India SMART UTILITY Week 2020

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ISGF India Smart Grid Forum

Masterclass

Technologies enabling Energy Transition: ESS Applications for Grid Modernization

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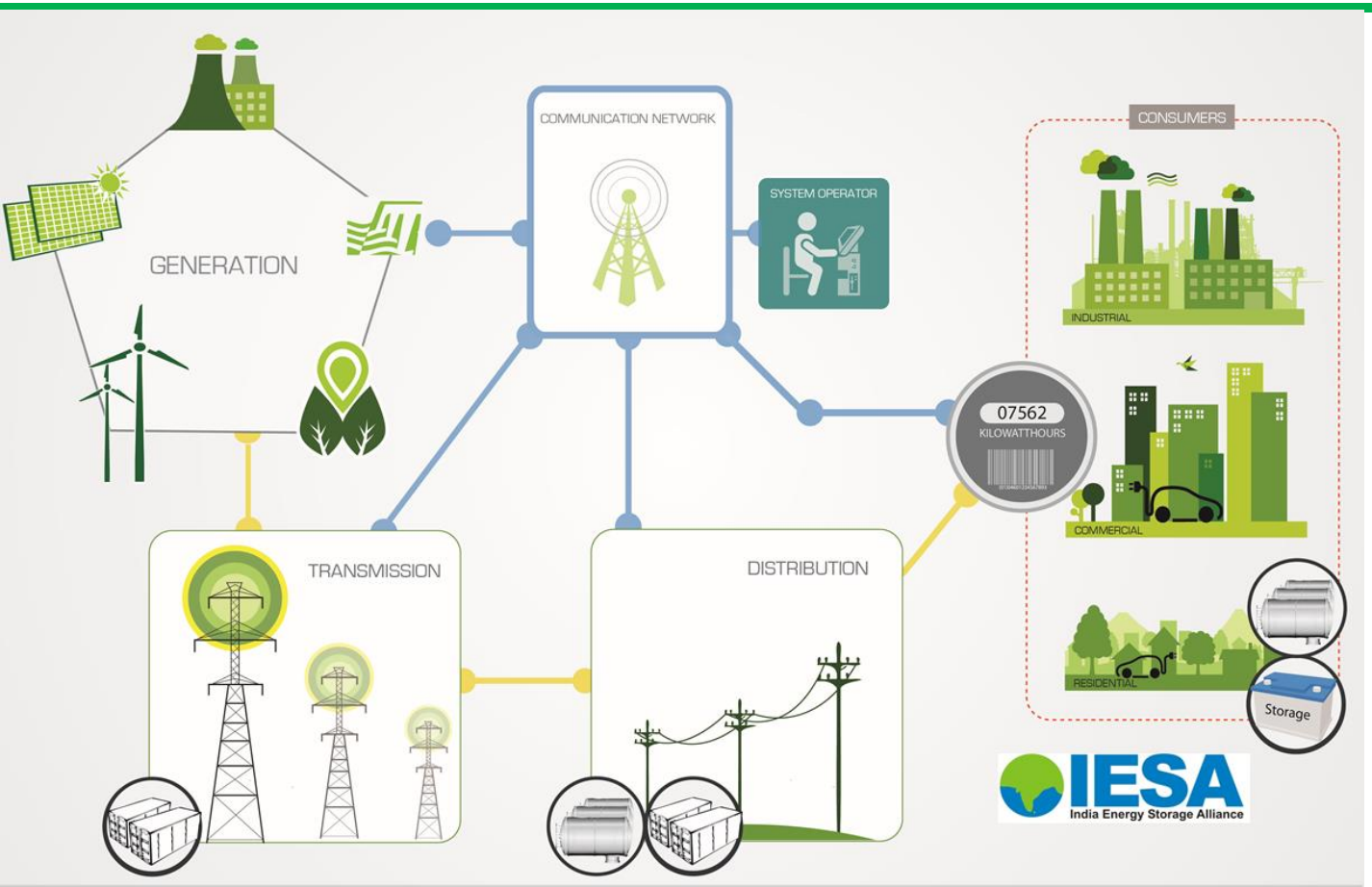
President, India Energy Storage Alliance (IESA) &

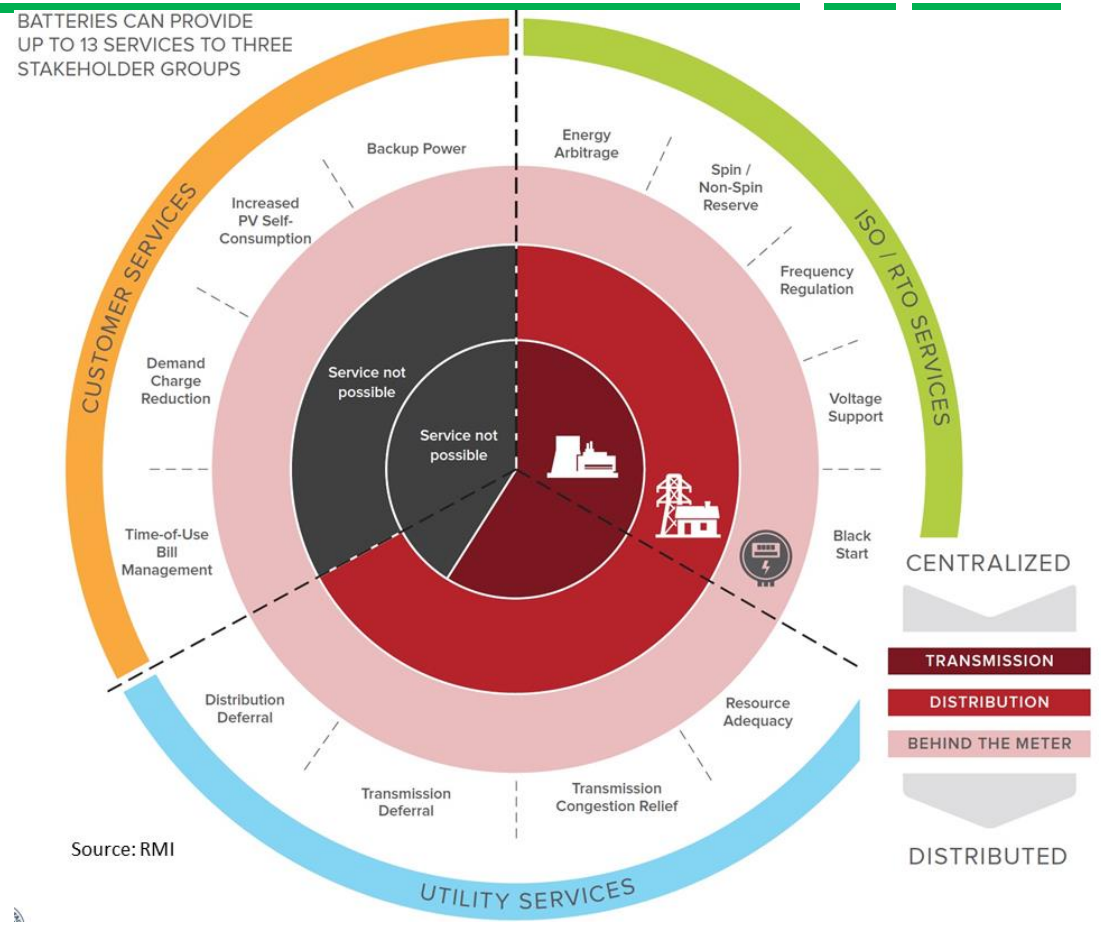
Chair, Global Energy Storage Alliance (GESA)

Customized Energy Solutions

IESA India Energy Storage Alliance

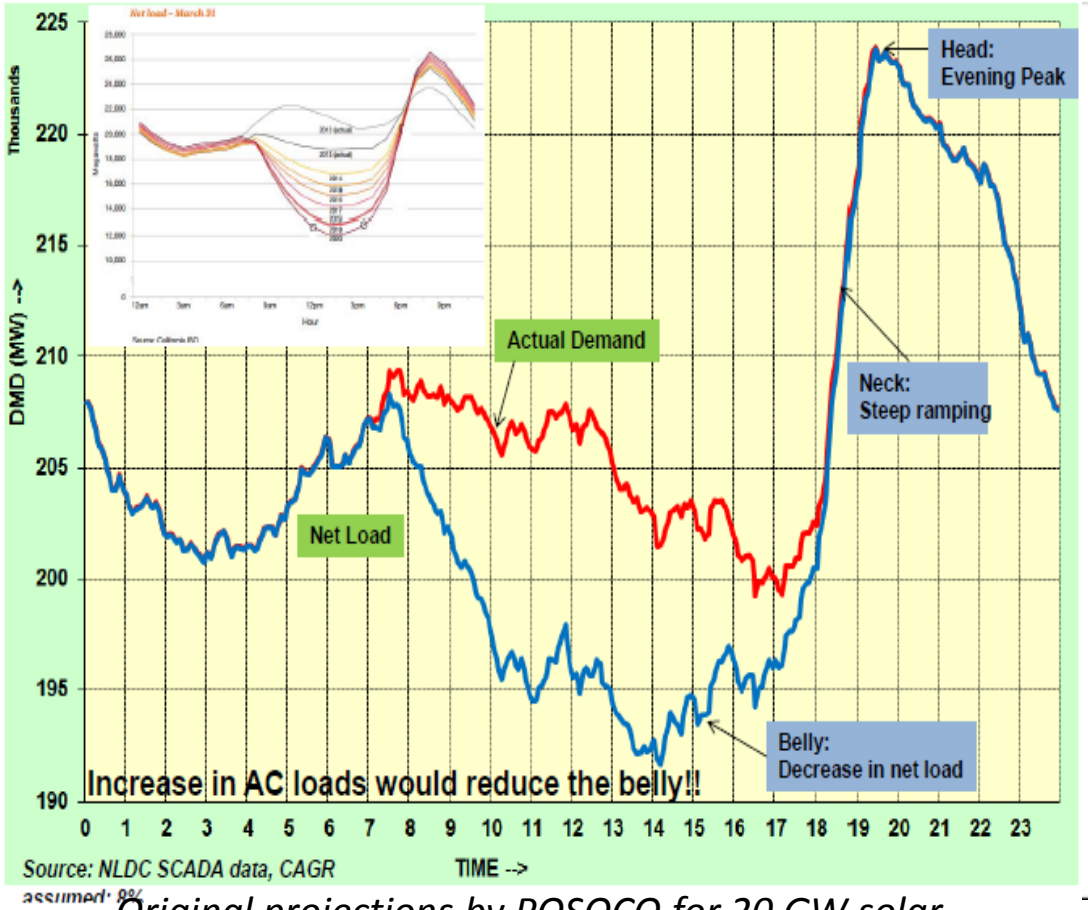
Role of Energy Storage in Modern Grid

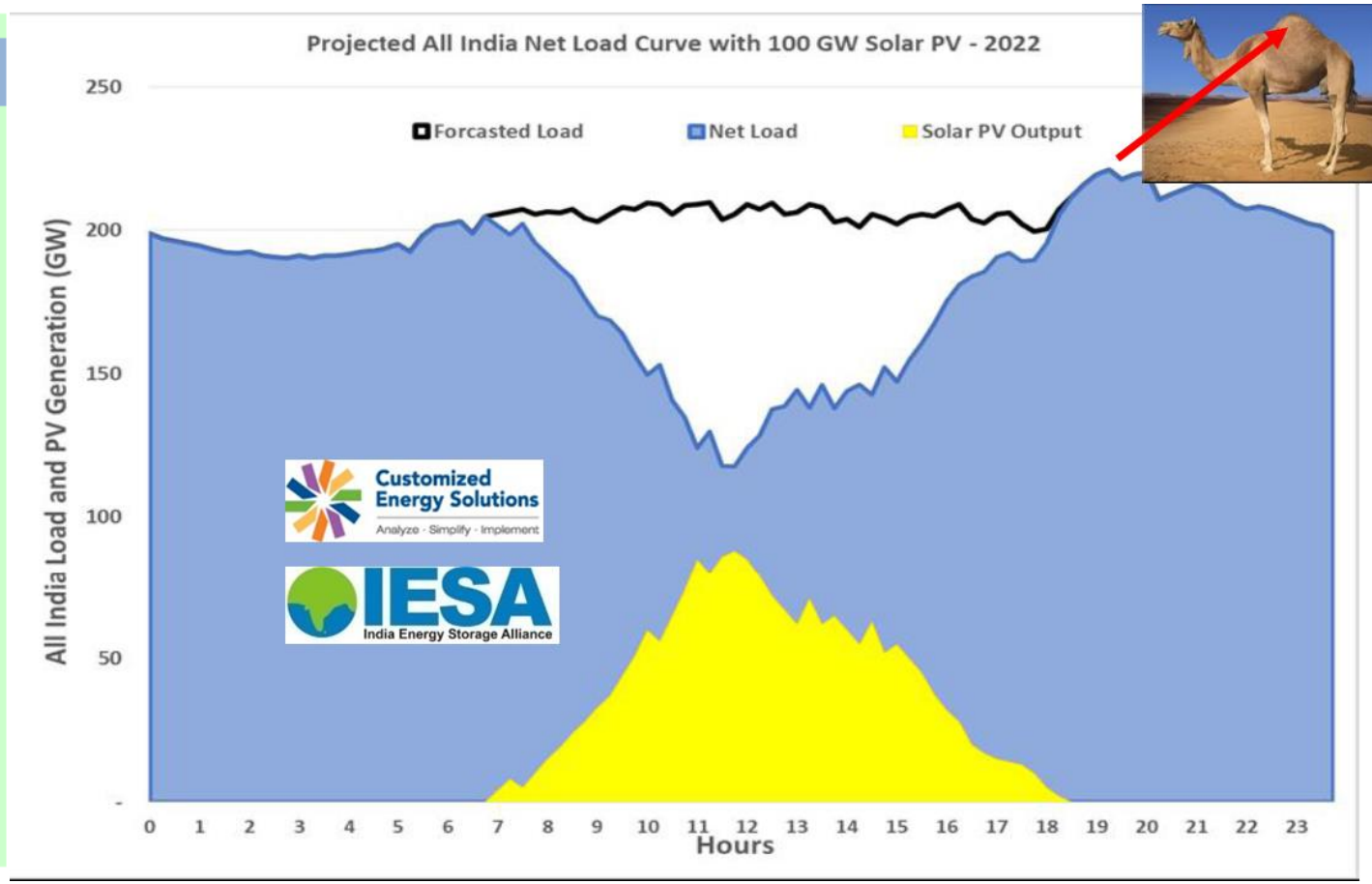




Energy storage can play a key enabling role in every aspect of modern grids including Generation, Transmission, Distribution and at Customer Premise (including electric vehicles).

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

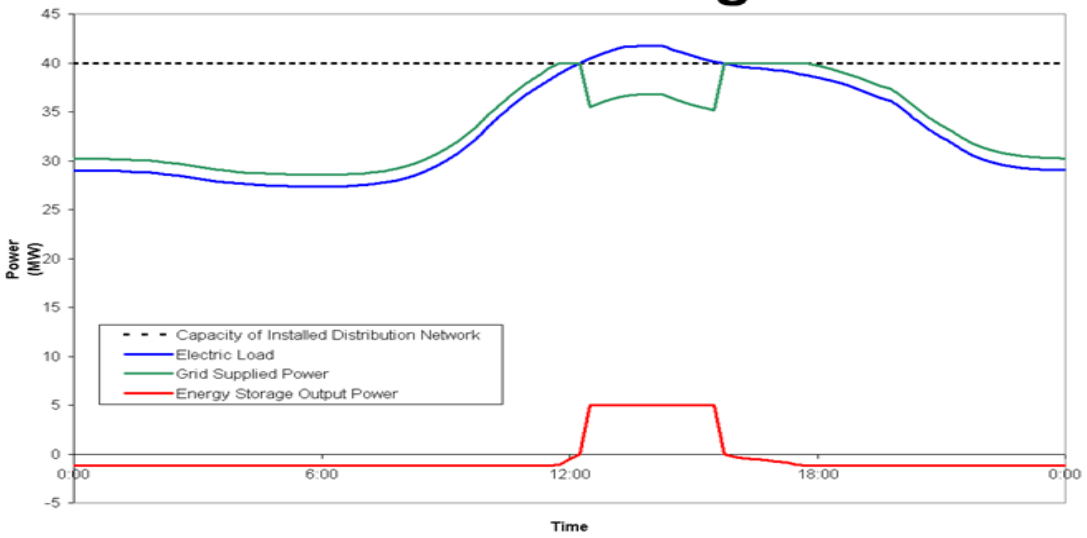




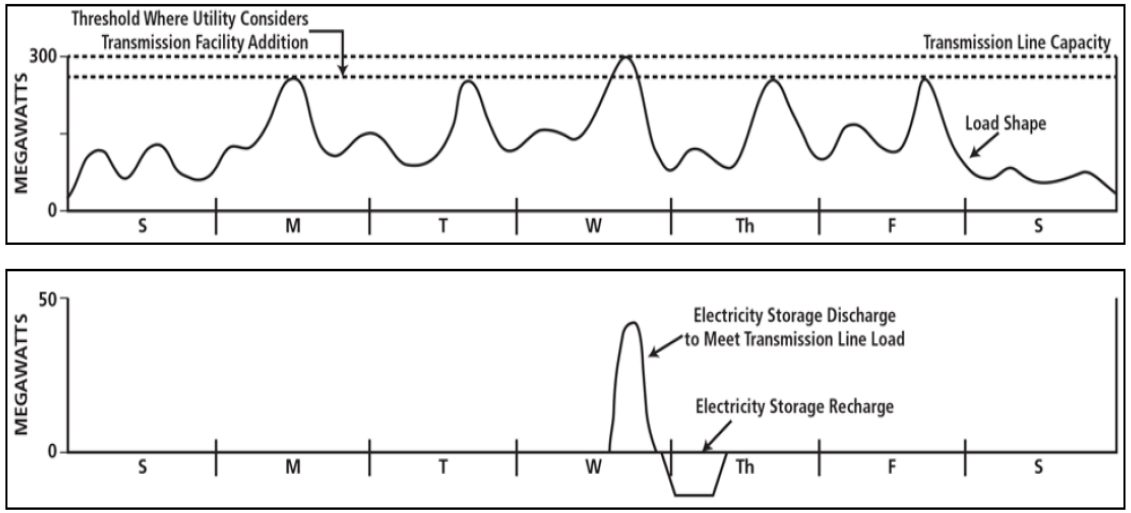
Original projections by POSOCO for 20 GW solar target

Storage Stationary Applications

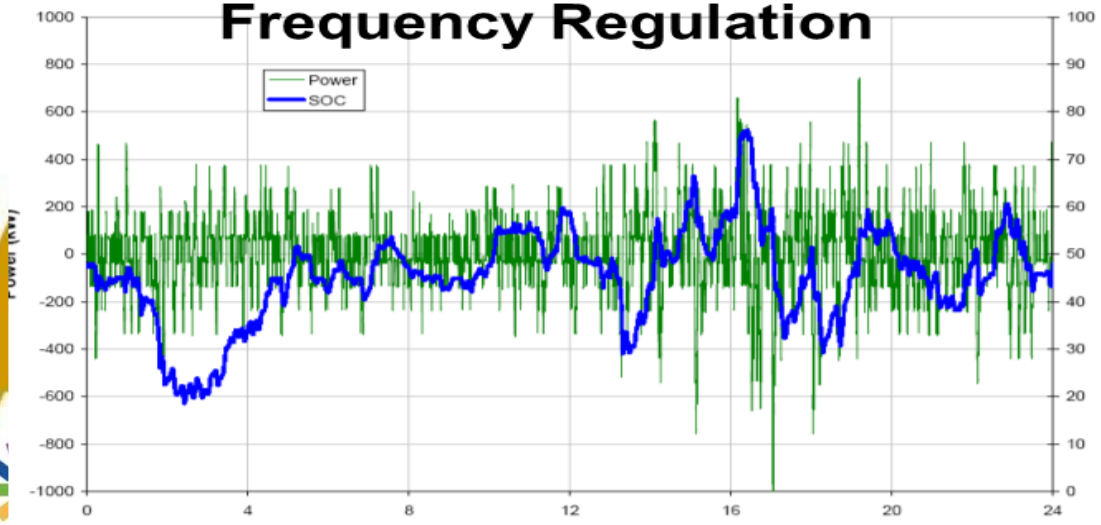
Peak Shaving



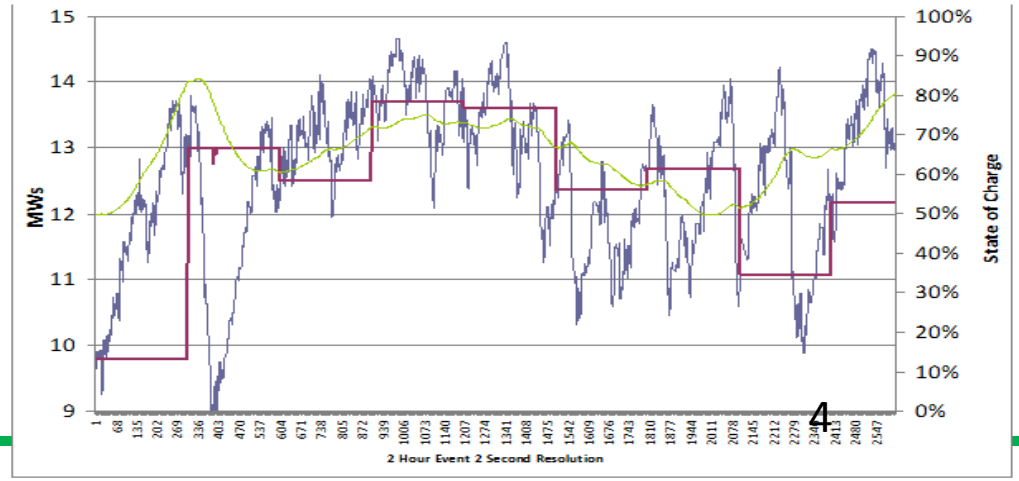
Load Levelling



Frequency Regulation

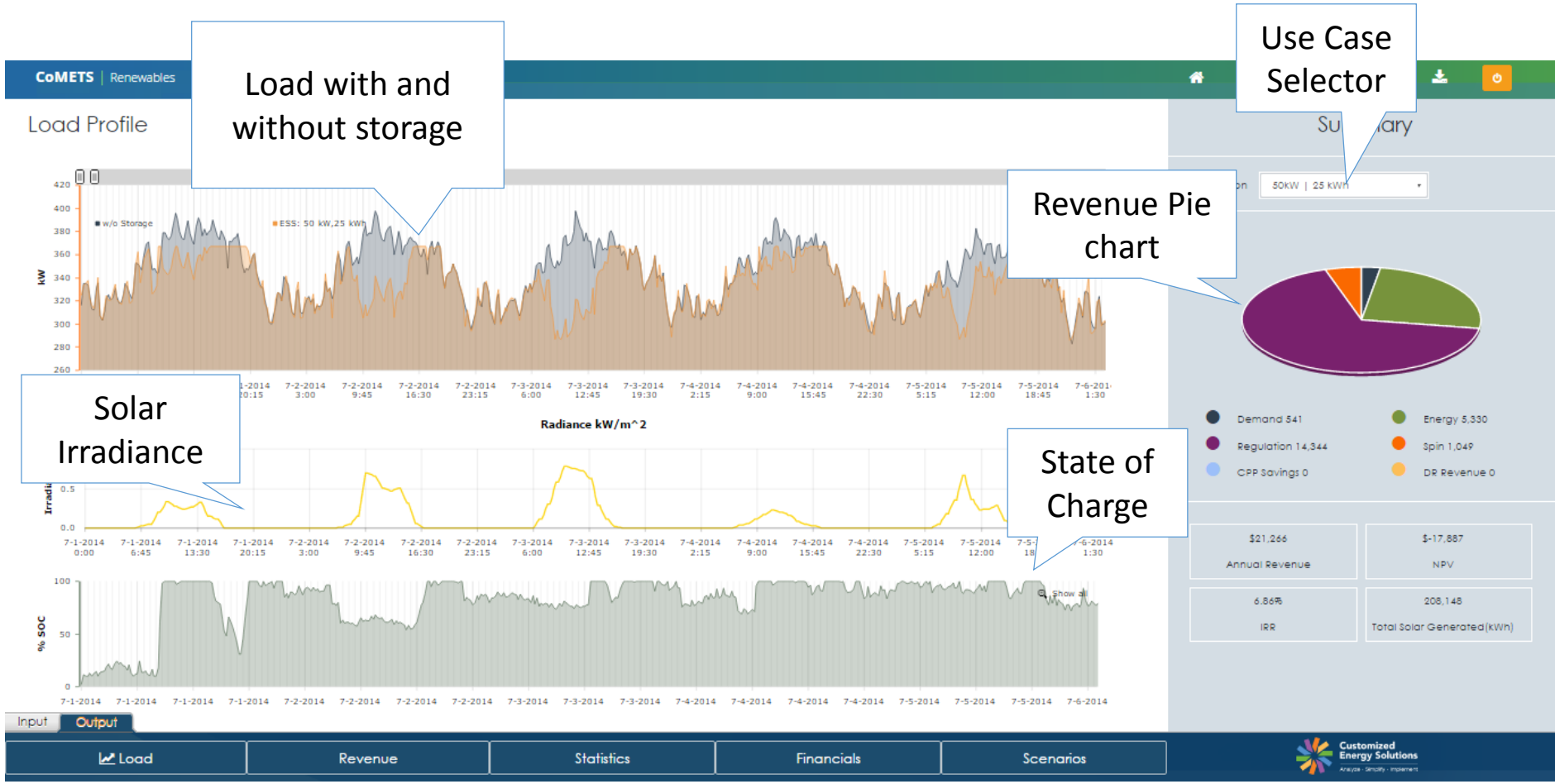


Wind Firming



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

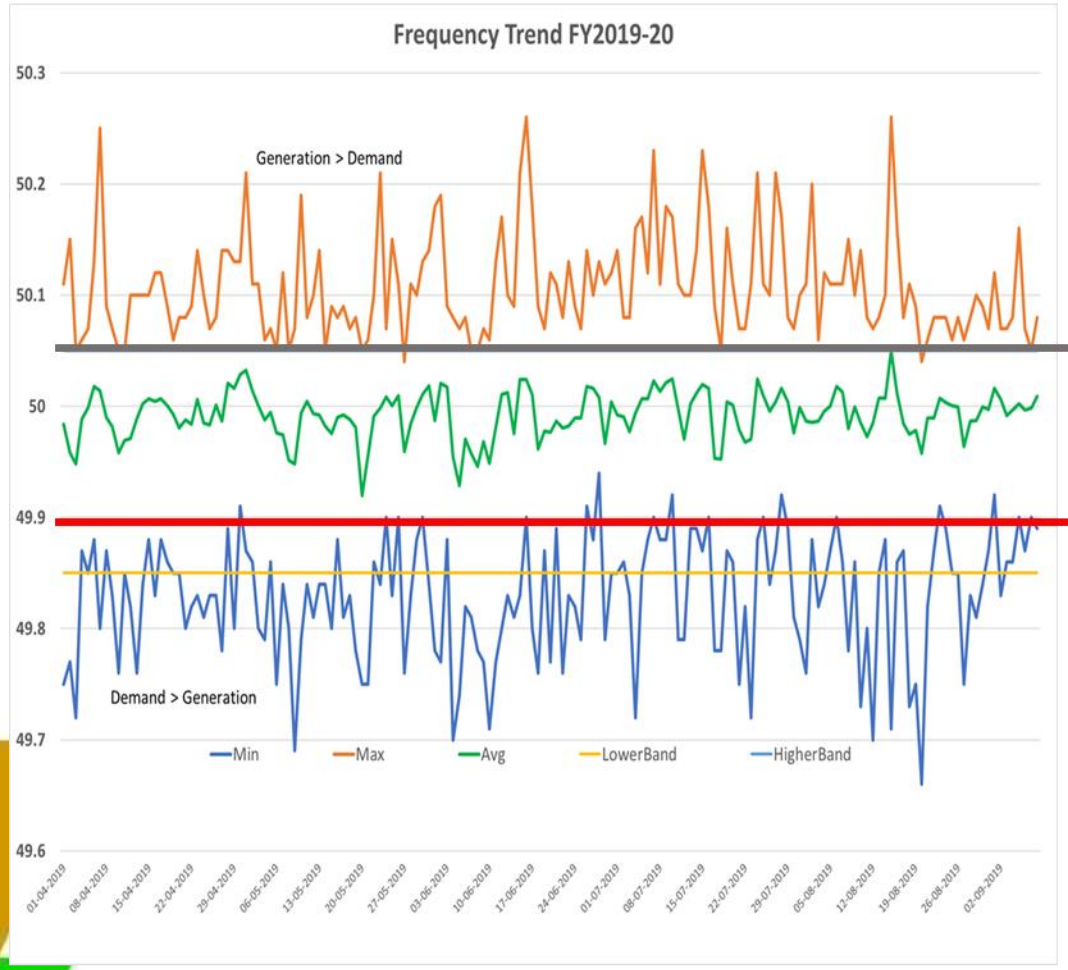
Evolution of Frequency Grid Band & DSM charges

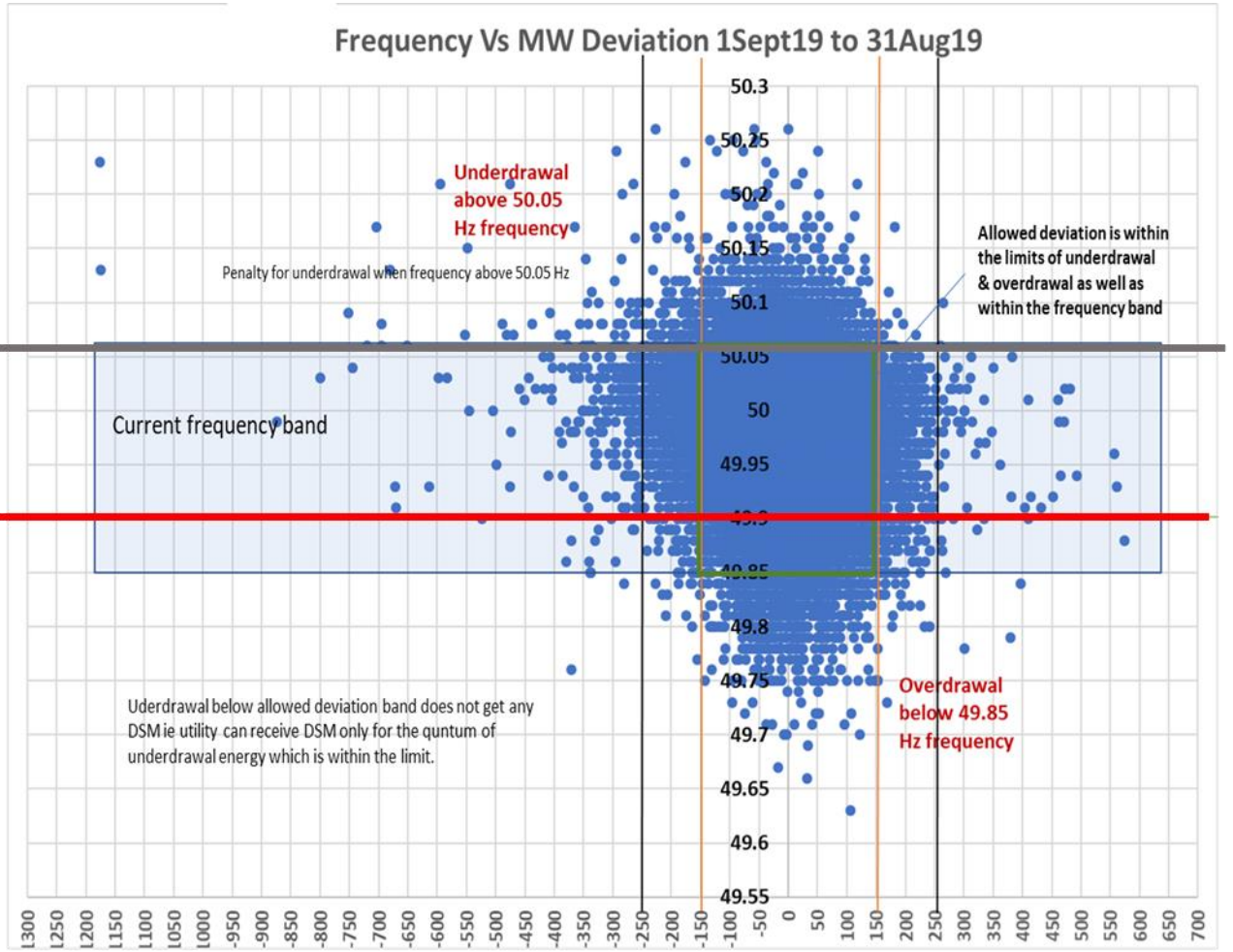
Period	Operational Frequency Band	Ceiling Rate (paise/kWh)	Benchmarking of Ceiling Rate	Slope (paise/kWh)	Step size
1st July 2002 – 31st March 2004	49.0 Hz – 50.5 Hz	420	DG set	5.6	0.02 Hz
1st April 2004 – 30th Sept 2004	49.0 Hz – 50.5 Hz	600	DG set	8	
1st October 2004 – 29th April 2007	49.0 Hz – 50.5 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) 35.60 (50.01 - 50.05)	0.01 Hz

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

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

Smarter Solution: Storage

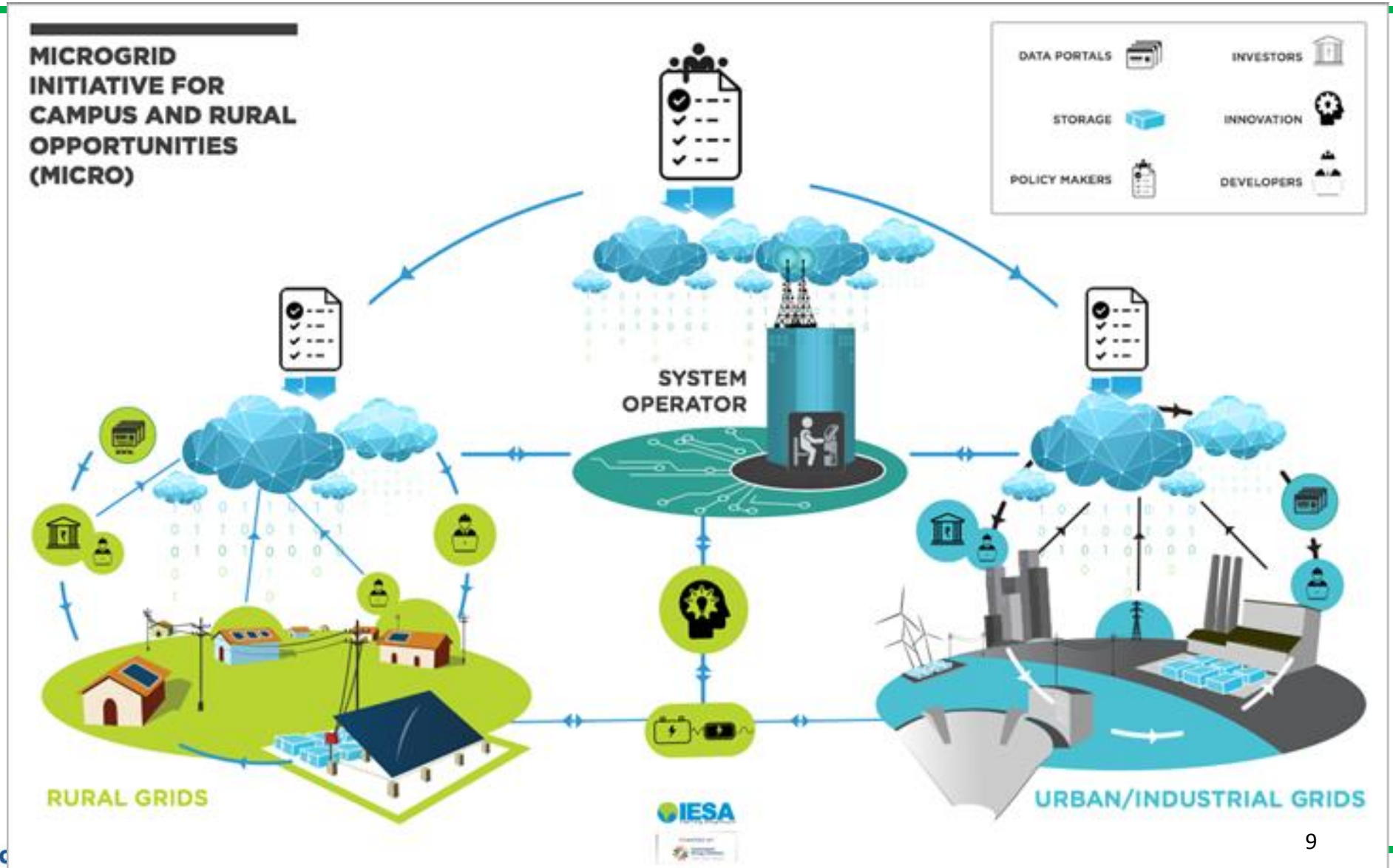
+

- 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

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)

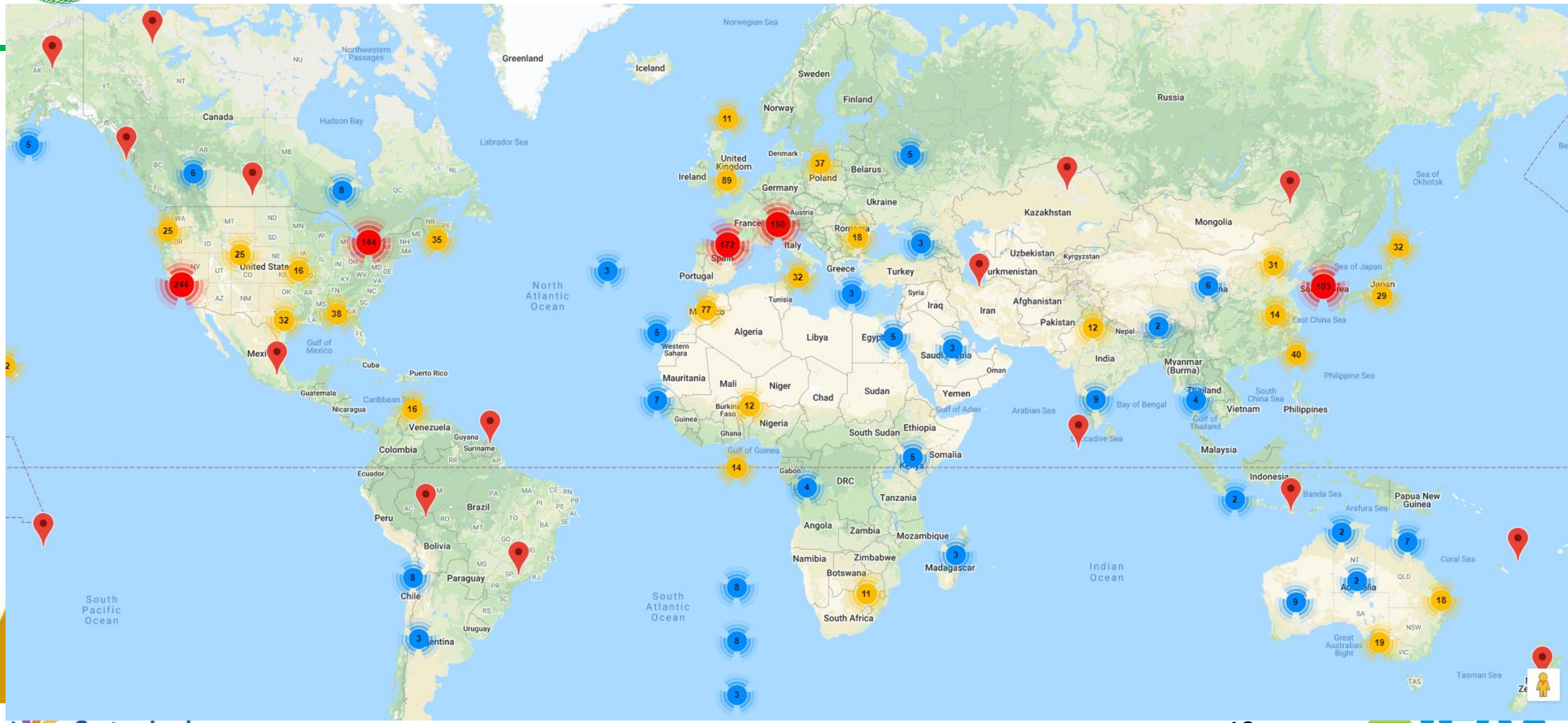
Electrical

Ultra Capacitors

Power Electronics

Bidirectional inverters / Charging Infrastructure

Global Adoption of Energy Storage



Source: DOE Energy Storage Database (Feb 2020)

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

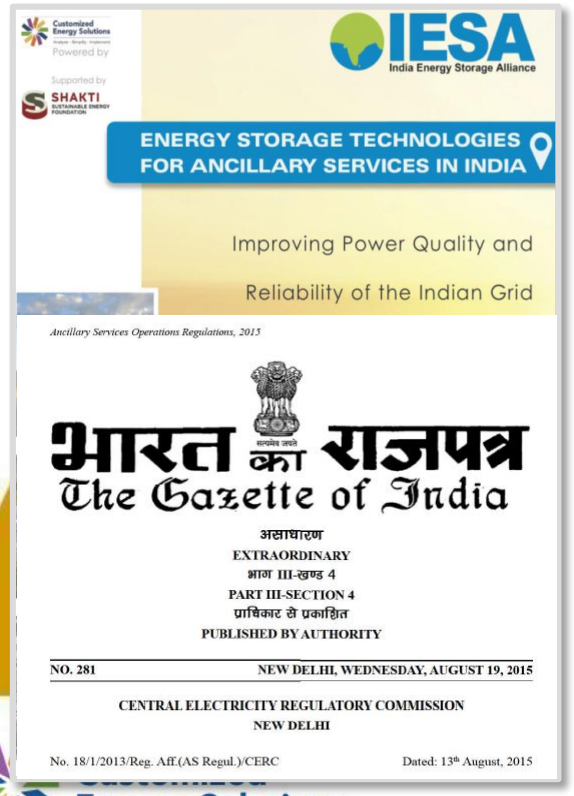
Oct 2015 CERC issues Ancillary Services Operations Regulation (August 2015) and Roadmap to operationalize Reserves in the country

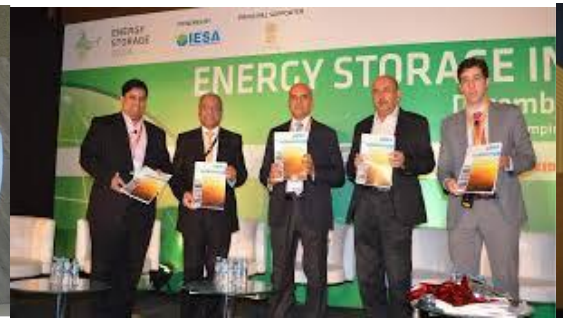
Jan 2017 CERC Staff Paper on ESS

May 2018 MNRE National Wind Solar Hybrid Policy

Jan 2019 CERC & CEA Regulations inclusion of Storage

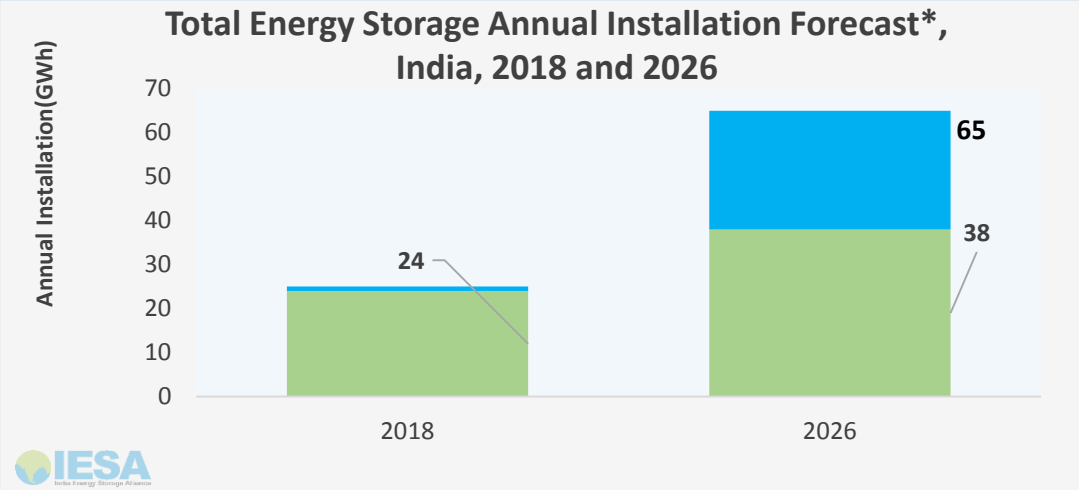
Mar 2019 National Energy Storage Mission and National Mission for Transformative Mobility

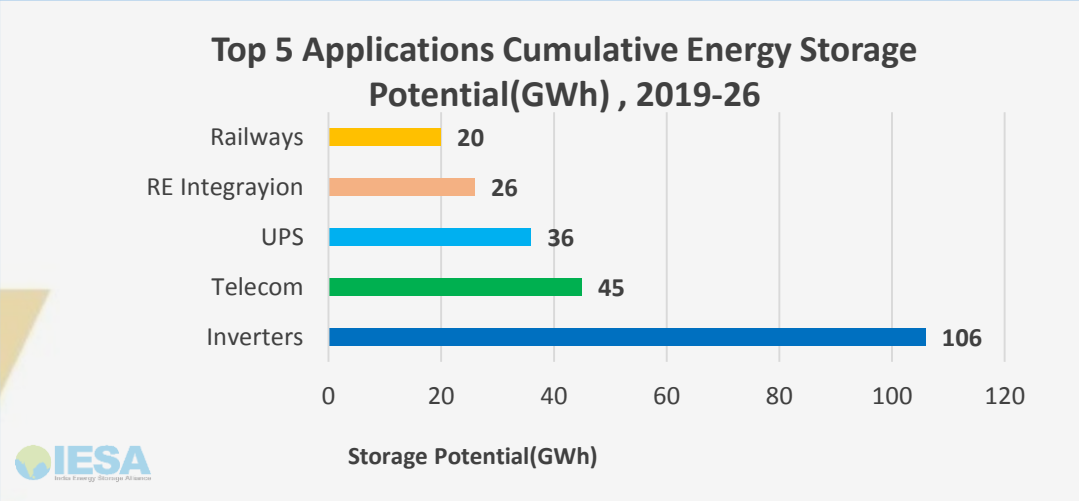




Stationary Energy Storage Market 2019 – 2026

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.

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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IESA India Energy Storage Alliance

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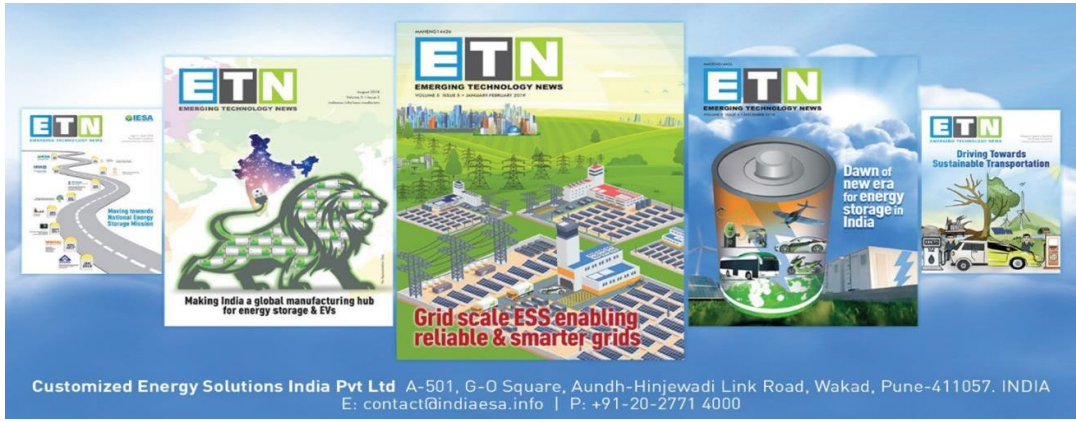

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