IESA
India Energy Storage Alliance

Role of Energy Storage in Maharashtra context

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Chair, Global Energy Storage Alliance
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Presented at

Maharashtra Power System Transformation Workshop

Organized by

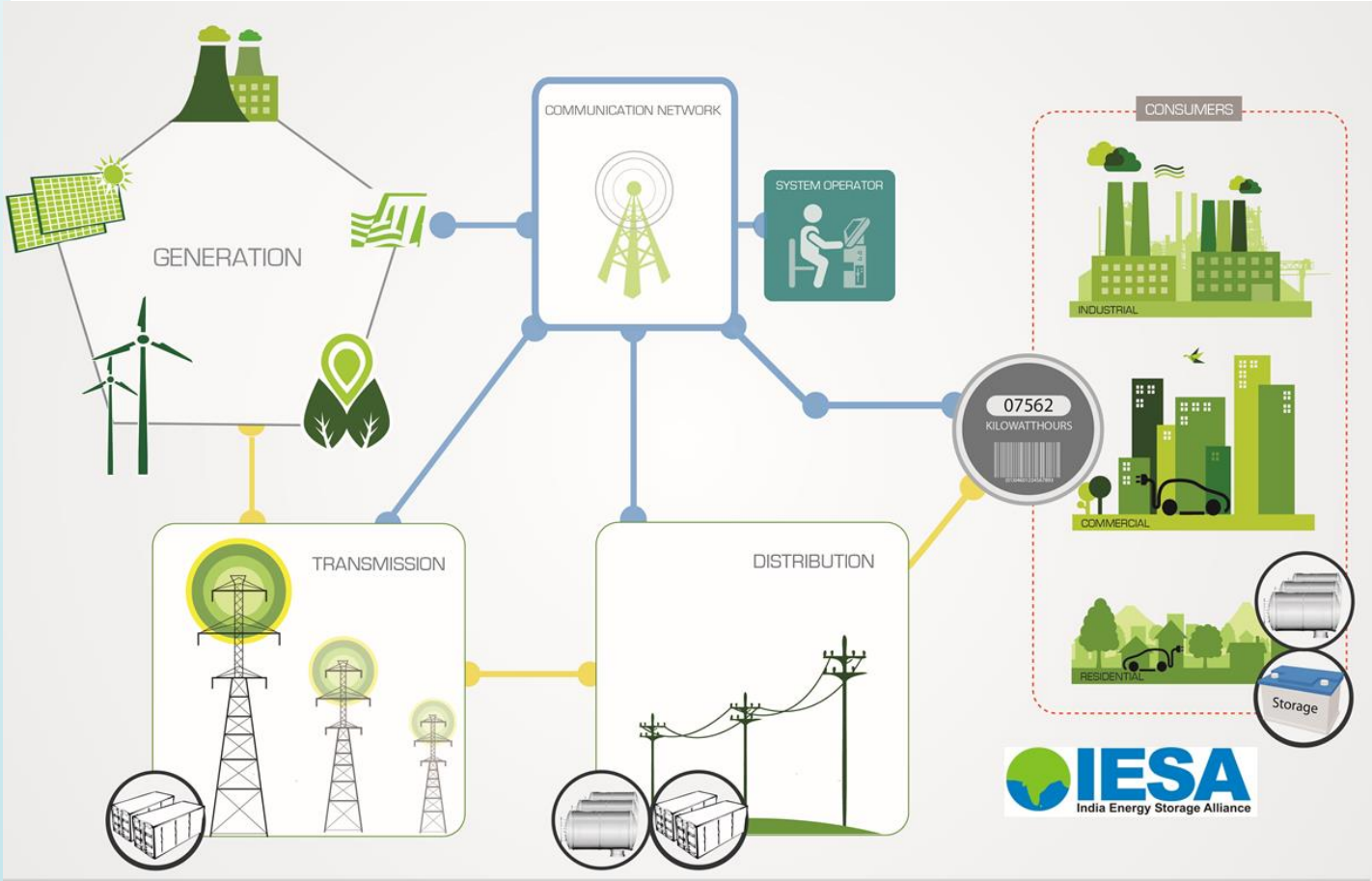
iea

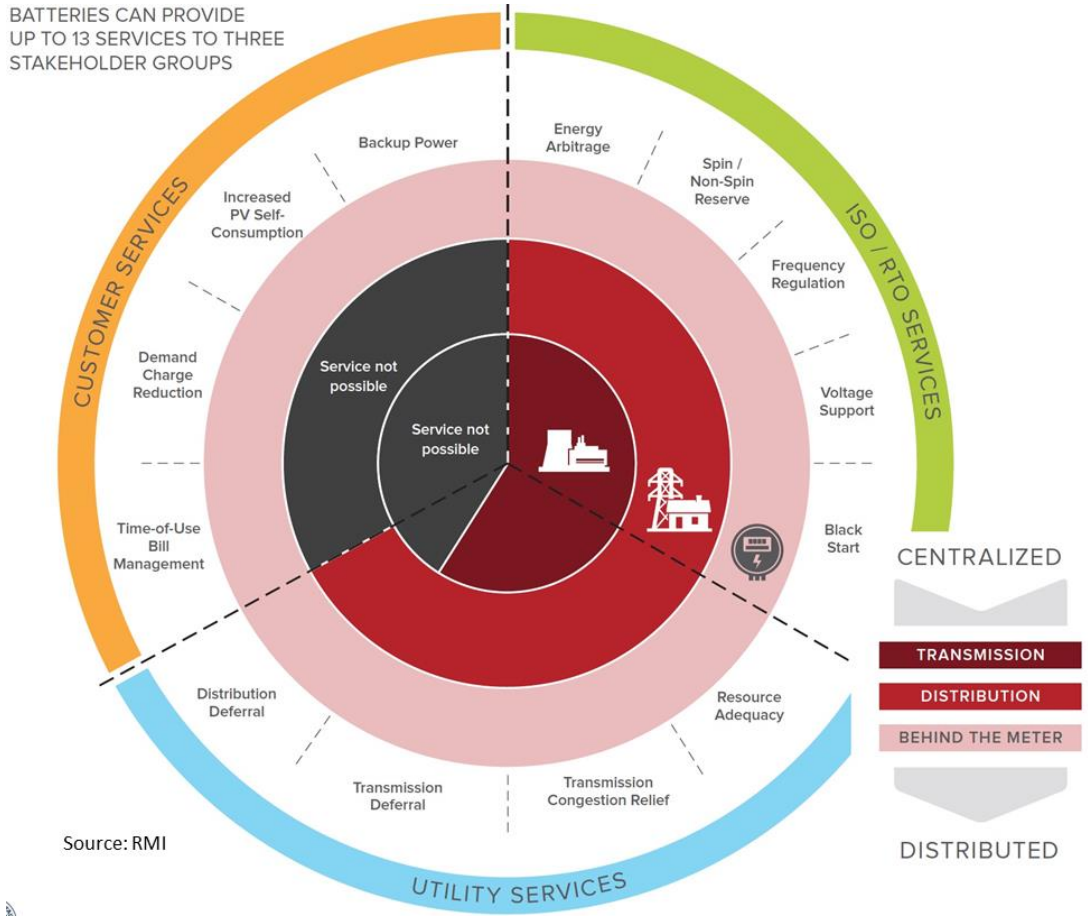
Partners:

NITI Aayog

Prayas (Energy Group)

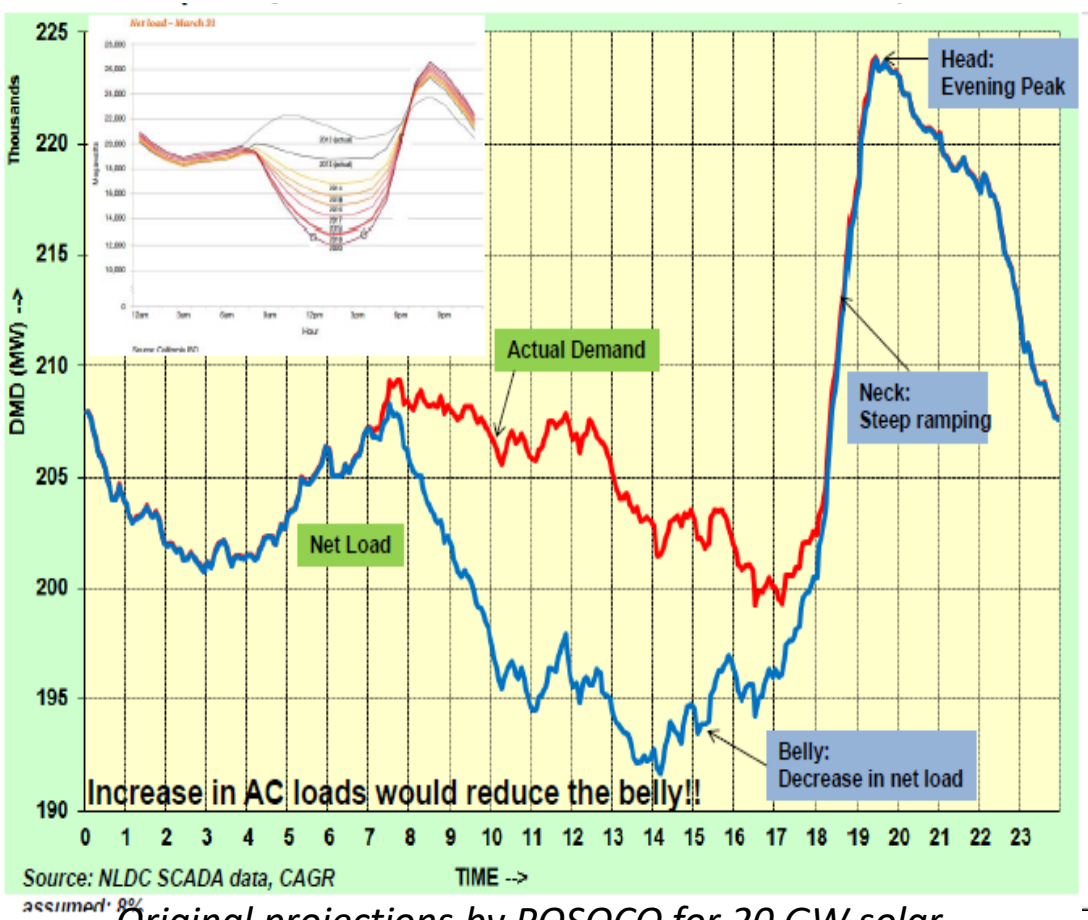
Role of Energy Storage in Modern Grid



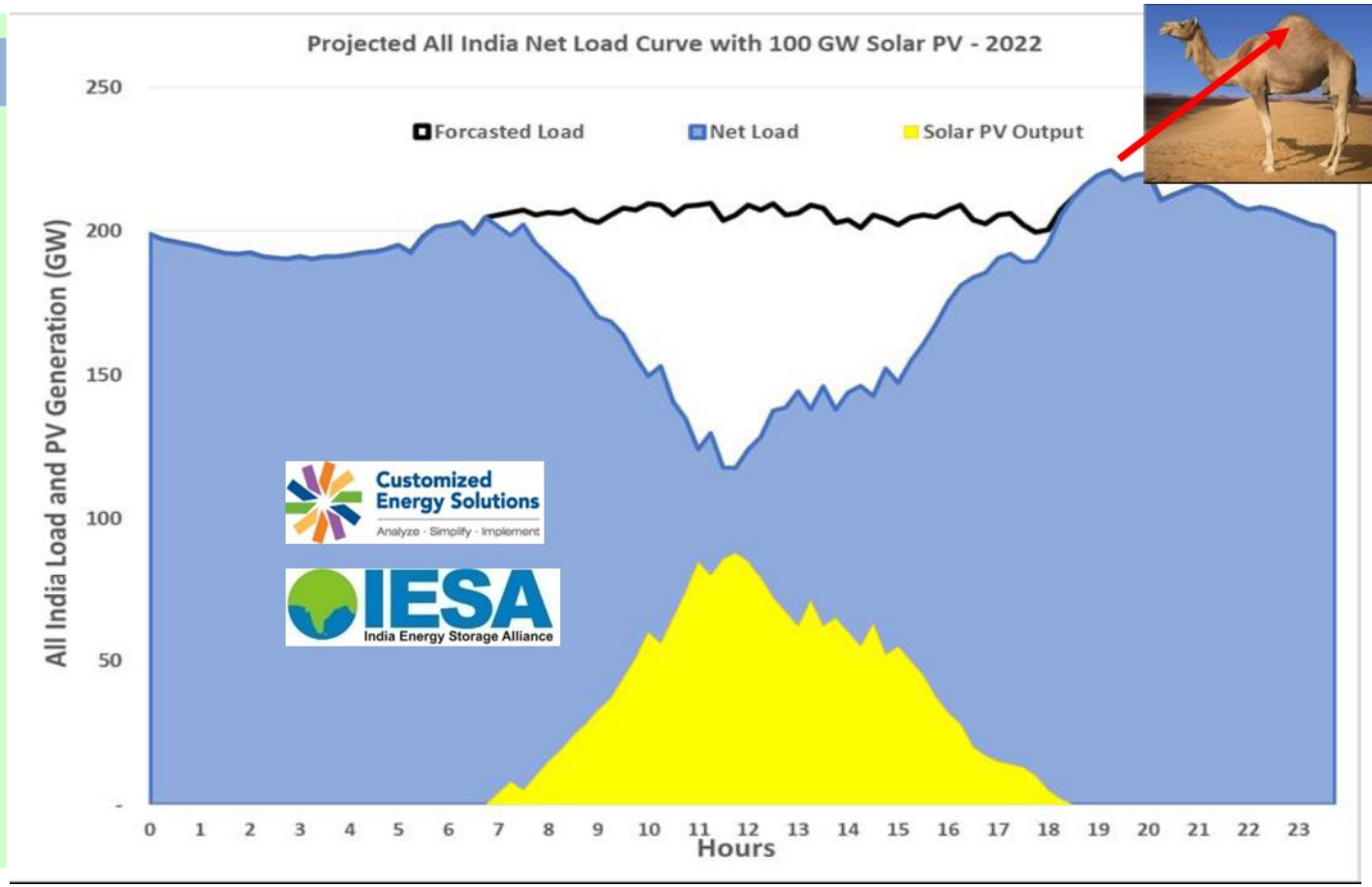


Energy storage can play a key enabling role in every aspect of modern grids including Generation, Transmission, Distribution and at Customer Premise (including electric vehicles).

Expected India Net Load Curve 2022 (with 100 GW of Solar Generation)

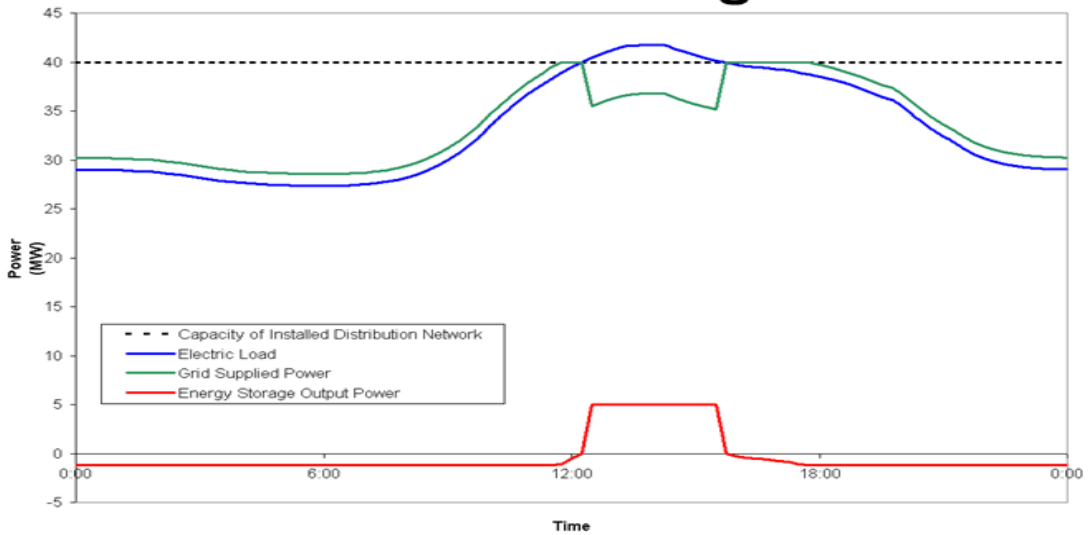


Original projections by POSOCO for 20 GW solar target

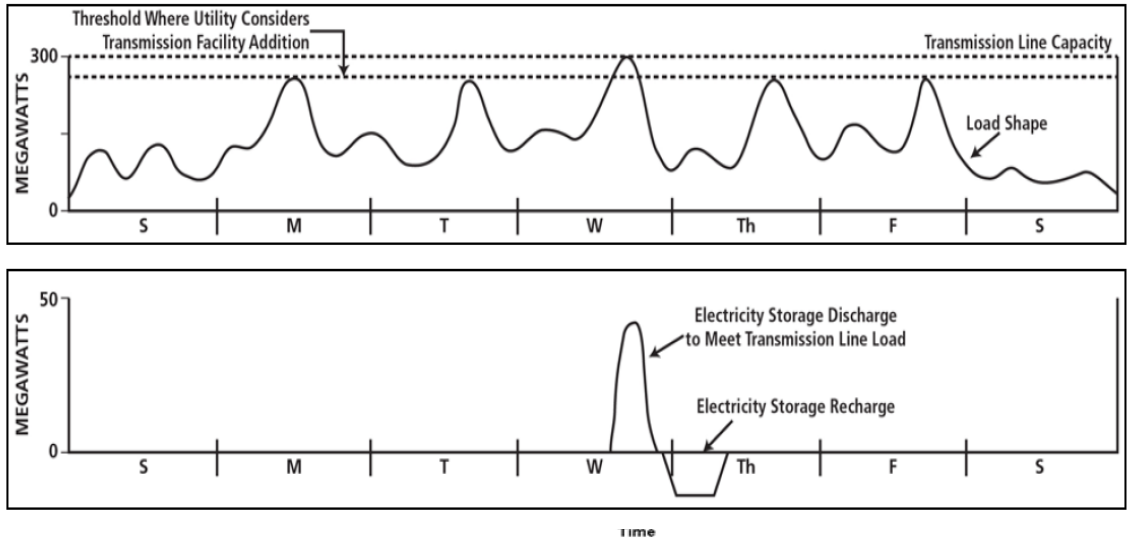


Storage Stationary Applications

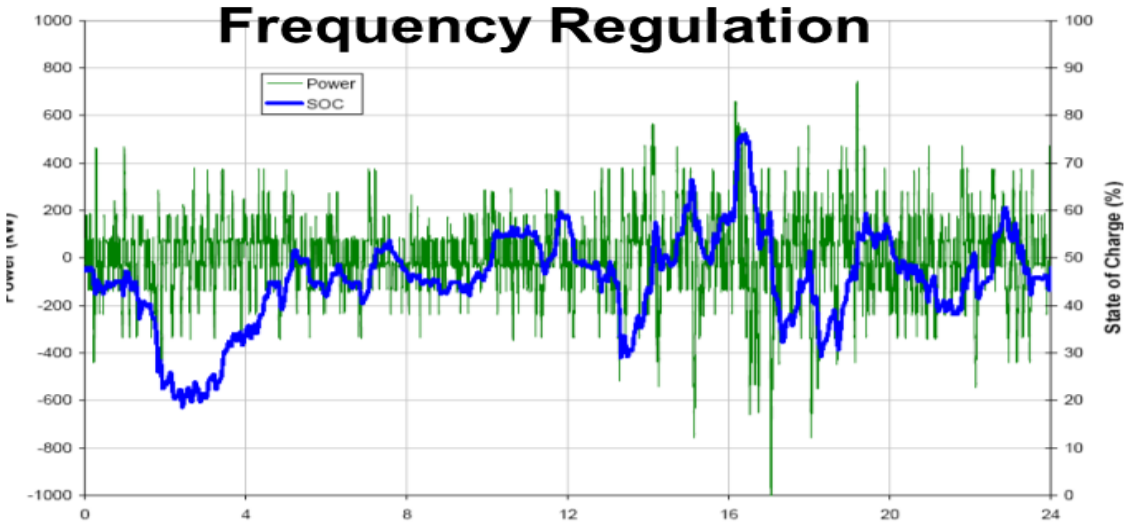
Peak Shaving



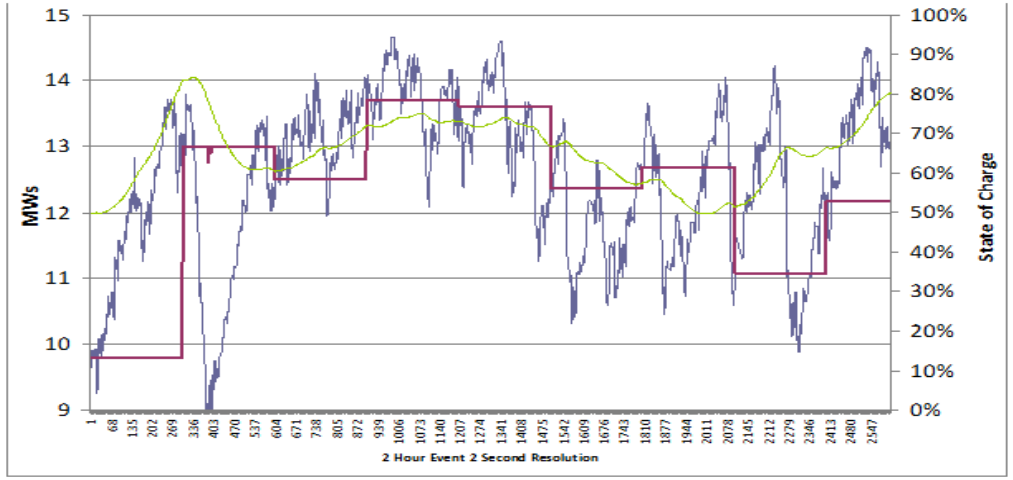
Load Levelling



Frequency Regulation

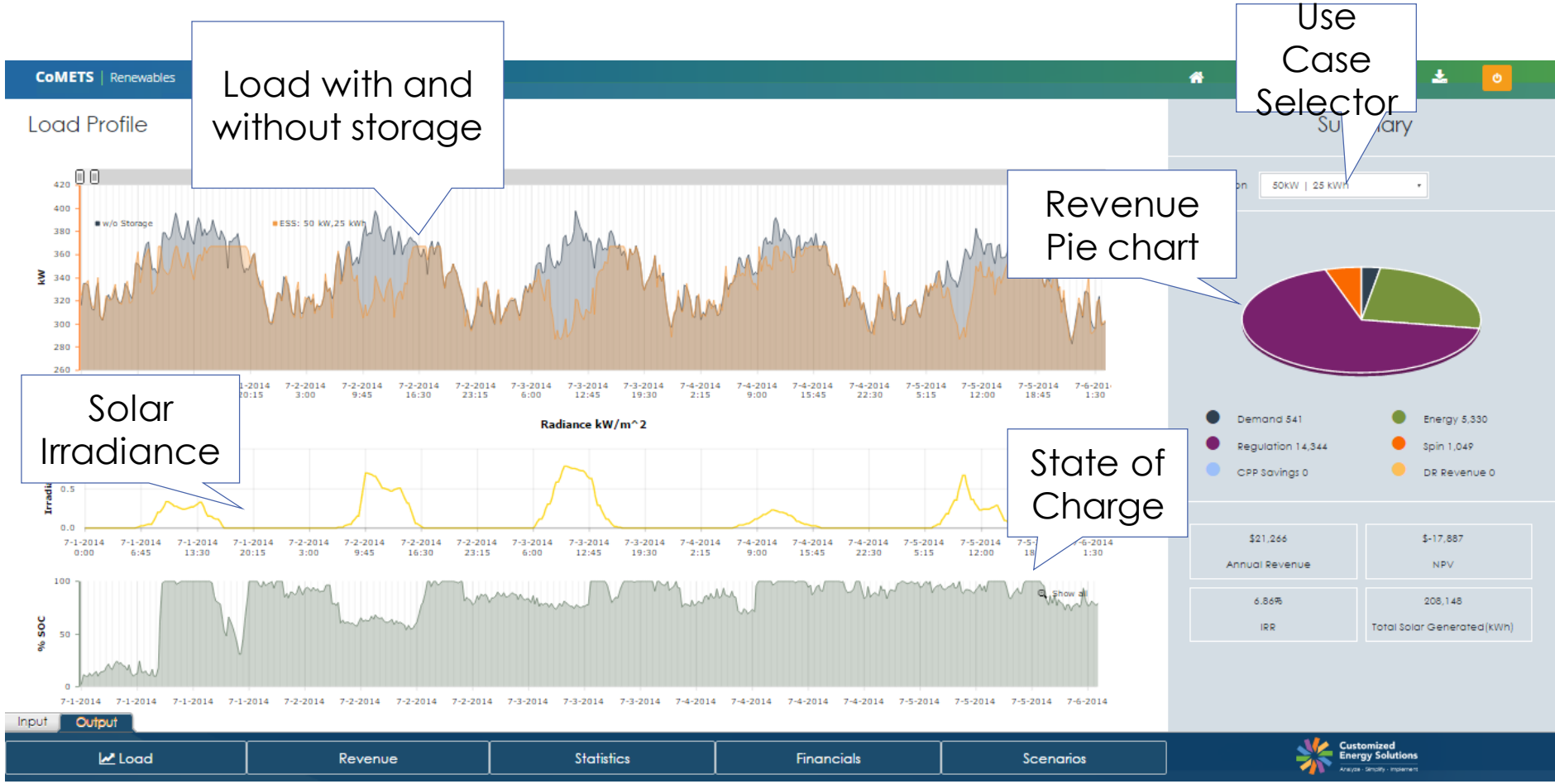


Wind Firming



Solar + Storage is Perfect Opportunity

- AES signed a PPA for solar + Storage in Hawaii for ~ 8 Rs/kWh in Jan 2017
- NextEra has now signed a PPA for lower than 3 Rs/kWH for similar project in Arizona in June 2017.
- Recent SECI tender saw prices of less than 5 Rs / kWH for RE+ storage firm power for 1st project of the kind.
- With scaling up of such projects, and domestic capability building, IESA expects RE+ storage to be lower than 4 Rs/ kWh



Source* COMETS: Comprehensive Market Evaluation Tools for Storage by CES

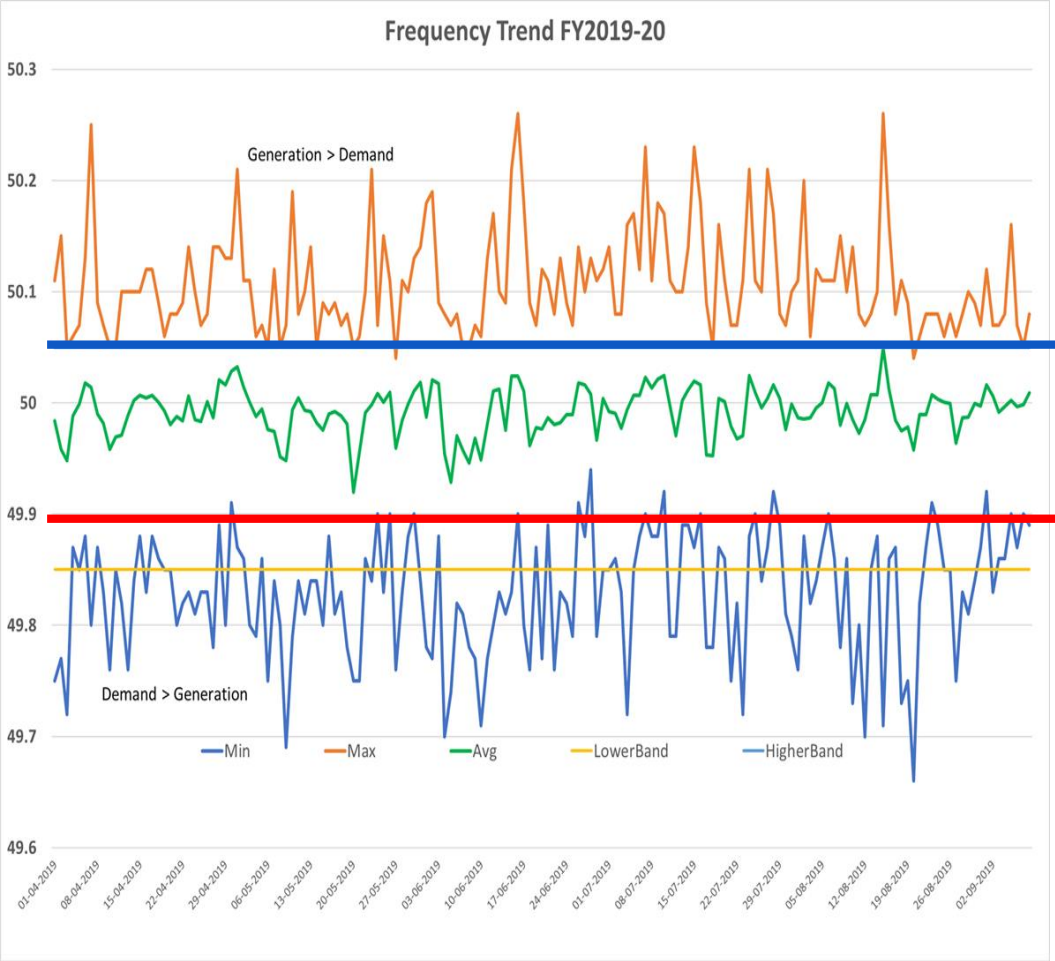
Evolution of Frequency Grid Band & MERC DSM charges

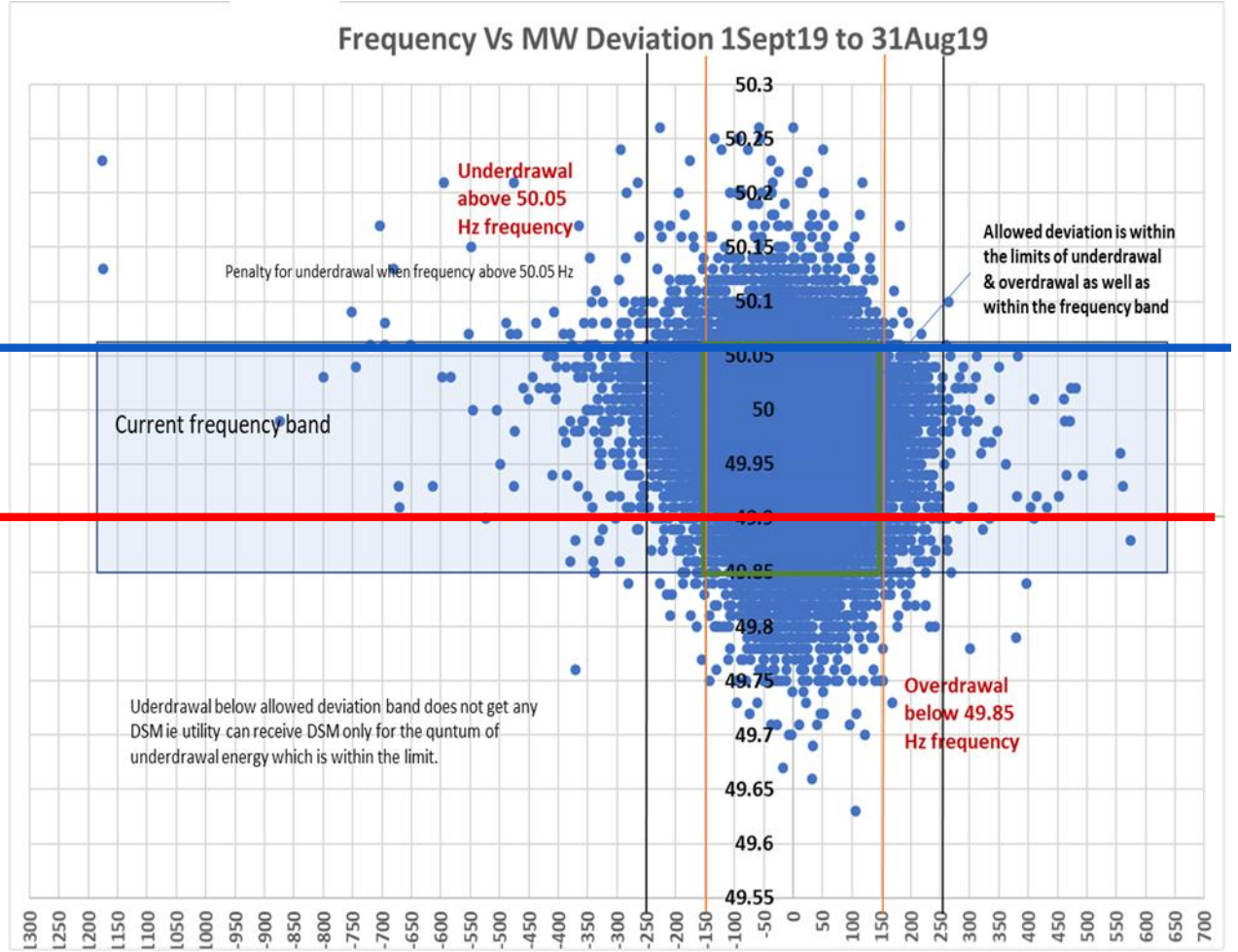
Period	Operational Frequency Band	Ceiling Rate (paise/kWh)	Benchmarking of Ceiling Rate	Slope (paise/kWh)	Step size
1st July 2002 – 31st March 2004	49.0 Hz – 50.5 Hz	420	DG set	5.6	0.02 Hz
1st April 2004 – 30th Sept 2004	49.0 Hz – 50.5 Hz	600	DG set	8	
1st October 2004 – 29th April 2007	49.0 Hz – 50.5 Hz	570	DG set	9	
30th April 2007- 6th Jan 2008	49.0 Hz – 50.5 Hz	745	Domestic Naphtha (Liquid Fuel)	6 (50.5-49.8)	
				9 (49.8-49.5)	
				16 (49.5-49.0)	
7th Jan 2008 – 31st March 2009	49.0 Hz – 50.5 Hz	1000	Combined cycle plants -Naphtha/RLNG	8 (50.5-49.8)	
				18 (49.8-49.0)	
1st April 2009 – 2nd May 2010	49.2 Hz – 50.3 Hz	735	RLNG based generating station with variation in fuel prices of around 5%	12 (50.3-49.8)	
				17 (49.8-49.2)	
3rd May 2010 to 16th Sep 2012	49.5 Hz – 50.2 Hz	873	Gas/liquid fuel based thermal generating stations of NTPC & NEEPCO	15.5(50.2-49.7)	
				47 (49.7-49.5)	
17th Sep 2012 to 16th Feb 2014	49.7 Hz – 50.2 Hz	900	Highest cost of generation is 896.02 Paise/kWh @Auraiya CCGT Station	16.5 (50.2-50.0)	
				28.5 (50.0-49.8)	
				28.12 (49.8-49.5)	
17th Feb 2014 onwards	49.90 Hz - 50.05 Hz	824	Highest cost of generation is 8.24 Rs/kWh @ Auraiya Gas Power Station	20.84 (49.70 - 50.00)	0.01 Hz
				35.60 (50.01 - 50.05)	

Particulars	Volume Limit		Applicable DSM, Additional Charge for DSM for Buyer		
	% of schedule	MW	<49.85 Hz	>=49.85 Hz to <50.05Hz	>= 50.05 Hz
Over-drawal (by Buyer)	<=12%	<=X	No Over-drawal permitted	DSM Charges Payable by Buyer	Zero DSM Charges payable
	>12% to <=15%	>X to <=X+10	Additional DSM shall be specified by the Commission considering behaviour of Buyers	DSM +20% of DSM payable by Buyer	
	>15% to<= 20%	>X+10 to <= X+20		DSM +20% of DSM+40% DSM payable by Buyer	
	>20%	>X+20		DSM +20% of DSM+40% DSM+100% DSM payable by Buyer	

Particulars	Volume Limit		Applicable DSM, Additional Charge for DSM for Buyer		
	% of schedule	MW	<49.85 Hz	>=49.85 Hz to <50.05Hz	>= 50.05 Hz
Under-drawal (by Buyer)	<=12%	<=X	DSM Charges receivable to Buyer	DSM Charges receivable to Buyer	No Under-drawal permitted
	>12% to <=15%	>X to <=X+10	Applicable DSM charges Zero for electricity above X	Zero DSM Charges applicable for electricity above X	Zero DSM Charges + ADSM at ACP (P) payable by Buyer
	>15% to<= 20%	>X+10 to <= X+20			
	>20%	>X+20			

Grid Frequency Pattern and need for DSM & Ancillary Services





Balancing Variable Renewable Resources Technology choice: Environmental Impact

Conventional Grid

+

- Manage renewable variation by fossil generators varying output
  - Decreases efficiency
  - Increases fuel consumption
  - Requires more maintenance
  - Increases emissions

Smarter Solution: Storage

+

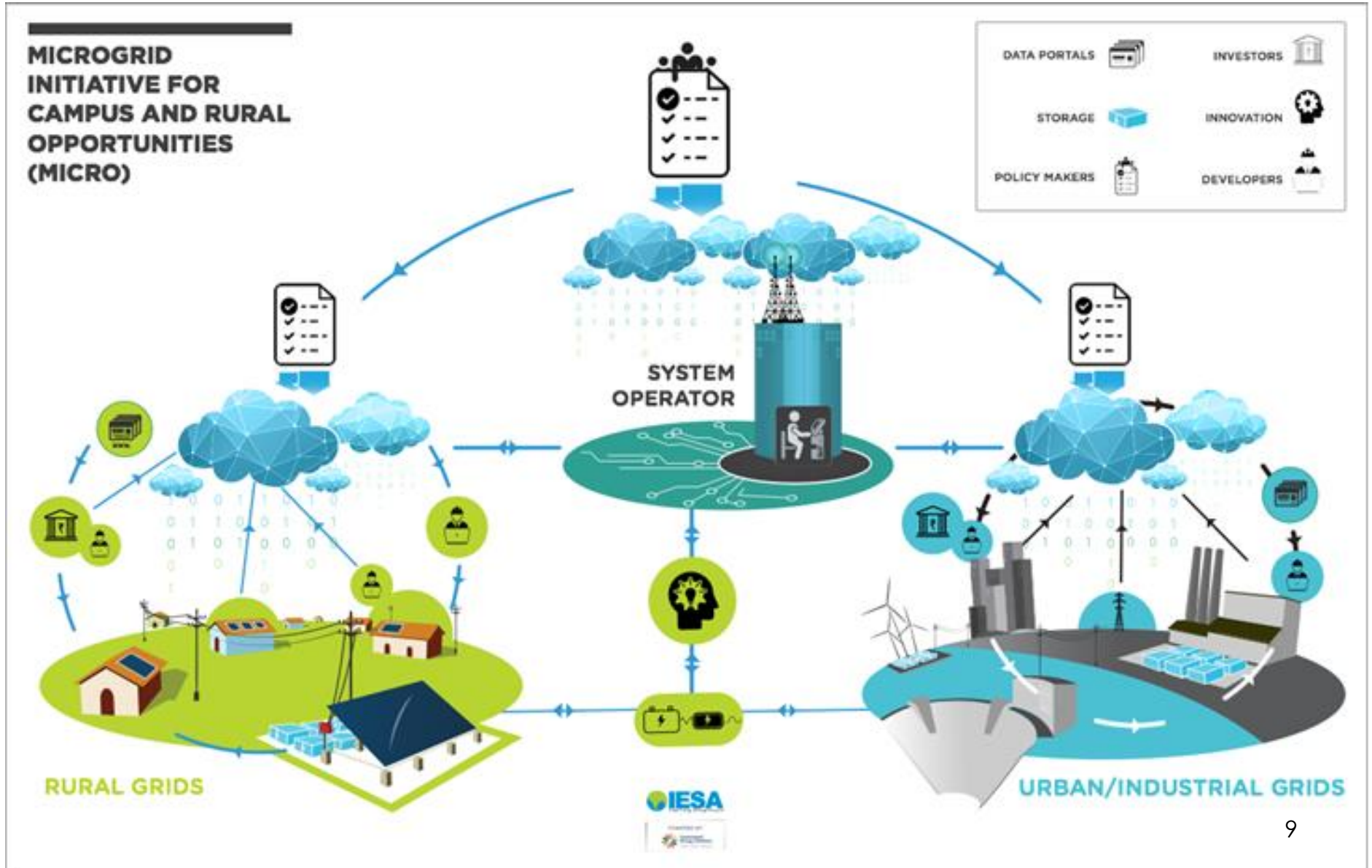
- Store energy when supply exceeds load; inject energy when load exceeds supply
  - High round trip efficiency
  - Low operating cost
  - Near instantaneous response
  - Zero direct emissions
  - Frees up generation capacity

8

20% of the CO2 emission reduction and up 100% of the NOX emission reduction expected from wind and solar power may be lost because of ramping fossil plants

* Katzenstein, W., and Jay Apt. Air Emissions Due To Wind And Solar Power. *Environmental Science & Technology*. 2009, 253-258.

Campus Microgrids could drive growth of Distributed RE + Storage in Maharashtra



Typical ESS System Configuration for Identified Applications

Segments / Applications	Sub Segments	Power Rating	Duration	DOD	Type of cycles	No of cycles / Year
Renewable Energy Integration	Wind Smoothening	10 MW- 200 MW	15 min - 1 h	<60%	Shallow	<18,000
	Wind Firming	10 MW-200 MW	4-6 h	>80%	Deep	<500
	Solar	10 MW-200 MW	3-6 h	>80%	Deep	<350
Load shifting or energy arbitrage	Commercial	10 KW - 20 MW	2-4 h	>80%	Mix	<400
	Industrial	500 KW - 50 MW	2-4 h	>80%	Mix	<400
Off grid applications	Rural Microgrid	1KW - 100 kW	2-8 h	>80%	Mix	<400
	Rural Schools / Hospitals	5 KW - 50 kW	2-8 h	>80%	Mix	<400
	Telecom Towers	2 KW - 5 kW	2-4 h	>80%	Mix	<700
Replacement of DG	Commercial	10 KW - 10 MW	2-4 h	>80%	Mix	<400
	Industrial	500 KW - 50 MW	2-4 h	>80%	Mix	<400
Transmission or Distribution Deferral		10-100 MW	4-8 h	>80%	Mix	<100
Ancillary Services	Frequency Regulation / Spinning / Ramp control	10 MW- 200 MW	15 min – 1 h	<60%	Shallow	<18,000
Reactive Power Management	Utility / C&I	3 KW - 10 MW	15 min – 1 h	N.A.	N.A.	N.A.

Energy Storage: Diverse Asset Class

Electro-Chemical

(Lead Acid / Lithium Ion / Flow batteries / Sodium / Metal Air batteries)

Mechanical

(Flywheel)

Bulk Mechanical

(Compressed Air)

Gravitational

(Pumped Hydro)

Thermal

(Ice / Molten Salt)

Chemical

(Hydrogen / Fuel Cells)

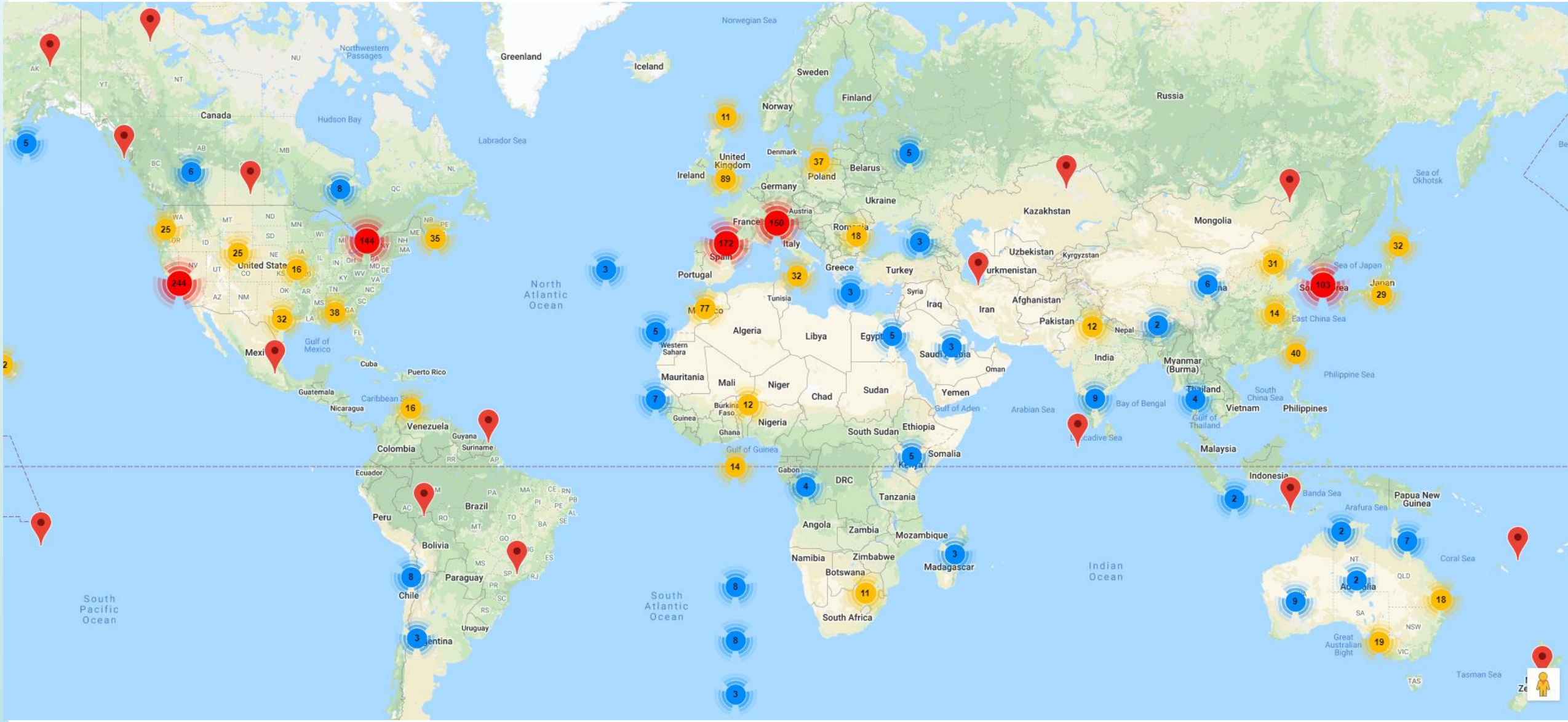
Electrical

Ultra Capacitors

Power Electronics

Bidirectional inverters / Charging Infrastructure

Global Adoption of Energy Storage

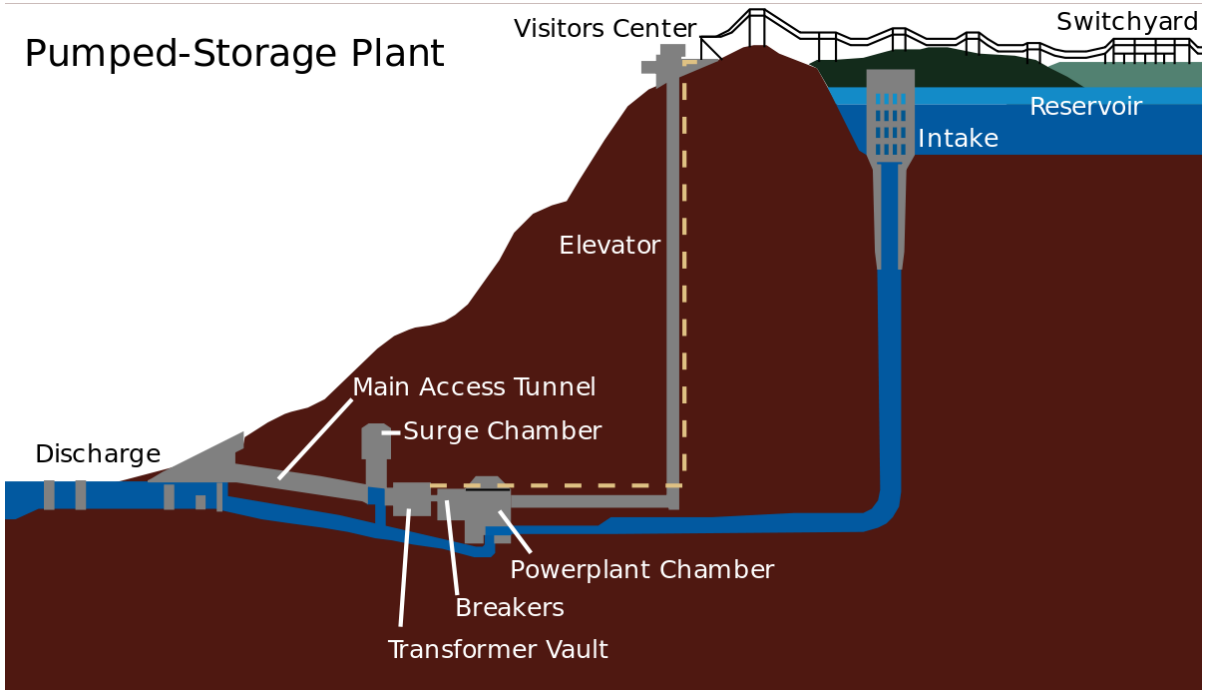


Source: DOE Energy Storage Database (Feb 2020)

Advanced Electrochemical Batteries such as Li-Ion are driving the growth of new ESS projects around the Globe

Tesla promised and delivered 100 MW – 129 MWh Energy Storage Project in South Australia in 100 Days from signing of Grid Interconnection Agreement in 2018.

Pumped Hydro



Name of the PHS Plants in Maharashtra	Units	Capacity	Year of Commission	Remarks
Ujjaini	1x12	12	1990	Operational
Bhira	1 x 150	150	1995	Operational
Ghatgar	2 x 125	250	2008	Operational
Paithon	1x12	12	1984	Operational
Koyna Left Bank	2x40	80	2022-23	Likely commissioning

Advantages

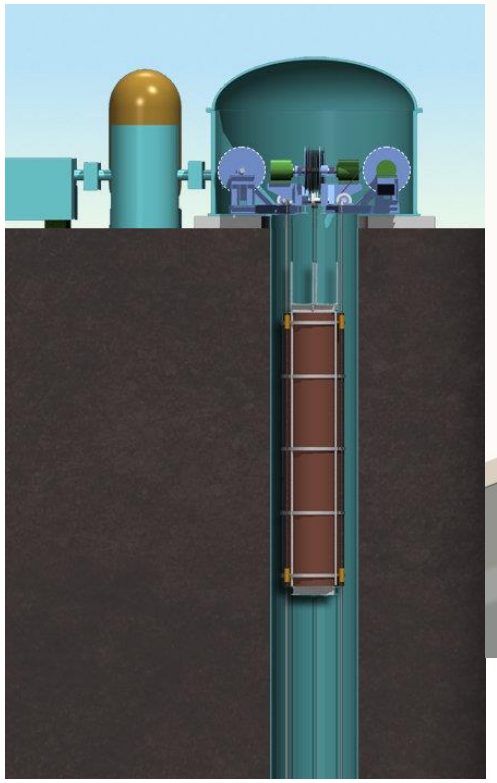
- Largest form of energy storage deployed around the globe
- Proven technology
- Advances in Variable Speed Drives make the facilities more flexible

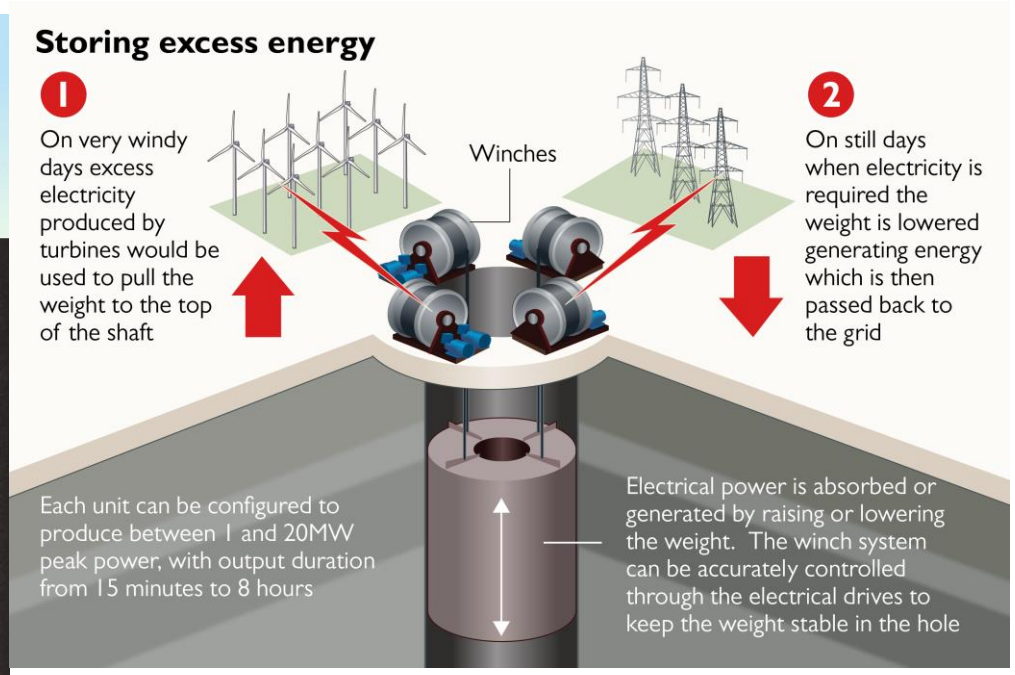
Challenges

- Geographical limitations
- Environmental approvals
- Overall cost
- Seasonal variability & agricultural policy linkage
- Due to climate change and anticipated rise in summer temperatures, evaporation loss could be significant

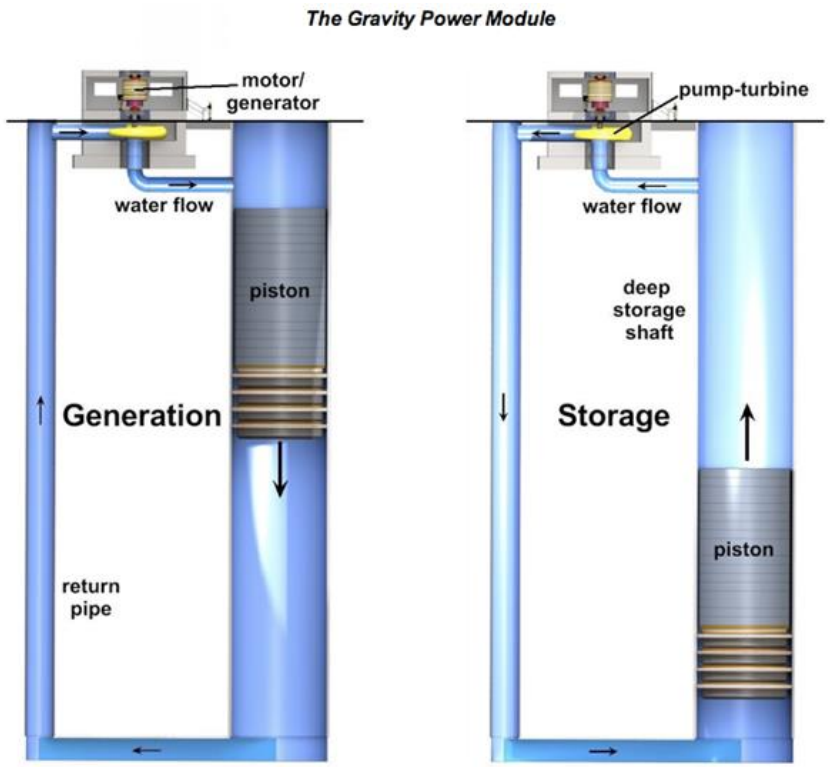
New approaches for Pumped Hydro

Gravitricity





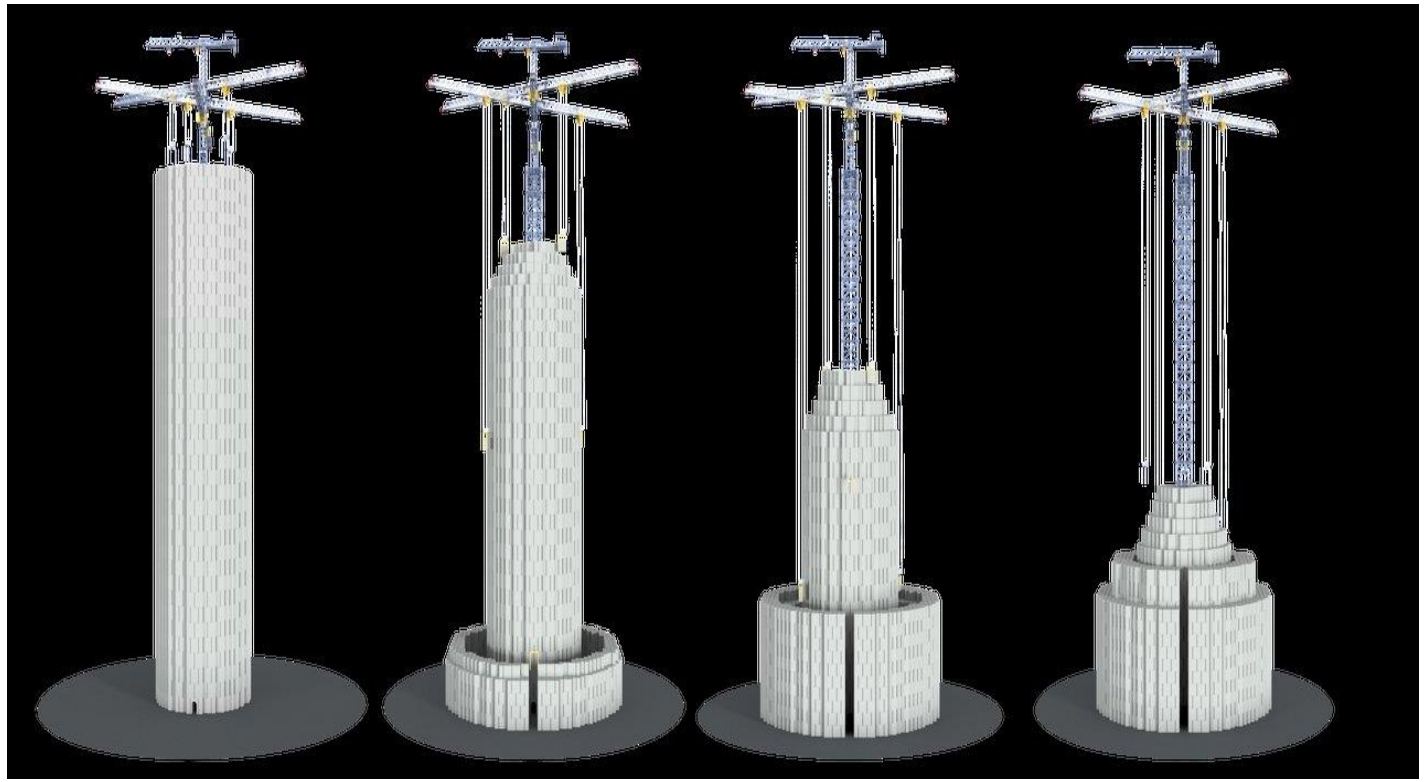
Gravity Power



Gravity Storage 2.0: Energy Vault

Energy Vault has created a new storage system in which a six-arm crane sits atop a 33-storey tower, raising and lowering concrete blocks and storing energy in a similar method to pumped hydropower stations.

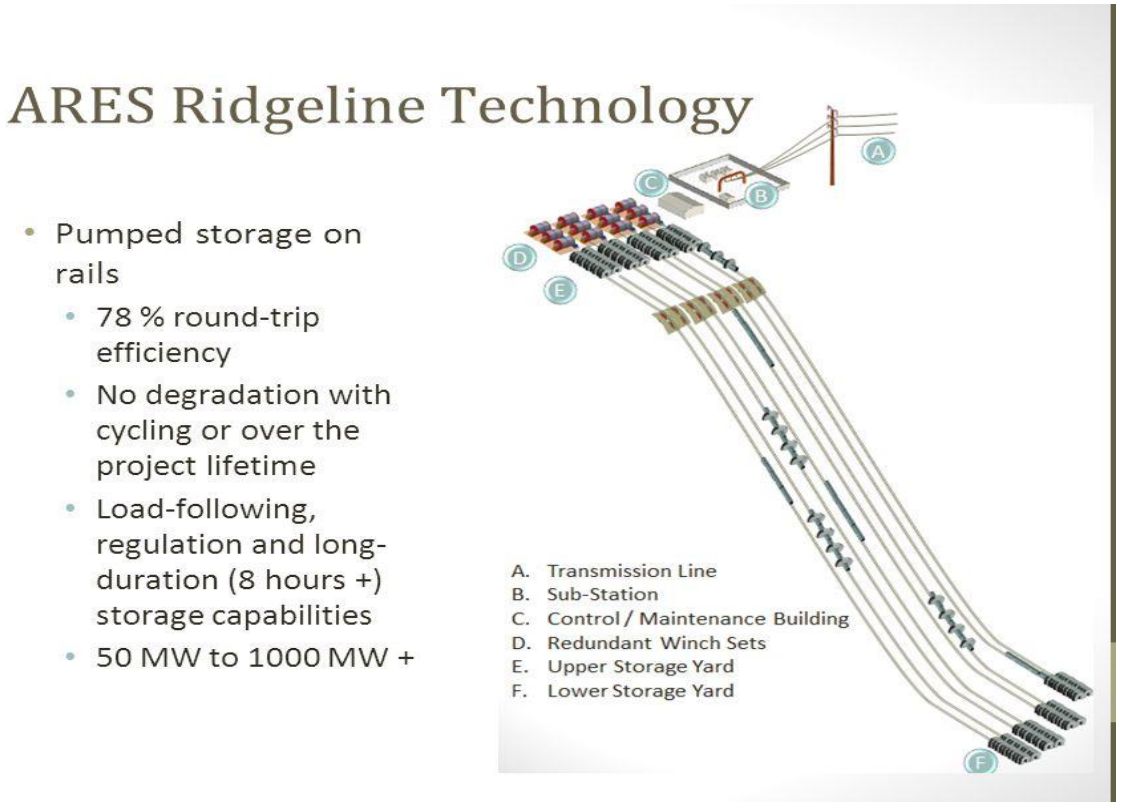
Modular design for RE Integration



Conceptual design of how Energy Vault Works

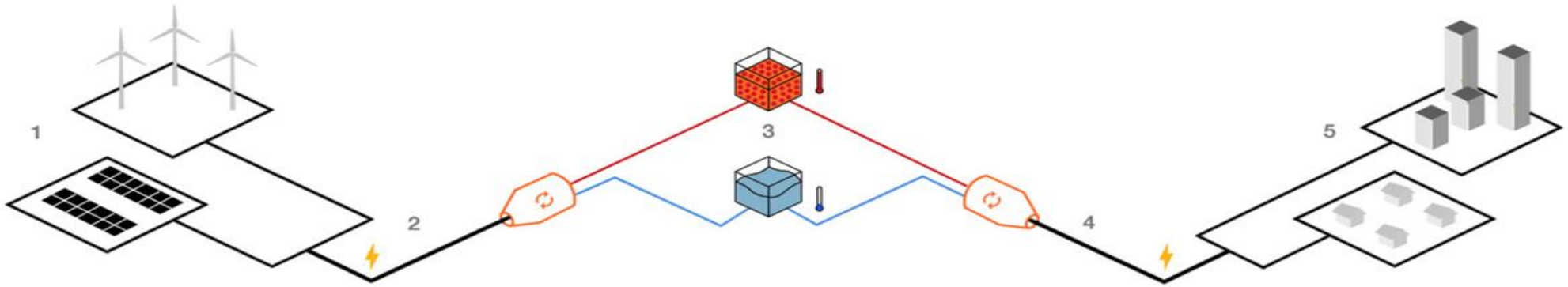
ARES – Advanced Rail Energy Storage

ARES is a Gravity based potential Energy Storage Technology which leverages the high efficiencies of rail transport



Malta: Electro-Thermal Energy Storage System

The Malta system is made up largely of conventional components and abundant raw materials – steel, air, salt, and commodity liquids. The technology capitalizes on existing manufacturing and construction ecosystems in the power and oil and gas industries.



1. Collects
Energy is gathered from wind, solar, or fossil generators on the grid as electrical energy and sent to Malta's energy storage system.

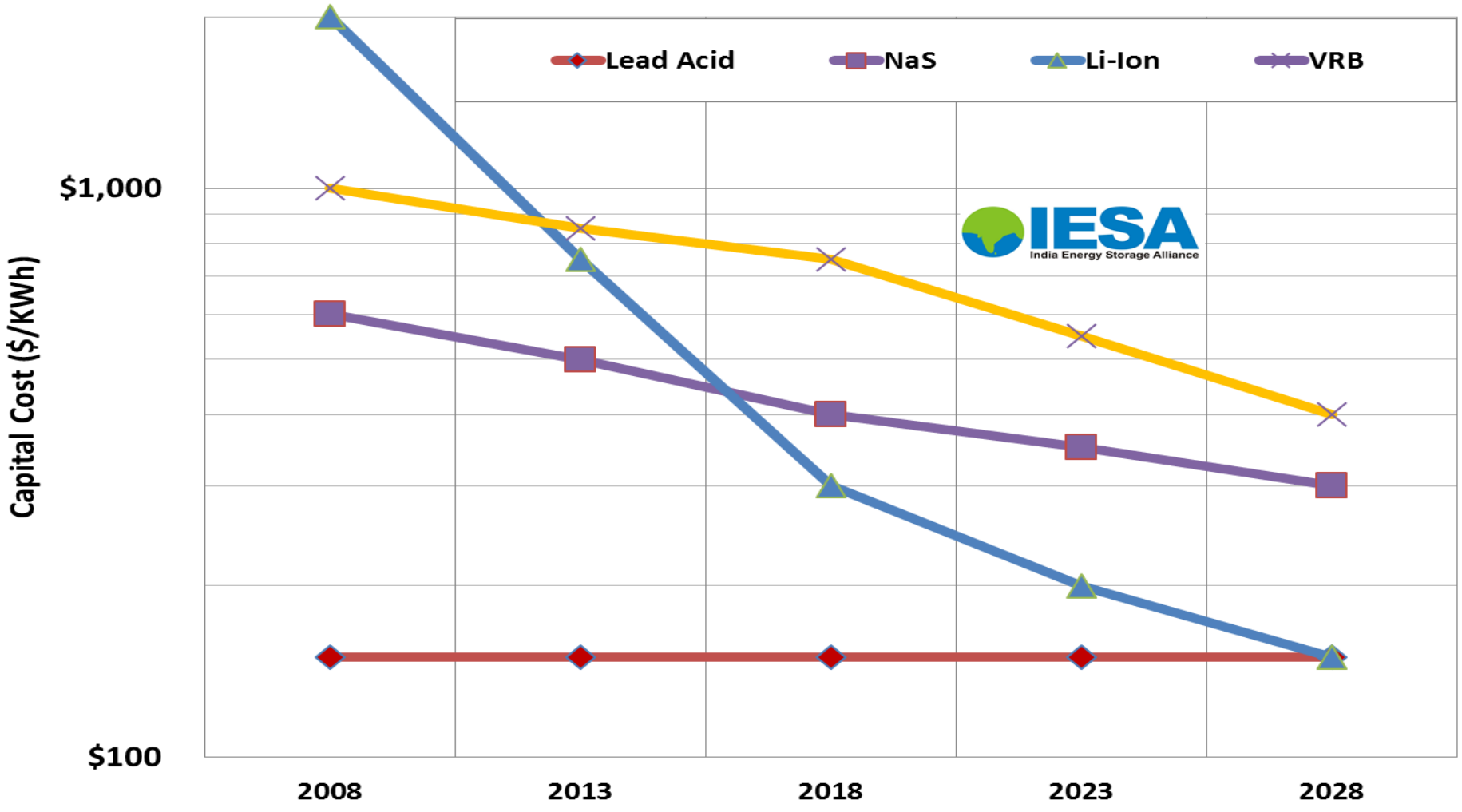
2. Converts
The electricity drives a heat pump, which converts electrical energy into thermal energy by creating a temperature difference.

3. Stores
The heat is then stored in molten salt, while the cold is stored in a chilled liquid.

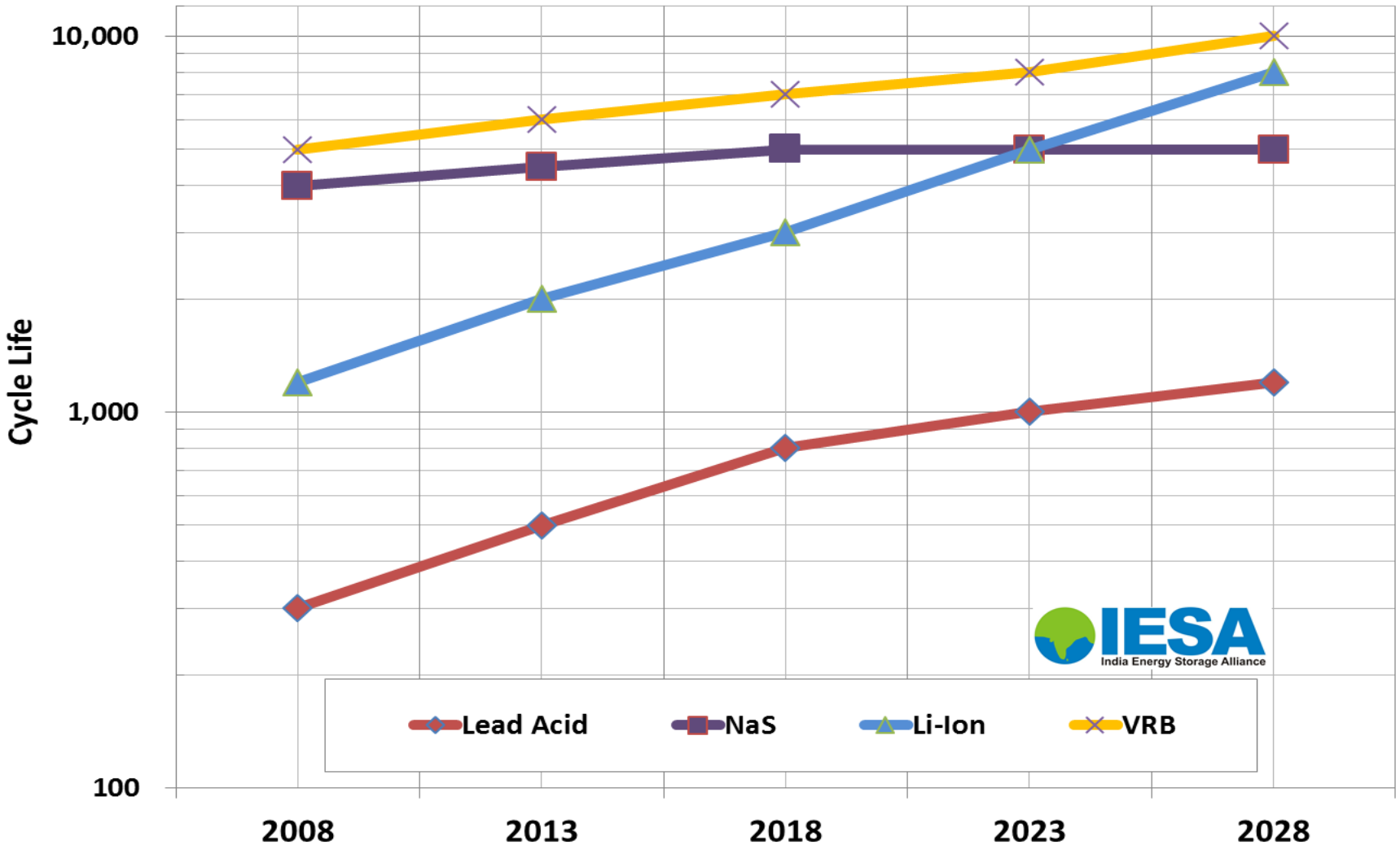
4. Reconverts
The temperature difference is converted back to electrical energy with a heat engine.

5. Distributes
Electricity is sent back to the grid when it is needed.

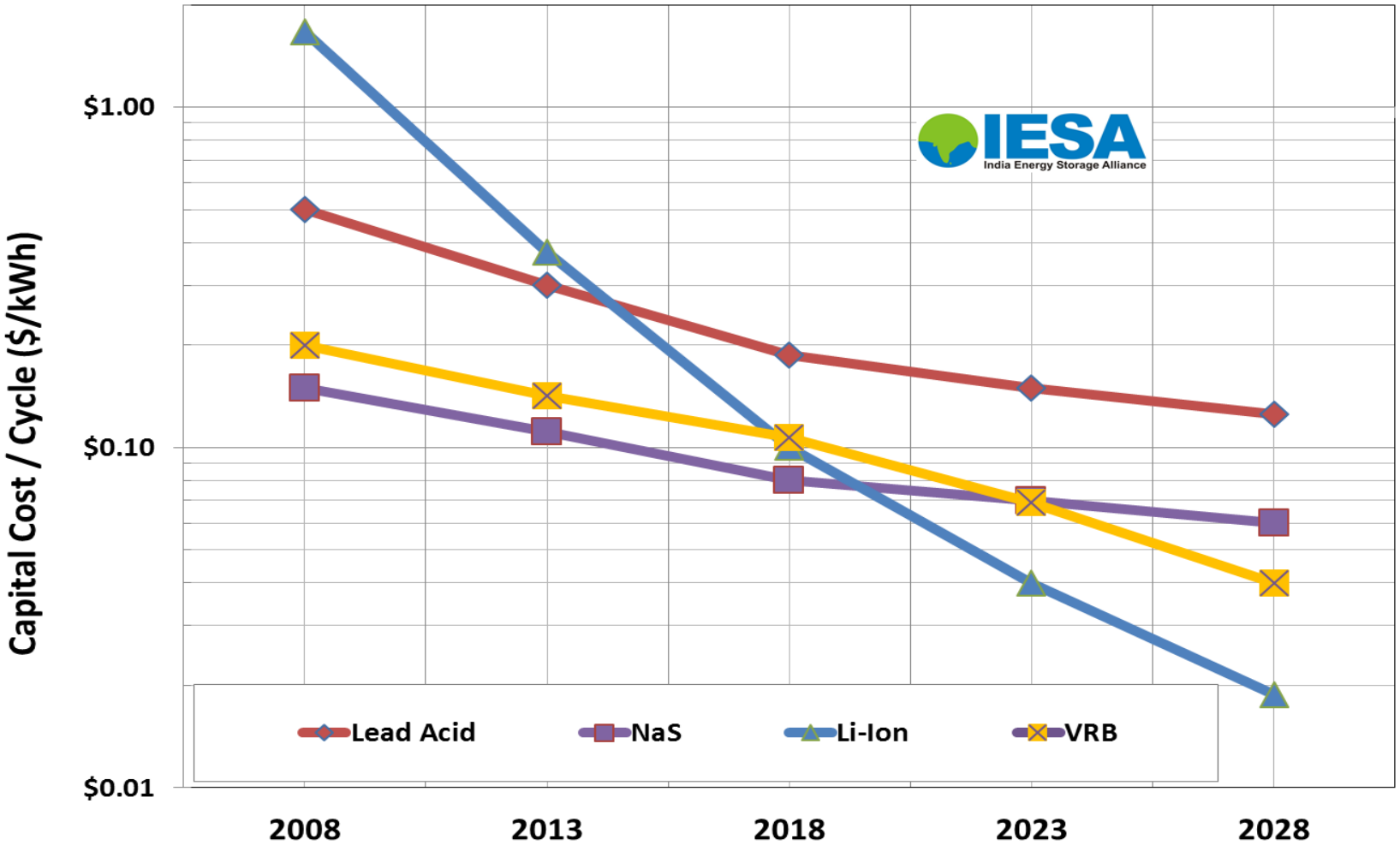
System Level Capital Cost Trends for ESS



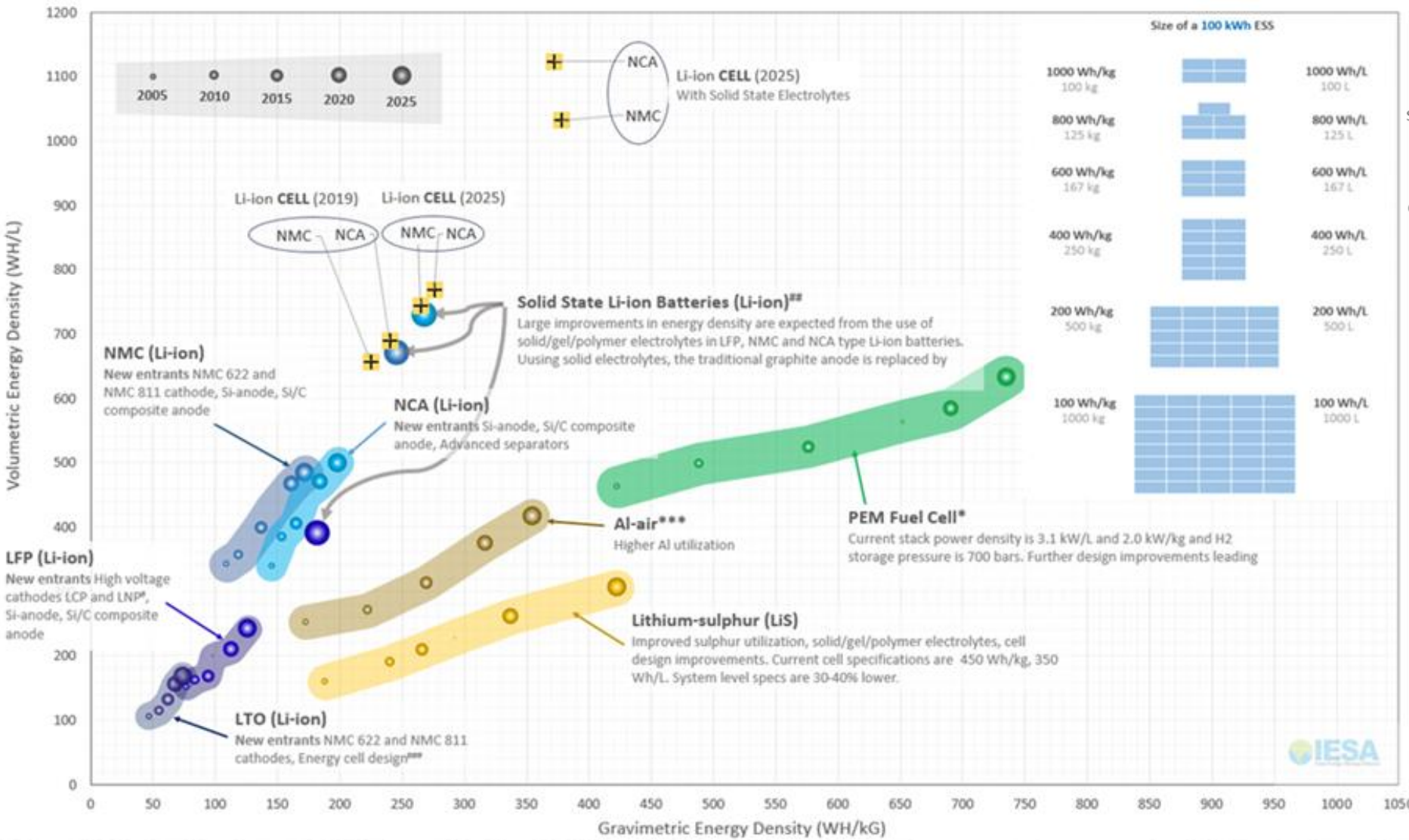
Cycle Life Trends for Batteries

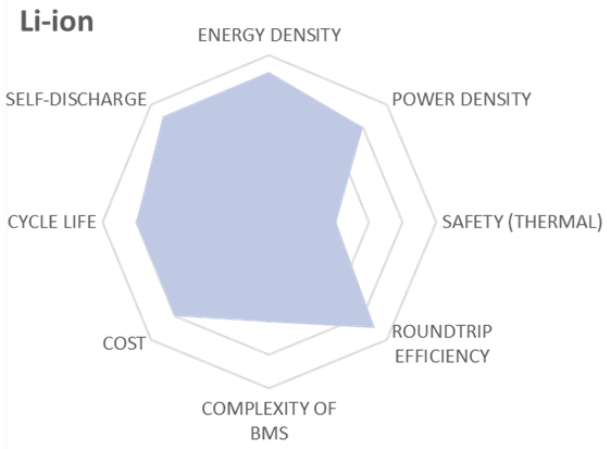


Levalized Cost of Energy Storage Trends



Cost reduction is not the only parameter driving growth of EVs





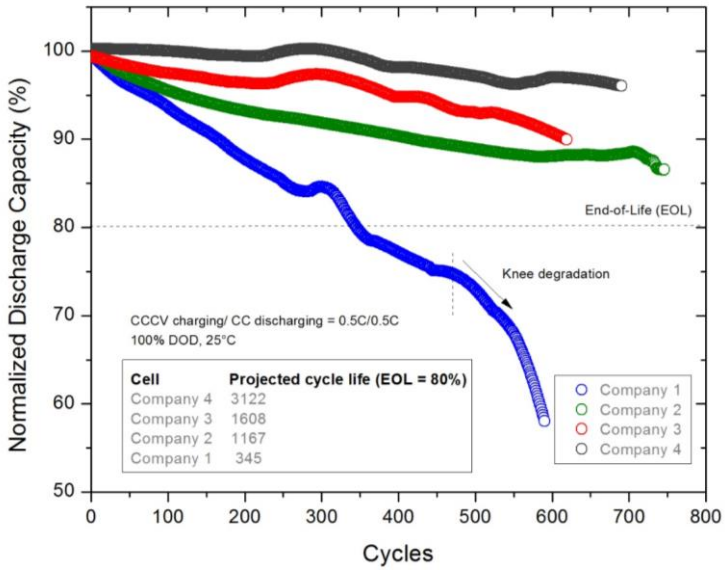
*PEM Fuel Cell system includes tank + stack + boost convertor. Values calculated for system designed for car with 500 km rangeand tanks storing 5 kg hydrogen at 700 bars. ** In Li-ion Batteries, the system level energy density is approximately 40% lower than cell level due to weight of BMS, thermalmanagement, electrical connectors and other components. # LCP = Lithium Cobalt Phosphate, LNP = Lithium Nickel Phosphate. ## Expected performance in 2025. ***Alair system includes weight/volume of stack, electrolyte storage tanks and pumps. No known commercial prototypes of Li-air battery. ### Thicker coatings and larger active material particles enhance energy density at the cost of power density.

This chart is prepared with available data and predictions as of 2019
Source: CES Internal Analysis

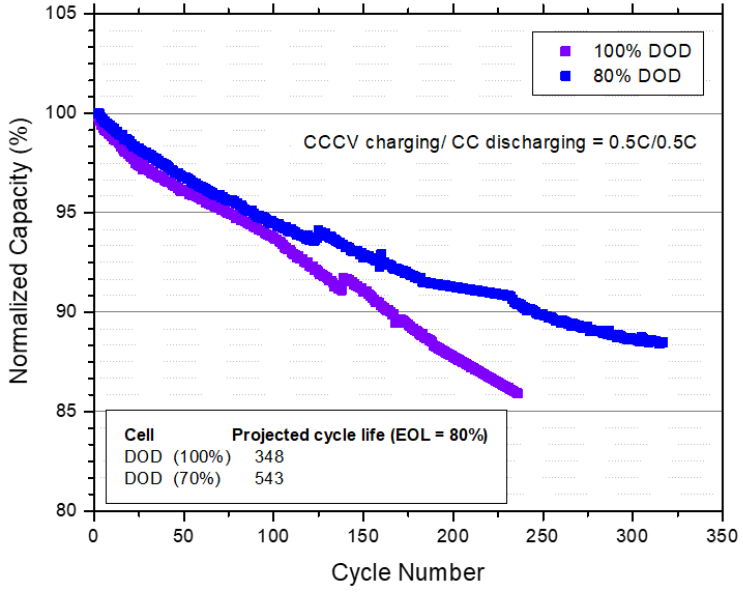
Understanding application requirements and conducting Performance Testing is essential for choosing right batteries for Grid Applications

Cycle Life validation for appropriate duty cycles and operating conditions including C-Rate & Temperature

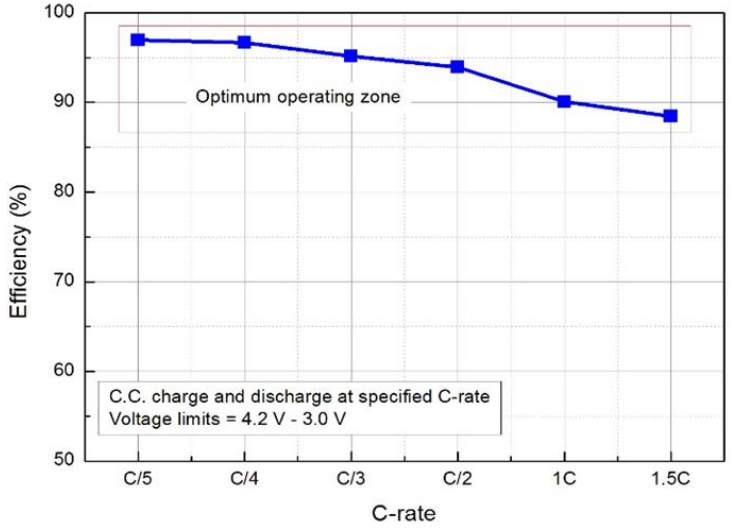
Cycle Life Validation

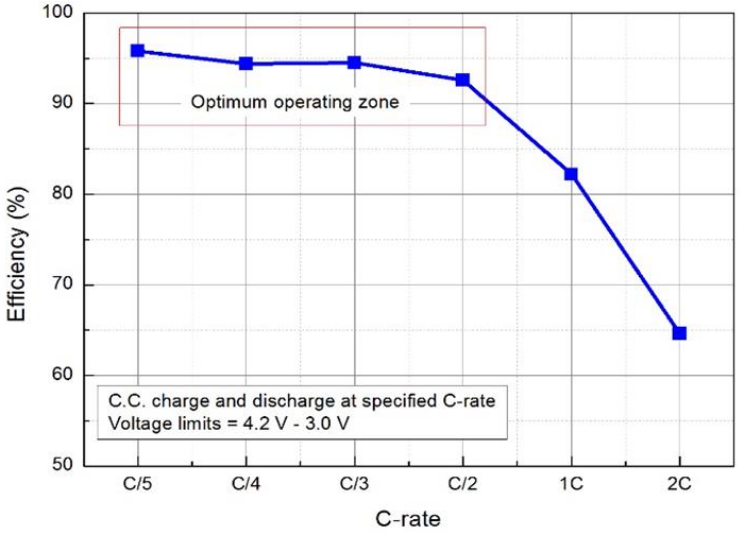


Impact of DOD



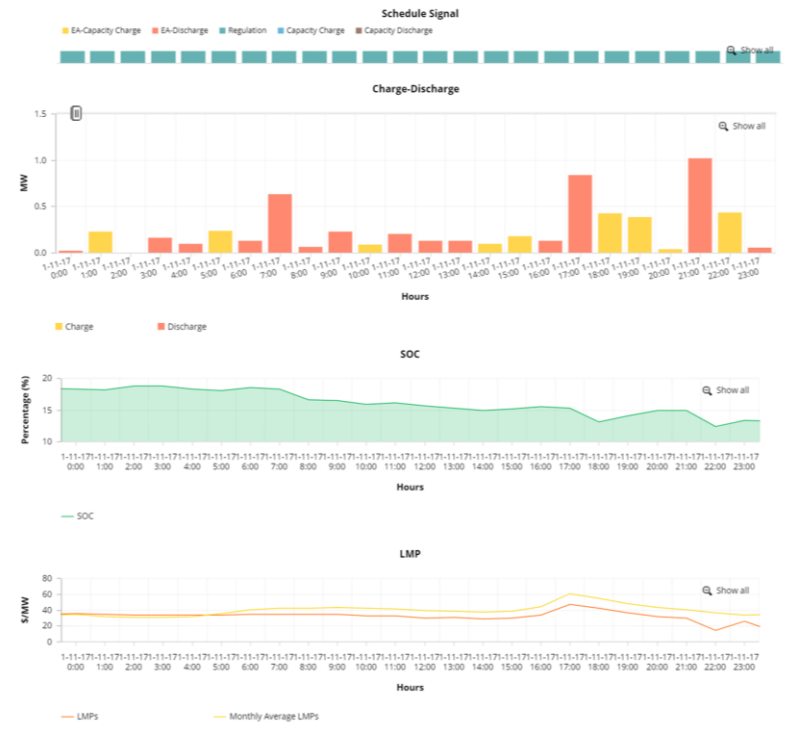
Impact of C-Rate on Round Trip Efficiency



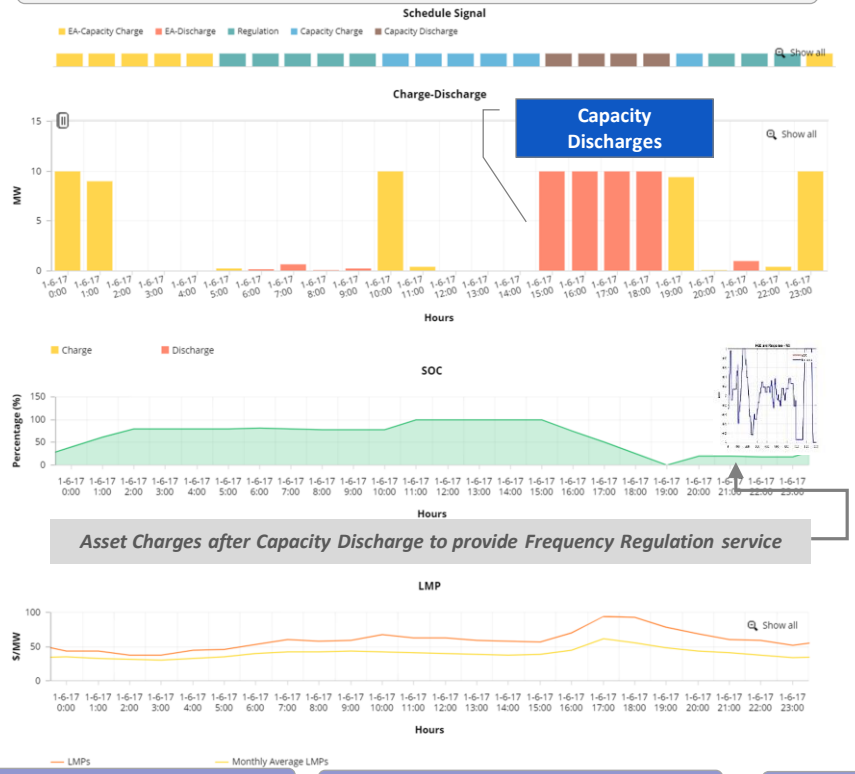


Case Study: Sample Dispatch

Ancillary Services – Frequency Regulation

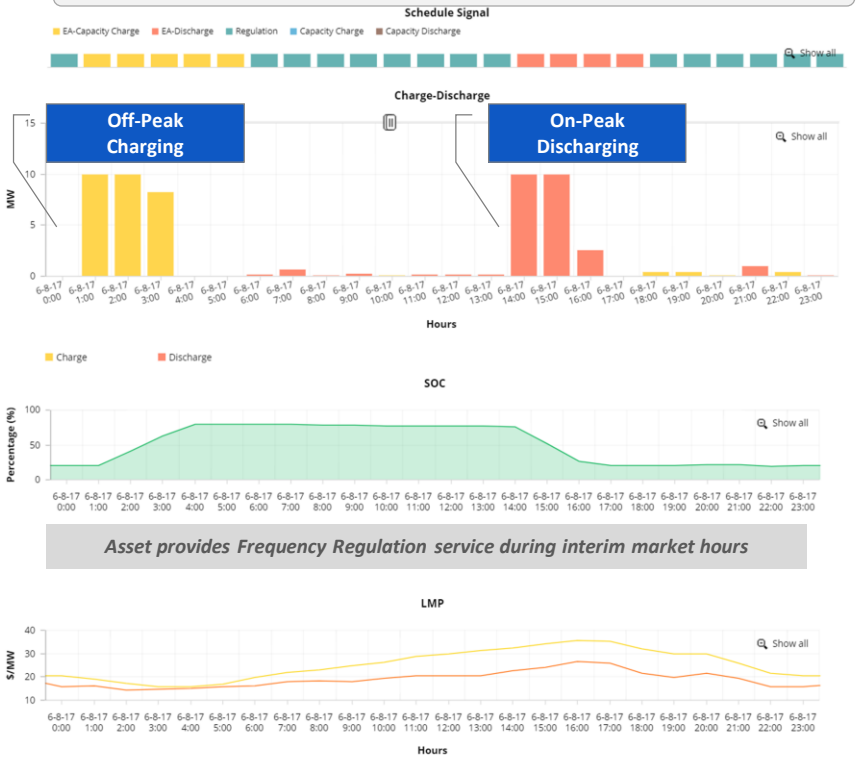


Capacity Discharges - To mitigate System Peak



Asset Charges after Capacity Discharge to provide Frequency Regulation service

Energy Arbitrage + Frequency Regulation



Asset provides Frequency Regulation service during interim market hours

Available Revenue Streams

- Capacity Savings
- Frequency Regulation
- Transmission Savings
- Energy Arbitrage

Source: COMETS: Comprehensive Market Evaluation Tools for Storage by CES

Utility Scale ESS projects in India-

Public and Private Sector Initiatives

*Source: PGCIL, Exicom

*Source: AES

THE EVOLVING POLICY FRAMEWORK FOR ADOPTION OF ENERGY STORAGE

2013:
MOP and CEA taskforce on Integration of Large Scale renewables in India

2014
Creation of MNRE Standing Committee on Energy Storage to develop Energy Storage Roadmap

Dec 2014
IESA releases report on the role of energy storage for providing ancillary services in India

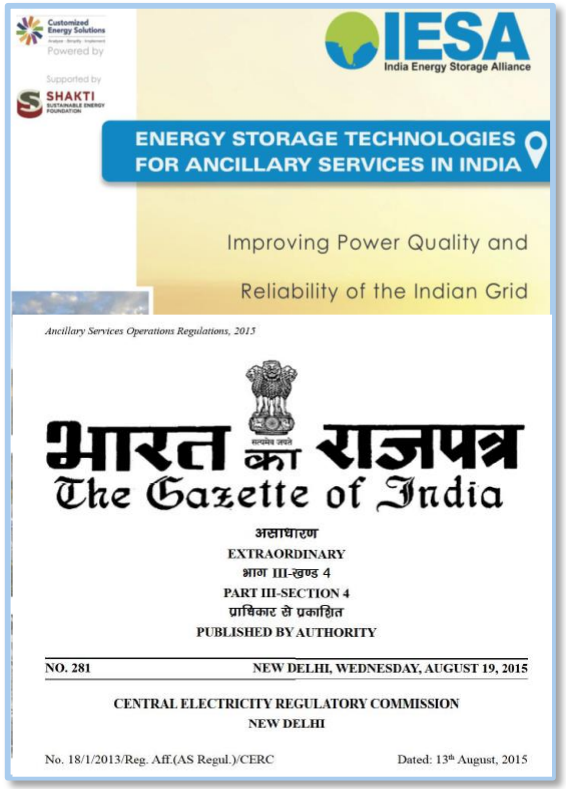
Oct 2015
CERC issues Ancillary Services Operations Regulation (August 2015) and Roadmap to operationalize Reserves in the country

Jan 2017
CERC Staff Paper on ESS

May 2018
MNRE National Wind Solar Hybrid Policy

Jan 2019
CERC & CEA Regulations inclusion of Storage

Mar 2019
National Energy Storage Mission and National Mission for Transformative Mobility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ENERGY STORAGE TECHNOLOGIES FOR ANCILLARY SERVICES IN INDIA

Improving Power Quality and Reliability of the Indian Grid

Ancillary Services Operations Regulations, 2015

भारत का राजपत्र
The Gazette of India

असाधारण
EXTRAORDINARY
भाग III-खण्ड 4
PART III-SECTION 4
प्राधिकार से प्रकाशित
PUBLISHED BY AUTHORITY

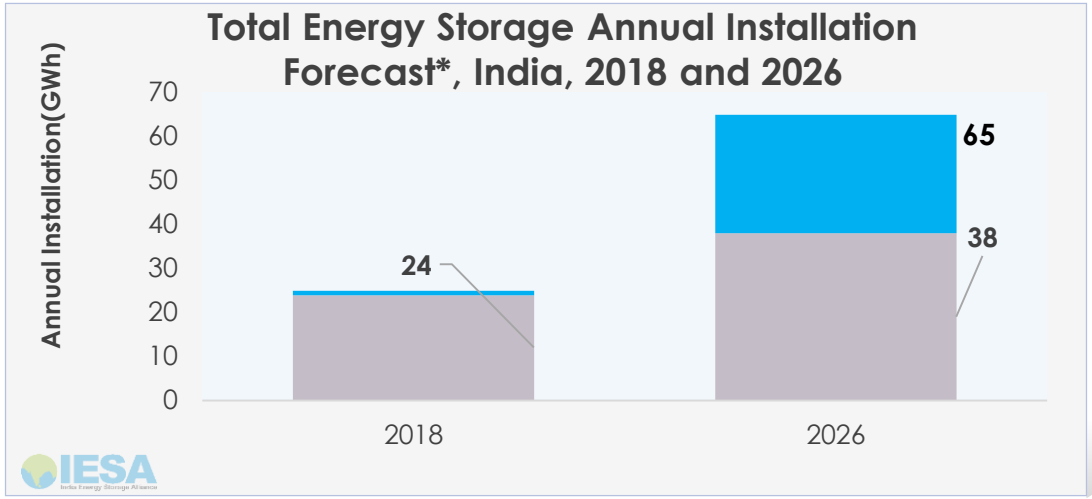
NO. 281 NEW DELHI, WEDNESDAY, AUGUST 19, 2015

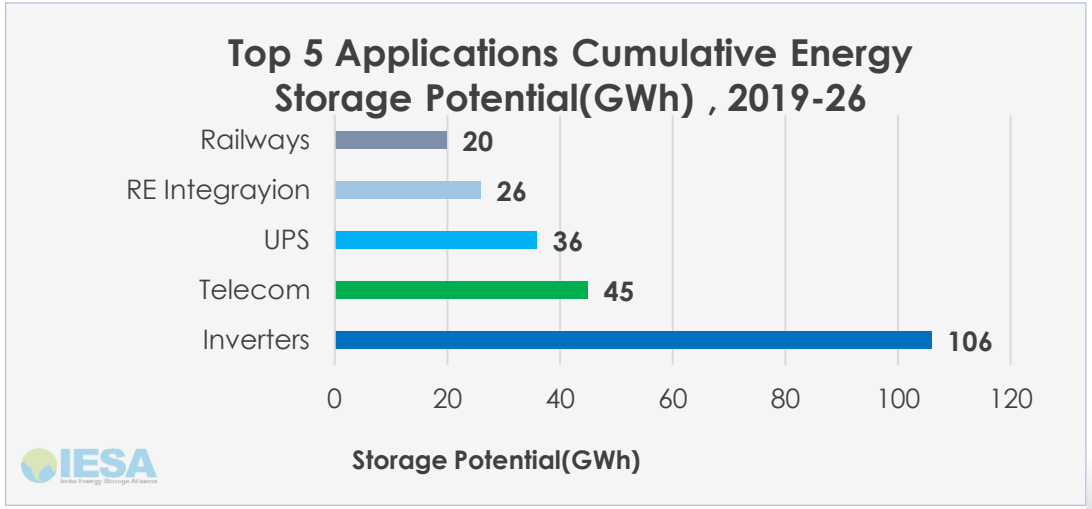
CENTRAL ELECTRICITY REGULATORY COMMISSION
NEW DELHI

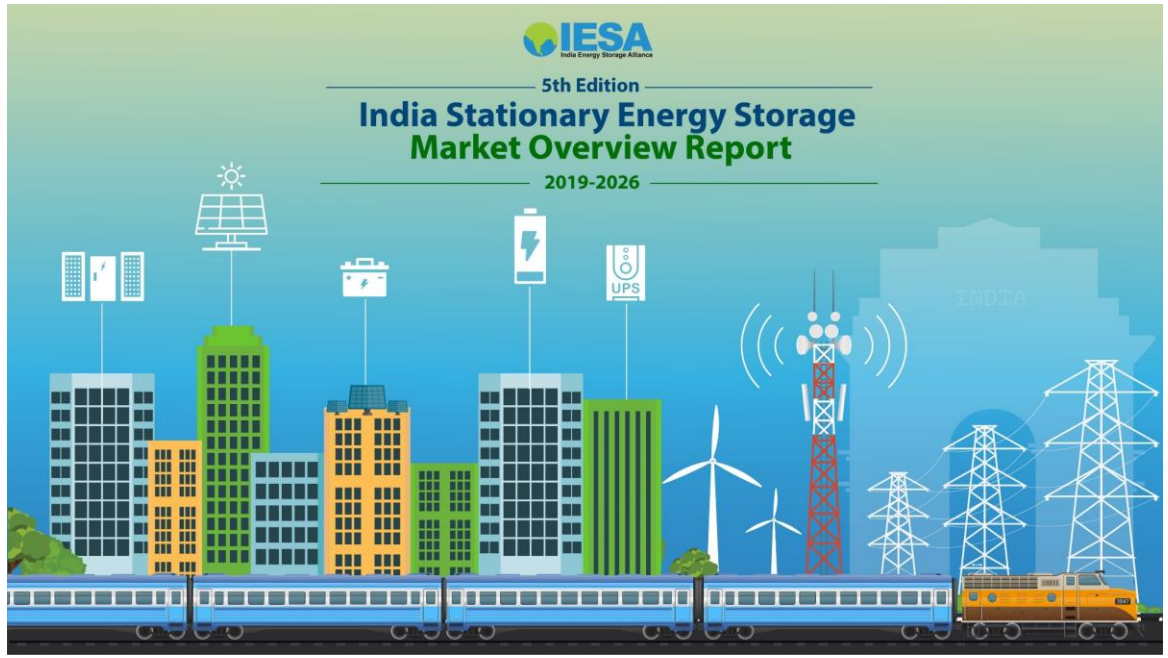
No. 18/1/2013/Reg. Aff.(AS Regul.)/CERC Dated: 13th August, 2015

Stationary Energy Storage Market 2019 – 2026

IESA Projects the cumulative market to be market could be between 265-350 GWh







**Source: IESA India Stationary Energy Storage Market Overview Report 2019*

Challenges for growth of RE and energy storage

- Lack of clear Policy Framework
  - ✓ Recognizing energy storage as a separate asset class
  - ✓ Net metering, demand response, grid reliability standards etc.
  - ✓ Generation based incentives vs hybrid solutions
  - ✓ Energy efficiency policies at equipment level vs efficiency at systemic level
  - ✓ Enforcement of existing power quality and reliability standards
- Distortion of price signals due to subsidies or lack of transparent pricing signals
- Excessive focus on capital costs vs life cycle costs for selection of public funded projects
- Lack of awareness about technology evolution and new business models
- Need for financing mechanisms.

Industry wish list

- Learning from global experience instead of insisting on pilots for proven technologies and applications.
- For pilots being considered, need to set a clear expectation for success and performance benchmark that can lead to mass adoption once pilot is successful.
- Need to create model templates for RFPs / clear requirement specifications to avoid ambiguity in bidding
- Need to adhere to the timelines for the projects if we need serious market players to focus and invest
- Need to encourage and support innovative business models
- Don't let perfect be enemy of solutions that are already practical and viable
- Need to take holistic approach in considering system costs rather than seeing this in bits and pieces and expecting the economies of scale to arrive from 1st project
- Need to look beyond just cost reduction at product level as 30-40% costs could be non product related.
- Need to have a clear roadmap similar to National Solar Mission that sets scale
- Need comprehensive Energy Storage Policy that covers Generation, T&D and DR
- Maharashtra should work with Multi National Agencies such as WB, ADB, AIIB for attracting funding for projects in Maharashtra

Conclusion

- Over past 5 years, the Policy Framework for Energy Storage in India has evolved
- Energy Storage sector is showing similar learning curve for cost reduction as exhibited by Solar Industry
- Various Energy Storage Technologies are seeing significant performance improvements and cost reduction trends over past decade and this is expected to continue over next decade
- Traditional Pumped Hydro although proven, has significant challenges in terms of environmental and operational limitations
- Apart from Electrochemical Batteries such as Lead Acid, Li-ion, flow batteries and metal air batteries, research is also taking place in Thermal and Gravity Storage
- It is important to understand the technology as well as application requirements
- Cost reduction is achieved not just by manufacturing scale up, but through learning curve and improvements such as energy density / cycle life as well as better understanding of system performance and safety aspects
- RE + storage has already started competing with existing peaker plants in the grid around the globe, and with further cost reductions, we anticipate they can also provide potential cleaner baseload generation
- IESA has set a vision to make India not just a market, but global hub for R&D and manufacturing of Advanced Energy Storage and EV systems by 2022.

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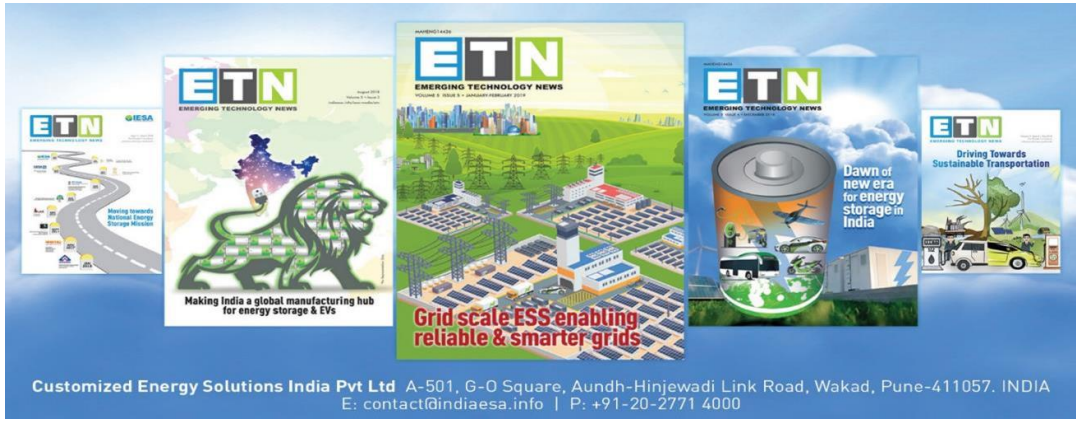

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