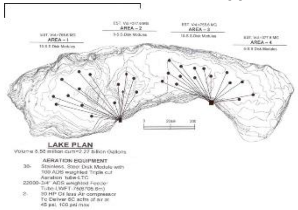


Oct 22, 2007 After Aeration

Interventions outside Lake

- Slope stabilisation
- Drainage line treatment
- Strengthening and protection the outlet / nallah from lake
- Sanitation around the lake
- Shoreline development
- Institutional development
- Management of Sewage
- Management of





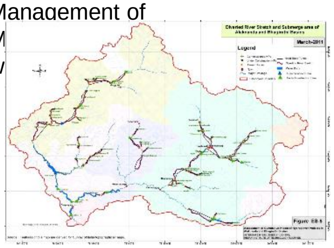
Interventions within Lake

- Oxidation at the bottom of the lake without disturbing thermal stratification through controlled aeration.
- Control fish Gambusia affinis by putting minnow traps.
- Renovation of outflow slucies.
- Regular monitoring of water quality.

Status Paper on River Ganga

- Cumulative Impacts of Hydropower Projects on River Alaknanda and Bhagirathi

HP Type	TOTAL No. of HP	Installed Capacity (MW)	Generating Units (MU)
COMMISSIONED			
Large	4	1,794	7,542
Small	9	57	319
Total	**13**	**1,851**	**7,860**
ONGOING CONSTRUCTION			
Large	7	2,469	10,273
Small	7	69	454
Total	**14**	**2,538**	**10,727**
UNDER PREPARATION			
Large	16	3,843	15,310
Small	26	801	3,206
Total	**42**	**4,644**	**18,516**
TOTAL			
Large	27	8,106	33,125
Small	42	927	3,978
Total	**69**	**9,033**	**37,103**



Main Recommendations:

- Variable Environmental Flow (EF) to be released.
- Regular flushing of beds at barrages
- Sufficient gap between two consecutive projects for river recuperation
- Construction of fish passes at barrages
- Regular collection of data on Valued Ecosystem Components to ensure sustainability
- Adaptive management and regular monitoring

A two year M.Tech Programme on "Environmental Management of Rivers and Lakes" and organizes training

SUPPORT PROVIDED TO ENVIRONMENTAL MANAGEMENT OF OTHERS RIVERS AND LAKES INCLUDING PREPARING GUIDELINES

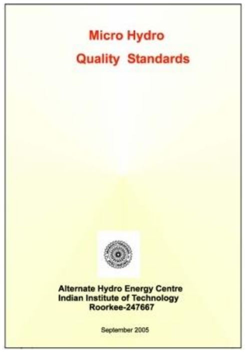
- Conservation and Management Plan for Dal and Nagin Lakes in J&K
- Conservation and management Plan for Kailana Lake (Jodhpur) and Gadisar Lake (Jaisalmer) Rajasthan
- Mangement Plan for Daya and Kuakhai River in Bhubneshwar, Orrisa and River Kshipra, Ujjain, Madhya Pradesh
- Reviewed Project Proposals of lakes of Hussain Sagar (Hyderabad), Kodaikanal (TN), Sukna (Chandigarh), Pushkar, Gansagar, Goverdhann Sagar, Gundovlay Talab, Jaisagar, Kushal, Rajasamand, Sambhar, Sujan

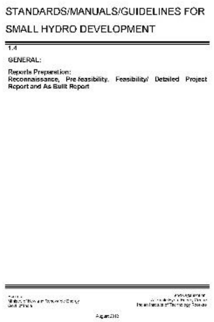
- Prepared Guidelines for Ministry of Environment & Forests, GoI
- Preparation of project reports under National River Conservation Plan and National Ganga River Basin Authority
- Guidelines for National Plan for Conservation of Aquatic Ecosystems

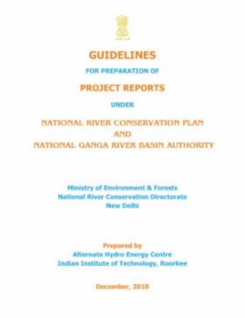
ALTERNATE HYDRO ENERGY CENTRE

STANDARDS/GUIDELINES FOR SMALL HYDRO

- Standards/Guidelines and manuals are useful for developers, manufactures, consultants, regulators etc.
- AHEC prepared 27 standards to boost the development of this sector. Also available on website.
- Also prepared standard for environmental management of rivers and lakes







Thank You