MINUTES OF THE 21ST STATE ADVISORY COMMITTEE (SAC) MEETING OF THE JOINT ELECTRICITY REGULATORY COMMISSION (FOR THE STATE OF GOA AND UNION TERRITORIES) HELD AT INDIA INTERNATIONAL CENTRE, LODHI ROAD, DELHI ON 29TH OCTOBER, 2025 AT 11:00 HRS.

1. The 21st Meeting of the SAC of the JERC (for the State of Goa & UTs) was held under the Chairmanship of Shri. Alok Tandon, Chairperson, JERC.

   The following SAC Members were present:

1.	Shri Alok Tandon	: Chairperson, JERC
2.	Smt. Jyoti Prasad	: Member (Law), JERC
3.	Shri S.D. Sharma	: Dir(F&L) / Secretary (I/c), JERC-Convener
4.	Shri I.S. Jha	: Member
5.	Shri Gurdeep Singh	: Member
6.	Shri Arun Goyal	: Member
7.	Shri S.K. Soonee	: Member
8.	Shri Reji Kumar Pillai	: Member
9.	Smt. Neerja Mathur	: Member
10.	Shri Anoop Singh	: Member
11.	Shri Neil Erlic Lucio De Souza	: Member

2. Shri Alok Kumar, Shri Rohit Bajaj and Shri Samir Kamra were unable to attend the meeting due to their busy schedules. Leave of absence was granted to them.
3. The Secretary (I/c)/ Convener welcomed all the esteemed members of the State Advisory Committee to the 21st SAC Meeting and requested the Hon'ble Chairperson for opening remarks.
4. The Chairperson welcomed all the members and also introduced the new members who were recently included in the SAC. He mentioned that as per JERC Regulations, two meetings of the SAC are to be held every year. Hence next meeting may be held in the month of March, 2026. He further informed the members that the Commission has implemented the Multi Year Tariff for all territories for the next five years.
5. The Secretary (I/c)/ Convener, with the permission of the Chairperson, started the presentation on the agenda Points of the 21st SAC Meeting with the point number 3 of the agenda which is the confirmation of minutes of 20th SAC

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Meeting. The Hon'ble Members of the SAC unanimously conferred the MoM of 20th SAC meeting. The Secretary (I/c)/ Convener further highlighted the action points prepared based on the inputs from Hon'ble SAC members during 20th SAC meeting and the action taken by the Commission.

Action points

a. The Secretary (I/c)/ Convener informed that one of the action point was to direct the utilities to increase their tied-up capacity in line with year-on-year increase in peak demand. The Commission in this regard issued letters on 30.06.2025 to the Utilities. The Chandigarh Power Distribution Limited (CPDL) sent its reply and response from other utilities are awaited. The Chairperson mentioned that the same has been taken care of in the Business Plan Order.

b. Another action point was to direct the Utilities to publish the compensation schedule through Newspaper/Website and include the link of website on their electricity bills where the website will display the SOP and contact details of CGRF. The direction had been issued to the Utilities. Shri Anoop Singh suggested that the best way is to put the compensation schedule on backside of the consumer bill. It was discussed and agreed that compensation schedule size are larger than the consumer bill and hence the link of standard of performance and compensation schedule may be put on the backside of the bill in prominent colours. The Secretary (I/c) confirmed that the direction to publish the SOP and compensation link on the electricity bills has already been communicated with the distribution utilities vide the letter on 30.06.2025.

c. Other action point was to direct the Utilities to float the proposal to consumers to participate in load reduction programme during peak hours. The Secretary (I/c)/ Convener informed that the letter dated 30.06.2025 regarding the same has been issued to the Utilities and response on the same are yet to be received from them. Shri Gurdeep Singh appreciated the action taken for the load reduction programme. He suggested that new start-ups / individual (or expert) may be invited for suggestion on implementation of multiple aspect of load reduction programme in order to avoid unnecessary capacity tie-up and subsequently reduce the power purchase cost.

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6. Shri Arun Goyal inquired on availability of ToD tariff for Commercial & Industrial Consumers. The Chairperson informed that all tariff orders have provision of ToD tariff and is mandatory for Industrial Consumers. For other categories, the ToD tariff will be made applicable once appropriate metering is available. He mentioned that ToD tariff is designed in three parts as consumption during 8 hours (Solar Hours) are charged at lower energy charges, normal hours at normal energy charges & peak hours at higher energy charges. These charges have been put at $\pm 20\%$ at normal rate of energy charges for most of the utilities for current MYT order. Shri Anoop Singh suggested that 8 hours are too large window and should be constrained at 5 hours since the procurement of costly power starts at the time of ramping of thermal power plants.
7. Shri I.S. Jha suggested that the peak hours should be aligned with non-solar hours, even if the peak demand at solar hours is marginally higher. Shri Gurdeep Singh suggested that the peak hours may be defined as per the price trends in the power exchanges.
8. Shri I.S. Jha mentioned the ToD may be defined on quarterly or seasonal basis. The Chairperson informed that the Commission was constrained by the lack of infrastructure of the utilities and MoP's direction to define solar hours for 8 hours duration.
9. Shri S.K. Soonee referred action points 1&4 of the previous MoM, and emphasised on the fact that defining solar hours, peak demand hours, ramp period of thermal generating plants, percentage of time where all tied-up capacity required for resource adequacy, etc. can be done via rigorous energy modelling, which is an achievable exercise. He along with Shri Anoop Singh further highlighted that the Resource Adequacy Guidelines by MoP and subsequently the Resource Adequacy regulations by various SERCs have not properly incorporated demand response. Implementing Resource Adequacy exercise without proper demand response may lead to the tie-up of additional capacity for the discoms, the cost of which will be borne by the retail consumers. He further mentioned that few SERCs like Maharashtra have made the exercise of demand response compulsory in their regulations.

Action points

1. To invite a startup company/ expert on implementation of load reduction programme/ demand response.

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10. Shri Anoop Singh shared his experience in context of demand response and mentioned that proper methodology of demand response has not been defined in MoP's Resource Adequacy Guidelines or FoR Model Regulations. He further mentioned that the demand response exercise should consist of two parts; first baseline estimate and second part is how utility implement it.
11. Shri I.S. Jha suggested that instead of implementation of reducing the demand from the consumer's side, focus should be made on increasing the per capita consumption for India to become a developed country.
12. Shri Anoop Singh clarified that the demand response necessarily means reducing the demand only during the emergent situations instead of reducing the demand for all hours off the day.
13. Member (Law) informed that a working group of FoR is currently working on Model Regulations for Demand Side Management. She further clarified that in the model regulations, there will be a demand aggregator who shall inform the entities to reduce their respective demand during an upcoming emergency situation and accordingly, incentives shall paid to the eligible entities.
14. Shri D' Souza informed the members regarding presence of lot of airbnb accommodations which are currently billed under domestic tariff category in Goa. The Chairperson further added that a category has been introduced in the recently issued tariff orders for consumer which use domestic premises for commercial purposes.
15. Shri Gurdeep Singh suggested that utilising the fixed infrastructure more and keeping the demand profile flat should be incentivised. Shri S.K. Soonee supported the point by referring to the presentation in the previous meeting where it was mentioned that for Goa, 10% of the capacity to meet the peak demand was required only for 2% of the time for year 2022. He said that the consumer should be encouraged to install and use Behind-the-Meter resources to meet the peak demand which is required only for few instances in a year.
16. Shri Reji Kumar Pillai mentioned currently utilities have not adequate infrastructure to implement the ToD / ToU tariff automatically. He shared the experience of experimental project done in Lucknow city approved by

Action points

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Regulator for period September 2022 to August 2023. He mentioned that they selected a group of 50 consumers and provided surcharge/ rebates to these consumers depending upon the time block in which the energy was consumed. This results into a saving of Rs 30-40 lakhs/months of reduction in the electricity bills of many IT parks and 5 star hotels. He emphasised that similar exercise can be done for the state of Goa.

17. Further, he also advised that BESS be made mandatory for consumers seeking connection for over 100 kW. He further suggested that incentives in the form of budgetary support shall also be provided to consumers opting for installation of rooftop solar integrated with BESS. **A reference to the Government may be made.**

18. Regarding tariff unbundling part, Shri Anoop Singh emphasized that tariff should be unbundled in three to four-part or even five-part regardless of whether competition in distribution and retail business happens or not. He gave an example of four part tariff consisting of network charge, energy demand charge, energy charge & customer-service charge. He further mentioned around 45% fixed charge component is present in discom's power purchase component while only around 10% of power purchase cost is recovered as a fixed cost. This results in high variable charges, the burden of which is mostly felt by small BPL consumers.

19. Shri S.K. Soonee added that the concept of charging tariff for kWh will become obsolete since adding more renewable energy plants will lead to zero marginal cost for generation in the future. Over the years, the consumer may have a five part tariff in which the energy charge component will be of a minimal value.

20. Shri Gurdeep Singh further added that providing subsidy on fixed component of tariff to a consumer category is much easier as compared to giving subsidy on variable component of tariff.

21. Regarding action points 5,6 and 7, the Secretary (I/c)/ Convener informed that letters have been shared with the utilities regarding the implementation of the action points.

22. The Secretary (I/c)/ Convener explained the next agenda item on regulations amended / issued by the Commission during first half of FY

Action points

2. Incorporation of demand response as obligation in RA regulation

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2025-26 and briefed the same to the SAC members. Below are the regulation-wise important points discussed:

Action points

a. **JERC (For holding inquiry to be conducted by Adjudicating Officer) Regulations, 2024 notified on 6th February, 2025**

i. The Secretary (I/c)/ Convener highlighted the key features of the Regulations.

ii. Shri Arun Goyal asked if the regulation is specifically issued regarding the RPO compliance. The Chairperson clarified that the regulation was issued based on the request from BEE to file the complaints regarding the non-compliance of energy audit.

iii. Shri Anoop Singh said that the as per BEE notification dt. 27.09.2025 regarding RCO, compliance of multiple designated consumers under common control shall be considered at holding company level. This may be difficult due to the limitations of getting data for an entity having existence in two or more States.

iv. Shri Arun Goyal further added that for year FY 2024-25, the actual renewable power available in the country was less than the RPO target for discoms, hence making it impossible for discom to comply with the RPO targets. Hence, penalty on the same may not be justifiable.

v. Shri I.S. Jha added that one of the major issues is related to star labelling like 5 star, 4 star or 3 star, which is not done on a periodic basis. The same should not be treated as one time exercise. He further advised on the broadening of the category of petitions which shall be filed by BEE under these regulations. Thirdly, he advised on the inclusion of timelines under these regulations. The Secretary (I/c)/ Convener pointed out that the same has been provided in the regulations. Shri I.S. Jha further added that the Commission should have appropriate manpower to handle the issues of energy efficiency which generally includes non-electrical loads like Waste Heat

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Recovery, etc. Shri Anoop Singh further advised the Commission to appoint manpower to deal with energy efficiency matters as enshrined in the BEE regulation. Shri I.S. Jha also advised the Commission to conduct public hearing in virtual mode too. The Chairperson informed that the Commission is already implementing in physical as well as virtual mode. Shri I.S. Jha also added the Commission should issue order under this regulation in such a way that it will create awareness of this regulation among the stakeholders in the electricity sector.

Action points

b. JERC (Framework for Resource Adequacy) Regulations, 2025 notified on 15th May, 2025

i. The Secretary (I/c) / convener briefed the regulations.

ii. Shri S.K. Soonee highlighted that the Resource Adequacy plans developed by CEA may not be sustainable for making the investment decisions.

iii. Shri Arun Goyal suggested inclusion of RA elements in the business plan orders issued by the Commission. The Chairperson clarified that a simplified version of RA plan has been incorporated in the business plan orders.

iv. The Secretary (I/c)/ Convener summarised the timelines mentioned in the RA regulations of the Commission.

23. The Secretary (I/c)/ Convener requested to Shri Reji Kumar Pillai for the presentation *"Digitalization and Digital Transformation of Electric Utilities".*

24. Shri Reji Kumar Pillai made presentation on Digitalization and Digital Transformation of Electric Utilities. The details of the presentation are placed at Annexure 'A'.

25. Smt Neerja Mathur enquired on planning of achievement of decarbonization by RE electrification. Shri Reji Kumar Pillai clarified that the decarbonization process is to be implemented in sequence. First, all the end use applications like cooking, heating, etc. in the households,

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industries, etc. are to be electrified. Once done, then the process of generation of electricity shall be decarbonized.

26. Shri Arun Goyal enquired about the rates at which electricity is traded under P2P model. Shri Reji Kumar Pillai mentioned that the charge is generally around Rs 5/kWh which does not include Rs 1/kWh approx. to discom for wheeling charges and Rs 0.40/kWh approx. towards platform fee. Shri Anoop Singh further enquired about the true cost of the platform on per unit basis. Shri Reji Kumar Pillai stated that the cost of platform will go down in the scenario of its full deployment with large number of people making transactions on the platform that will bring more economy. Shri Anoop Singh further enquired about the applicability of wheeling charges under P2P since the consumer is already paying fixed cost to the distribution licensee.

27. Shri I.S. Jha requested Shri Reji Kumar Pillai to do a live demonstration of the AI tools discussed in the presentation during the next SAC meeting. Shri Reji Kumar Pillai agreed to do the same.

28. The Secretary (I/c)/ Convener thanked Shri Reji Kumar Pillai for insightful presentation and with permission of the Chair requested to Shri Gaurav Maheshwari on the behalf of Shri Rohit Bajaj for presentation on Power Market Update.

29. Shri Gaurav Maheshwari presented on Power Market Update.

30. The Chairperson enquired about the countries involved in "Cross Border Trading" with India. Shri Gaurav Maheshwari stated that Nepal and Bhutan are involved in "Cross Border Trading" with India. Bangladesh currently don't have exchange based mechanism.

31. One of the major highlights was that RTM's share became larger than DAM's share in the exchange portfolio during FY 2025-26. Prof Anoop Singh pointed out that uncertainty in generation due to high RE portfolio in the grid is the cause of making the decisions related to power procurement close to real time. Shri S.K. Soonee added that this phenomenon will further increase with introduction of 5 minute time block in the country in place of existing 15 minute time block.

Action points

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32. Another major highlight was the bidding session for DAM which has been modified from 10:00 AM - 12:00 PM to 10:00 AM - 11:00 AM of previous day.

33. Shri I.S. Jha suggested to remove the capping of Rs 10/kWh so that the generator can recover its cost by participating in the market. This will increase the overall flexibility in the power system.

34. Shri S.K. Soonee suggested to bring the floor price below the zero value. Shri Anoop Singh supported the point by saying that electricity can be stored in the negative price territory. Shri S.K. Soonee further added that demand response can be achieved by bringing the floor price below the zero value.

35. Shri Arun Goyal mentioned that the share of electricity transaction via the markets have not increased from last few years and the share has remained in the range of 6-7%.

36. Shri I.S. Jha emphasised that SECI should release a single tender for RE and storage in order to reduce the transmission costs. Shri S.K. Soonee countered the point by stating that adding more storage in the grid will lead to more wastage of energy. Shri Anoop Singh supported the point by saying that ideally a battery should not charge another battery in a power system in order to avoid the wastage of energy.

37. The Chairperson enquired on the pricing of GDAM power. Shri Gaurav Maheshwari stated that the average price of GDAM quantum in the month of October 2025 was Rs 3.30/kWh. Shri I.S. Jha emphasised that ideally the cost in GDAM should be lower due to low price of green power during solar hours. The higher average cost may be due to clearing of wind power during non-solar hours.

38. Shri Anoop Singh enquired about the issuance of REC on the green power traded via DAM. Shri Gaurav Maheshwari clarified that presently there is no mechanism of trading REC on the trading platform via DAM although it has been incorporated in the procedure.

39. One important highlight was that the average price of TAM was higher than that of DAM. Shri I.S. Jha commented that the main reason of higher average price of TAM is that it provides certainty to buyers.

40. The details of the presentation are placed at Annexure 'B'.

Action points

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41. With permission of the Chair, Shri S.K. Soonee made presentation on Security Constrained Economic Despatch (SCED) implementation outcome in different state & national level and proposal for consideration to action points order for pilot by the JERC.

42. He shared that SCED was implemented at national level by NLDC on 1st April, 2019 as per the direction of CERC on more than 100 plants. This has led to a saving for ~Rs 5,000 Crores and operational ease of 40% plants.

43. Additional benefits were visibility of reserves and associated cost on block-wise basis.

44. Shri I.S. Jha queried regarding the factors and constraints taken into account to implement the study. Shri S.K. Soonee responded that intra-state generators, central generators, open access, transmission constraints and other factors have been considered in this exercise.

45. Shri S.K. Soonee mentioned that while the SLDC has the statutory responsibility, discoms can also do this study to optimize their power purchase cost.

46. He added that SCED should be incorporated in the State Grid Code Regulation to implement the exercise at the State/UTs level. Implementing this exercise for utility like DNH&DD may potentially lead to a savings of approximately Rs. 15 lakhs/ day.

47. Shri S.K. Soonee mentioned that few states have also done the pilot and incorporated in State Grid Code. Shri S.K. Soonee suggested that the Commission may pass order for pilot implementation of SCED for utilities & SLDC. Further, the Discoms / SLDCs, may take action for implementation of SCED as following order:

- train/hire manpower,
- MoU sign with local Academia,
- interface for input data & preparation of the SCED engine,
- interface for output data,
- parallel running for 3 months,
- develop a portal for visualization
- submit the report to the Commission.

Action points

3. Direct the mainland utilities to implement the pilot SCED and submit the report to the Commission.

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He also assured to guide in case of problem arises during implementation of SCED.

48. The details of the presentation are placed at Annexure 'C'.

49. The meeting concluded with a Vote of Thanks to the Chair.

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(Rajesh Dangi)
Secretary (I/c), JERC

Annexure – A

Joint Electricity Regulatory Commission
(for the State of Goa and UTs)
21st State Advisory Committee Meeting
29th October 2025, New Delhi

Digitalization and Digital Transformation of Electric Utilities

Presented By

Reji Kumar Pillai

President - India Smart Grid Forum

Chairman - Global Smart Energy Federation

About India Smart Grid Forum (ISGF)

- ISGF, established as a Public Private Partnership (PPP) initiative of Government of India in 2011, is spearheading the mission to accelerate electric grid modernization, electric mobility and energy transition in India
- The India Smart Grid Forum (ISGF) has evolved as a Think-Tank of global repute on Smart Energy, Electric Mobility and Energy Transition
- 200+ members comprising of ministries, utilities, technology companies, academia and research
- **8 Working Groups:** Grid Modernization and Smart Cities; Smart Metering (AMISPs); IoT, AI and Analytics; Digital Architecture and Cyber Security; Policy, Regulations and Business Models; Renewables & Microgrids; Flexibility & Electric Mobility; Smart Gas; and Smart Water
- ISGF has been driving the digitalization of utilities and is actively involved in standards development, technology demonstration pilots; training and capacity building and various advisory and research activities

More about ISGF: www.indiasmartgrid.org and ISGF's Key Contributions in the Backup Slides

Indian Power Sector - Future Projections

Installed Capacity (GW)

Electricity Generation (GW)	August 2025 (Actual)	2027-32*
Thermal	243	284
Large Hydro	49	62
Nuclear	8	20
Solar	123	365
Wind	52	122
Small Hydro	5	6
Biomass	11	16
Pumped Storage Plants (PSP)	4	26
Total	**495**	**901**

India has taken Big Leap from 1.3 GW in 1947 to 495 GW in 2025! – 350X in 77 Years

*Sources: National Electricity Plan (NEP) 2022-32 by CEA and **https://npp.gov.in**

"**Watt's the Future**" Report by Omniscience Capital – June 2025

Power Demand in BU*	2023	2035
Total Demand – nearly tripling in 12 years!	**1399**	**4041**
Industry	590	1650
Commercial & Services	181	798
Agriculture	241	333
Railways	33	60
Data Centre	-	300
EV – Numbers in million EV – Power Demand in BU	3.9 25	162 162
Per Capita Consumption (kWh)	**1400**	**2575**
*BU is one billion kWh or Trillion Watt-Hour		

Omniscience Capital Report estimates INR 60-65 Lakh Crore (trillion) investment between 2025 and 2035 in the Indian Power Sector

The Evolving Power Sector Landscape

The Globally the Power Sector is undergoing a paradigm shift driven by Five major transitions:

- **Decarbonization**
- **Digitalization**
- **Decentralization**
- **Disintermediation**
- **Decreasing Consumption** (in some geographies)

These changes are creating new challenges:

- **Managing grid complexity and huge variabilities in generation and demand**
- **Managing two-way power flows on distribution grids**
- **Containing operational costs while meeting sustainability goals**

Energy Transition Scenario – Global Perspectives

- **137 countries, 330 cities and 1249 companies have set NET ZERO targets** varying from **2035 (Finland) to 2070 (India);** EU, UK, USA, Canada**,** Brazil etc. by 2050, China and Russia by 2060.
- 27 countries have legally binding Net Zero laws, 24 have issued policies; rest of them issued pledges
- **100+ companies have pledged to be NET Zero by 2030**: Apple, Alphabet, Meta, IBM, Microsoft, Nvidia, Alibaba, Byte Dance, Costco, Airbus, Boeing; **SBI, TCS and Coal India**
- Electrification has emerged as the main strategy for energy transition – **electrify everything and decarbonize the power sector!**
- Over **2 billion machines** that are presently run on fossil fuels are likely to be electrified in the coming decades
- Global Power Generation Capacity of **9 TW in 2024** is estimated to double to **17-18 TW by 2050**; and to **25 TW by 2070**
- At COP 29, 130 countries pledged to triple RE capacity by 2035
- **80 million kilometers** of new Transmission and Distribution lines to be built in next 25 years at a cost of $21 trillion – almost equivalent to the existing global grid that we bult in 130 years!

Ref: www.zerotracker.net

Key Challenges in the Power Sector

1. **Inaccurate Demand Forecasting:** Leads to planning errors and imbalance costs
2. **Renewable Generation Variability:** Causes grid instability and dispatch challenges
3. **Project Delays and Cost Overruns:** Due to poor planning, risk management, and coordination
4. **Unplanned Equipment Failures:** Reactive maintenance increases downtime and costs
5. **Suboptimal Plant Operations:** Inefficient control settings reduce output and raise emissions
6. **Grid Congestion and Power Quality Issues:** With rooftop solar and EV loads on distribution grid
7. **Limited Visibility into Asset Health:** Legacy systems lack predictive diagnostics
8. **Manual, Inefficient Market Operations:** Bidding and trading decisions lack real-time intelligence
9. **Cybersecurity Threats:** Increased exposure due to digitization of assets and systems

Digital Technologies could help resolving many of these challenges

Digitalization of Utilities – Enabler for Energy Transition

- Digital Utilities can **Optimize Asset and Operations** with Advanced Analytics supported by AI and ML leading to:
  - ***Granular estimation of demand to avoid excess generation capacities***
  - ***Visibility of power flows in real-time to avoid overloading and excess capacities***
  - ***Defer costly system upgrades through efficient management of existing resources***
  - ***Engaging customers through digital platforms for innovative programs***
- Digitalization of Utilities facilitates integration of **Distributed Energy Resources (DER)** and **Electric Vehicles** to achieve **Emission Reduction/NDC** targets
- Digital Utilities can balance Demand and Supply in real-time through **Demand Response, ToU** and other programs
- Digital Utilities can Increase **Power System Flexibility** – Energy Storage Systems (ESS), Smart Microgrids, EV Integration, Virtual Power Plants (VPP)

Digitalization of Utilities - Objectives, Strategy and Roadmap

Digitalization of Utilities

➢**DIGITALIZATION** means using digital technologies to fundamentally change how we develop and operate the electricity network to deliver an economic and efficient service for customers: **USING DATA**

➢**DIGITIZATION** is the process of collecting information about the electricity grid using sensors and control equipment - collecting some information for the first time and converting analogue information into digital data that can be processed by computers for digitalization: **COLLECTING DATA**

OBJECTIVES

SINGLE SOURCE of the TRUTH for the DATA that provides greater detail for ALL stakeholders

Convert the DATA in to useful INFORMATION to benefit customers, deliver insight for network planning and launch new services

STRATEGY

Digitalization Strategy to be aligned with the **Business Strategy, Innovation Strategy, Digital Strategy** and **IT Strategy:**

- Using the Business Strategy as a foundation to develop solutions to meet the changing business and customer needs - ***FORWARD RADAR***
- Leveraging innovation programs to develop next level of data and digitalization solutions
- Future IT developments are suitably aligned to the needs of future business operations
- As the volume of data increases, the digital strategy is aligned to facilitate the changes
- Present the information in the right format and timescales

ROADMAP

- Data Visibility
- Infrastructure and Asset Visibility
- IT-OT Integration and Operational Optimization
- Open Markets
- Agile Regulations

SMART METERING IS THE KEY FIRST STEP IN THE DIGITALIZATION JOURNNEY FOR UTILITIES

Digitalization – Facilitators

➢IT Systems – to be rationalized and modernized

- Replacing and upgrading ad-hoc legacy applications; embracing and investing in new technologies, integration tools and common data platforms. **IT Systems will also need to be further integrated with operation technologies related to power delivery systems**.
- IT systems have traditionally been focused on the core principles of security, reliability and resilience; but now must move to a culture of open data and digitalisation - make systems more accessible, agile and adaptable to change, whilst continuing to **enhance Cyber Security controls**.
- A **Hybrid Cloud Architecture**, utilising infrastructure, platform and software as a service solutions (**IaaS, PaaS and SaaS**)

➢Telecommunication - modern, robust and secure telecoms systems

- As the **numbers of assets and equipment connected to the network increase**, the cost and capability of managing the monitoring and control using **traditional radio telecoms will become restrictive**
- The **radio infrastructure for future network need to be scalable for future network growth and data demands**, whilst ensuring efficiency, effectiveness in operation, **resilient to power failure and to be at the point of need**
- **Coordination between digitalisation, innovation and telecoms** to ensure solutions meet the needs of today, tomorrow and beyond

Challenges of Digitalization (1/2)

- **AWARENESS** – across the organization
  - Understanding the **Benefits of Digital Technologies**
  - Need for a **Smart Grid Roadmap** for Digital Utility Transformation
  - **IT - OT Integration Architecture** and Business Process Realignment
  - Global Practices – what worked well and what did not
- **POLICY AND REGULATORY SUPPORT**
  - Strong **MANDATE** from Governments and Utility Management to undertake Digitalization in a well planned manner
  - Regulatory support for pilot projects – **Regulatory Sandboxes**
  - **Business Models** for Return on Investments in New Technologies
- **SKILLED WORKFORCE**
  - **Training and Reskilling** of workforce across the organization on new systems
  - **Retaining Trained Personnel** in respective functions – despite promotions/retirements until next in line are capable of maintaining the systems
  - Adequate **Budget for Training** and capacity building to be provisioned in the project estimate
  - For COTS software trained personnel available in the market
- **CUSTOMER ENGAGEMENT**
  - Customers to be trained and engaged in using new systems and programs

Challenges of Digitalization (2/2)

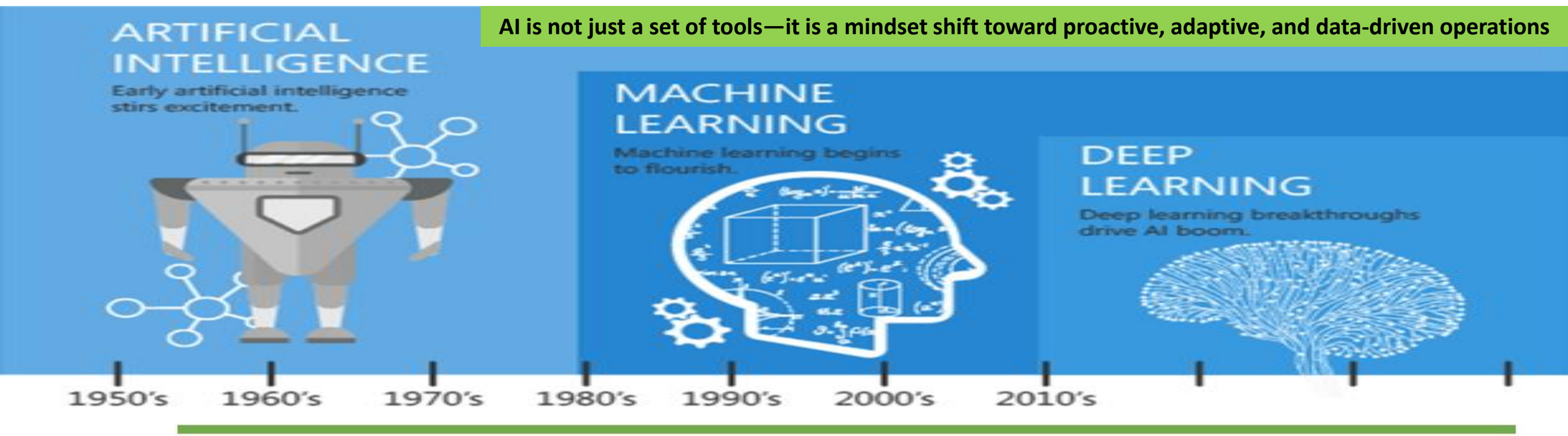
- **TECHNOLOGY**
  - **COTS** v/s **home grown** or **proprietary systems**
  - **Legacy Systems** – retire or retain ?
  - How to **integrate legacy systems** with proprietary protocols? In most cases APIs may not help end to end integration
  - Integration of **OT-IT** systems
  - **IT Architecture** – Service Oriented Architecture (SOA) with micro-services and state-of-the-art middleware and data historians
  - **Communication Systems** – ubiquitous and secure communication systems to connect different devices on the grid, customer premises, field offices, regional offices and HQ
  - **Own Data Centre** v/s **Cloud Services** v/s **Hybrid Models**
  - **Analytical Tools** - appropriate tools to analyze the humungous data generated from digitization
  - **Cyber Security** – by design

Artificial Intelligence (AI)

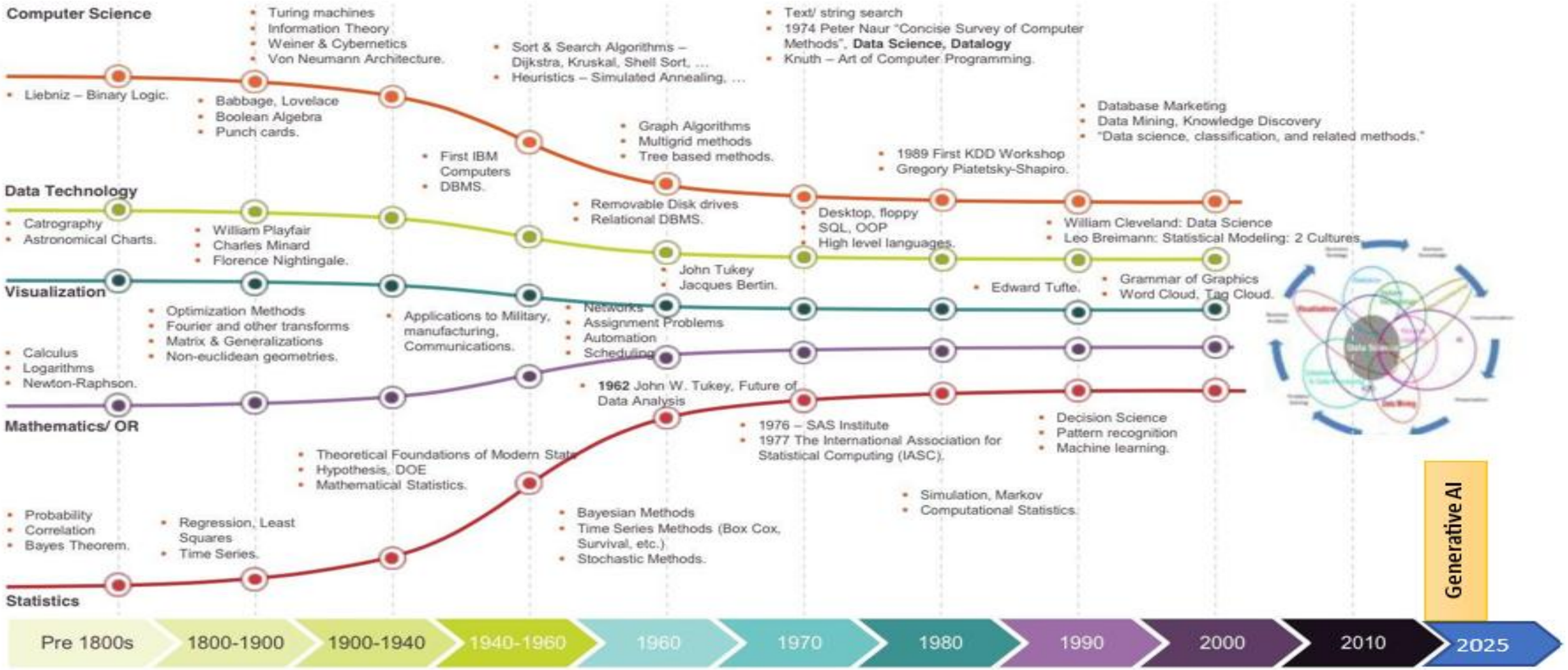
Artificial Intelligence (AI) refers to computational techniques that enable machines to mimic human intelligence. In the power sector, AI enhances planning, operation, and decision-making through:

- **Machine Learning (ML):** Learning from historical data to predict outcomes
- **Deep Learning (DL):** Analyzing complex data like images or time-series signals
- **Computer Vision:** Processing images from drones and CCTV for visual inspections
- **Natural Language Processing (NLP):** Interpreting reports, documents, or speech inputs
- **Reinforcement Learning:** Self-learning algorithms for control and optimization

AI is not just a set of tools—it is a mindset shift toward proactive, adaptive, and data-driven operations



History of Computing and AI Development

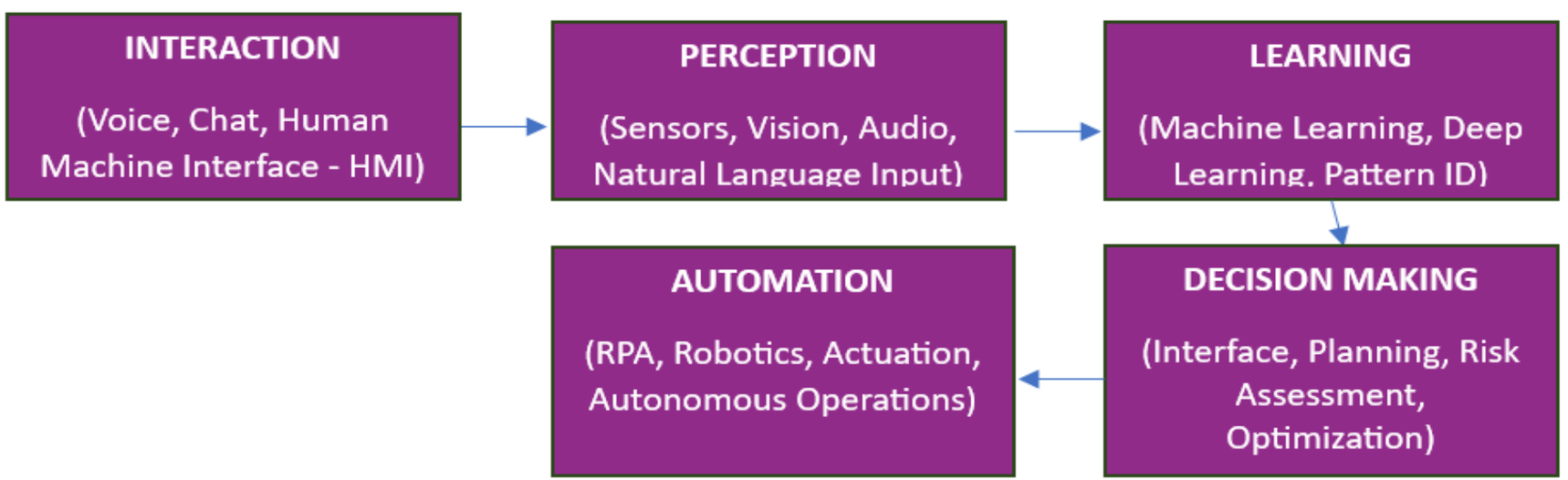


Types and Functional Layers of AI

Types of AI

- Artificial Narrow Intelligence (ANI)
- Artificial Social Intelligence (ASI)
- Generative AI
- Artificial General Intelligence (AGI)
- Digital Super Intelligence (DSI)
- Augmented Intelligence

Functional Layers of AI



Programming Languages for AI Development (1/2)

Sl No	Language	Features	Use Cases
1	Python	Easy syntax, rapid prototyping, and large ecosystem of libraries such as TenserFlow, PyTorch, Hugging Face Transformers, Keras, Scikit-learn etc	Over 80% of AI projects are powered by Python. Natural language processing (Chatbots) image generation (Stable Diffusion), Research, prototyping, model building, model training
2	Julia	Gaining traction for high performance numerical computing applications. Ideal for scalable GenAI simulations. Libraries include Flux.ji, Gen,ji etc. 50% YoY growth in recent years	Good for crunching large matrices and linear algebra data. Reinforcement Learning, real-time GenAI models
3	Rust	Good for edge AI, embedded systems, deploying GenAI Models with constrains; better where safety, memory-control and speed matter. Libraries are tch-rs, ndarray, burn etc	Used for AI Tooling and Inference Engines, Edge AI deployments, Safe GenAI pipelines, Systems-level optimization
4	R	Statistical prowess and visualization; good at exploratory data analysis for GenAI datasets. Caret is a key library; used in Random Forest ML algorithm	Statistical modelling, GenAI evaluation such as bias detection, bioinformatics. Growing fast in academia and research circles

Programming Languages for AI Development (2/2)

Sl No	Language	Features	Use Cases
5	Java	Enterprise scalability, multithreading, robust for integrating GenAI into large apps. Libraries are: Deeplearning4j, Weka, Apache Mahout	Recommendation systems, Android GenAI apps
6	Java Script	Web-native, enables browser based GenAI demos and real-tome apps. Libraries: TensorFlow.js, Brain.js, ml5.ja	Interactive GenAI tools, web ML prototypes
7	Mojo	Python compatible with hardware acceleration; capable of AI specific optimizations	GenAI training on GPUs/TPUs, efficient inference; though introduced in 2024, several startups are using Mojo with 10X speedups
8	Lisp	Symbolic AI and metaprogramming; now popular for advanced GenAI logic. Library is CLML	Knowledge representation, theorem proving in GenAI
9	C++	Low level control and speed; good for optimizing GenAI models at runtime. Libraries are TensorFlow C++ API, OpenCV, Caffe	High performance computing and Robotics
10	Swift	Modern, safe and optimized for Apple ecosystem GenAI. Libraries are Core ML, Create ML	iOS/macOS apps like on-device GenAI

AI Tools – Open Source v/s COTS

Commercial Off The Shelf (COTS) Tools

- MS EXCEL
- SAS
- SPSS
- KXEN
- MATLAB
- Angoss
- Statistica
- Tableau

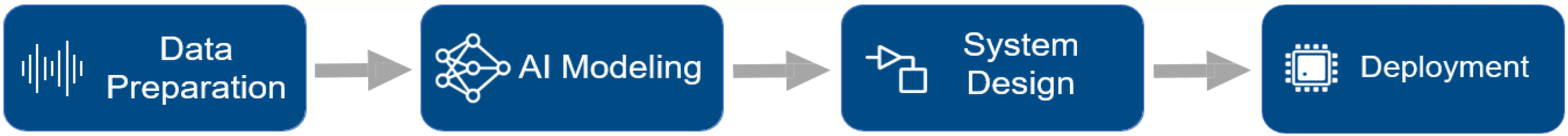
Open Source

- R
- Weka
- Python
- Julia
- Java

Popular Tools

- R
- Python
- SAS
- SPSS
- MATLAB
- KXEN
- Tableau
- Orange

AI Workflow



Data Preparation

- Data cleansing and preparation
- Human insight
- Simulation-generated data

AI Modeling

- Model design and tuning
- Hardware accelerated training
- Interoperability

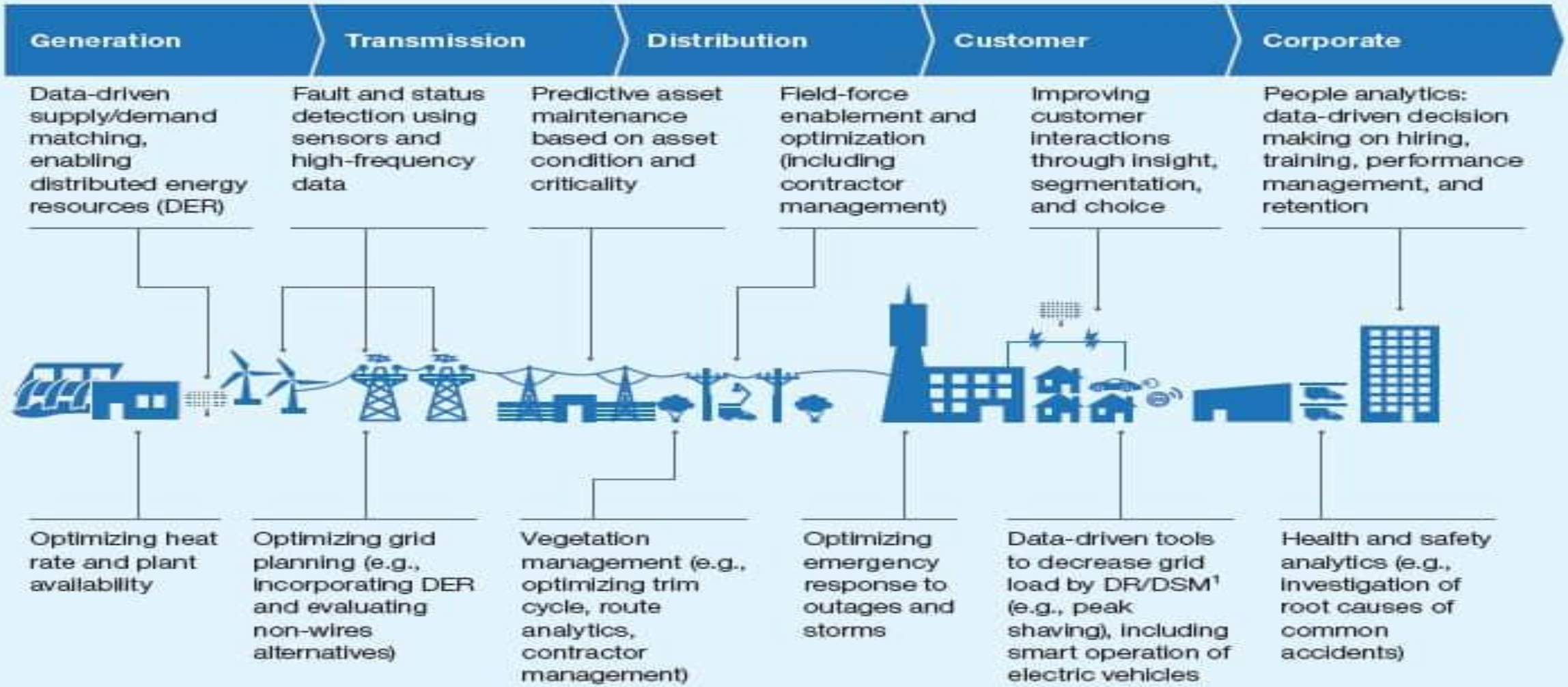
Simulation & Test

- Integration with complex systems
- System simulation
- System verification and validation

Deployment

- Embedded devices
- Enterprise systems
- Edge, cloud, desktop

Applications of AI and ML in the Power Utility Value Chain



Key Domains for AI and Advanced Analytics

Customer Operations

Use Cases across...

1. Customer Strategy
2. Customer Operations
3. Revenue Cycle
4. Products & Services

...that will:

- Enhance cust. experience
- Automate low value interactions

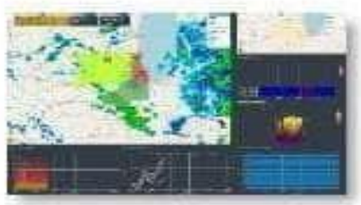
Grid

23 Use Cases across...

1. Asset Management
2. Grid Operations
3. Extended Systems

...that will:

1. Improve Reliability
2. Improve Customer Sat.
3. Reduce O&M Expenses
4. Capture new Revenue

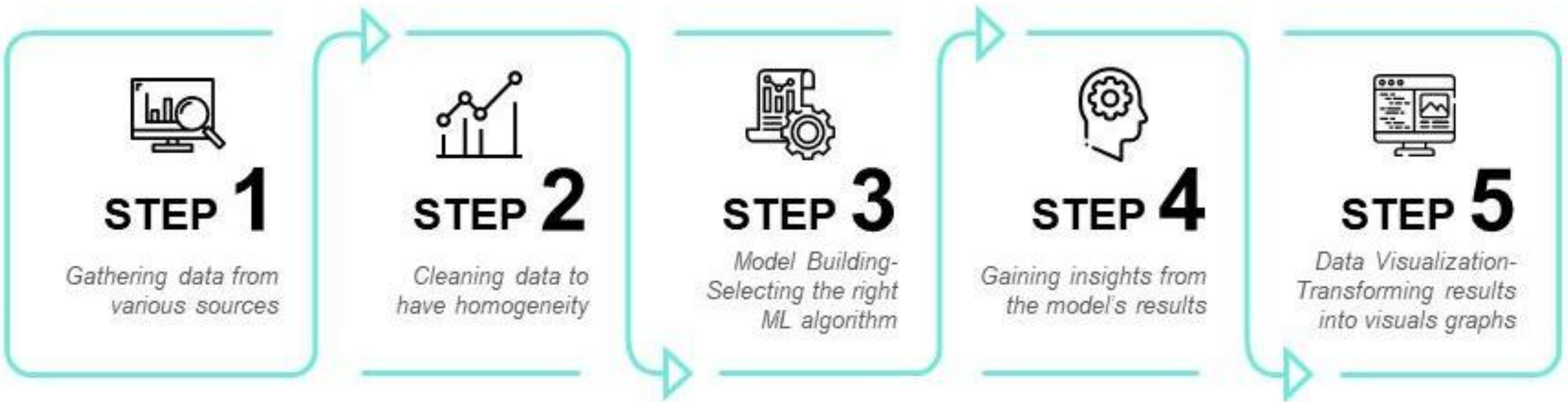


Advanced Metering Infrastructure

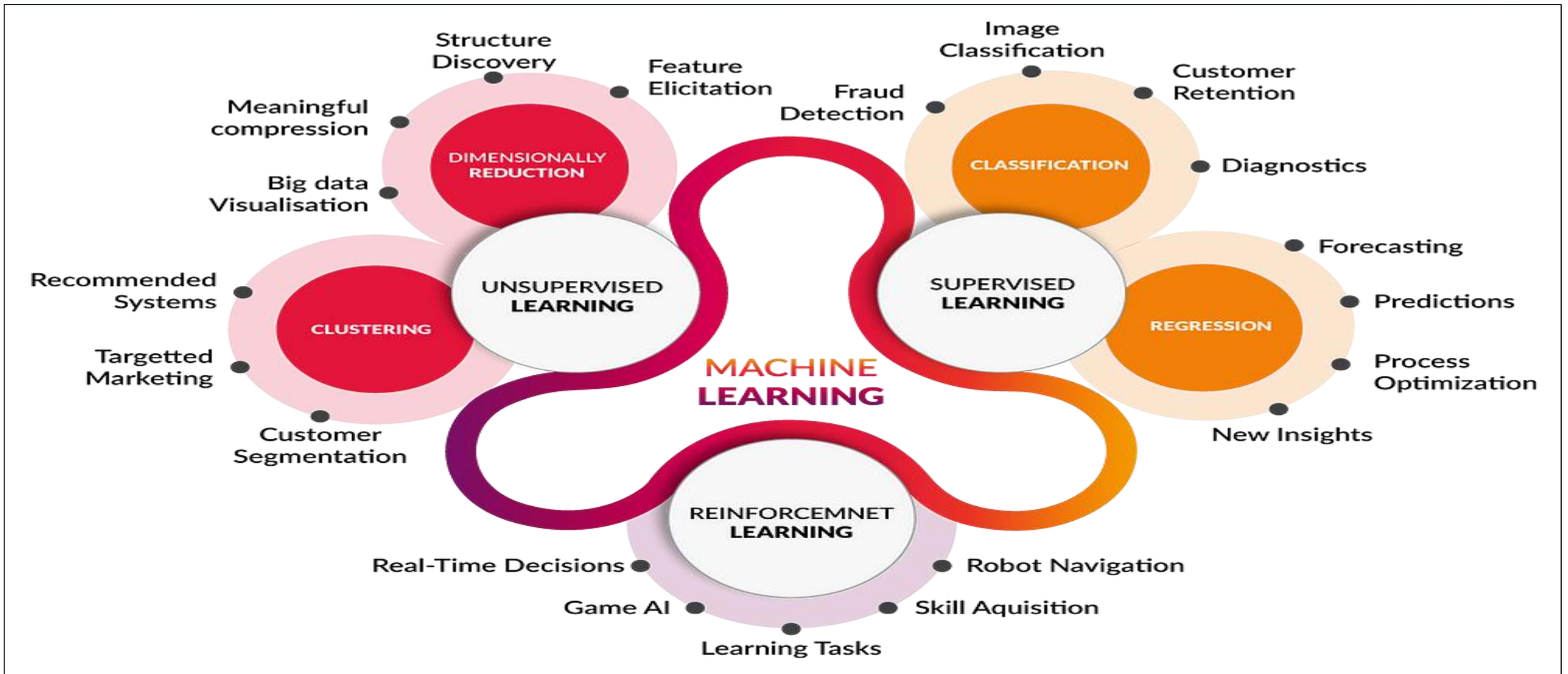
33 Use Cases across:

1. Meter Operations
2. Network Operations
3. Theft Detection
4. Inactive Meters

Machine Learning - Process



Types of Machine Learning



Comparison of Machine Learning Categories

Category	Supervised Learning	Unsupervised Learning	Deep Learning	Ensemble Learning
ML Techniques	➢ Classification ➢ Logistic/Linear Regression ➢ Multivariate Regression	➢ Clustering ➢ Natural Language Processing (NLP)	Neural Networks	Random Forest
Potential Customer Problem	➢ Classifying product segments ➢ Predicting machine problems to avoid downtime ➢ Identifying linear patterns in machine behaviour	Identifying similarities or characteristics e.g. if it is shaped like a car, it could be grouped as a car	Solving complex problems involving multimodal inputs (e.g., smart plant facility)	Capturing nonlinear and probabilistic relationships between an outcome and its components using Bootstrap Aggregation
Data/Input Format	Structured imagery, numeric, strings /characters, sensory data with well identified labels	Unstructured imagery, numeric, strings /characters, sensory data with semi identified labels	Multiple structured data types e.g. imagery, audio, numeric, strings /characters, sensory etc. from multiple sources	Structured imagery, numeric, strings /characters, sensory data with well identified labels
Applications	➢ Predictive and prescriptive maintenance ➢ Predictive decision support ➢ Production optimization ➢ Product optimization ➢ Product segmentation ➢ Predictive root cause analysis ➢ Asset management and quality control	➢ Pattern processing ➢ Anomaly or defect detection for quality control ➢ Asset performance management ➢	➢ Complex production optimization ➢ Quality control ➢ Speech and pattern recognition ➢ Complex anomaly detection ➢ Autonomous processing ➢ Asset management	➢ Powerful and accurate Predictive and prescriptive maintenance ➢ Predictive decision support ➢ Product segmentation ➢ Predictive root cause analysis ➢ Asset performance analysis and quality control ➢

AI Use Cases in Power Sector (1/6)

- **Predictive Maintenance of the Power Infrastructure**: Predictive maintenance models designed using AI algorithms to monitor the condition of critical power assets such as power plants, wind turbines, solar farms, transformers, substations, and transmission and distribution lines. By analysing real-time data from IoT sensors, historical performance metrics, and environmental conditions, AI tools can detect early signs of wear and tear, and potential faults to undertake predictive maintenance – help meet regulatory compliances (SAIDI/SAIFI/CAIDI/CAIFI) and significantly improving customer satisfaction by ensuring uninterrupted power supply.
- **Renewable Energy Forecasting**: AI could play a crucial role in improving the accuracy of renewable energy (RE) generation forecasts, especially for variable sources like solar and wind. Using advanced machine learning models, AI tools could analyse historical generation data, weather forecasts, and satellite imagery to predict energy output with higher precision. More accurate forecasting ensures efficient utilization of renewable energy, reduce RE curtailments, reduce reliance on fossil fuel-based backup generation, and improved grid stability
- **Grid Management with DER**: Through advanced analytics, AI tools could identify grid imbalances, predict fluctuations in demand and supply, and adjust power generation and distribution accordingly. This leads to improved grid stability and reduced transmission losses. AI-powered systems can also automate fault detection and self-healing processes, ensuring faster recovery from outages.

AI Use Cases in Power Sector (2/6)

- **Power Theft Detection**: Power theft remains a significant challenge in many places in India, contributing to high AT&C losses. AI-based systems could analyse consumption patterns, meter data, and historical usage to detect irregularities and potential cases of unauthorized electricity usage. By deploying machine learning algorithms, utilities can identify theft-prone regions, predict future occurrences, and prioritize inspection efforts. These systems can also differentiate between technical losses and deliberate tampering, ensuring targeted interventions.
- **Dynamic Load Forecasting**: AI-driven dynamic load forecasting models play a critical role in distribution network management by accurately predicting electricity demand at granular levels, such as feeder, transformer, and consumer clusters. By analysing real-time data of energy consumption patterns, weather conditions, and regional demand trends, AI enables utilities to forecast load variations with high precision. This allows for better distribution system planning, reducing the risk of overloading or underutilization of network assets. Additionally, accurate load forecasting reduces the power purchase cost, minimizes technical losses, improves voltage stability, and enhances the reliability of supply.
- **Integration of Electric Vehicles**: AI tools are necessary for efficient management of EV charging operations by optimizing charging schedules with respect to other must-run loads on the distribution grid. ML models predict charging demand based on user behaviour, traffic data, and weather conditions, ensuring efficient utilization of charging infrastructure. AI also enables vehicle-to-grid (V2G) interactions, where EVs can act as distributed energy resources, contributing to grid stability during peak demand periods. AI-driven solutions are essential for managing the rapid growth of EV adoption in India.

AI Use Cases in Power Sector (3/6)

- **Power Trading Optimization**: AI tools transforms power trading by analysing real-time market data, forecasting price trends, and automating bidding strategies. It enables utilities and independent power producers to make informed decisions about power purchases and sales, maximizing revenue and minimizing costs. AI algorithms also identify arbitrage opportunities, optimize contract structures, and manage risk associated with price volatility. This enhances transparency and efficiency in power markets, fostering competition and benefiting end consumers through lower electricity costs.
- **Optimization of Energy Storage Systems**: AI enables intelligent management of energy storage systems (ESS), ensuring their efficient integration into the grid. By analysing grid demand patterns, renewable energy availability, and market price signals, AI can optimize charge and discharge cycles of energy storage systems. This enhances their operational efficiency, reduces degradation, and extends the lifespan of storage assets.
- **Tripping Analysis at Grid / Substation Level:** Deploying AI and ML models for analysing of tripping at the grid or substation level may help effectively examine factors like tripping frequency, voltage levels, fault locations, restoration time, and fault details. By analysing these parameters, utilities can identify patterns and vulnerabilities in specific regions, equipment, or voltage ranges. This helps improve grid reliability, reduce outages, and enhance fault resolution, leading to more efficient and resilient power supply.

AI Use Cases in Power Sector (4/6)

- **Distribution Transformer Monitoring:** Failure of distribution transformers (DTs) is one of the major issues plaguing in the DISCOMs in India. With the help of AI monitoring of distribution transformers may be made robust enough to ensure their optimal performance and predict potential issues. Key variables including the transformer's age, temperature (oil and gases), loading, frequency, user type, dissolved gases in the oil, Buchholz and other relay's breakdown / fault details etc maybe mapped into the AI model to help predict the transformer's lifespan and schedule predictive maintenances, accordingly.
- **Network Reliability Analysis and Regulatory Compliance:** Since reliability indices like SAIFI, SAIDI, CAIFI, CAIDI etc are the most vital and comprehensive indicators of a distribution utility's operational performance, utilizing AI tools can offer valuable insights for reliability improvement by focusing a deep-down analysis on factors like geographic division, contribution of fault types, seasonality effect in reliability, impact of weather factors – wind, precipitation, fog, temperature, etc.
- **Revenue Maximization:** Distribution utilities face challenges in collecting revenue efficiently and timely and seeks ways to receive payments earlier. By deploying AI and ML technologies, utilities can implement solutions like payment behaviour analytics, customer risk scoring models, and customer default forecasting to enhance revenue collection. AI-driven payment behaviour identifies trends and predicts payment patterns, allowing utilities to proactively engage with at-risk customers. Risk scoring models assess customer creditworthiness, enabling targeted follow-ups and flexible payment terms for high-risk accounts. Additionally, forecasting models can predict potential defaults, helping utilities take preventive actions and improve cash flow.

AI Use Cases in Power Sector (5/6)

- **Textual Data Analytics – Insights from Call Logs:** Analysis of customer service calls and call logs having valuable textual information about issues reported by customers or field teams will help capture details such as the nature of customer complaints, power outages, fault reports, service requests, and maintenance activities. By applying AI tools for data analysis, utilities can extract meaningful insights from this unstructured data. For instance, AI can identify common fault patterns, detect recurring issues in specific areas, and track the frequency and severity of outages. Analysis of customer feedback from these logs helps utilities understand service quality and identification of areas requiring improvement.
- **SCADA Analytics:** Transmission and Distribution utilities face challenges in managing massive SCADA data, analysing historical network behaviour, and linking events to corresponding measurements. By modelling the electrical network using AI based solutions, utilities may simulate scenarios, evaluate the impact of operational changes, and ensure the optimal configuration of assets. This is especially critical for high-voltage networks where reliability and safety are paramount.
- **Training Simulations using Virtual Reality and Metaverse:** Virtual Reality (VR) could transform the training and skill development in the power sector by providing a safe and immersive environment. It allows users to interact with virtual objects and scenarios, offering realistic simulations for complex or high-risk tasks, such as working on live power lines. VR enables workers to practice procedures in a controlled setting, reducing on-the-job accidents and fatalities. It improves knowledge retention of safety protocols and enhances skill development through hands-on experience.

AI Use Cases in Power Sector (6/6)

- **Augmented Reality (AR), Assisted Reality (aR), and Digital Twin based Applications**: The deployment of Augmented Reality (AR), Assisted Reality (aR), and Digital Twins in the power sector may be a revolutionary step toward enhancing operational efficiency, safety, and knowledge management. Digital twins are virtual replicas of physical assets or systems, which can integrate seamlessly with AR/aR to provide immersive, real-time overlays of system conditions, enabling field personnel to visualise and interact with operational data in context. This combination allows remote maintenance and troubleshooting by displaying live system data and offering expert guidance directly to field workers on-site. AR-powered training, supported by Digital Twin simulations, offers hands-on learning experiences using interactive visuals on equipment.
- Key applications include capturing expert knowledge, remote support, virtual installations, digital audits, inspections, and evolving to a predictive maintenance regime, making power systems smarter, safer, and more reliable.
- **Robotics Solutions:** Robots could play a big role in inspecting and maintaining power stations, wind turbines, solar farms, power transmission lines, substations, distribution equipment, and detecting faults, making these tasks safer and more efficient. In renewable energy, robots could improve how solar panels are cleaned and wind turbines are inspected, helping them work better. Drones could also make it easier to inspect power lines, carry-out aerial surveys for identifying load growth areas, identifying illegal constructions and growth of vegetation near / under power lines etc.

Comparison of Machine Learning Models

Category	Supervised Learning	Unsupervised Learning	Deep Learning	Ensemble Learning
ML Techniques	• Classification • Logistic/Linear Regression • Multivariate Regression	• Clustering • Natural Language Processing (NLP)	Neural Networks	Random Forest
Potential Customer Problem	• Classifying product segments • Predicting machine problems to avoid downtime • Identifying linear patterns in machine behaviour	Identifying similarities or characteristics eg: if it is shaped like a car, it could be grouped as a car	Solving complex problems involving multimodal inputs (eg: smart plant facility)	Capturing nonlinear and probabilistic relationships between an outcome and its components using Bootstrap Aggregation
Data/Input Format	Structured imagery, numeric, strings /characters, sensory data with well identified labels	Unstructured imagery, numeric, strings /characters, sensory data with semi identified labels	Multiple structured data types eg: imagery, audio, numeric, strings /characters, sensory etc from multiple sources	Structured imagery, numeric, strings /characters, sensory data with well identified labels
Applications	• Predictive and prescriptive maintenance • Predictive decision support • Production optimization • Product optimization • Product segmentation • Predictive root cause analysis • Asset management and quality control	• Pattern processing • Anomaly or defect detection for quality control • Asset performance management	• Complex production optimization • Quality control • Speech and pattern recognition • Complex anomaly detection • Autonomous processing • Asset management	• Powerful and accurate Predictive and prescriptive maintenance • Predictive decision support • Product segmentation • Predictive root cause analysis • Asset performance analysis and quality control

Machine Learning Applications in the Power Utility Domain (1/3)

Algorithm / Approach	Applications in the Power Utility Domain
Supervised Learning	➢ Revenue Maximization and Customer Risk Scoring ➢ Load and Price Forecasting ➢ Power Quality Event Classification
Unsupervised Learning	➢ Customer Profiling and Consumption Segmentation ➢ Detection of Abnormal Load or Theft Patterns ➢ EV-charging behaviour clustering
Ensemble Learning	➢ Loss Reduction – Identification of Pilferage Points ➢ Power Theft and Non-Technical Loss Classification ➢ Transformer Failure and Fault Prediction
Automated Machine Learning (AutoML)	➢ Automated Model Selection for Forecasting and Procurement ➢ Optimisation of Power Procurement Strategy considering Distributed Generation (DG) and Storage ➢ Predictive Analytics for Energy Trading and Market Participation

Machine Learning Applications in the Power Utility Domain (2/3)

Algorithm / Approach	Applications in the Power Utility Domain
Deep Learning (DL)	➢ Image Analytics – Solar Module, Drone and Thermal Imaging for Asset Condition Monitoring ➢ Automated Meter Reading and Visual Inspection (CNN/YOLO) ➢ Physics-Informed DL for Power Electronics and Grid Simulation ➢ Digital Twin Modelling of Substations and Generation Assets
Recurrent Neural Network (RNN)	➢ Customer Complaint and Sentiment Analytics ➢ Call Log and Communication Insights ➢ Energy Market and Price Prediction ➢ Load Forecasting with Temporal Correlation
Artificial Neural Network (ANN)	➢ Network Reliability Prediction (SAIFI, SAIDI, CAIFI, CAIDI) ➢ Transformer Ageing and Health Assessment ➢ MV/LV Feeder Alarm Analytics ➢ Voltage Profile Optimisation

Machine Learning Applications in the Power Utility Domain (3/3)

Algorithm / Approach	Applications in the Power Utility Domain
Reinforcement Learning (RL) / Multi-Agent Learning	➢ Real-Time Grid Control and Adaptive Demand Response ➢ Distributed Energy Resource (DER) Coordination ➢ Microgrid Energy Management and Storage Dispatch ➢ Dynamic Tariff and Load Balancing Decisions
Explainable AI (XAI)	➢ Transparent and Auditable ML Models for Regulatory Compliance ➢ Root-Cause Analysis for Grid Failures ➢ Model Explainability in Predictive Maintenance
Generative AI (GenAI)	➢ Intelligent Virtual Assistants for Customer Support ➢ Automated Report and Insights Generation ➢ Synthetic Data Generation for Model Training and Anomaly Simulation

ML Algorithms for Utility Solutions (1/4)

Algorithm / Technique	Application in Utility Solutions
A) Regression Techniques	
i. Linear Regression	➢ SCADA Data and Alarm Trend Analytics ➢ Transformer Parameter Prediction ➢ Energy Price Correlation Modelling
ii. Polynomial Regression	➢ Load Forecasting under Non-Linear Seasonal Variation ➢ Temperature-Dependent Generation Modelling
iii. Advanced Regression (Lasso, Ridge, ElasticNet, Quantile Regression)	➢ Renewable Forecasting (Solar/Wind) ➢ Battery Ageing and Storage Performance Prediction ➢ Tariff and Market Price Optimisation
B) Classification Techniques	
i. Naïve Bayes	➢ Loss Reduction – Customer Category Pilferage Detection ➢ Power Theft / Non-Technical Loss Classification ➢ Revenue Risk Scoring
ii. Decision Tree	➢ Fault Isolation and Equipment Failure Detection ➢ Consumer Default Risk Prediction

ML Algorithms for Utility Solutions (2/4)

Algorithm / Technique	Application in Utility Solutions
iii. Random Forest	➢ Predictive Maintenance of Transformers and Feeders ➢ Cyber-Anomaly Detection in Grid Communications
iv. Support Vector Machine (SVM)	➢ Power Quality Event Classification ➢ Voltage Sag/Swell Identification ➢ Intrusion Detection in Smart Meters
v. Logistic Regression *(estimates probabilities for classification)*	➢ Customer Churn / Payment Default Prediction ➢ Demand Response Participation Likelihood
vi. K-Nearest Neighbour (KNN)	➢ Load Pattern Classification ➢ Demand Response Event Grouping
vii. Gradient Boosting Algorithm (GBA)	➢ Power Loss Prediction ➢ Transformer Failure Probability Scoring
viii. Adaptive Boosting (AdaBoost)	➢ Real-time Fault Classification in Distribution Networks
ix. Extreme Gradient Boost (XGBoost)	➢ Network Anomaly Prediction ➢ Transformer Condition Assessment
C) Clustering	
i. K-Means Clustering	➢ Customer Segmentation by Consumption Behavior ➢ EV-Charging Pattern Clustering ➢ Detection of Unusual Energy Use Clusters

ML Algorithms for Utility Solutions (3/4)

Algorithm / Technique	• Application in Utility Solutions
ii. Latent Dirichlet Allocation (LDA)	➢ Topic Modelling of Customer Complaints ➢ Sentiment and Feedback Insights from Call Logs
D) Collaborative Filtering	
i. Alternating Least Square (ALS)	➢ Recommendation of Optimal Power Procurement and DER Dispatch Strategy ➢ Personalized Demand Response Incentives
E) Dimensionality Reduction	
i. Principal Component Analysis (PCA)	➢ Reliability Analytics (SAIFI, SAIDI, CAIFI, CAIDI) ➢ Transformer Ageing and Performance Indicators ➢ Feeder Alarm Correlation and Root-Cause Identification
F) Deep Learning	
i. Convolutional Neural Network (CNN)	➢ Automated Meter Reading and Asset Detection ➢ Solar and Wind Asset Image Analytics ➢ Drone-based Inspection of Transmission Towers
ii. Recurrent Neural Network (RNN)	➢ Load Forecasting and Demand Prediction ➢ Complaint Trend and Sentiment Analytics ➢ Energy Market Time-Series Prediction
iii. Artificial Neural Network (ANN)	➢ Reliability Index Prediction ➢ Transformer Health Estimation ➢ Feeder Alarm Correlation and Outage Forecasting
iv. You Only Look Once (YOLO)	➢ Real-Time Visual Detection of Meter Panels and Equipment ➢ Safety Gear and Intrusion Monitoring via CCTV

ML Algorithms for Utility Solutions (4/4)

Algorithm / Technique	Application in Utility Solutions
G) Reinforcement Learning / Multi-Agent Systems	➢ Adaptive Demand-Response Control ➢ DER and Storage Dispatch Optimisation ➢ Peer-to-Peer Energy Trading Strategies ➢ Real-Time Microgrid Operation
H) Explainable AI (XAI)	➢ Interpretability of Fault Classification Models ➢ Transparent Decision-Support for Regulators ➢ Model Accountability and Root-Cause Insights
I) Generative AI (GenAI)	➢ AI-based Customer Chatbots and Virtual Energy Advisors ➢ Automated Report Generation from SCADA/AMI Data ➢ Scenario Simulation and Synthetic Data Generation for Training

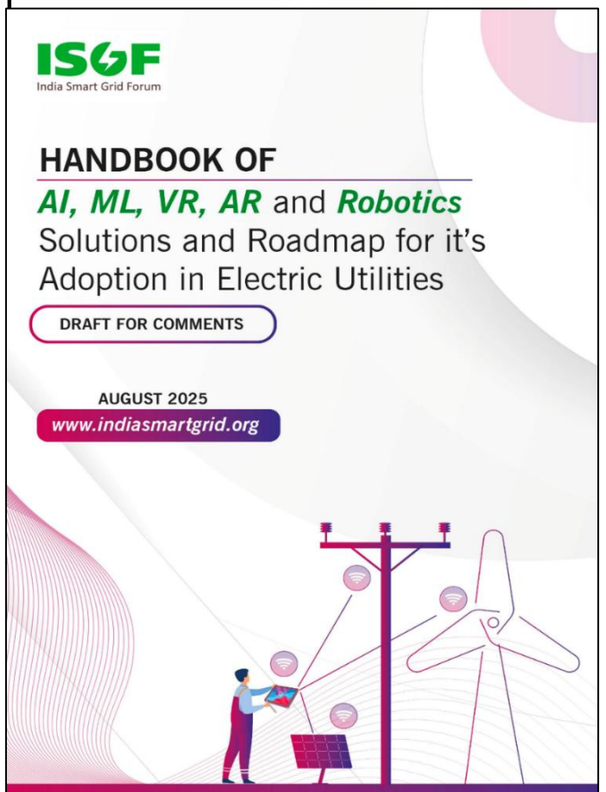
Handbook of AI, ML, VR, AR, aR and Robotics Solutions

Scope and Objectives

- Serve as a comprehensive guide for Indian utilities to evaluate and adopt AI, ML, VR, AR, and Robotics
- Consolidate global and Indian use cases, best practices, and lessons learned
- Outline implementation strategies, challenges, and policy frameworks for large-scale deployment
- Bridge the gap between emerging digital technologies and ground realities of Indian utilities
- Present a structured roadmap for phased adoption with short-, medium-, and long-term milestones
- Guide stakeholders on critical enablers: infrastructure readiness, workforce skilling, and regulatory support

Contents

- Introduction to AI, ML, VR, AR, aR and Robotics Technologies
- **Overview of Successful Use Cases – 174 use cases from 31 countries**
- Policies, Regulations and Standards related to AI, ML, VR/AR and Robotics
- Implementation Roadmap
- **Digital Transformation Case Study of DBS Bank**



Summary of Use Cases Covered Across Power Sector

Use Case Category	Number of Use Cases Covered Category-wise			Total
	Main Report	Appendix A	Appendix B (only web links)	
Generation	8	12	16	36
Transmission	6	9	15	30
Distribution	9	12	21	42
System Operations	8	4	18	30
Power Trading	8	-	10	18
Robotic Process Automation (RPA)	6	-	6	12
Security Operations Centre (SOC)	2		4	6
Total	**47**	**37**	**90**	**174**

The Handbook highlights **174 use cases** of AI/ML, AR/VR/aR, Robotics and Digital Twin technologies across **Generation, Transmission, Distribution, System Operations, Power Trading, RPA,** and **SOC** functions.

45 out of 174 Use Cases are from Indian Utilities

The distribution of use cases highlights the significant emphasis on **Distribution (42)** and **Generation (36)**, reflecting ongoing innovation in asset management, grid monitoring, and consumer services.

ISGF Training Programs

ISGF has been conducting specialized training programs to build capacity of relevant stakeholders since 2013

1. **Smart Grid Foundation Course**: 3 Days Classroom + 2 Days Site Visits
2. **Smart Grid Bootcamp**: 1 Day
3. **Cyber Security for Power Systems**: 2 Days
4. **Advanced Metering Infrastructure**: 2 Days
5. **E-Mobility and Charging Infrastructure**: 2 Days
6. **Certificate Course in Smart Grids**: 10 Weeks

Online Training Programs - Live Classes and Recorded: over 1000 persons trained on this platform since May 2020

1. **Smart Grid Foundation Course: 45 Hrs**
2. **Cyber Security for Power Systems: 14 Hrs**
3. **Advanced Metering Infrastructure: 26 Hrs**
4. **E-Mobility and Charging Infrastructure: 28 Hrs**
5. **Artificial Intelligence and Robotics for Utilities and Smart Cities: 95 Hrs**
6. **Blockchain Applications for Utilities: 27 Hrs**
7. ***Transformer Models and Generative AI Tools: 6 Hrs***
8. ***Technical Training on OCPP: 4 Hrs***

ISGAN Award of Excellence 2022

In recognition of ISGF's pioneering role in training and capacity building of workforce for electric grid modernization and energy transition, prestigious ISGAN Award of Excellence 2022 was conferred on ISGF.

Award of Excellence
Winner | 2022

Recognizing excellence in smart grid projects around the world

WINNER

The ISGAN Awards of Excellence 2022,
in partnership with the Empowering People Initiative
for

Smart Grid Workforce Development for an Inclusive Energy Transition

has been awarded to

Development of Smart Grid Ecosystem
India Smart Grid Forum

23 September 2022

Luciano Martini
Chair
International Smart Grid Action Network

Arsenio Hollas
Lead
Empowering People Initiative

International Smart Grid Action Network (ISGAN)
www.iea-isgan.org

ISGF's Recently Completed Projects

Demonstration of Vehicle to Grid Technology in India and Charging of EVs with Green Electricity

India Smart Grid Forum

- The batteries in EVs are charged with electricity from the grid; and the EV batteries can send electricity back to the grid during peak hours to support the grid. This technology is called **Vehicle-to-Grid or V2G**
- ISGF has demonstrated AC V2G successfully in technical collaboration with University of Delaware, USA – **retrofitted 4 Tata Nexon EVs**
- The **11kW Bidirectional Modular Power Unit (BMPU)** installed in the Tata Nexon were procured from Watt&Well, USA and the **AC bidirectional chargers (19 ~ 52 kW)** were procured from Nuvve Holding Corp, USA.

Technology Partners:

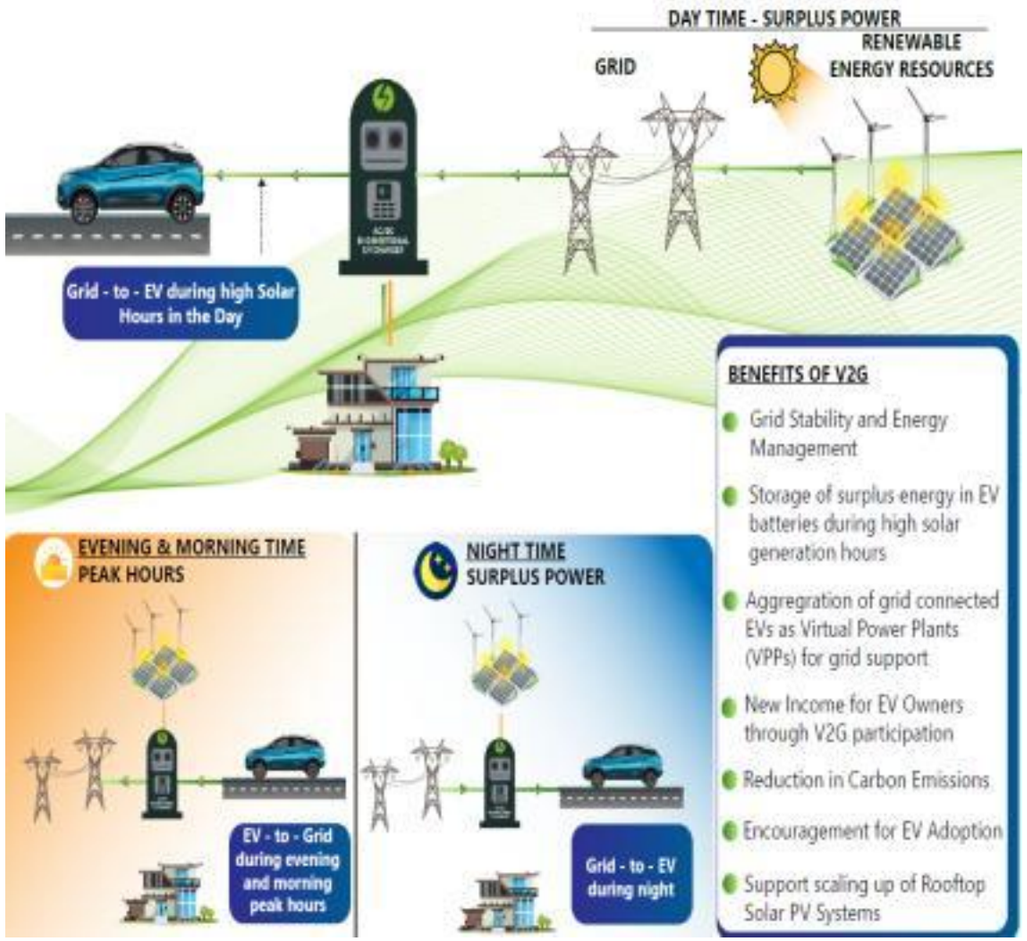
- University of Delaware (UDEL) – Technology Support
- Nuvve Holding Corp – Bi directional Charger
- Watt & Well - BMPU

Project Partners and V2G Demonstration Sites:

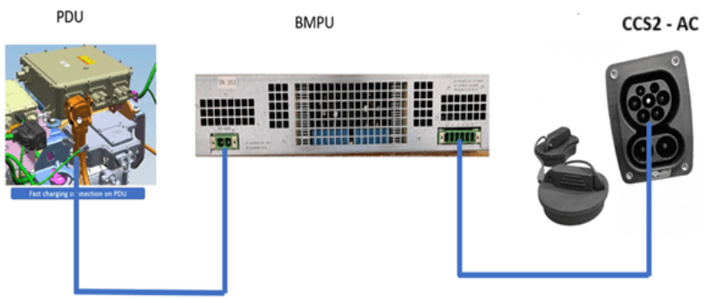
- BSES Rajdhani Power Limited (BRPL), Delhi
- BSES Yamuna Power Limited (BYPL), Delhi
- Tata Power Delhi Distribution Limited (TPDDL), Delhi
- Agency for New and Renewable Energy Research and Technology (ANERT), Trivandrum, Kerala

Project Observers:

- Central Electricity Authority
- Tata Motors Limited and Tata EV



V2G Pilot Project in India



Architecture

Bidirectional Modular Power Unit (BMPU)

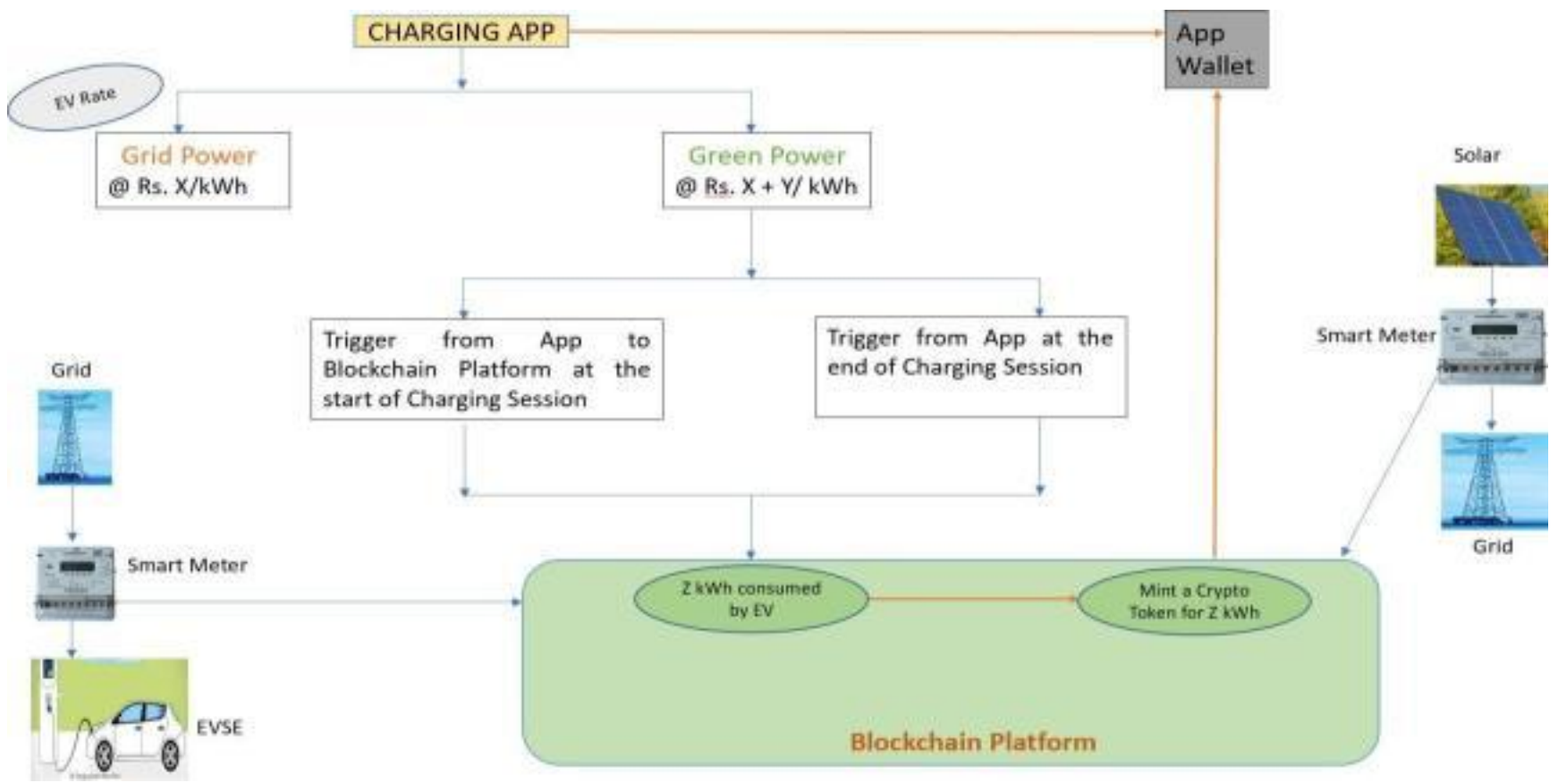
Bidirectional Charger

EV Communication Controller

Charging of EVs with Green Electricity – First Time in the World

- ISGF with technical support from **KrypC Technologies, EarthtronEV, Kimbal and ElectreeFi** successfully tested charging of EVs with green electricity in Delhi and issued Green Energy Certificates on Blockchain platform Crypto Tokens.

Framework



Green Energy Certificate

Electrifying Agriculture: A Sub-National Roadmap for the Adoption of Electric Tractors

- Nearly 55% of Indian population involved in Agriculture
- Tractors play a crucial role in increasing farm productivity through mechanization of several agricultural operations
- Mechanization is growing fast — tractors alone make up **80% of the Agri-machinery** market
- Tractors significantly reduce the **time required for planting, irrigating, harvesting and transportation of the crops**
- According to the Ministry of Environment, Forest, and Climate Change, the agriculture sector accounts for **nearly 18.4% of India's total greenhouse gas emissions**, with diesel powered machinery being a major contributor
- Diesel powered machinery, notably tractors, accounts for approximately **12-18%** of the total cost of agricultural production and Tractors account for about **7.4% of India's annual diesel consumption**
- **Maharashtra is one of India's leading states**, both economically and agriculturally, with ample production of important food and cash crops, including sugarcane and flowers etc.
- India Smart Grid Forum (ISGF) undertaken Feasibility Study on **"Electrifying Agriculture: A Sub-National Roadmap for the Adoption of Electric Tractors in Maharashtra" in 2025**

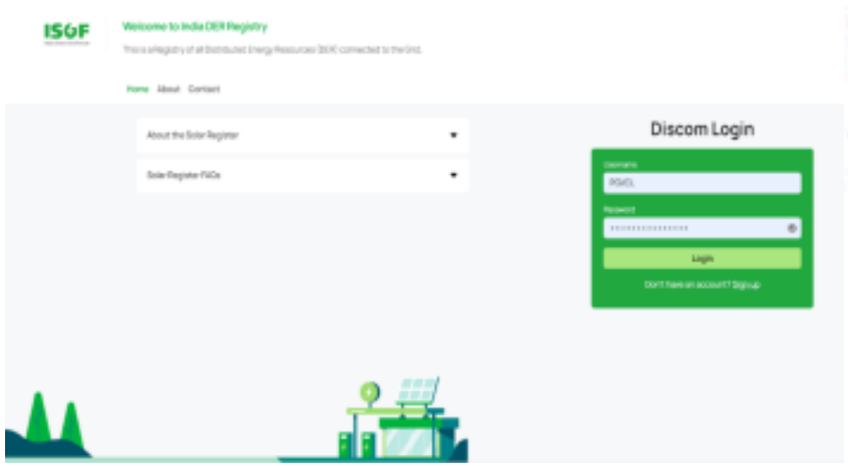
After ISGF published the report in June 2025, Maharashtra Government allotted subsidy of Rs 1 lakh for first 1000 electric Tractors

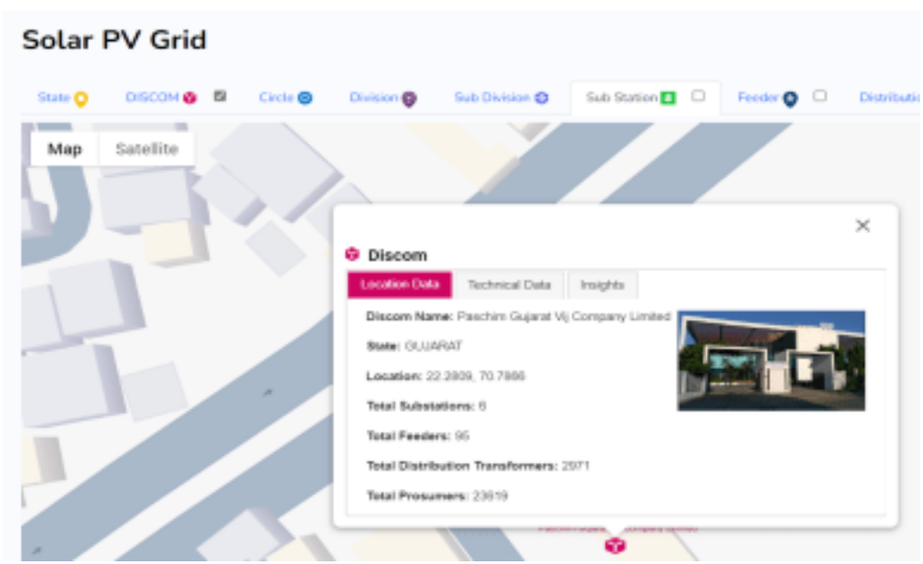
National Registry of Rooftop Solar (RTS)

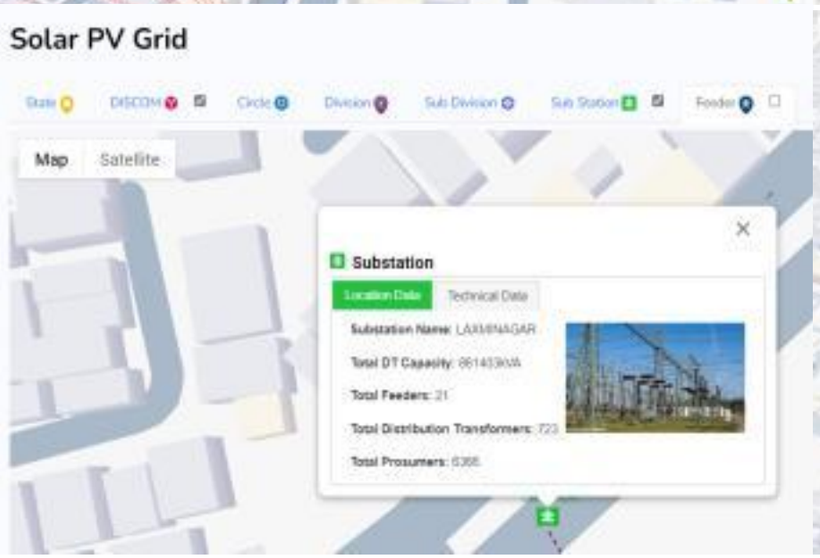
- India presently has about 2 million (18 GW) of rooftop solar (RTS) systems connected to the low voltage (LV) grid. Under the ongoing program “PM Surya Ghar Yojana” another 10 million RTS (30 GW) will be added to the grid in next 3 years which will create serious issues for the utilities to manage the MV/LV grids
- To monitor the generation and performance of the grid connected RTS systems, it is very important to have a Utility-wise, Feeder-wise and DT-wise registry of RTS installations. The DISCOM-wise registry can be scaled up to State-wise and to a National Registry
- ISGF has prepared the National RTS Registry which will help in effective management and integration of RTS systems
- This Registry Architecture is highly scalable to include millions (or billions) of devices connected to the grid – it can be expanded from a RTS registry to a National DER registry with all the DERs connected to the grid such as BESS, EVSE, industrial grade heating and cooling appliances etc which can provide flexibility services to the grid

Registry being handed over to CEA – porting to NIC and will integrate with PM Surya Ghar Portal 2.0

RTS Registry Architecture







Building the Foundation for Energy Internet

Peer-to-Peer (P2P) Trading of Rooftop Solar Energy – Pilots in India

Three successful pilot projects of P2P Trading of Rooftop Solar Energy on blockchain platform were carried out by ISGF and our technology partner Powerledger in India between 2020 and 2022.

1. Uttar Pradesh (UP), India:

- Pilot implemented under the **regulatory sandbox** approach to test thetechnical feasibility and customers willingness to participate in P2P trading
- **12 participants (9 prosumers and 3 consumers)** were recruited in the pilot project - **Project Go-Live: Dec 2020**
- Pilot project price discovery was around **INR 5.60/kWh (Win-Win for Prosumers and Consumers)**
- **UP Electricity Regulatory Commission (UPERC) issued P2P Regulations in April 2023**

2. Delhi, India:

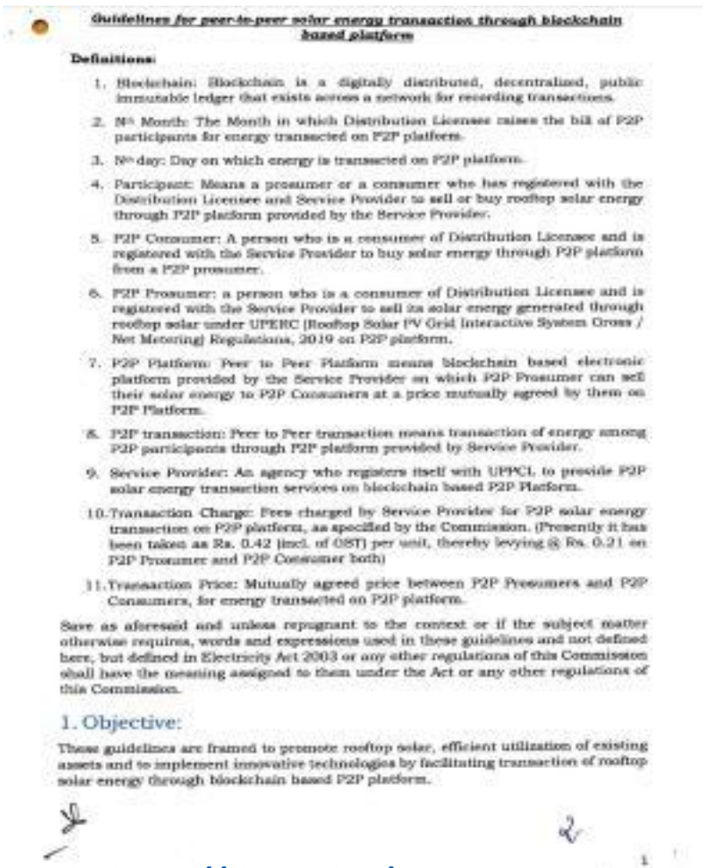
- P2P trading of solar power from over 2 MW of solar PV undertaken in 2021 in Delhi with Tata Power Delhi Distribution Ltd (TPDDL)
- **117 participants** were identified and recruited in the pilot project; **Project Go-Live: Nov 2021**
- Based on the project results, **ISGF + Powerledger + TPDDL** had submitted detailed findings and recommendations to Delhi Electricity Regulatory Commission (DERC) in November 2021
- DERC published **Peer to Peer Energy Transaction Guidelines, 2024 in June 2024**

3. Kolkata, India

- Built a P2P trading platform on blockchain for CESC Kolkata in 2022 and run a 6-month pilot with 1002 C&I Customers with AMR meters (26 MW PV installations); **Project Go-Live: August 2022**
- Formulated a viable business model for CESC
- Documented the outcomes of the project; but not yet presented to West Bengal Electricity Regulatory Commission (WBERC)

Regulations for P2P Solar Energy Transactions in India

Guidelines for Peer-to-Peer Solar Energy Transaction through Blockchain by UPERC in April 2023



Guidelines for peer-to-peer solar energy transaction through blockchain based platform

Definitions:

1. Blockchain: Blockchain is a digitally distributed, decentralized, public immutable ledger that exists across a network for recording transactions.
2. Nth Month: The Month in which Distribution Licensee raises the bill of P2P participants for energy transacted on P2P platform.
3. Nth day: Day on which energy is transacted on P2P platform.
4. Participant: Means a prosumer or a consumer who has registered with the Distribution Licensee and Service Provider to sell or buy rooftop solar energy through P2P platform provided by the Service Provider.
5. P2P Consumer: A person who is a consumer of Distribution Licensee and is registered with the Service Provider to buy solar energy through P2P platform from a P2P prosumer.
6. P2P Prosumer: a person who is a consumer of Distribution Licensee and is registered with the Service Provider to sell its solar energy generated through rooftop solar under UPERC (Rooftop Solar PV Grid Interactive System Gross / Net Metering) Regulations, 2019 on P2P platform.
7. P2P Platform: Peer to Peer Platform means blockchain based electronic platform provided by the Service Provider on which P2P Prosumer can sell their solar energy to P2P Consumers at a price mutually agreed by them on P2P Platform.
8. P2P transaction: Peer to Peer transaction means transaction of energy among P2P participants through P2P platform provided by Service Provider.
9. Service Provider: An agency who registers itself with UPPCL to provide P2P solar energy transaction services on blockchain based P2P Platform.
10. Transaction Charge: Fees charged by Service Provider for P2P solar energy transaction on P2P platform, as specified by the Commission. (Presently it has been taken as Rs. 0.42 [incl. of GST] per unit, thereby levying @ Rs. 0.21 on P2P Prosumer and P2P Consumer both)
11. Transaction Price: Mutually agreed price between P2P Prosumers and P2P Consumers, for energy transacted on P2P platform.

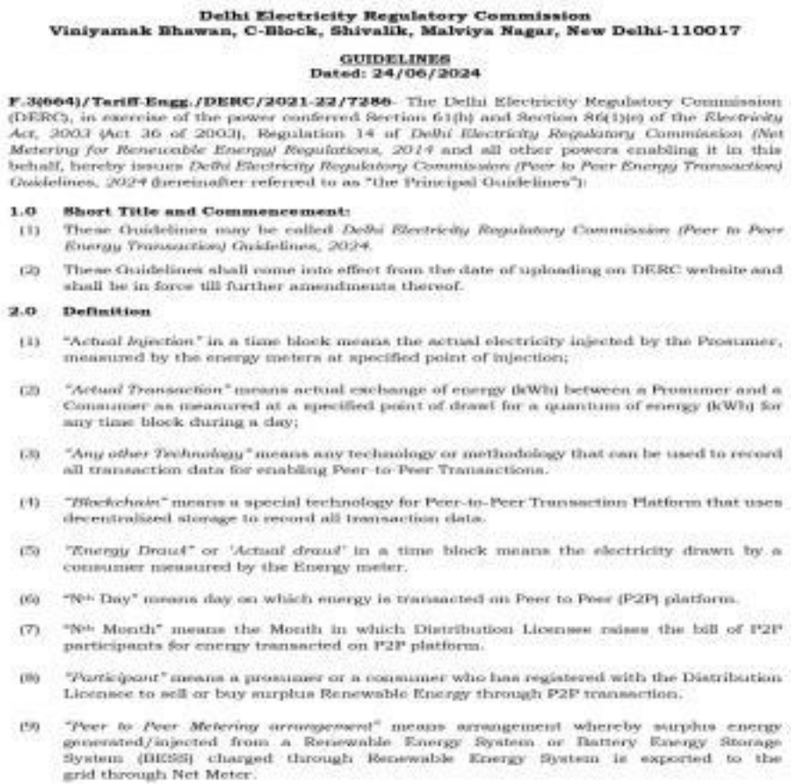
Save as aforesaid and unless repugnant to the context or if the subject matter otherwise requires, words and expressions used in these guidelines and not defined here, but defined in Electricity Act 2003 or any other regulations of this Commission shall have the meaning assigned to them under the Act or any other regulations of this Commission.

1. Objective:

These guidelines are framed to promote rooftop solar, efficient utilization of existing assets and to implement innovative technologies by facilitating transaction of rooftop solar energy through blockchain based P2P platform.

Link: https://shorturl.at/p1SQx

Peer-to-Peer Energy Transaction Guidelines, 2024 by DERC in June 2024



Delhi Electricity Regulatory Commission
Viniyamak Bhawan, C-Block, Shivalik, Malviya Nagar, New Delhi-110017

GUIDELINES
Dated: 24/06/2024

F.3(664)/Tariff-Engg./DERC/2021-22/7286- The Delhi Electricity Regulatory Commission (DERC), in exercise of the power conferred Section 61(h) and Section 86(1)(e) of the *Electricity Act, 2003* (Act 36 of 2003), Regulation 14 of *Delhi Electricity Regulatory Commission (Net Metering for Renewable Energy) Regulations, 2014* and all other powers enabling it in this behalf, hereby issues *Delhi Electricity Regulatory Commission (Peer to Peer Energy Transaction) Guidelines, 2024* (hereinafter referred to as "the Principal Guidelines"):

1.0 Short Title and Commencement:

(1) These Guidelines may be called *Delhi Electricity Regulatory Commission (Peer to Peer Energy Transaction) Guidelines, 2024*.

(2) These Guidelines shall come into effect from the date of uploading on DERC website and shall be in force till further amendments thereof.

2.0 Definition

(1) "*Actual Injection*" in a time block means the actual electricity injected by the Prosumer, measured by the energy meters at specified point of injection;

(2) "*Actual Transaction*" means actual exchange of energy (kWh) between a Prosumer and a Consumer as measured at a specified point of drawl for a quantum of energy (kWh) for any time block during a day;

(3) "*Any other Technology*" means any technology or methodology that can be used to record all transaction data for enabling Peer-to-Peer Transactions.

(4) "*Blockchain*" means a special technology for Peer-to-Peer Transaction Platform that uses decentralized storage to record all transaction data.

(5) "*Energy Drawl*" or '*Actual drawl*' in a time block means the electricity drawn by a consumer measured by the Energy meter.

(6) "Nth Day" means day on which energy is transacted on Peer to Peer (P2P) platform.

(7) "Nth Month" means the Month in which Distribution Licensee raises the bill of P2P participants for energy transacted on P2P platform.

(8) "*Participant*" means a prosumer or a consumer who has registered with the Distribution Licensee to sell or buy surplus Renewable Energy through P2P transaction.

(9) "*Peer to Peer Metering arrangement*" means arrangement whereby surplus energy generated/injected from a Renewable Energy System or Battery Energy Storage System (BESS) charged through Renewable Energy System is exported to the grid through Net Meter.

Link: https://shorturl.at/PiqH4

Implementation of Peer-to-Peer Solar Energy Transaction Regulations by KERC in August 2024

KARNATAKA ELECTRICITY REGULATORY COMMISSION

Notification

No. 3/03/1/560 dated 06.08.2024

KERC (Implementation of Peer to Peer Solar Energy Transaction) Regulations, 2024

PREAMBLE

Link: https://shorturl.at/uK6id

Demonstration of Project for Peer-to-Peer Trading of Rooftop Solar Energy in Uttar Pradesh Powered by Unified Energy Interface (UEI)

- ISGF currently working on a first-of-its-kind demonstration project for P2P trading of rooftop solar energy in **Lucknow**, powered by the innovative **Unified Energy Interface (UEI) architecture** — a significant step toward building a **Digital Energy Grid** of the future.
- The project is under testing with limited participants since 15 July 2025

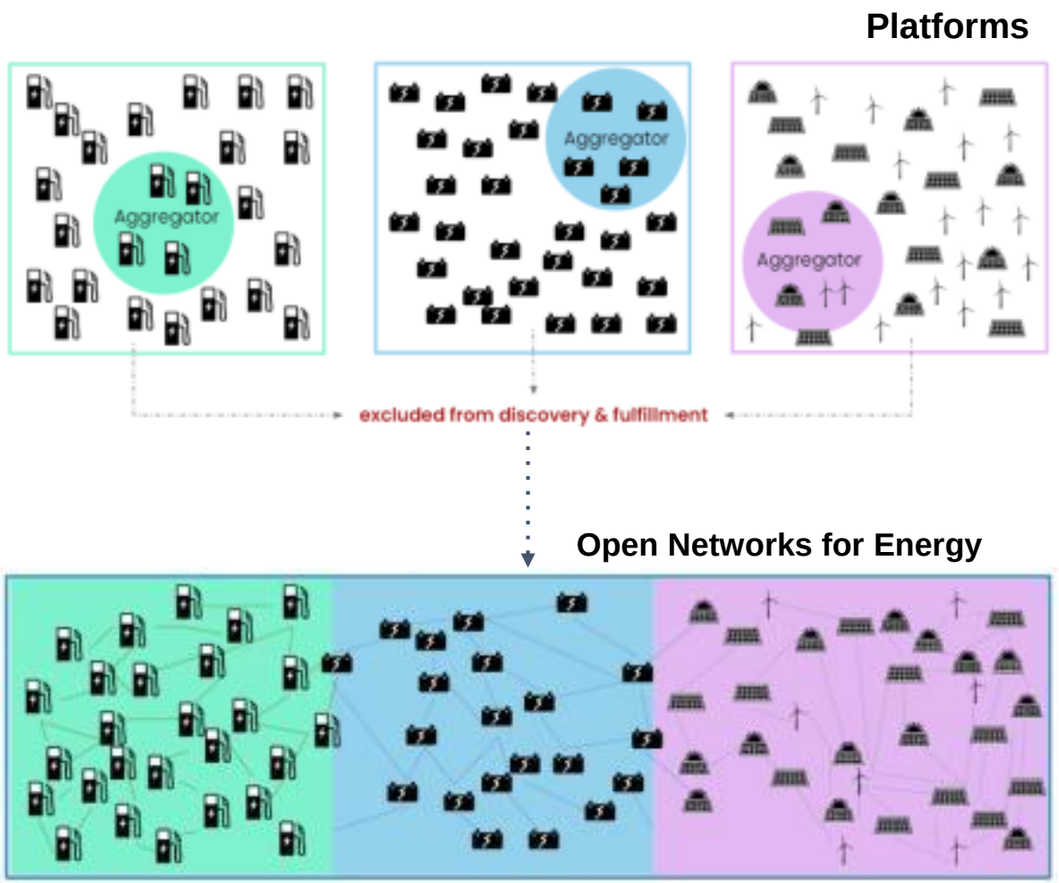
Unified Energy Interface (UEI) - Open Energy Network

UNIFIED ENERGY INTERFACE

Unified Energy Interface (UEI) is an **open network for energy** to enable transactions between digital energy systems

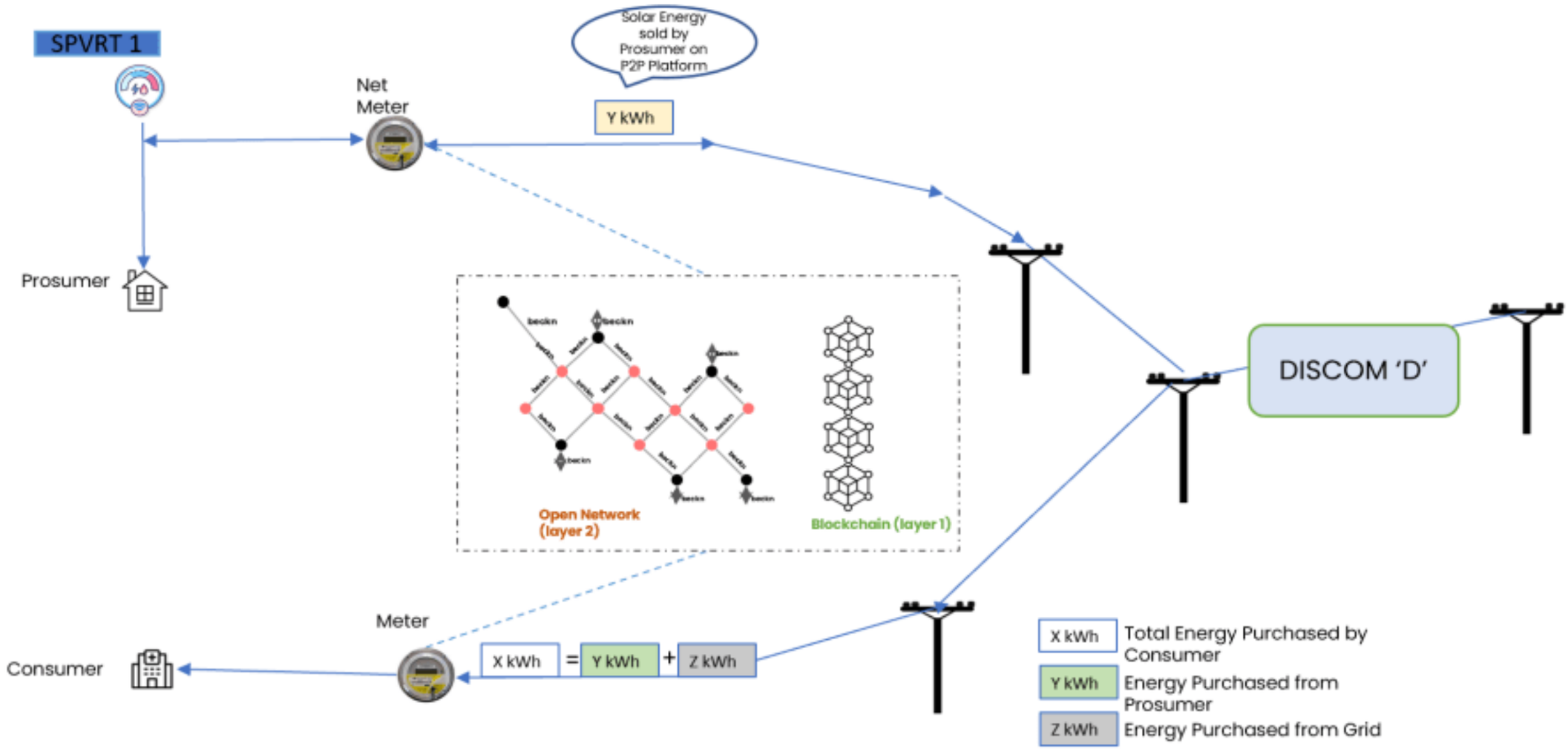
Solves for

Discovery
Ordering
Fulfilment
Post-fulfilment

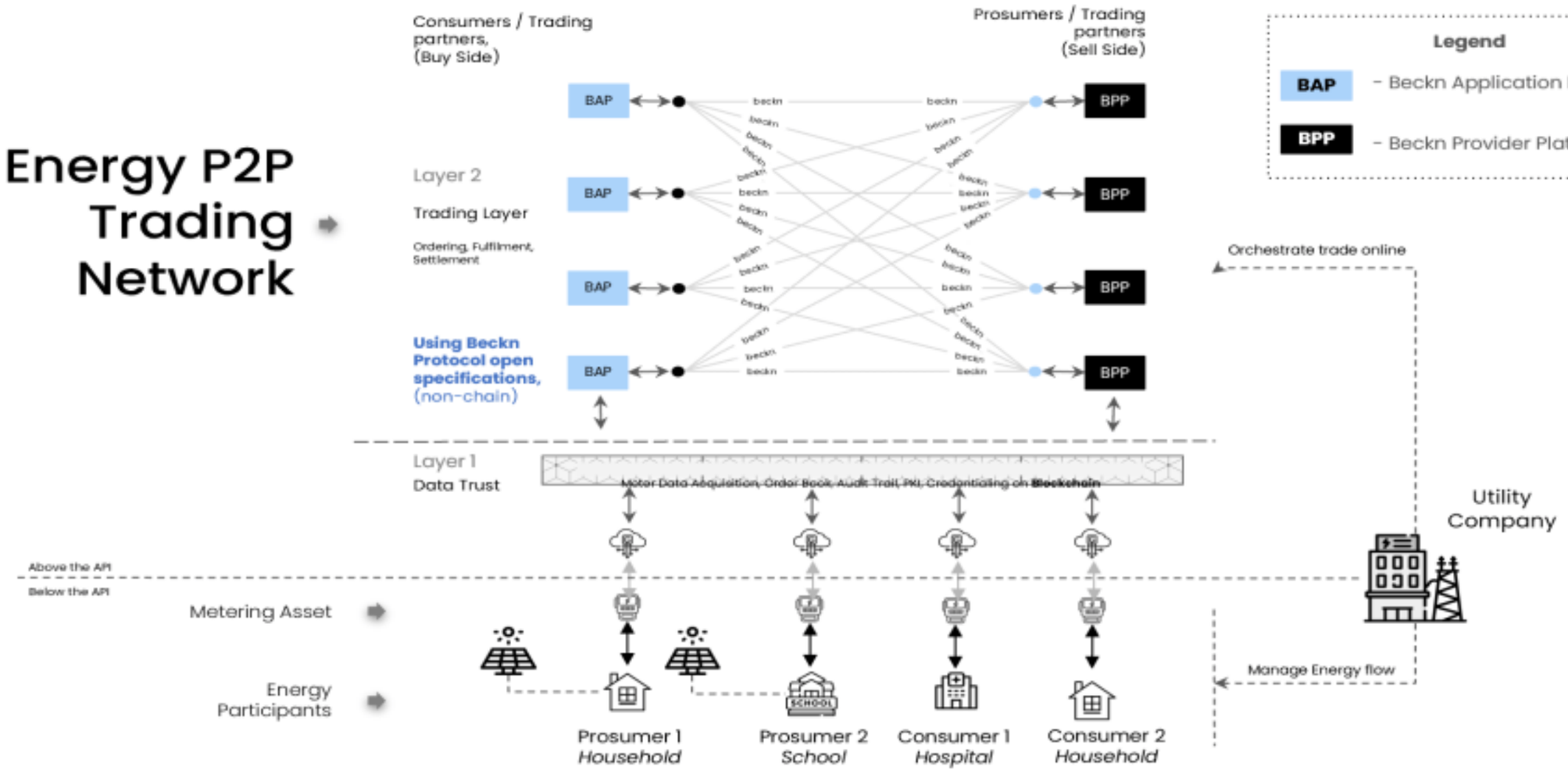


Market Expansion | Autonomy at Nodes | Asynchronous & Combinatorial innovation

P2P Energy Trading Platform Architecture



Energy P2P Trading Network – Beckn Protocol



Distribution Utility Meet (DUM) 2025

Distribution Utility Meet

(Since 2017: held in November)

- DUM is the unified voice of the DISCOM community to influence policy and regulations for grid modernization
- DUM provides an effective platform to DISCOMs to leverage each other's experiences and resources for successful nationwide smart grid rollouts
- Website: www.dumindia.in

India Smart Utility Week (ISUW) 2026

India Smart Utility Week

(Since 2015 : Held in March)

- International Conference and Exhibition on Smart Grids, Renewable Energy, E-Mobility and Smart Cities
- Knowledge sharing platform for Policy Makers and Regulators, Utilities, Technology Providers, Academia and Research, Entrepreneurs and Technology Enthusiasts
- Best practices and show case next generation technologies and products
- Website: www.isuw.in

THANK YOU FOR YOUR KIND ATTENTION

Contact Us

reji@rejikumar.com @rejipillai

India Smart Grid Forum

CBIP Building, Malcha Marg, Chanakyapuri, Delhi-110021

www.indiasmartgrid.org

www.globalsmartenergy.org

www.rejikumar.com www.isuw.in

www.dumindia.in

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ISGF Key Contributions (1/2)

1. **Smart Grid Vision and Roadmap for India** - Issued by Ministry of Power in Aug 2013
2. **Framework for National Smart Grid Mission (NSGM)** and **Model Smart Grid Regulations** in **2015**
3. **M2M Communications Roadmap** and **Rollout of IPv6 for Power Sector**
4. **Approval for release of 7 MHz of license-free spectrum for M2M Communications** and **GoI approval for Private Wireless Networks under 5G for Captive Use**
5. **Cyber Security Preparedness Assessment of Electric Utilities** and **Manual on Cyber Security for Power Systems -** in collaboration with NCIIPC and VJTI
6. **Green Number Plates for Electric Vehicles -** ISGF White Paper 2014; and ISGF Study Report 2017
7. **Separate Electricity Tariff for Electric Vehicle Charging -** ISGF presentation to FOR in 2016
8. **Business Model for Smart Metering as a Service** proposed by ISGF in 2017 White Paper has been adopted by MoP and DISCOMs under RDSS program for rollout of 250 million smart meters
9. **Right-Sizing of Electric Bus Battery** – ISGF Study Report on Electrification of Public Transportation in Kolkata argued for right sizing the batteries in buses according to route length in the city; and brought down the price of electric buses < Rs 1 crore in 2018
10. **Electric 2-Wheelers and 3-Wheelers to be sold without batteries –** proposed by ISGF in the Study Report in 2017; GOI approved in 2021 which paved the way for **Battery Swapping Stations**
11. **New Buildings to be built with EV Charging Points in 20% of the Parking Space –** proposed by ISGF in White Paper in 2018; and approved by TCPO in 2019
12. **Electric Cooking** – ISGF White Paper in 2020; and BEE adopted Electric Cooking as a component of the
13. **GO-ELECTRIC** program

ISGF Key Contributions (2/2)

14. Energy Storage Roadmap for India: 2019 to 2032 issued by NITI Aayog in 2019
15. **District Cooling Systems (DCS)** – ISGF White Paper in 2020; and BEE included DCS in the India Cooling Action Plan; prepared Technical Specs for DCS; today there are over 100 DCS projects in India
16. **Replacement of Diesel Generators with Battery Energy Storage Systems (BESS)** – ISGF White Paper in 2020;adopted in MOP's ESS Framework in 2023
17. **Electrification of School Buses:** ISGF White Paper in 2023; ***Vision 2030: PM Public Transport Sewa launched in April 2024 envisages*** **50,000 electric buses for schools**
18. **Introduced several innovative technologies in the Indian Power Sector – including Blockchain Technology for Peer-to- Peer (P2P) Trading of Rooftop Solar Energy – P2P Regulations issued in Uttar Pradesh, Delhi and Karnataka**
19. **BIS Standards for Smart Meters, EVSE, LVDC Grids; and adoption of many IEC and IEEE standards by BIS**
20. **National Registry for DERs – www.indiaderregistry.in**
21. **Successful demonstration of V2G Technology in India and Charging of EVs with Green Electricity**
22. **IEC - IEEE World Smart Energy Coordination** Workshop series: 7 editions held
23. **Bilateral Workshop** Series with EU, USA, France, Germany, Brazil etc.
24. **Indian Delegations** to several International Events
25. Facilitated formation of **All India Discoms Association (AIDA) - www.aida-india.org**

Key Difference – Traditional AI and Generative AI

Aspect	Traditional AI	Generative AI
Definition	Systems following pre-defined rules to perform tasks.	AI that generates new contents resembling learned material Example - ChatGPT
Approach to Problem-Solving	Rule-based systems for structured problem-solving.	Models like Generative Adversarial Networks (GAN) to generate adaptable solutions.
Learning Capability	Limited to rules set by humans.	Advanced learning, improves without explicit programming.
Applications	Structured tasks like data analysis and automated tasks.	Creative tasks like art and text synthesis.
Flexibility	Less flexible, requires code changes for new tasks.	Highly flexible, adapts to new data types quickly.
Data Requirements	Operates with smaller, structured datasets.	Needs large datasets for quality outputs.
Examples	Rule-based Chatbots, Deep Blue, Prolog	Deepfakes, AI music composition, generate poetry.

Comparative Analysis

Attribute	Traditional AI	Generative AI
Characteristics	Deterministic, relies on structured data and explicit programming.	Probabilistic, thrives on variability and adaptability.
Working Principle	Based on logic, rules, and machine learning algorithms that analyze and process data for decision-making or predictions.	Employs models like GANs that learn data distribution to generate new, similar instances of data.
Data Requirements	Requires large amounts of labeled, structured data for effective training and accurate outcomes.	Can work with less structured or unlabeled data, learning patterns to generate new content.
Real-World Applications	Found in predictive analytics, automated customer service, and diagnostic tools in healthcare.	Utilized in creative industries for generating art, music, literature, and in data augmentation for AI training.
Computational Requirements	Generally requires less computational power compared to Generative AI, suitable for a wide range of hardware.	Demands significant computational resources for training, especially for large models, limiting accessibility.
Adaptability	Less adaptable to new or unseen data without retraining or adjustments to the model.	Highly adaptable, capable of generating outputs for a wide range of scenarios even with limited specific training.
User Interaction	Interaction primarily revolves around input-output based tasks, with limited capacity for generating new user-driven content.	Enables dynamic interaction by creating content in response to user inputs, offering personalized experiences.
Impact on Creativity	Enhances human productivity in creative tasks through automation and analysis, but does not inherently generate new creative works.	Directly contributes to the creative process by generating novel content, expanding the boundaries of human creativity.
Workforce Implications	May lead to job displacement but also creates opportunities for roles in AI development, management, and oversight.	Challenges and augments creative professions, leading to collaborative models where humans and AI work together.

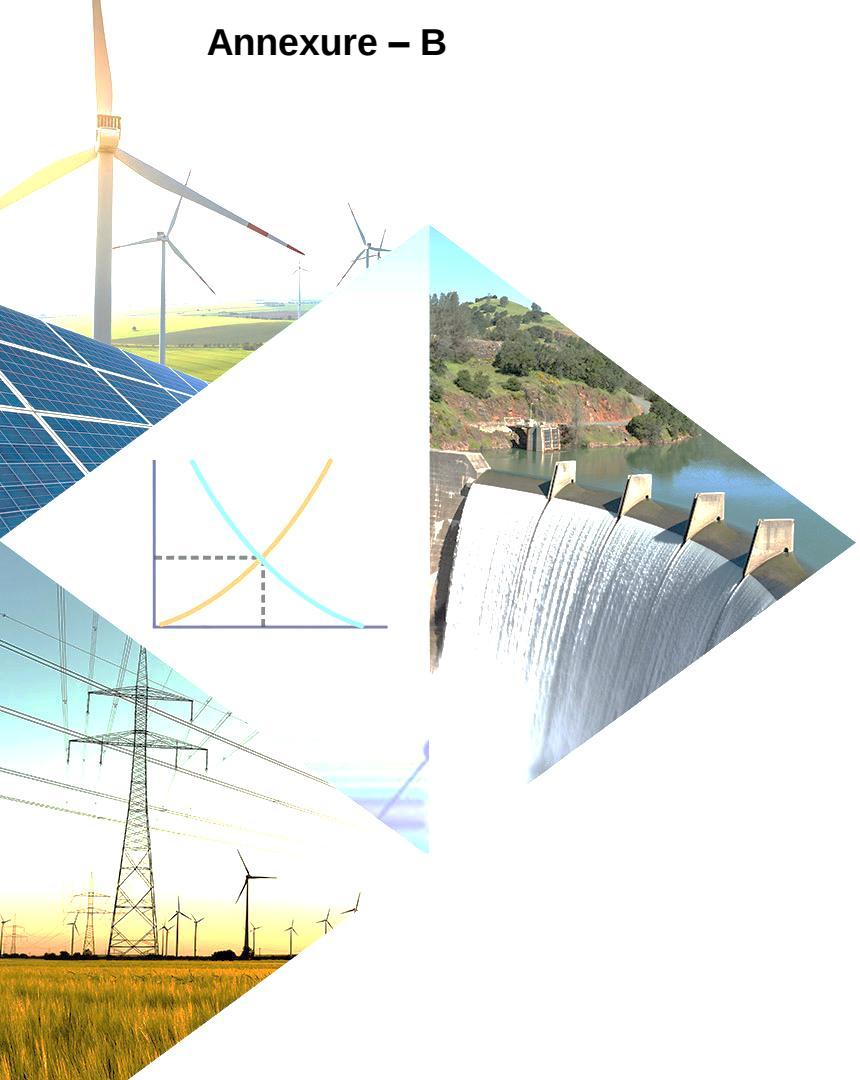
Popular Gen AI Tools and Use Cases

Tool Name	What It Does	Where It Helps
ChatGPT	Answers questions, writes emails, explains reports	Drafting letters, summaries, understanding policies
Microsoft Copilot	Smart support in Excel, Word, Outlook	Making tables, presentations, reports, emails
Google Gemini	Smart search, document help, chat assistant	Quick research, note-making, document writing
Perplexity	Smart search with real-time citations and summaries	Understanding new policies, energy & tech research
Otter.ai / Fireflies.ai	Converts voice to text, transcribes meetings	Meeting notes, interviews, webinars
Canva (Magic Write)	AI-powered slide and design creation	Reports, posters, banners, presentations
Tome AI	Auto-creates PowerPoint-style decks from a prompt	Fast project slides and idea presentations
Krisp.ai	Removes background noise during calls	Online meetings, webinars, professional calls
Stability AI	Generates AI-based images (Stable Diffusion model)	Visuals for presentations, posters, explainer content
Grok (XAI)	Super-fast large language model (ChatGPT alternative)	Instant responses for technical and policy questions

Note: Basic versions of all AI tools above are **free; there are different subscription plans for advanced versions.**

Annexure – B

Annexure – B



Power Market Update

State Advisory Committee
JERC - UTs

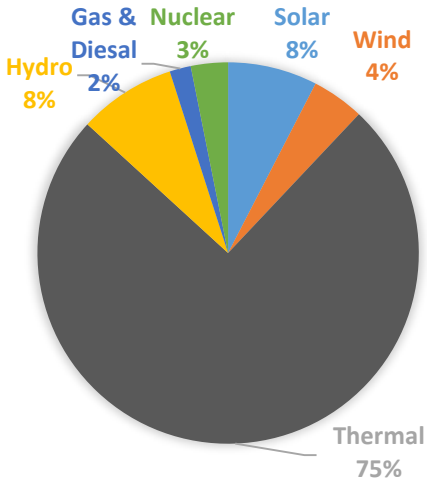
29th October 2025

Gaurav Maheshwari
Vice President – Regulatory Affairs, IEX

Power Sector- Background

Generation Mix

Indian Generation Mix – FY'25



- Thermal generates 75% of India's electricity
- Renewables contribute ~20% to Generation
- Highest Peak Demand ~ 250 GW (May 24)

Transmission

World's Largest Network

- Inter-reg. trans. Cap.: 119 GW (FY'25); → 168 GW (FY'32)
- 4.92 Lakh CKM of trans. Lines (FY'25); → 6.48 Lakh CKM (FY'32)
- One Nation One Grid
- Green Corridor: RE rich states; projects for evacuation of RE into National grid
- 99.9% times no congestion

Distribution & Consumption

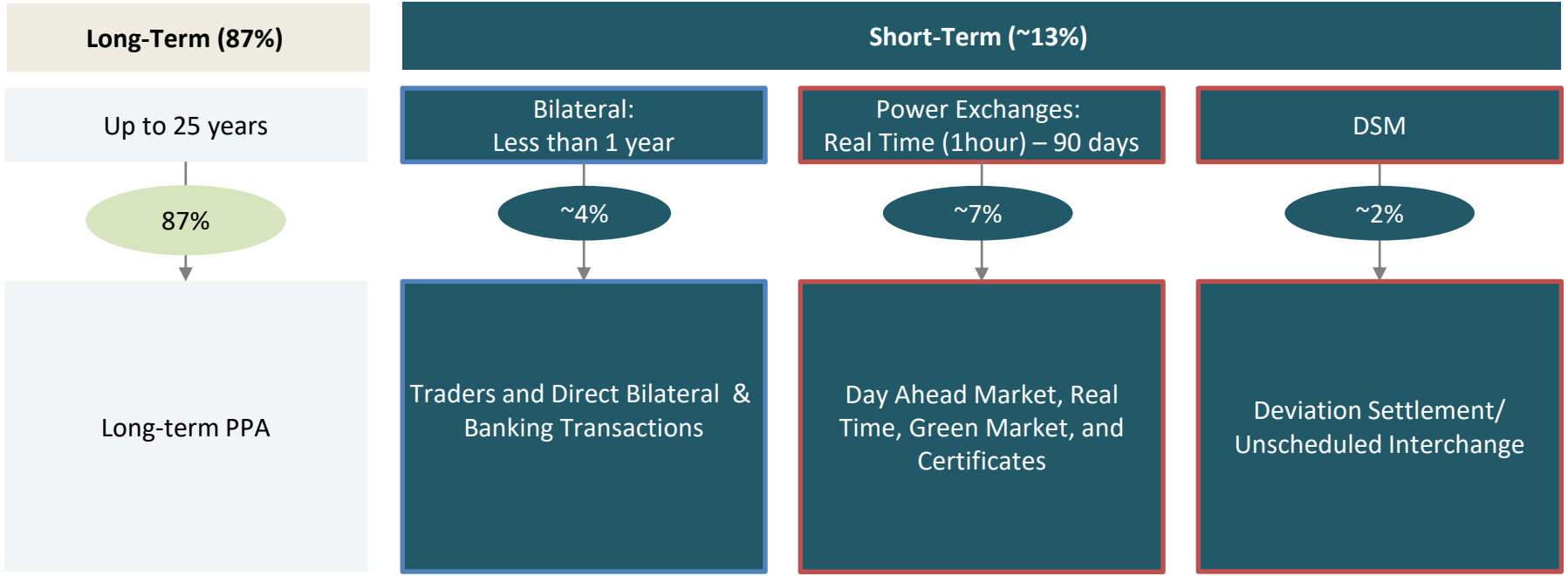
Reforms Underway

- Declining Avg. AT & C Losses:
  - FY'22 – 16.4%
  - FY'23 – 15.4%
  - FY'24 – 17.6%
- Improving credit ratings of distribution companies
- Generators being paid on timely basis
- DISCOMS resorting to power procurement optimization

Source: CEA, MoP

Sector Construct

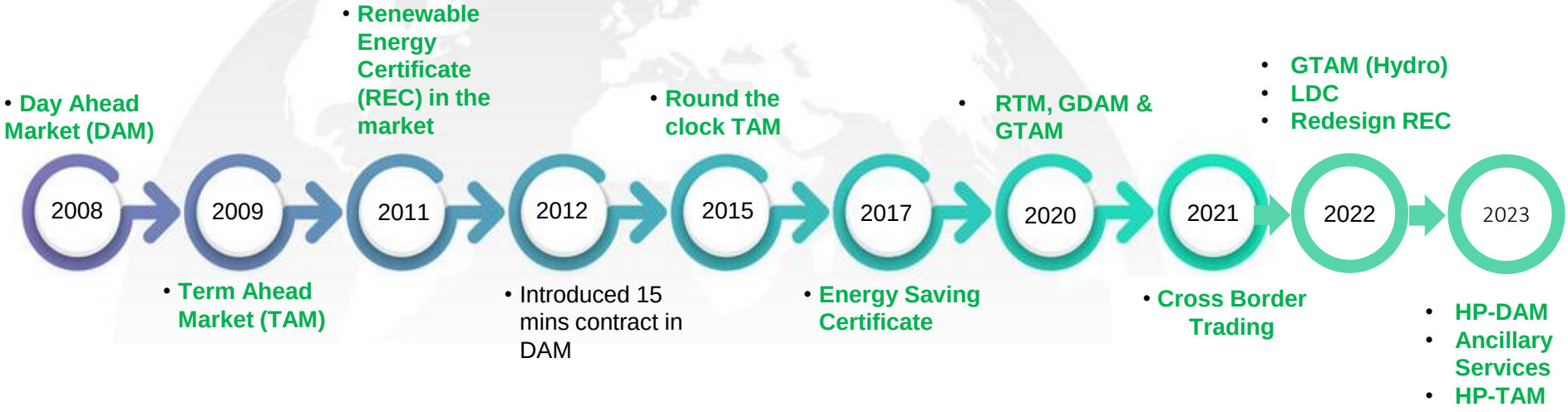
Total Power Consumption FY'24: 1,739 BU



- Over the years, as India has significantly reduced its energy deficit
- Fluctuation in power demand , surplus long term power contracts, and more variable renewable energy being integrated into the grid, have all contributed to trend of increased share of short term power sale (especially through power exchanges)

Overview of Power Exchanges

Market evolution



Products at Power Exchange

Integrated DAM

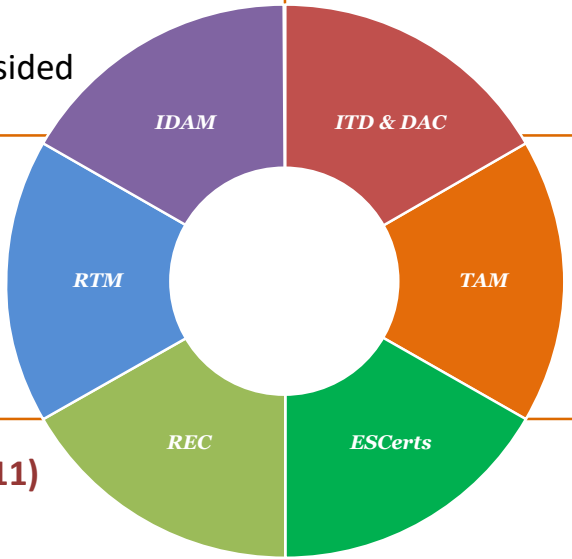
DAM + GDAM+ HP DAM

- Delivery for next day
- Price discovery: Closed , Double-sided Auction

ITD & DAC

Conv. + Green

- Continuous trading process
- Hourly trading



Real Time Market (2020)

- Half Hourly market
- Double sided closed auction with uniform price

Term Ahead Market

Conv. + Green (2022)

- Daily, Weekly, Monthly and Any Day Single Sided Contracts
- Trading available up to 3 months

Renewable Energy Certificates (2011)

- Green Attributes as Certificates
- RE generators not under feed-in tariffs & Obligated entities;

Energy Saving Certificates

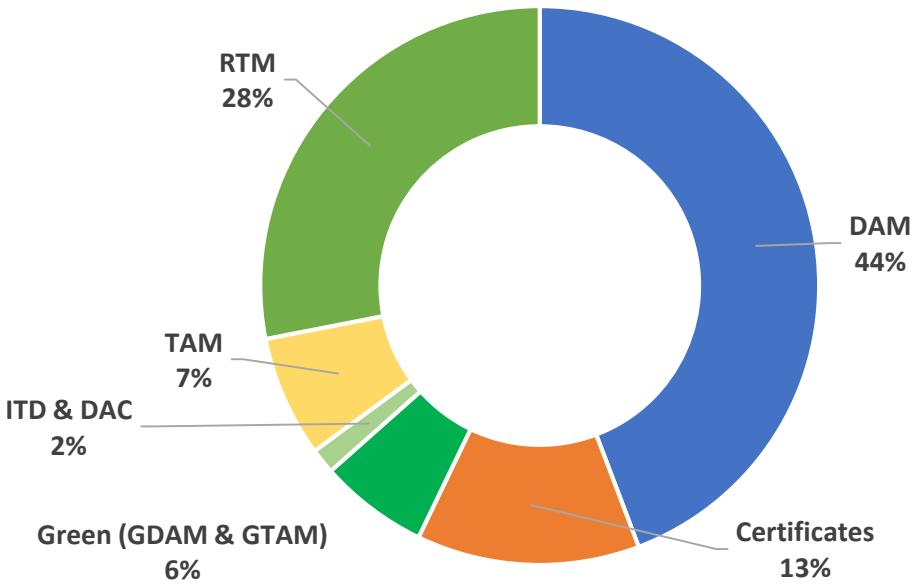
- Trading currently paused due to BEE notification

Ancillary Services

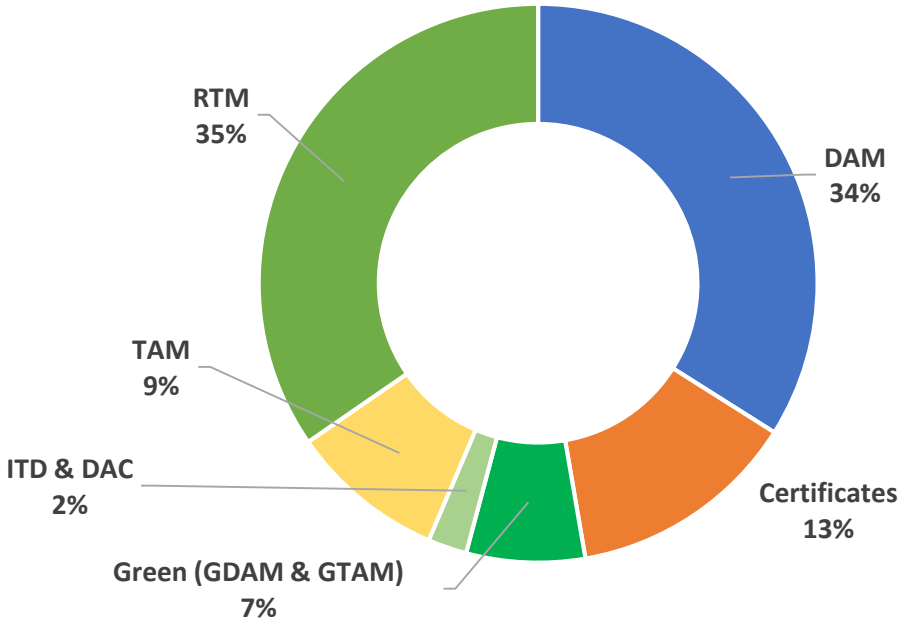
- DAM & RTM Ancillary Services market (May 2023)

Product Mix

FY 25



FY 26



- **Electricity Mix Comparison (FY 25 vs FY 26):** FY 26 till Sept saw a shift in electricity mix with higher RTM (35%) and Green (7%) share.

IDAM-Collective Transaction Trading Process

Bidding

10:00 AM to 11:00 AM

Integrated Bidding session for GDAM, DAM, HP-DAM and DAM-AS.

Matching and funds availability

By 11:45 AM

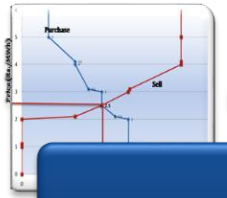
Publish Provisional Results.

Communication of Transmission Corridor required for IDAM to NLDC

Review corridor

By 12:15 PM

NLDC to confirm available transmission corridor for scheduling for GDAM, DAM & HP-DAM.



Result

By 01:00 PM

Final ACV and ACP. Market splitting if congestion.

Exchange will publish Final Results & submits the application for scheduling to NLDC

Confirmation

By 01:30 PM

Confirmation by NLDC

Exchange will issue Final Obligation to members

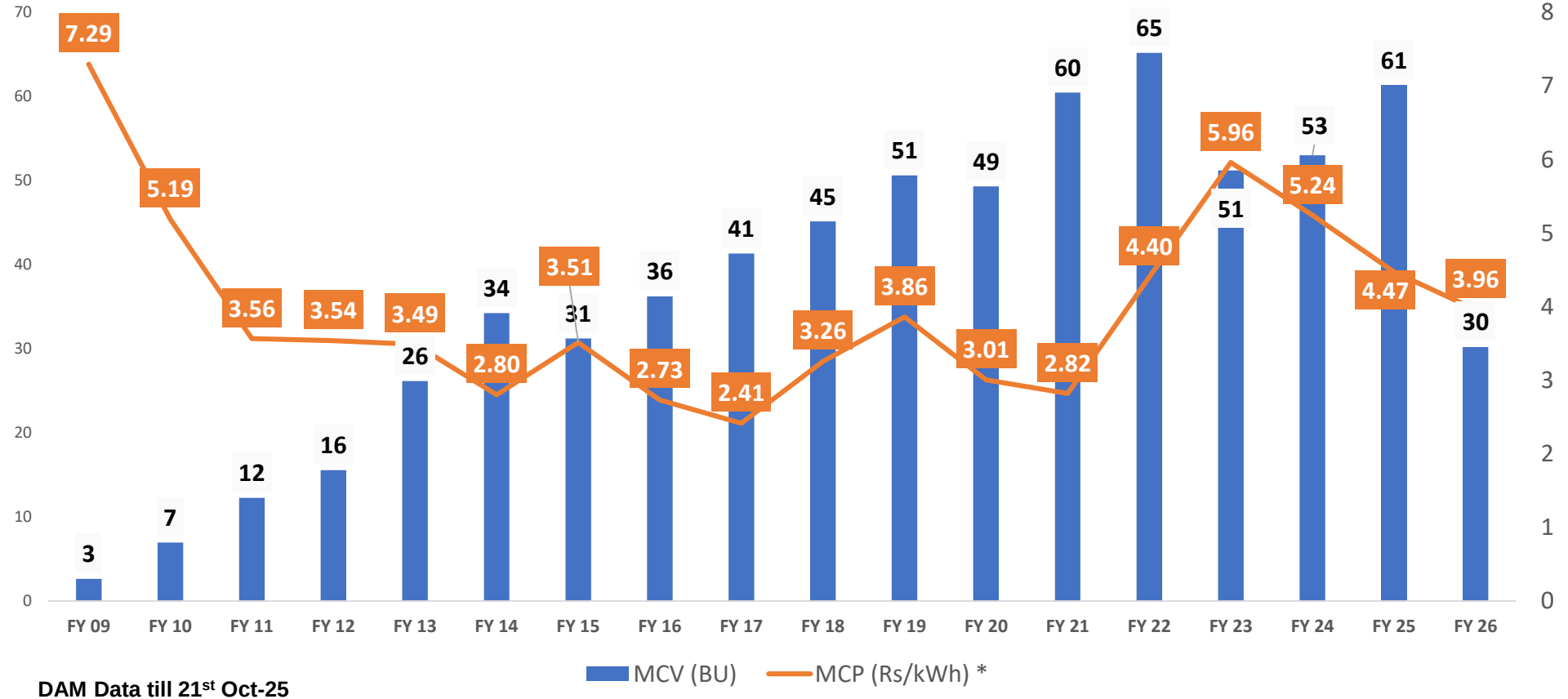
File to be sent by Exchange to banks for actual debits

Scheduling

By 01:30 pm

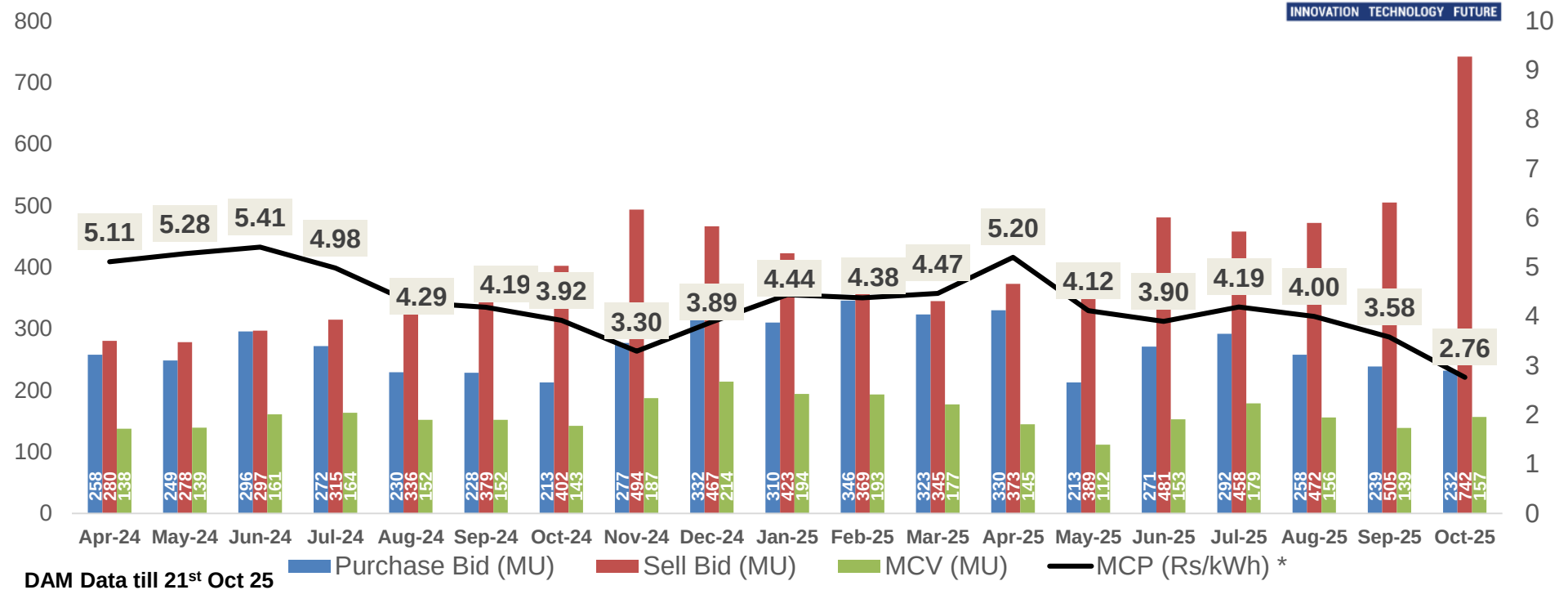
Final Schedule sent to RLDC for incorporation

Yearly DAM Snapshot



DAM Data till 21st Oct-25

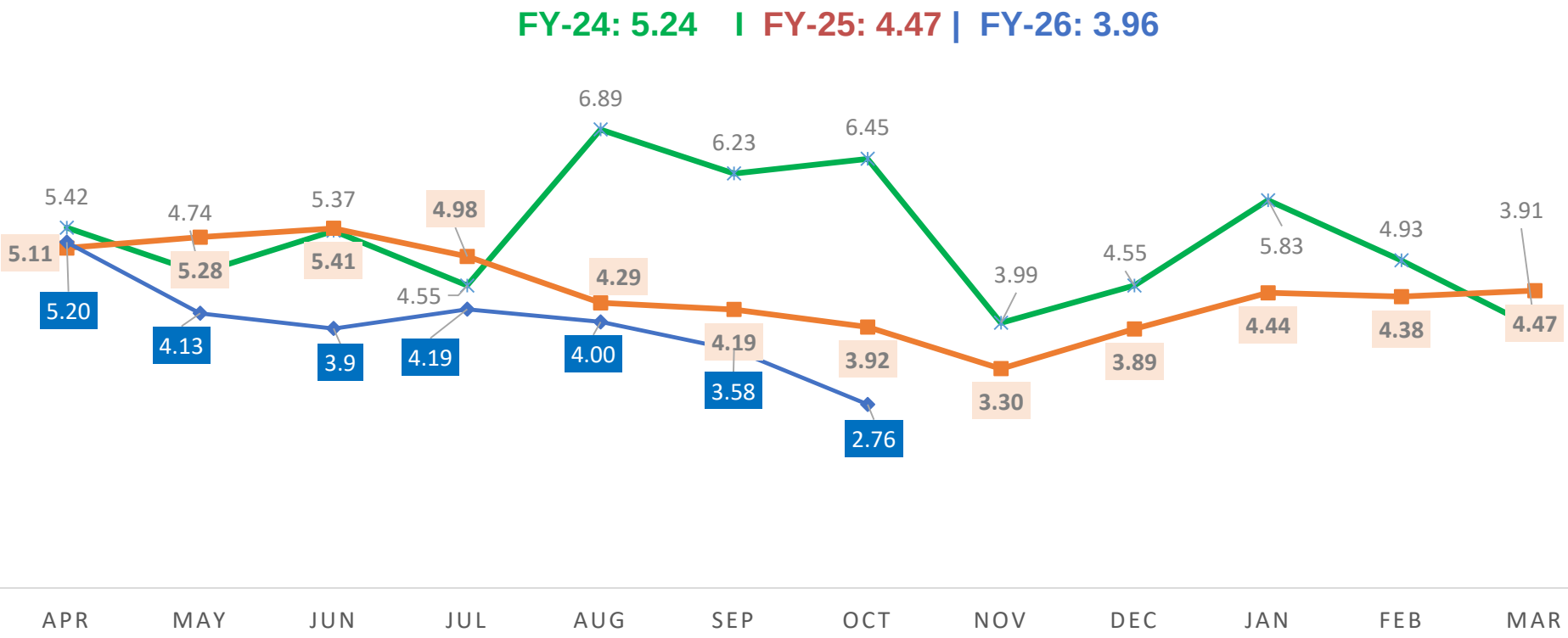
Monthly DAM Market Snapshot



DAM Data till 21st Oct 25

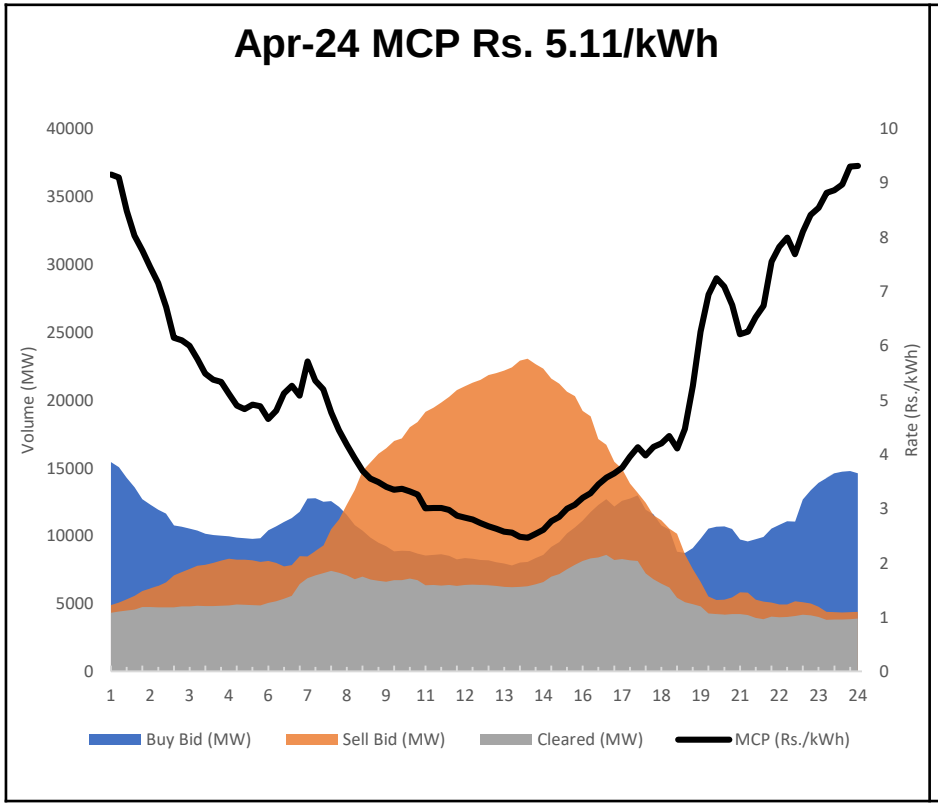
- Mandate sell of URS power in the DAM & RTM market
- Mandated imported coal and gas-based plants to sell power on exchanges under Section 11
- Healthier coal stock led to increase in supply

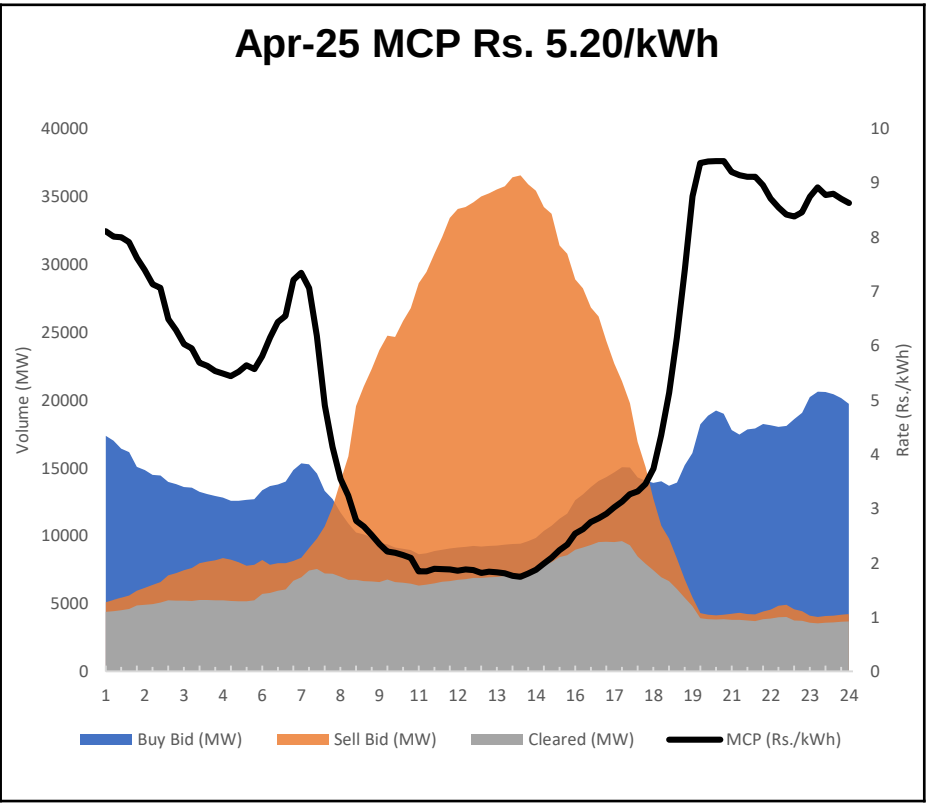
Price Trends (Rs./kWh) at DAM



DAM Data till 21st Oct 25

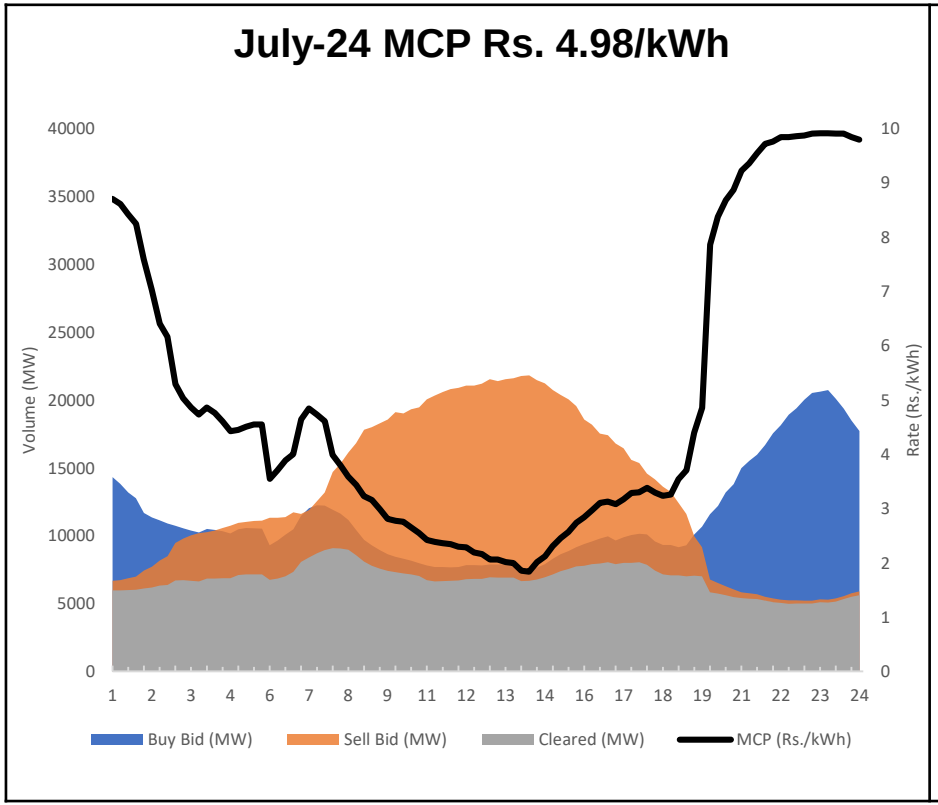
DAM Snapshot for Month of April

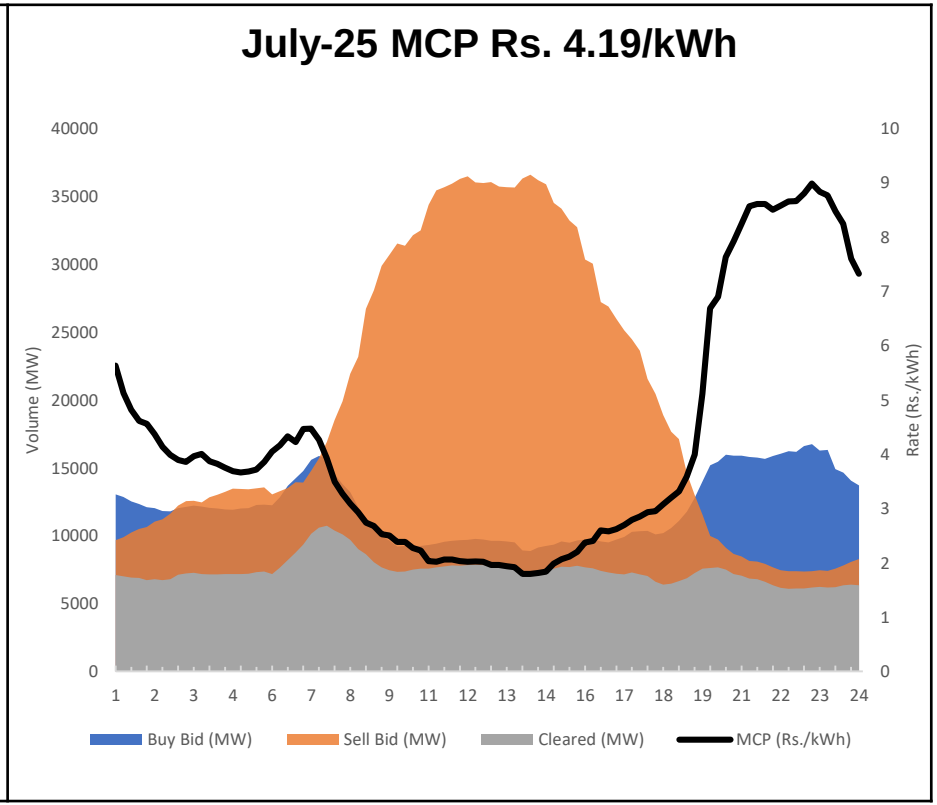




Sell bids rose by 33%, presenting an opportunity to optimize procurement costs during solar hours

DAM Snapshot for Month of July

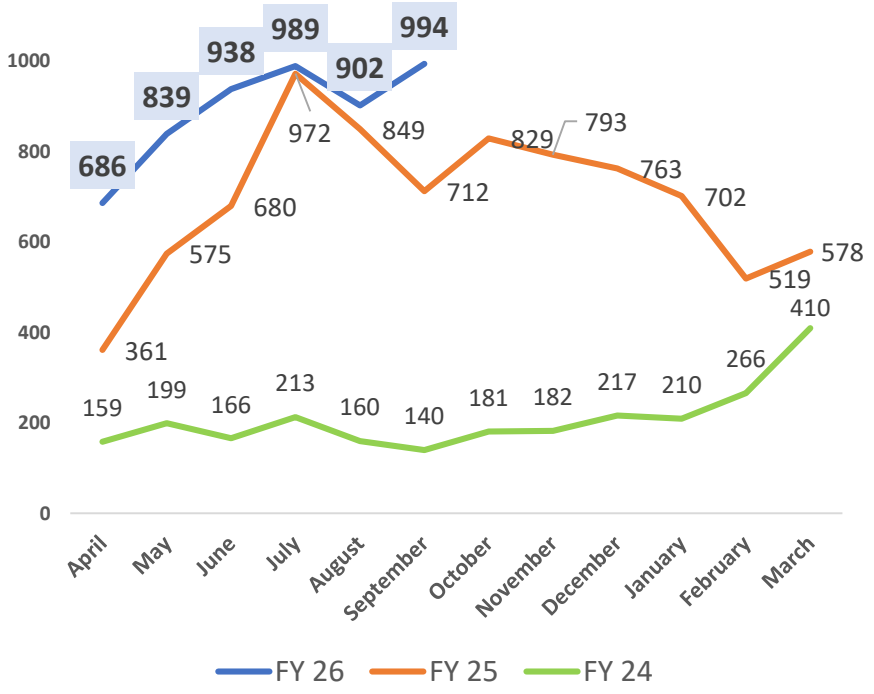




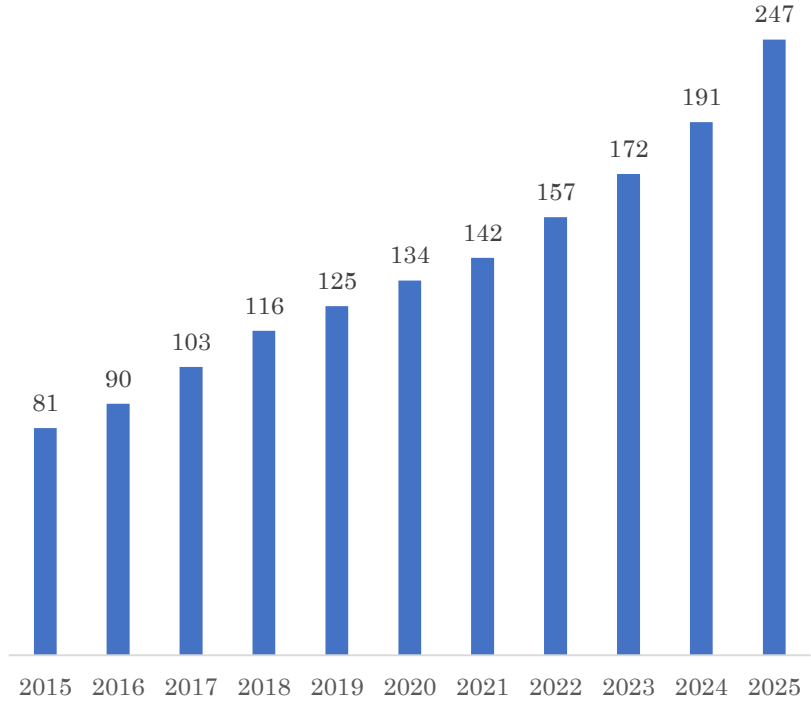
Sell bids surged by 45%, reflecting enhanced market liquidity driven by the commissioning of new Thermal and RE

Green Market Momentum: Liquidity on the Rise

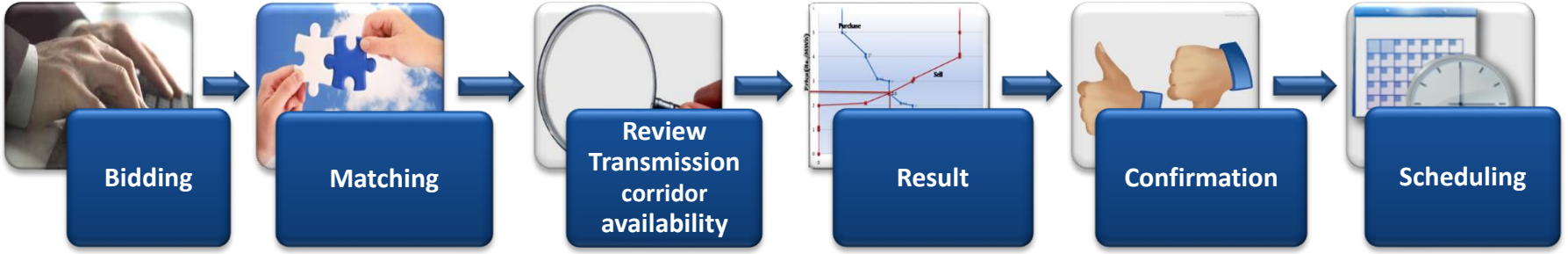
Green Volume (Sell Bids in GDAM) Increased by 233% YoY in FY 25



RE Installed Capacity

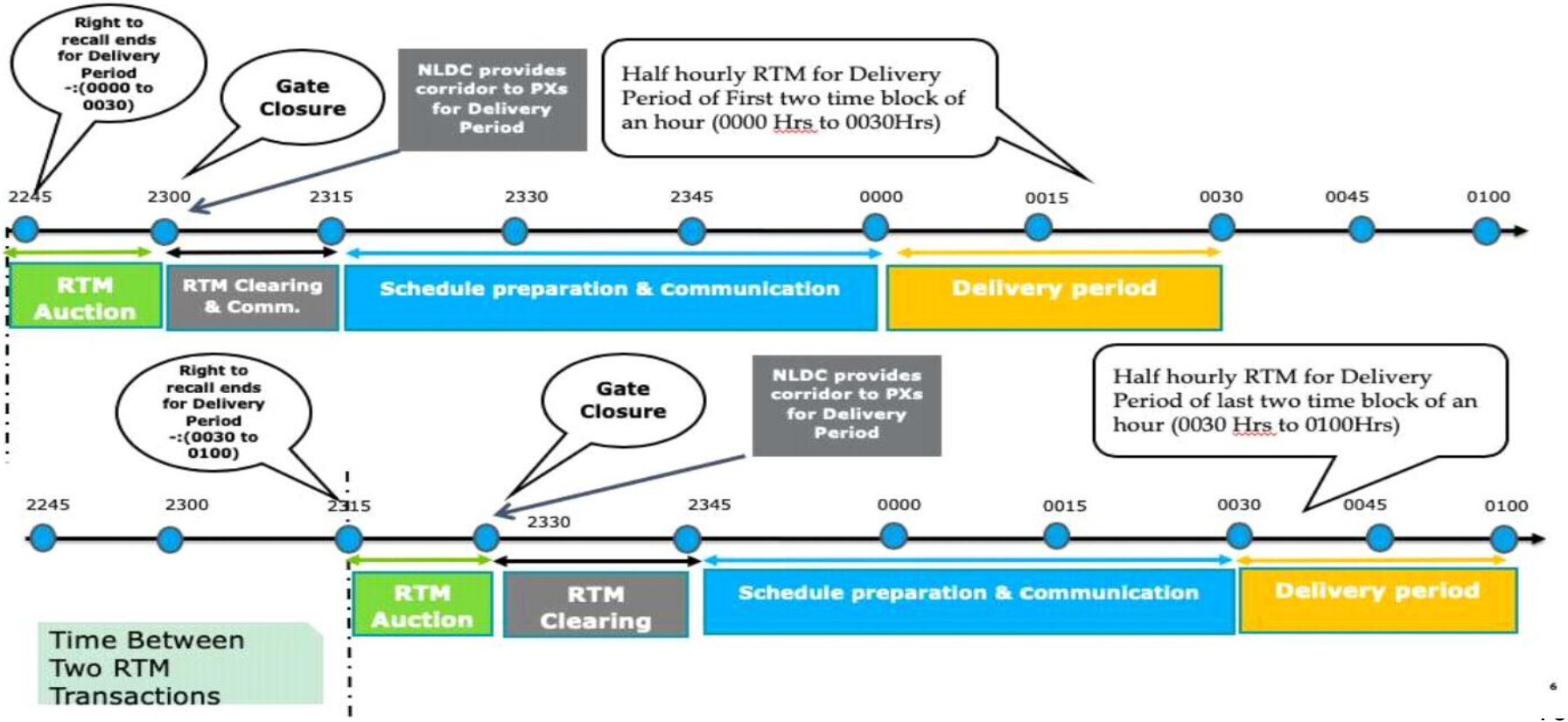


RTM Trading Process: Delivery 12:00-12:30 AM



10:45 pm to 11:00 pm	At 11:00 pm	At 11:05 pm	11:09 pm	11:15 pm	11:30 pm
Bids for 15-min each or block bids can be placed	MCP & MCV calculated	Corridor availability verified with NLDC	Final ACV and ACP calculated. Market splitting if congestion	Results shared with NLDC & Members	Final Schedule sent to RLDC for incorporation

Real Time Market Timelines

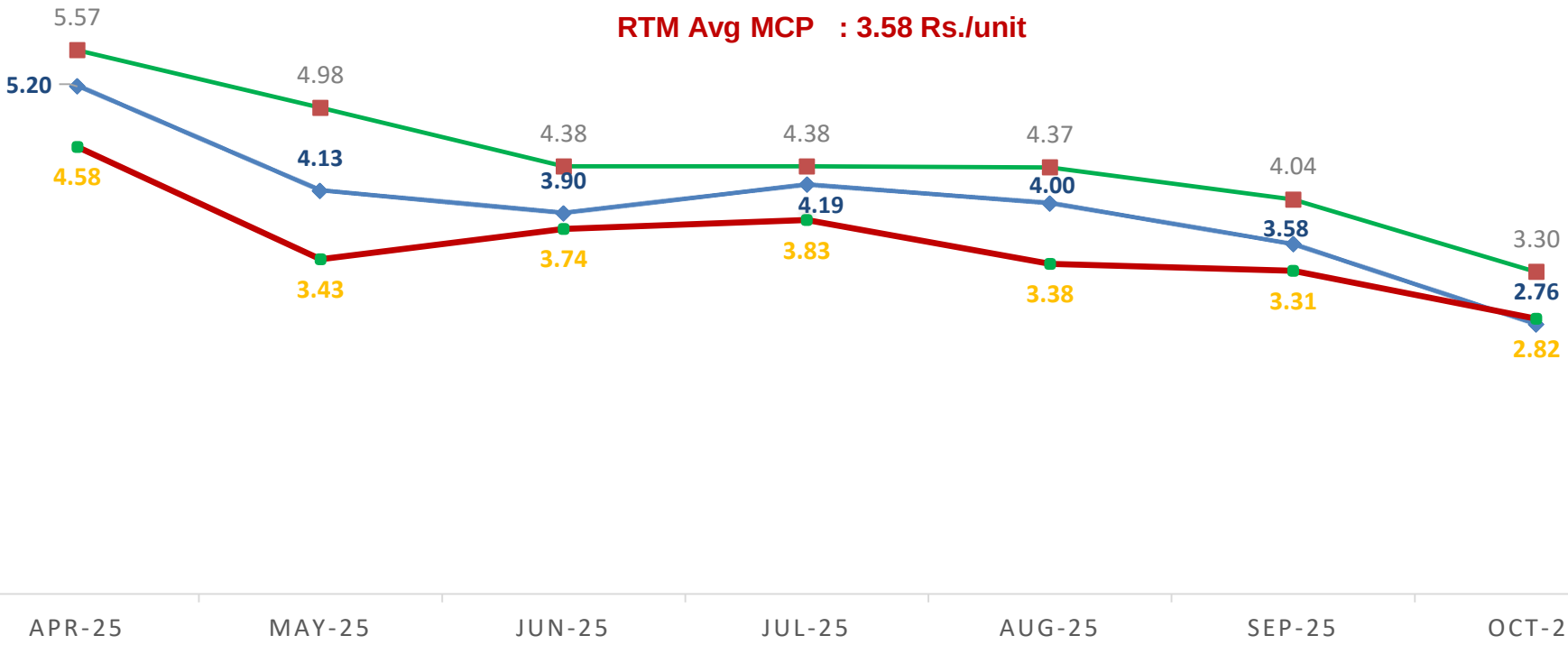


Price Trends (Rs./kWh) DAM,RTM & GDAM (FY26)

GDAM Avg MCP: 4.43 Rs./unit

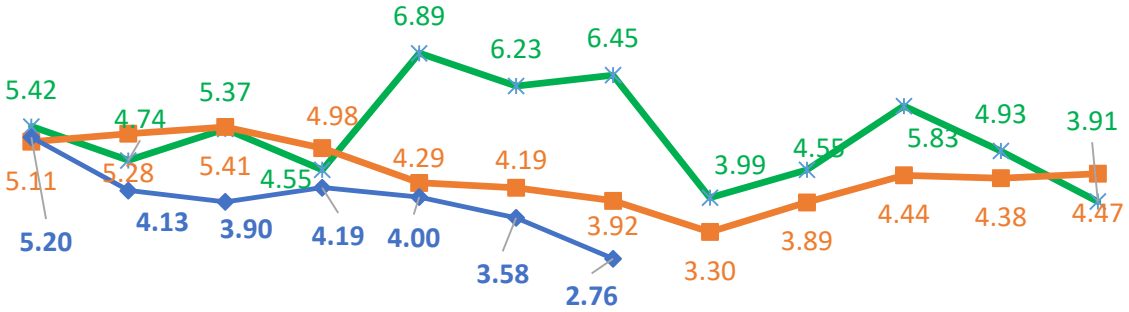
DAM Avg MCP : 3.96 Rs./unit

RTM Avg MCP : 3.58 Rs./unit

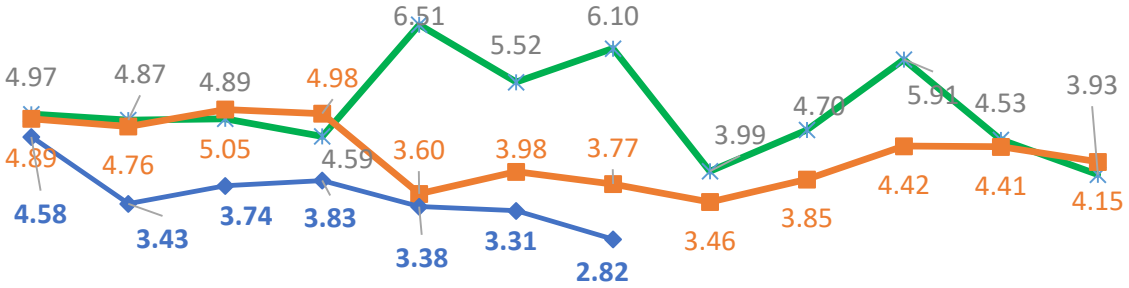


DAM Data till 21st Oct-25

Price Trends (Rs./kWh) in DAM & RTM



DAM : FY-24: 5.24 I FY-25: 4.47 I FY-26: 3.96



RTM : FY-24: 5.04 I FY-25: 4.28 I FY-26: 3.58

APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR

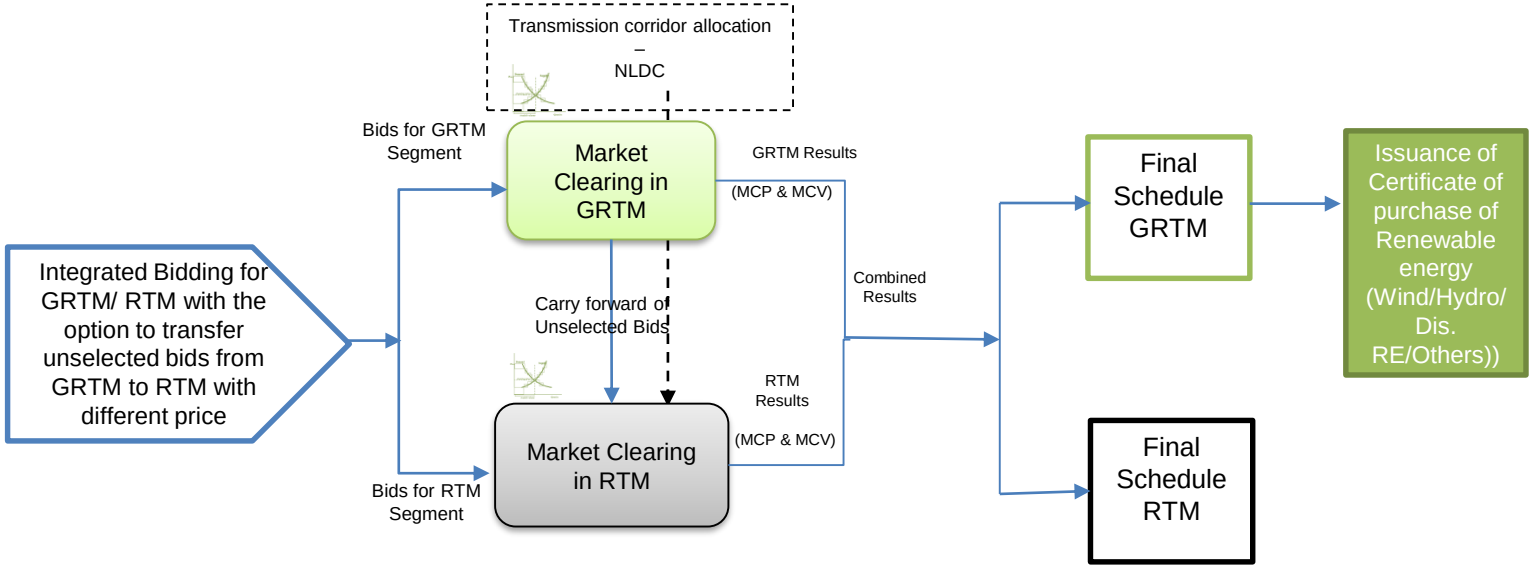
DAM FY 25 vs FY 26 (YoY):

- Sell bids ↑ 42% YoY
- Cleared volumes ↓ -3%
- Purchase bids ↑ 4%,
- Market Clearing Price ↓ 15%

RTM FY 25 vs FY 26 (YoY):

- Sell bids ↑ 54%
- Cleared volumes ↑ 39%
- Purchase bids ↑ 16%,

IEX proposal- Green Real Time Market (G-RTM)



Eligibility

Sellers: Standing Clearance issued by respective LDC specifying maximum quantum and Category of Renewable Energy Generation (e.g., Wind/ Hydro/ Other RPO etc.)

Buyers: All eligible Open Access buyers

RPO – Buyers can fullfill RPO from G-RTM

Simultaneous Bidding for all segments

Bids to be placed separately for GRTM and RTM in a single session with Order Carry Forward option

Market clearing in a sequential manner

- ✓ Market will be cleared in a sequential manner: GRTM-> RTM
- ✓ Option for uncleared bids to carried forward from GRTM to RTM

IEX proposal- Peak DAM & RTM Contracts

- High Price DAM introduced at IEX in March 2023 to bring imported coal based plant, gas based plants using imported RLNG & Naphtha and BESS in market.
- Despite clear demand-supply deficit in market during peak periods, buyers have not shown interest in HP-DAM, leading to limited liquidity in HP-DAM
- To address this imbalance technologies such as Battery Energy Storage Systems and Pumped Storage Plants (PSP) are well-suited to meet this demand.

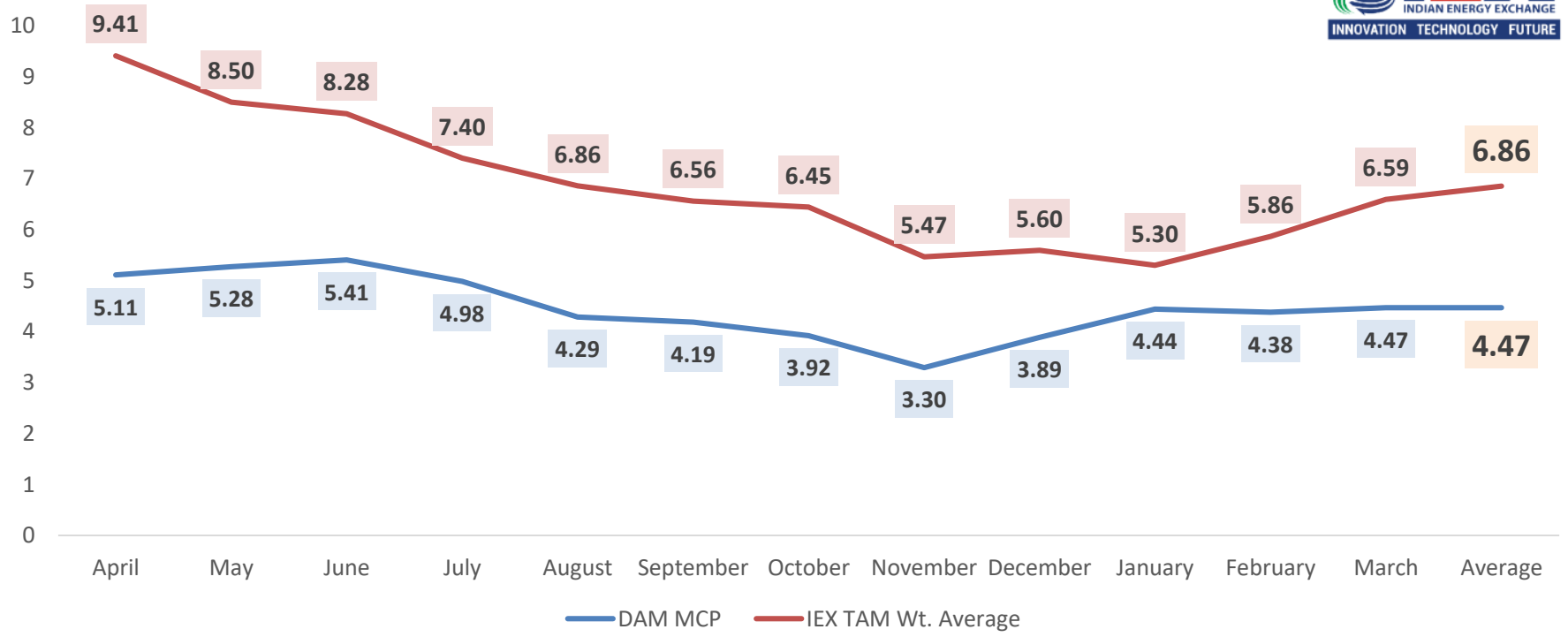
Name of the Contract	Eligibility	Bid Price	Bidding time	OCF Option	Delivery
PEAK DAM Contract	BESS, Hydro PSP & eligible HP-DAM Sellers	Max Bid Price: Between Rs. 10/kWh and Rs. 20/kWh Min Bid Price: Rs. 0/kWh	10:00 – 11:00 hours within I-DAM	Available to buyer & seller	Next day (T+1)
PEAK RTM Contract			Within existing RTM Sessio		

ITD, DAC, TAM / GTAM - Contracts Specification

Particulars	Intraday	DAC	Daily	Weekly	Monthly	ADSS*
Contract National/Regional	15 Mins Same day Delivery	15 Mins Next day Delivery	TAM – Energy traded in MW GTAM - Energy traded in MWh (Profile)			
Trading	Continuous Trading		Auction			IPO & Reverse Auction
Trading Days	Daily		Daily (T+2 to T+90)	Daily (W+2 to W+12)	Upto 3 Months	(T+2 to T+90)
Trade Hours	00:15 to 19:30	13:00 to 23:30	12:00-17:00			As per buyer requisition
Delivery Hours	04:00 to 24:00	00:00 to 24:00 / As per Profile				
Pay In/ Pay Out	T+1	D/D+1	D-1/D+1			

**Any Day-Single Sided*

Price Differential Analysis: TAM vs DAM



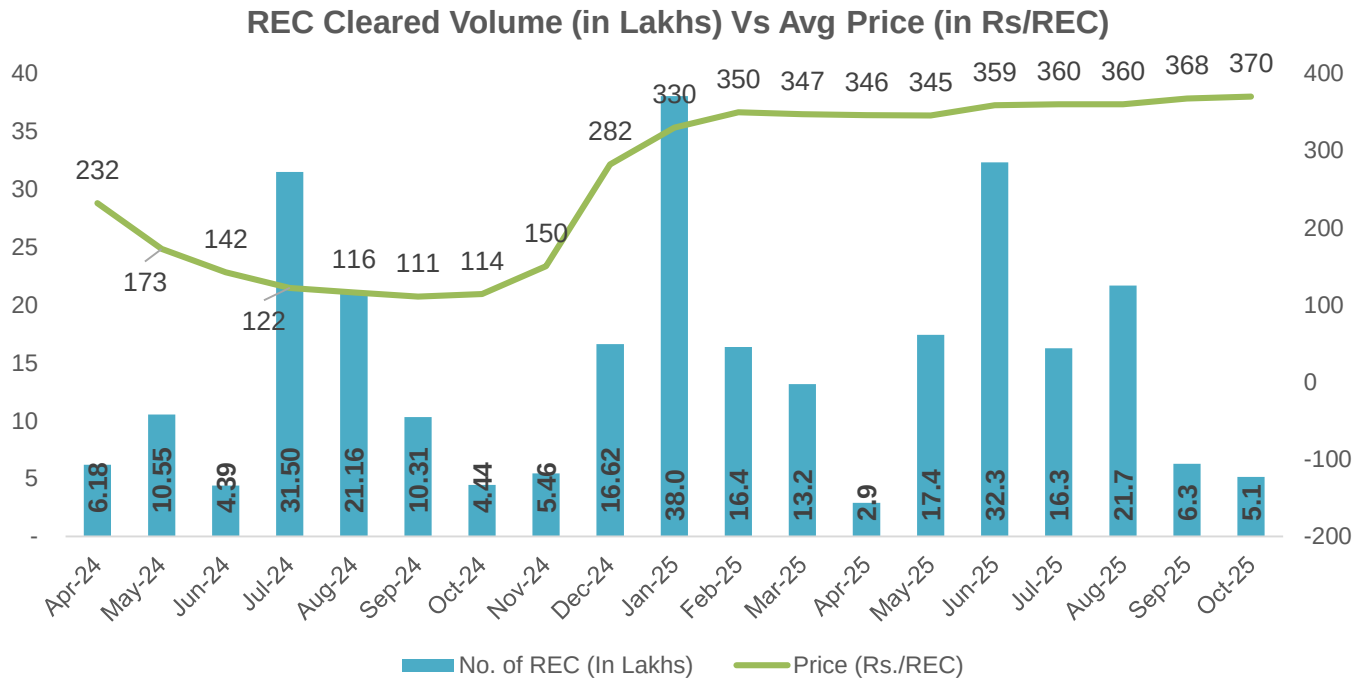
- DAM Prices are approximately 34% lower than prices in TAM Market segment, indicating a cost premium for bilateral procurement.

IEX Proposal-11 Month Contracts

Name of the Contract	Commencement of Bidding	Last day of bidding	Bidding time	Delivery Duration Start	Delivery Duration End
Daily Contracts	On Daily Basis	Two days before delivery day	**12:00 – 18:00 hours**	T+2 days	**11 months**
Weekly Contract	Monday of the **trade week**	**Saturday** of the one week prior to delivery	12:00 – **18:00** hours	TW+1	**11 months**
Monthly Contract	First Day of the **trade** month	**Two days prior to the delivery day**	12:00 – **18:00** hours	TM+1	**11 months**
Any Day Single Sided Contract	On Daily Basis	Two days prior to the delivery day	00:00 – 24:00 hours	T+2 days	**11 months**

- Seller's flexibility to supply from alternate source
- Providing 15% variation in the TAM/GTAM contracts
- In All TAM contracts, the additional margin has been brought to 20% of the trade value

Renewable Energy Certificates (REC) Market Snapshot



Draft 1st Amendment to CERCREC Regulations – Sep 2025

- ✓ Definitions of Designated Consumer, RCO and VPPA introduced
- ✓ Multiplier –
  - ✓ Solar/Wind – 1
  - ✓ Hybrid RE – 1.5
  - ✓ Biomass/Biofuel/Co-Gen/LHP/MSW – 2.5
  - ✓ SHP – 2
  - ✓ PSP/BESS – 3.0
- ✓ Application for Issuance can be made by Discom/OAC within 3 months of date od certification by SERCs
- ✓ RECs can be directly transferred from RE Generator o VPPA consumer

Current RECs Inventory (3.3 Crore) & lower prices discovered at exchanges, provides a favourable opportunity for the buyers to comply with RPO.

Regulatory & Policy Update

MoP Notification - Renewable Energy Consumption (RCO dated 27.09.2025)

Sl. No.	Year	Wind energy	Hydro energy	Distributed renewable energy*	Other renewable energy	Total renewable energy
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	2024-25	0.67%	0.38%	1.50%	27.36%	**29.91%**
2.	2025-26	1.45%	1.22%	2.10%	28.24%	**33.01%**
3.	2026-27	1.97%	1.34%	2.70%	29.94%	**35.95%**
4.	2027-28	2.45%	1.42%	3.30%	31.64%	**38.81%**
5.	2028-29	2.95%	1.42%	3.90%	33.09%	**41.36%**
6.	2029-30	3.48%	1.33%	4.50%	34.02%	**43.33%**

- No change in the RCO trajectory
- Obligations under Wind, Hydro, and Other RE components are fungible, while Distributed RE is non-fungible.
- RCO fulfilment methods- DCs may fulfil the specified RCO through one or more of the following methods:
  - Consumption of RE, either directly or through an energy storage system;
  - Purchase of RECs
  - Payment of the buyout price specified by CERC (75% of the amount shall be transferred to the respective State Energy Conservation Funds)
- For all designated consumers under the EC Act, no additional RPO shall apply under the Electricity Act, and the State-level RPO targets shall be subsumed within the RCO targets specified in this notification.

IEX Proposal- for Revision of Green Contracts

Revision in classification of RPO Framework

MoP Order dtd 29.01.2021	MoP Order dtd 22.07.2022 & 19.09.2022	MoP Notification dtd 20.10.2023
Solar RPO	Wind RPO (COD after 31.03.2022)	Wind RE (COD after 31.03.2024)
Non-Solar RPO	HPO (COD after 08.03.2019)	Hydro RE (COD after 31.03.2024)
HPO	Other RPO	Distributed RE
		Other RE

Proposed revision in Green Contracts

Name of the Contract	Classification of RPO
Green Day Ahead Market	Wind/ Hydro/ DRE/ Other
Green DAC & ITD	Wind/ Hydro/ DRE/ Other
Green TAM	Wind/ Hydro/ DRE/ Other

Eligibility

Sellers: Eligibility conditions for participation of sellers in the respective sub-segment of Green Contracts shall be as per the MoP notification dated 20.10.2023 or its amendment

Buyers: All eligible Open Access buyers

RPO – Buyers can fullfill different RPO categories from Green contracts at the Exchange.

Electricity (Late Payment Surcharge and related matters) Amendment Rules, 2024 – Implemented w.e.f. 01st October 2025

NLDC Procedure – URS offer in the Market (Section –F):

- Applicability: All inter and intrastate generating stations, Electricity Trading Licensees, Interstate Transmission Licensees, Distribution Licensee or other user of Transmission system shall be covered under this procedure except energy limited resource such as Hydro Generating Station, Energy Storage System and renewable generators.
- The generating companies shall offer, the URS power, including the power available against the DC of the unit under shut down, in the power exchange, subject to technical constraints.
- The above power if not cleared in DAM, shall be offered by generator in other market segments including the RTM
- Such offer of power in the market shall be at a price <=120% of its energy charge, as determined or adopted by the Appropriate Commission
- In case of failure to offer such URS power in the power exchange(s), such quantum up to the DC shall not be considered as available for computing the payment of fixed charges for generator.

Electricity (Late Payment Surcharge and related matters) Amendment Rules, 2024.. Contd..

By 0900 hrs.

- Discom to intimate its schedule for requisitioning power from each generating company with which it has an agreement

DAM/RTM

- Generating companies shall offer the un- requisitioned surplus power, including the power available against the declared capacity of the unit under shut down (i.e., DC on bar and DC off bar), in the Power Exchange(s), subject to technical limitations such as ramping and start up capability, etc. as specified by the Central/State Commission as the case may be.
- Generating companies shall offer such un-requisitioned surplus power to Day Ahead Market first and if power is not cleared or is partially cleared in Day Ahead Market, it shall be offered in other market segments including Real Time Market
- Gencos shall ensure bids for the power offered for sale <= 120% of its EC + applicable tx. Charges
- In case it is found any genco has offered at >120% of EC for any time block(s), then the same quantum, whether cleared or uncleared in the market shall be considered as deemed not offered.

Exception

- If there is mismatch in timing of finalisation of day-ahead schedules in State Grid Codes with IEGC, the InSGS may offer the URS power in DAM as per provision of IEGC and any URS power not cleared in DAM can be scheduled by DISCOMs.
- If the generating station is not able to bid the URS quantum in the Real Time Market considering the fact that the DISCOM may requisition the URS during/after the RTM bidding session, due to mismatch in revision of real time schedule in State Grid codes and IEGC, the URS power available at the time of offering in the RTM session shall be considered as deemed offered

Electricity Amendment Rules 2005 (19th Sept 25)

- The Energy Storage System shall be utilised either as independent energy storage system or as part of generation, transmission or distribution.

- The Energy Storage System may be developed, owned, leased or operated by a generating company or a transmission licensee or a distribution licensee or a consumer or a system operator or an independent energy storage service provider.

- The Energy Storage System owned and operated by and co-located with a generating station or a transmission licensee or a distribution licensee or a consumer, shall have the same legal status as that of the owner:

  Provided that if such an Energy Storage System is not co-located with, but owned and operated by, the generating station or distribution licensee or consumer, the legal status shall still be that of the owner but for the purpose of scheduling and dispatch and other matters it shall be treated at par with a separate storage element.

- The developer or owner of the Energy Storage System, shall have an option to sell or lease or rent out the storage capacity in whole or in part to any consumer or utility engaged in generation or transmission or distribution or to a Load Despatch Centre or any other person."

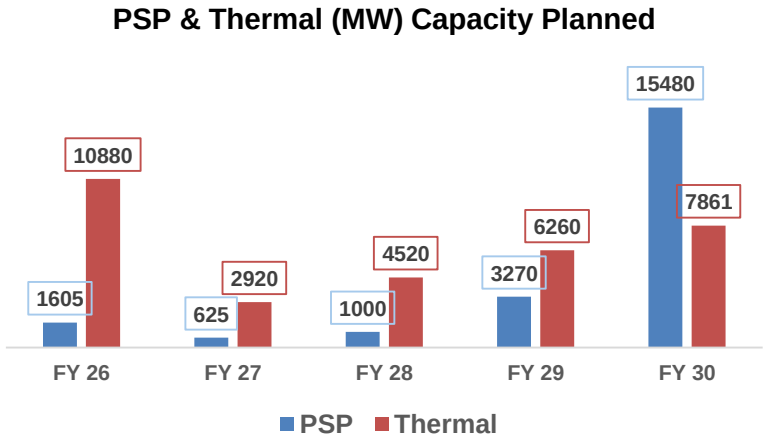
Way Forward

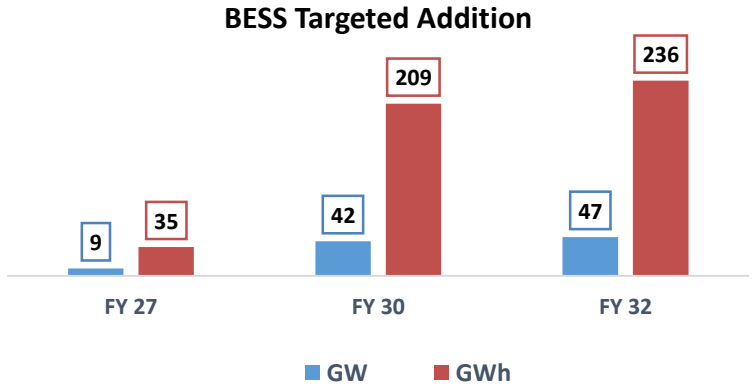
- ✓ **Future capacity addition- 33 GW Thermal (till FY 31)**:
  - Overall improvement in availability will result in reliable supply from spot markets.
  - Also increase in supply will provide opportunities for optimising expensive thermal units.
  - Every year around 25 GW RE Power get commissioned led to increase in sell liquidity

- ✓ **Improvement in peak power supply due to:**
  - Addition of BSES and PSP systems
  - Also, battery prices are decreasing, In recent auctions 2.08 Lakhs/MW/Month price was discovered with VGF and 2.8 Lakhs/MW/Month price was discovered without VGF.

- ✓ Recently **Financial Derivatives have been launched** on MCX and NSE. Derivatives will give an opportunity to hedge prices for future months.

- ✓ **New Products like Green RTM , Peak Hour Contracts** shall help Discoms to explore multiple avenues to meet their demand at most cost effective prices.





Thank You

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Annexure – C

Annexure – C

Security Constrained Economic Dispatch Presentation to JERC SAC

By : S K Soonee

SAC MOM JERC, 27 (5) ACTION- 13TH DECEMBER 2024

26. Shri Mediratta also commented on the importance of procurement of power from power exchanges. He explained that obligated entities may always be in shortage of renewable power since the RPO compliance trajectory is increasing. Hence they may not be able to meet their targets with tied up capacity alone. The presentation is attached as Annexure 'C'.

27. Shri S.K. Soonee appreciated the presentation of Shri Rajesh Kumar Mediratta regarding the optimisation of power purchase cost of the DISCOMS. He further added that states/UT of Goa and DNHDD while meeting their demand and satisfying all the constraints, can discover their shadow prices by running Security Constrained Economic Dispatch (SCED). After the discovery of the shadow price, power exchange can be used to procure physical power and this will reduce the overall power purchase cost.

5. Exploring the possibility of implementation of SCED in order to optimize power purchase costs.

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Background of SCED

The SCED has been implemented at the National Level by NLDC on 1st April, 2019 as per the direction of CERC

- ✓ Number of power plants **~ 100** +
- ✓ Capacity **~100 GW IC (Scheduled ~ 50-60 GW)**
- ✓ Daily fuel Cost **~ 350-400 Cr/Day**
- ✓ Daily saving caused by SCED **~ Rs 3-4 Cr/day (1%)**
- ✓ Overall, so far **~5000 Crore saved and disbursed**
- ✓ Operational ease for **Plants ~ 40 % decrease**
- ✓ Lots of Intangible benefits – Inhouse, Scalable
- ✓ Certainty of Fuel for the cheaper plants, PLF
- ✓ Helps in RE integration, Reserve provision etc

Implementation Status in States of India

Regulatory Initiatives:

Maharashtra: Included in the draft Grid Code under the definition

Karnataka: Included in draft Grid Code under the responsibility of SLDC

Pilot Study under Regulatory Order:

SLDC, Maharashtra: Submitted a report to MERC based on an offline study.

Presently, the automatic run of SCED has been implemented, and the report is being prepared.

Visualisation dashboard to analyse results

Saving observed is of the order of **1 – 2 %**

Additional information, like SMP and DUALs / Marginals available

Implementation Status in States of India

Pilot off-line study:

- ✓ **Gujarat:** Study completed with one month's data by IIT, Gandhinagar. A paper submitted to ICPS–2025 to share the results
- ✓ **Madhya Pradesh:** A Study has been done in-house with one month's data. Cost savings observed.
- ✓ **Uttar Pradesh:** Study completed with one month's data by IIT, Kanpur. A paper submitted to ICPS–2025 to share the results.
- ✓ **Delhi:** Discussions with BRPL regarding data cleaning are complete. IIT-Bombay is currently analysing the data.
- ✓ **Himachal Pradesh:** SLDC HP is collaborating with IIT Roorkee.

Implementation Status in States of India

- ✓ **Telangana:** A preliminary study has been conducted by IIT Hyderabad.
- ✓ **Andhra Pradesh:** Already utilising Linear Programming (LP) for scheduling activities. The pilot offline study is expected to start shortly.
- ✓ **Karnataka:** A detailed plan is being prepared to start the pilot off-line study.
- ✓ **DVC:** DVC too has requested an optimisation study. Discussions scheduled in the first week of Nov'25
- ✓ **IEGC – 2023 has already incorporated SCED under the responsibility of RLDCs / NLDC.**
- ✓ **SERCs are gradually adopting the SCED under the responsibility of SLDCs.**
- ✓ **A pilot study could be directed to examine the advantages of SCED**
- ✓ **sharing valuable information for planning and in assisting Regulator's.**

Proposal for Consideration

Action points Order for Pilot by JERC

1. Interface for input data
2. Preparation of the SCED engine
3. Association with any local Academia
4. Interface for output data
5. Parallel running for 3 months –
6. Develop a portal for visualization
7. Stakeholder consultation
8. Submit report to JERC within six months

Discussion