Key Findings of the Report
on
'Role of Pumped Hydro Energy Storage (PHES) in India's Renewable Transition'

Presented by

V. K. Agrawal (Technical Director) & **Rajiv Ratna Panda** (Technical-Head)

Integrated Research and Action for Development (IRADe)

Webinar on Role of Pumped Hydro Energy Storage in India's Renewable Transition
4 August, 11:30 am (IST), New Delhi, India

Share of Renewables in Installed capacity in India

Current All India Gen. Capacity

Total : 371 GW
Coal : 198 GW
Lignite : 6.61 GW
Gas : 24.99 GW
Diesel : 0.50 GW

Thermal
222 GW (62 %)

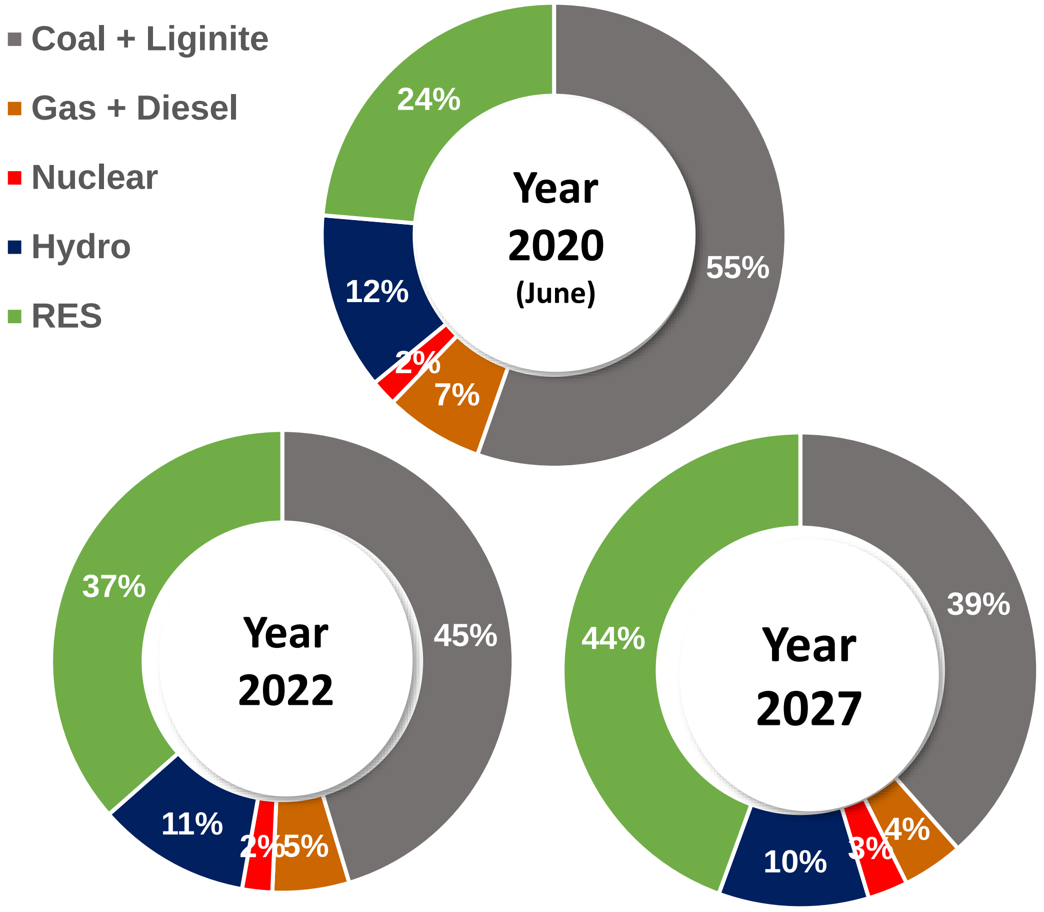
Nuclear : 6.78 GW (2 %)
Hydro : 45.7 GW (12%)
RES : 87.7 GW (24%)

As on June,2020

Current Status RE : 87.7 GW

Wind : 37.8 GW
Solar : 35.1 GW
Biomass : 9.9 GW
Smaller Hydro : 4.7 GW
Waste to Power : 0.1 GW

India Power installed capacity mix



With enhanced capacity of renewables, grid balancing is going to be a challenge

Main Interventions for the Study

- Deployment of large RE and Challenges towards grid Balancing
- Comparative Study of different Storage Technologies
- Role and Utility of Pumped Hydro Energy Storage (PHES) as a Significant Option
- Roadmap for Tapping Regional Hydro Potential in South Asia & Recommendations

Dialogues during 1st Roundtable on 27th March 2019 and Key Discussion Points

Key Organizations Participated :

Thought Leaders from Energy Sector, Think-Tanks & NGOs

• IRADe	• NPTI	• CBIP
• Brookings	• REWS	• ICRIER
• CEEW	• ORF	• CII
• DFAT	• TAF	• TERI

Key Discussion Points During 1st Roundtable :

- Likely Deployment of RE in the Grid ;
- Possible Avenues towards Balancing ;
- Comparative of different Storage Technologies;
- Global Energy Storage Experiences;

Four main avenues which help towards balancing

Demand Side Management

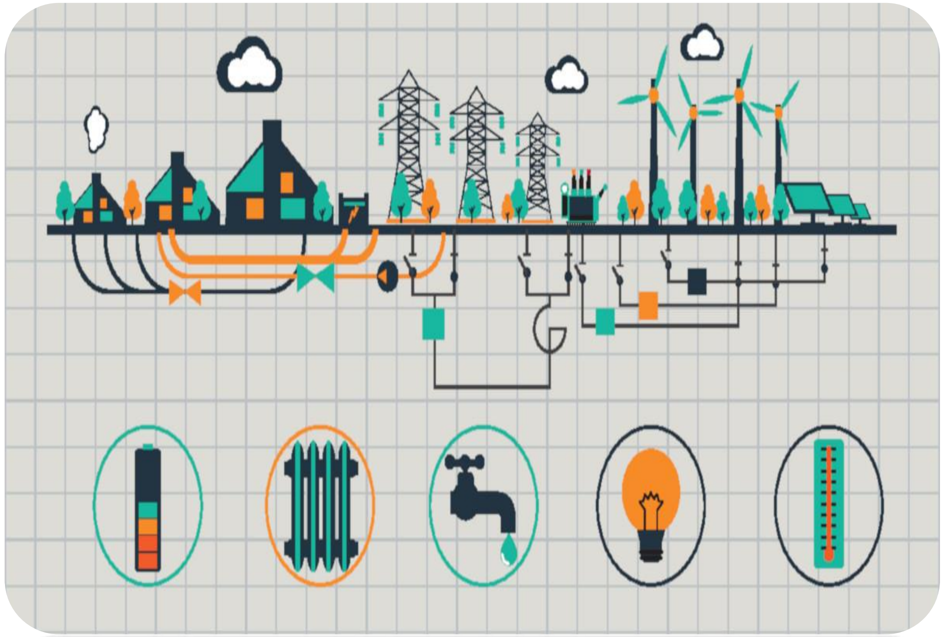
Thermal Flexibility

Grid Flexibility

Storage Technologies

Demand Side Management

- **Advancement in Distribution Infrastructure & Policy**
  - ✓ Time of the Day Metering;
  - ✓ Segregation of feeders;
  - ✓ Matching Tariff Design;
  - ✓ Adequate incentives;



✓ **Needs special attention and policy/regulatory push;**

Thermal Flexibility

Enablers :

- Large Pool of Thermal Generation (230 GW);
- Latest CERC Norms backing down up to 55%;
- No Additional Capex towards Capacity Addition;

Limitations :

- Inferior heat rate at low PLF;
- Excessive wear & tear;
- Additional cost towards Retrofits;
- Limited Ramping up/down capability;

Thermal flexibility is an important option, however has its own limitations

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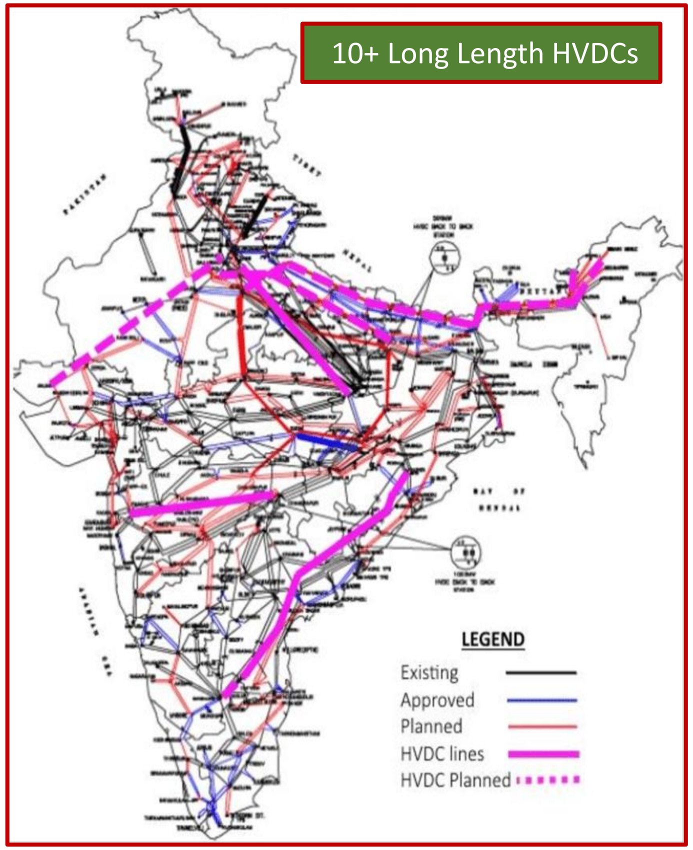
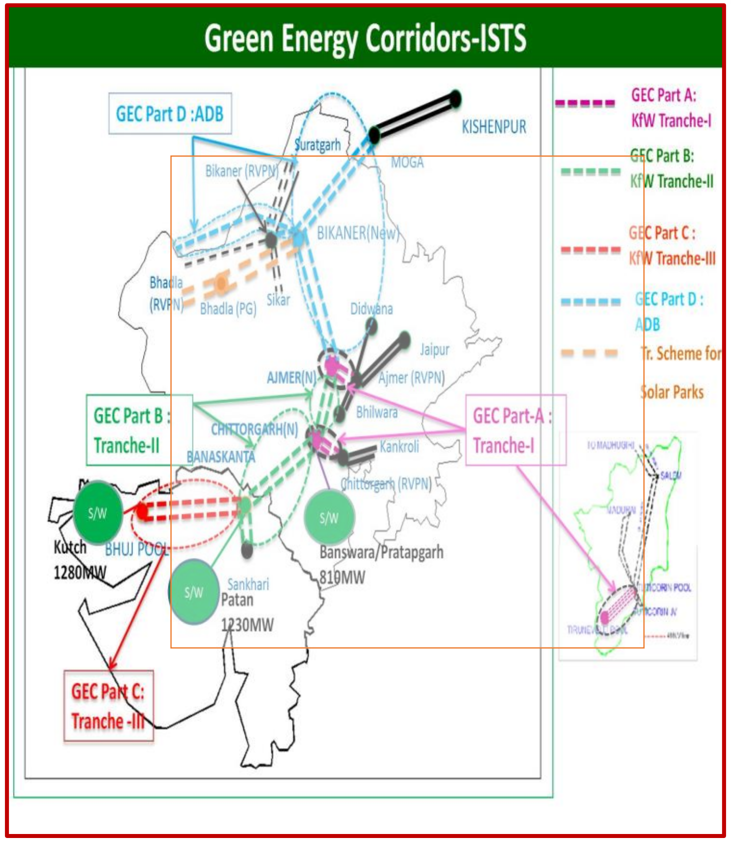
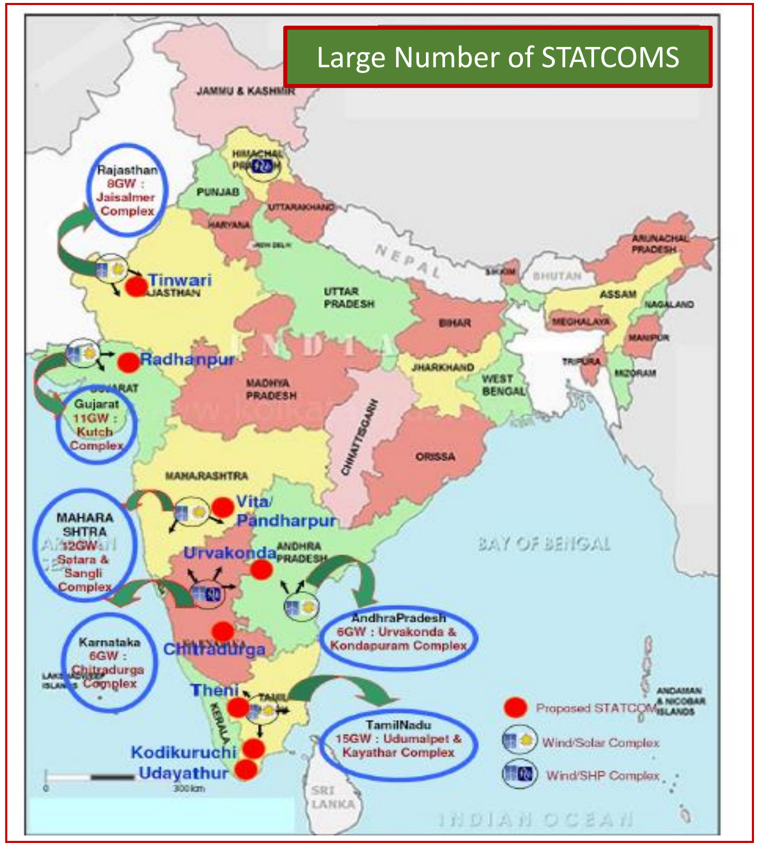
Grid Flexibility

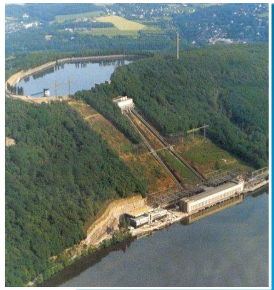






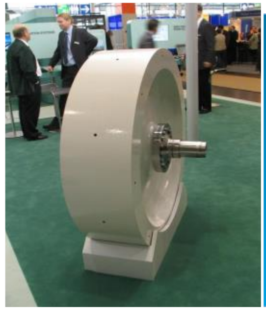
One Large Synchronously Connected Grid with 425,000 Ckt.+ EHV Network

Grid Balancing Sources/Energy Storages



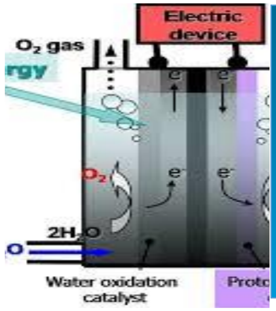
Pumped Hydro Energy Storage

Electro Chemical Storage

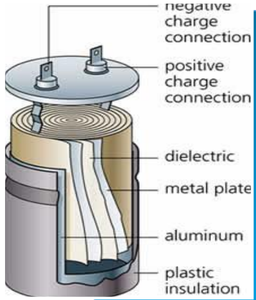


Electro Mechanical Storage

Thermal Storage



Chemical Storage



Electrical Storage

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Dialogues during 2nd Roundtable on 16th April 2019 and Key Discussion Points

Key Organizations Participated :

Policy Makers, Regulating Agencies and Stakeholders from Govt. & other Agencies

• MoP	• CEA	• POSOCO
• DERC	• NHPC	• WBPDCL
• SJVNL	• GUVNL	• GREENKO

Key Discussion Points During 2nd Roundtable :

- Current scenario of PHES plants in India;
- Avenues for going for off–river closed loop PHES;
- Different Business model options for PHES;

Comparative of Energy Storage Technologies: Duration, Maturity and Applications

Storage	Duration (hrs)	Maturity	Application
Mechanical Energy Storage System			
Pumped hydroelectric	6 –1 0	Commercial & Mature	Load levelling; Peak shaving; Renewable integration
Compressed air energy storage (underground)	20	Commercial	Load levelling ; Renewable integration
Flywheels	0.25	Commercial	Frequency regulation
Electrical and Magnetic Storage System			
Superconductive magnetic energy storage		Demo	Power quality; Frequency regulation; Voltage Support
Electrochemical capacitors	~ 1 min	Demo	Power quality; Frequency regulation; Voltage Support
Electrochemical Storage System			
Advanced lead acid batteries	4	Demo	Power quality; Frequency regulation; Voltage Support; RE integration
Lithium ion batteries	0.25–1	Commercial	Power quality improvement; Frequency regulation
Sodium sulfur	7.2	Commercial	Time Shifting; Frequency regulation; Renewable source integration
Vanadium fow redox	5	Demo	Peak shaving Time shifting Frequency regulation RE integration

Source: https://www.adb.org/sites/default/files/publication/225731/energy-storage-grids.pdf

Battery Storage & PHES technologies are complimentary in nature and depends on the application & time period;

Global Operational Energy Storage Power Capacity by Technology Group – May 2017

Type	Total Capacity (GW)	Total Capacity (%)
Pumped Hydro Energy Storage	169 GW	96 %
Thermal Storage	3.3 GW	1.9%
Electro-Chemical Storage	1.9 GW	1.1%
Electro-Mechanical Storage	1.6 GW	0.9%
Total	**176 GW**	

Source : IRENA Document Oct. - 2017

Across the Globe the main source of Energy Storage is Pumped Hydro Energy Storage (PHES)

Technological Advancement _Off River Closed Loop Pumped Hydro Energy Storage (PHES)

The PHES facilities can be of two types

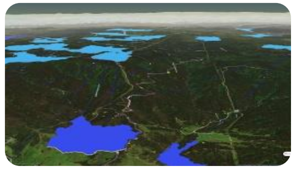
(i) Hybrid (open loop) PHES

Both pumped and natural flow water is used to generate electricity.

(ii) Off- river closed loop PHES,

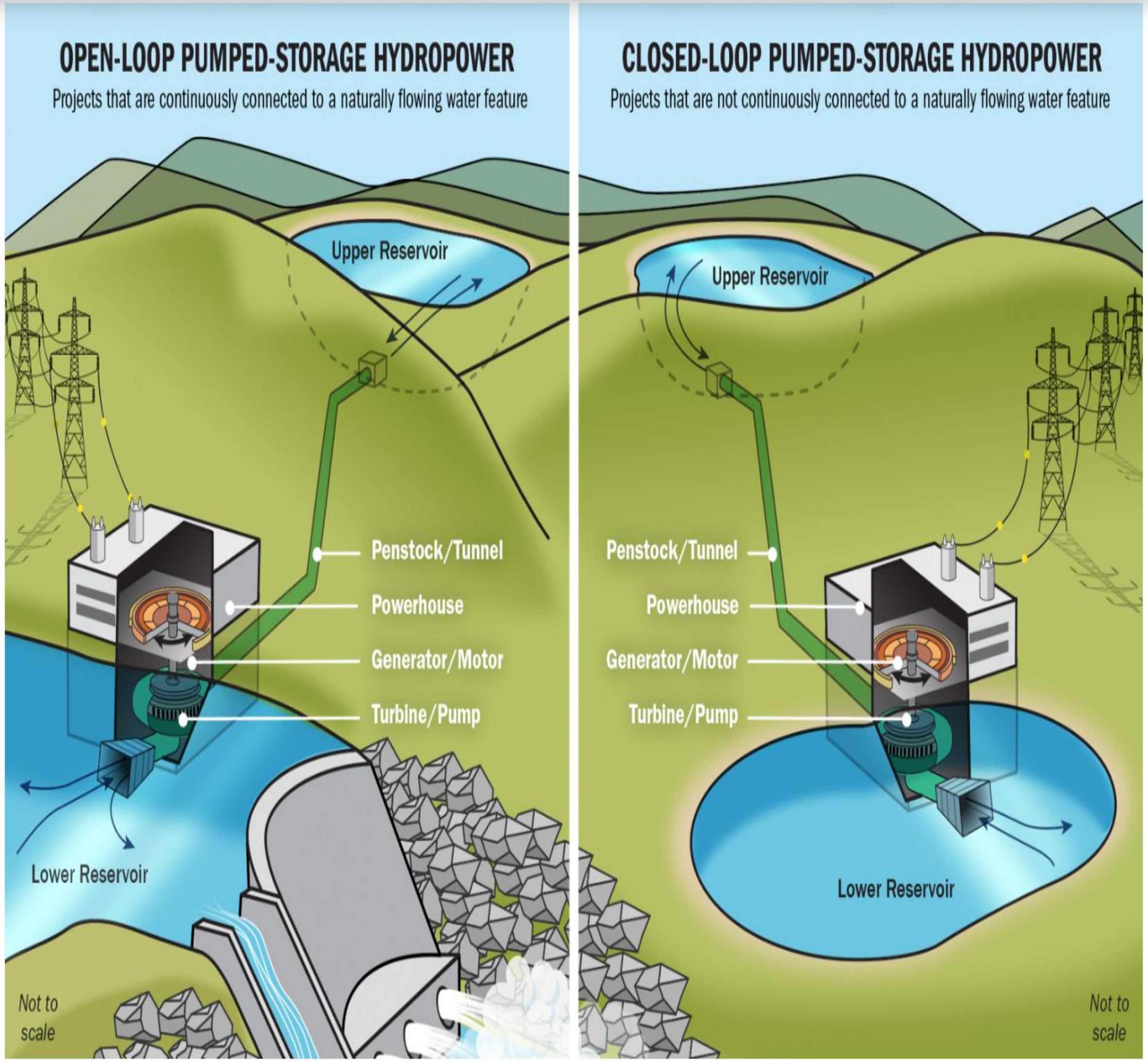
Same water is used for pumping and generation, with make-up water for evaporation through water stream, rain and/or any other source;

Off-river Closed Loop PHES Advantages :





- ✓*Reservoirs can be natural and artificial.*
- *Lesser Cost in case of Natural reservoirs*
- ✓*Reduced environmental impacts*
- ✓*Cheaper option for balancing & RE integration*



Source: https://www.energy.gov/eere/water/articles/new-approach-pumped-storage-hydropower

South Asia Regional Perspective

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Regional Conference on 12th June 2019 : Key Findings and Recommendations

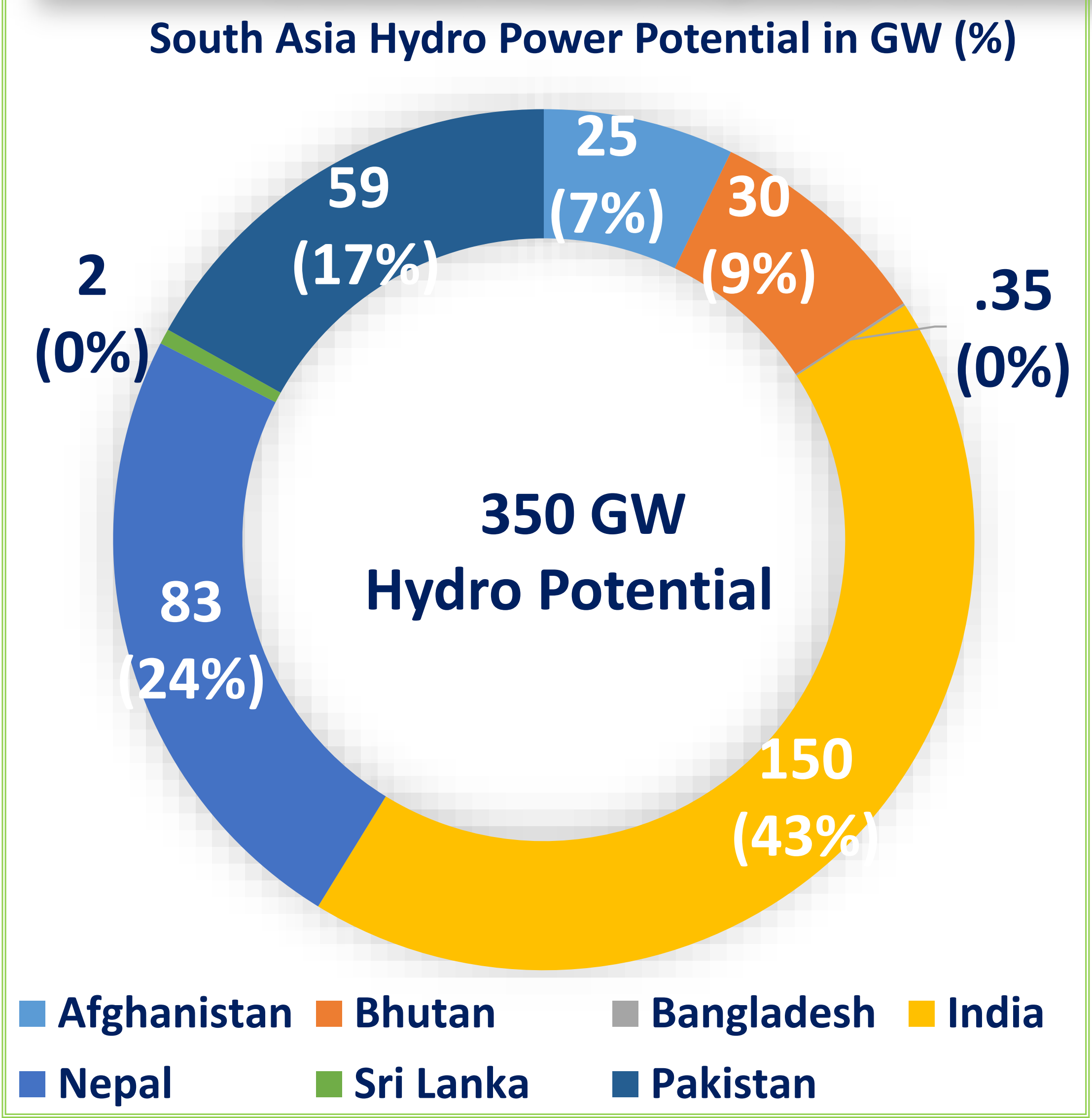
BBIN

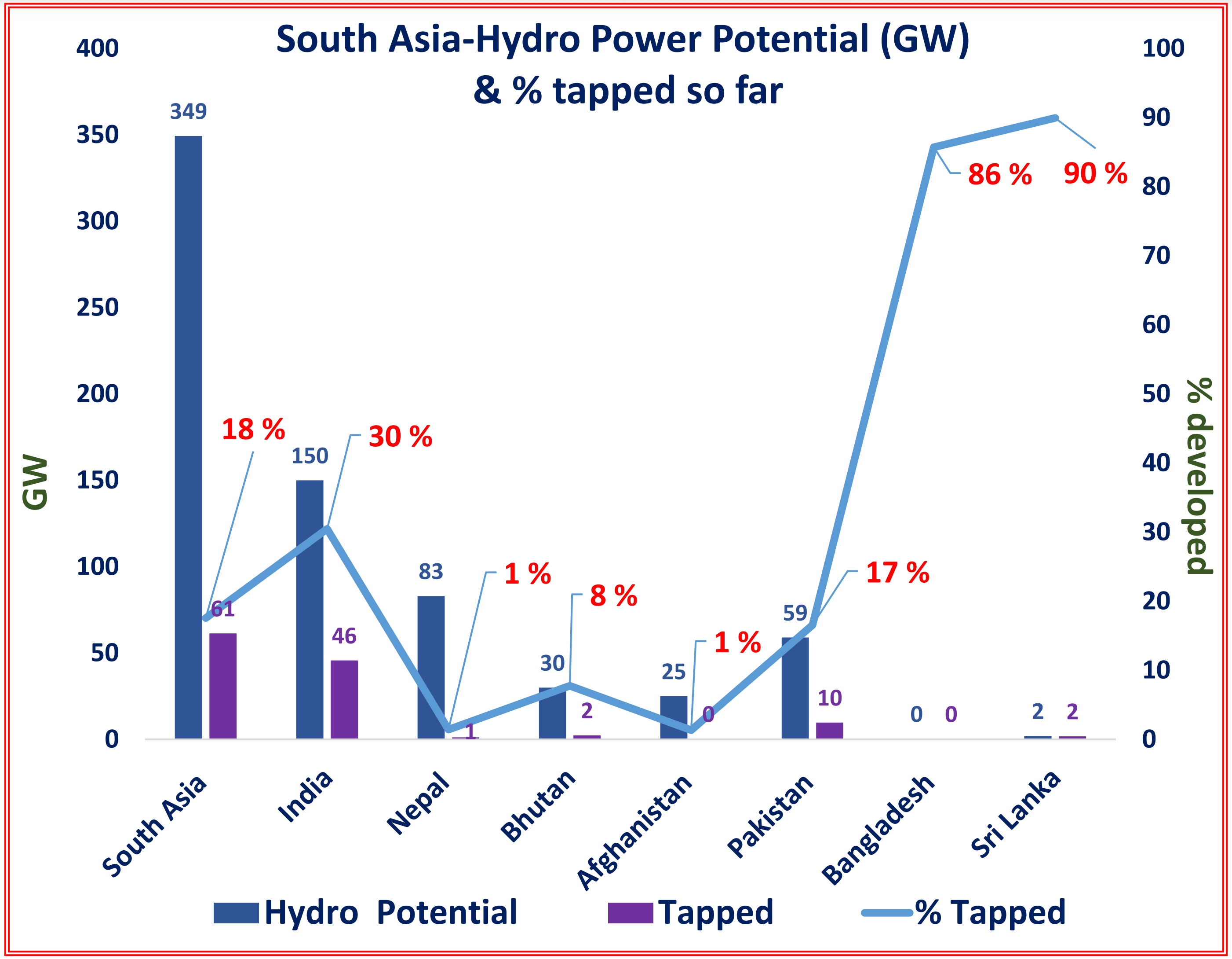
Representatives from BBIN

Bhutan
Bangladesh
India and
Nepal

- **Policy makers**
- **Thought Leaders**
- **Power utilities**
- **System Operator**
- **Private Sector**

South Asia Hydro Power Potential and Potential Exploited





SA Regional Perspective-Benefits of Regional Grid Balancing & RE Grid Integration

Rapid Renewable Energy Expansion in South Asia

175 GW by 2022

450 Gw[1] 2030

Bangladesh

7.9 Gw[2] by 2041

Sri Lanka

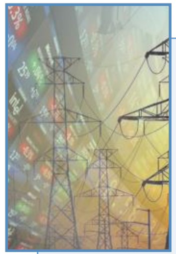
50% Generation[4] from RE by 2030

Pakistan

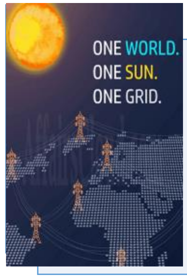
16 Gw[3] by 2040

Hydro Power through CBET and optimised grid balancing

A tool for flexibility, managing RE Intermittency, in SA.



Opportunity-Developing Regional Power Market-Trading of balancing services, Ancillary Market



One Sun One World One Grid' (OSOWOG)-A grand Vision

Successful 9 PM, 9 Minute-A generation flexibility of ~ 400 MW was achieved from hydropower plants in Bhutan[5]

New power market initiatives in India also offers an opportunity to leapfrog

In 2016, 80% of Denmark's wind generation[6] was balanced through CBET through the utilization of Norway's hydro resources

[1] http://cea.nic.in/reports/others/planning/irp/Optimal_generation_mix_report.pdf [3] https://nepra.org.pk/Admission%20Notices/2019/09-September/IGCEP%20Plan%20(2018-40).pdf [2]https://powerdivision.portal.gov.bd/sites/default/files/files/powerdivision.portal.gov.bd/page/4f81bf4d_1180_4c53_b27c_8fa0eb11e2c1/Revisiting%20PSMP2016%20%28full%20report%29_signed.pdf [3] https://nepra.org.pk/Admission%20Notices/2019/09-September/IGCEP%20Plan%20(2018-40).pdf [4] For Sri Lanka 50% renewable energy (including major hydro) by year 2030, https://www.pucsl.gov.lk/wp-content/uploads/2020/06/PUC-LI-AP19-01-May-28-PUC-reply-to-revised-LCLTGEPrev1-3.pdf [5] Successful 9PM, 9 minutes event Highlights the Outstanding Cooperation in Electricity Grid Management in South Asia https://posoco.in/download/report-on-pan-india-lights-off-event-9-pm-9-minutes-on-5th-april-2020/?wpdmdl=28819

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Achieving commercial viability in case of PHES_ Business Model Options

(Option 1)-

Asset based on Existing Conventional Approach

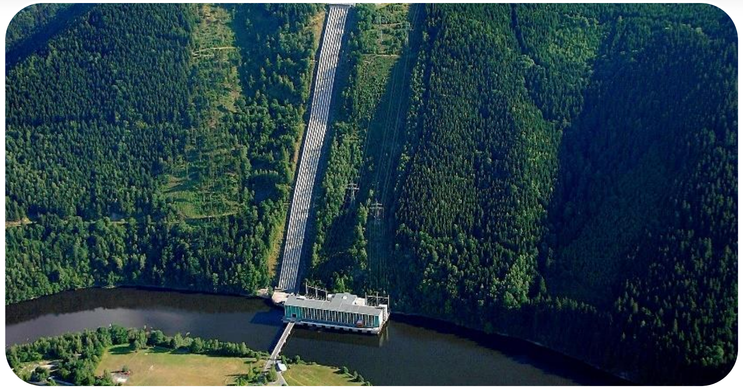
Challenges

- Being a negative energy source, tariffs work out to be quite high;
- Do not stand competitive in the face of declining tariffs;
- Lack of private sector participation and competition;

(Option 2)

As a Regulatory Asset (towards grid supporting measures)

- Brought on the lines of Grid/Transmission Elements ;
- To be operated at the requirement of Grid Operator ;
- Tariffs to be decided by regulator and charged as pooled assets;



(Option 3)

As Market Based Asset under Ancillary Services

- Designed to provide balancing power for certain minimum hours on each day;
- Full capacity charges if available for agreed duration with incentives for extra;
- The tariff for output (balancing) power to be decided based on comp. bidding;

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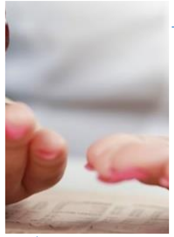
Key Findings and Way Forward

✓Accelerating DSM to support grid balancing



✓Valuing cost of balancing power

✓Different storage tech. to be deployed based on usage & economics

✓Batteries will play an important role, but mainly for short periods

✓For bulk electric energy time shift (Arbitrage), PHES is the solution as storage

✓Off-river closed loop PHES Potential & a 'Long Term Outlook' needed

✓Exploring Innovative business & financing models for PHES

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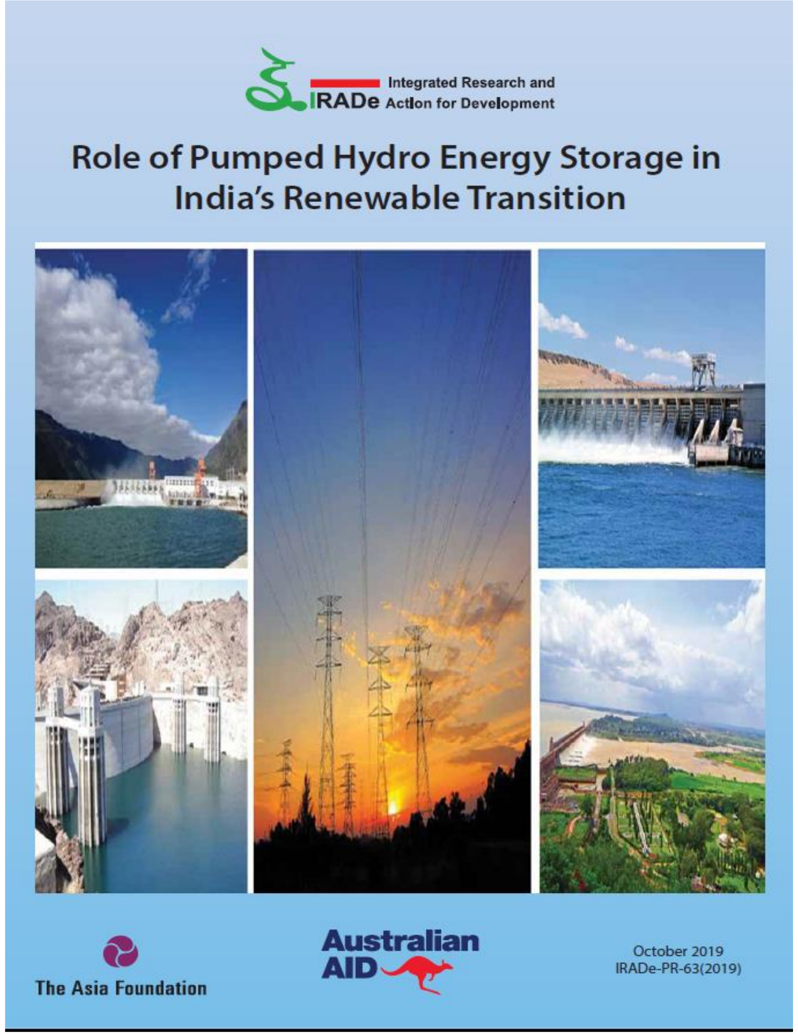

Thank You