

Large Scale Grid Integration of Renewable Energy: Early Actions & Lessons from India



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केन्द्रीय विद्युत विनियामक आयोग
CENTRAL ELECTRICITY REGULATORY COMMISSION



Renewable Energy (RE) Targets for India and Policy Measures

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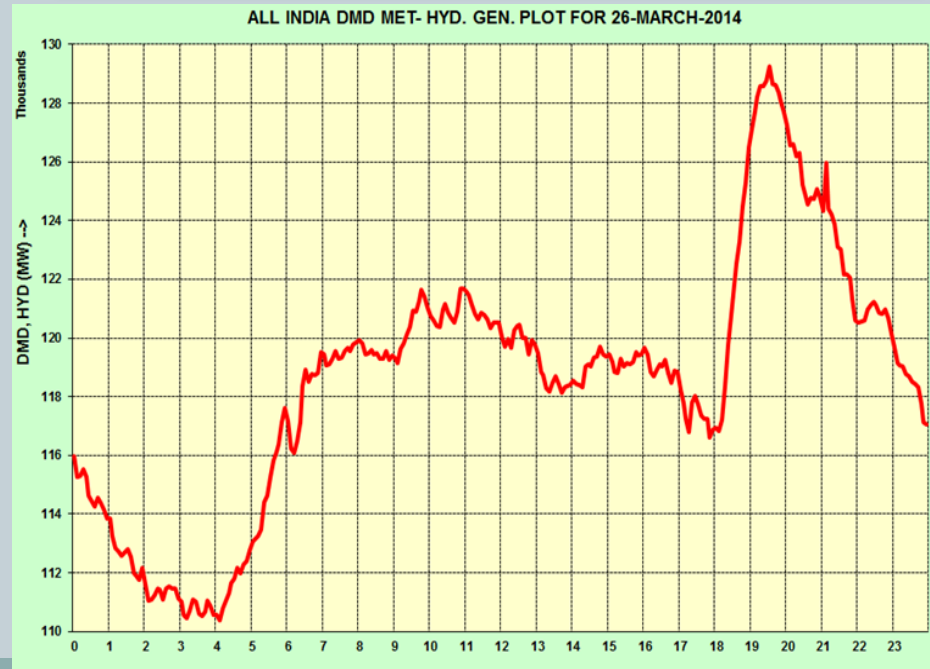


Indian Grid: a snapshot

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- 5 regional grids now interconnected- all India synchronized grid as of December 2013
- Installed Capacity: >300 GW
- Peak Demand: 150 GW
- 907 Generating Stations
- Per capita consumption: 1010 kWh/yr

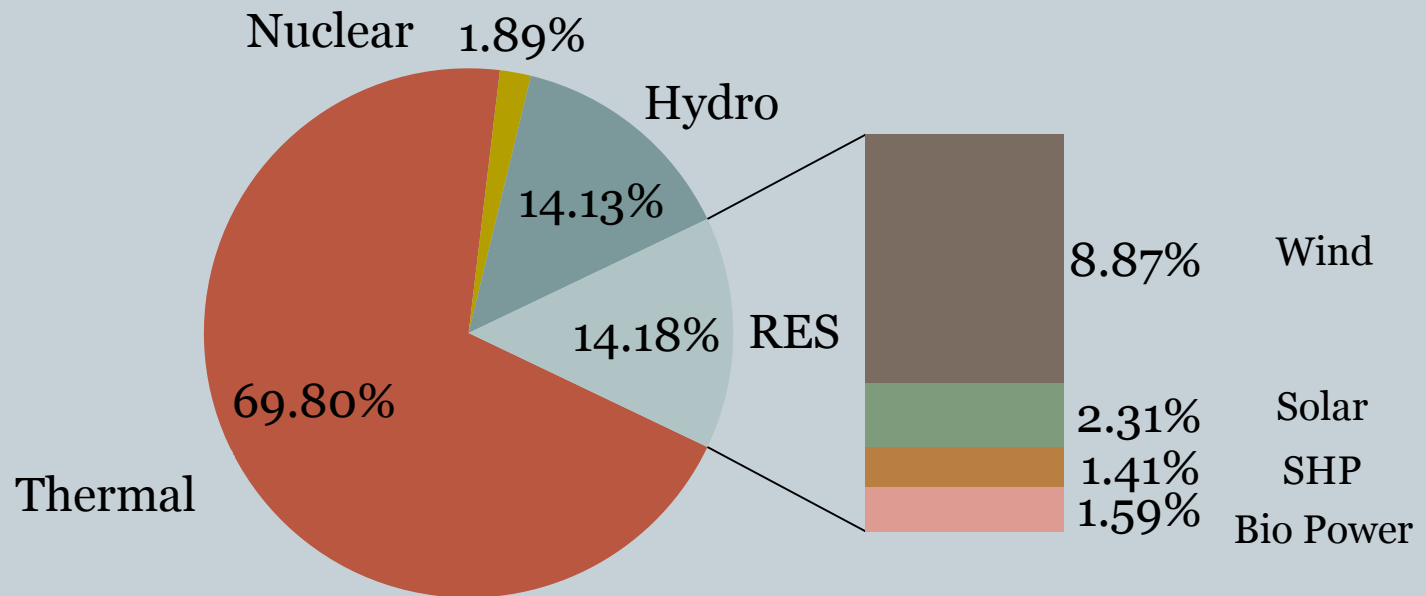
Morning Peak @ 140 MW/min for 40 minutes
Evening Peak @ 200 MW/min for 40 minutes



Generation Overview

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- Total Installed Capacity of ~303 GW
- Renewable Energy (RE) Capacity of 43 GW (more than 14% of installed capacity), as on April 30, 2016



India enacted the National Action Plan on Climate Change (NAPCC) & Jawaharlal Nehru National Solar Mission (JNNSM) in 2009-2010

INDCs by India at CoP21

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Comprehensive and balanced: includes Adaptation, Mitigation, requirement for Finance, Technology transfer, Capacity Building

- To reduce the emissions intensity of GDP by 33 - 35% by 2030 from 2005 level.
- To achieve 40% of electric power installed capacity from non-fossil fuel by 2030: **175 GW of Renewables by 2022**
- To create additional carbon sink of 2.5 -3 billion tonnes of CO₂ equivalent through additional forest and tree cover

Backdrop:

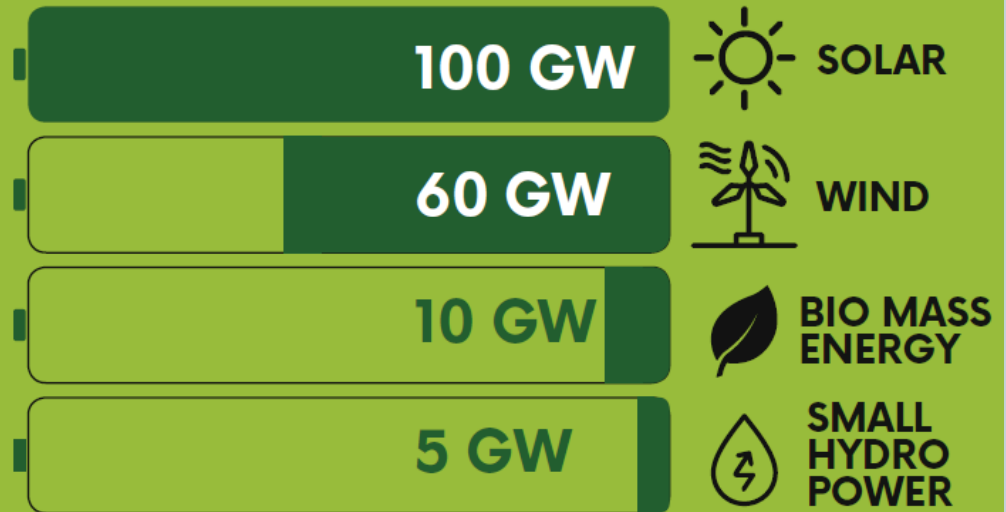
- *Per capita CO₂ emissions of India are one-tenth of US & one-third of world avg*
- *Rapid growth till 2030: power, infrastructure, housing, poverty eradication etc*

Renewable Energy Goal by 2022

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- India has set a target of reaching 175 GW of Renewable Energy capacity by 2022 (from the present level of 43 GW ~ 14% of total capacity and 6% of generation)

**INCREASE OVERALL
RENEWABLE
CAPACITY BY
MORE THAN 5 TIMES
FROM 32 GW IN 2014
TO 175 GW BY 2022**



Region-wise Renewable Energy targets by 2022

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Technology	Solar Power (in MW)	Wind Power (in MW)	Bio Power (in MW)	Small Hydro Power) in MW)
Northern Region	31,120	8,600	4,149	2,450
Western Region	28,410	22,600	2,875	125
Southern Region	26,531	28,200	2,612	1,675
Eastern Region	12,237		244	135
North-Eastern Region	1,205			615
Others	30	600	120	
ALL INDIA	99,533	60,000	10,000	5,000

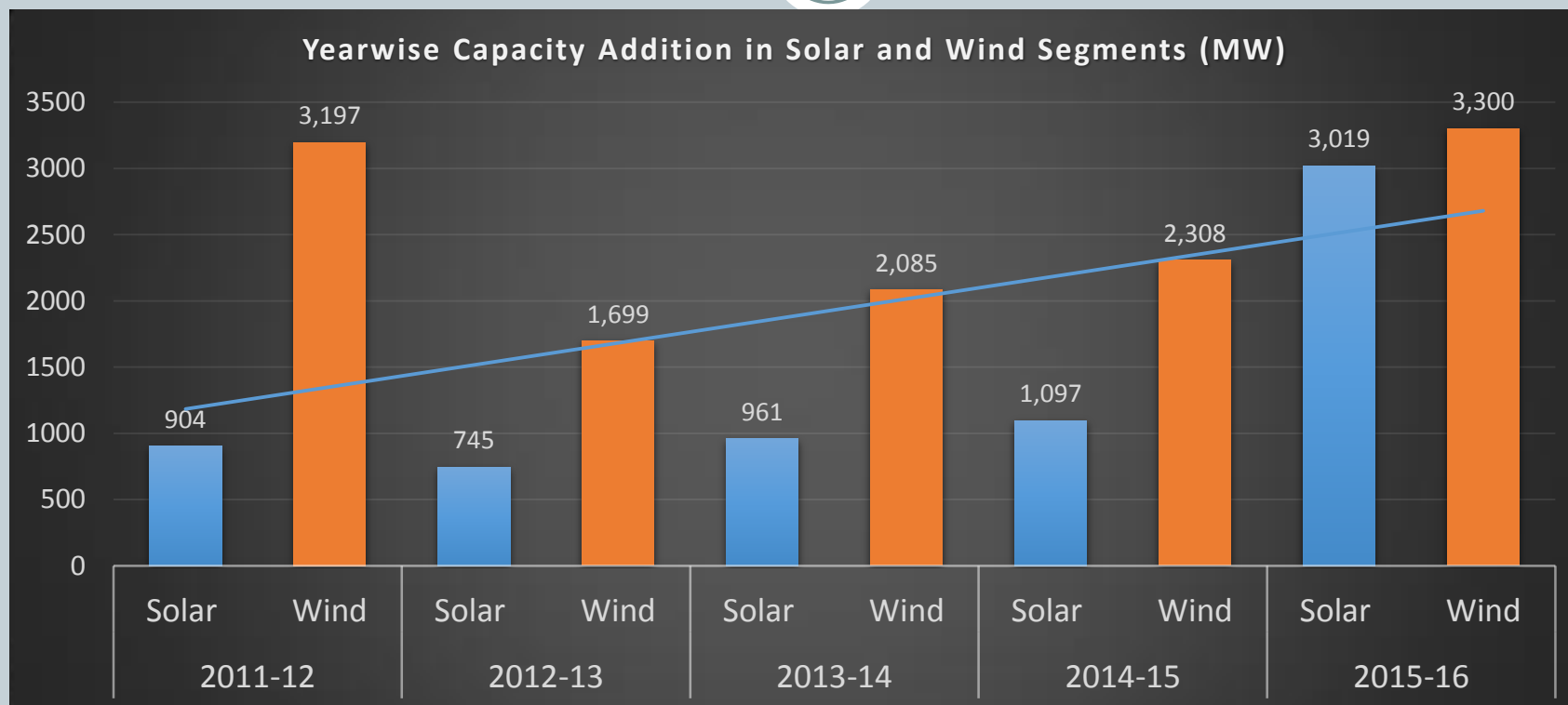
➤ Further broken down into State level targets

Source: MNRE

➤ Each state will have a solar Renewable Purchase Obligation (RPO) of 8% for Solar by 2022

6.7 GW of Solar & 12.6 GW of Wind capacity added in last 5 yrs

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Technology

Installed capacity as on April 30,
2016 (in MW)

Wind Power

26,867

Solar Power

6,998

Bio Power

4,831

Small Hydro Power

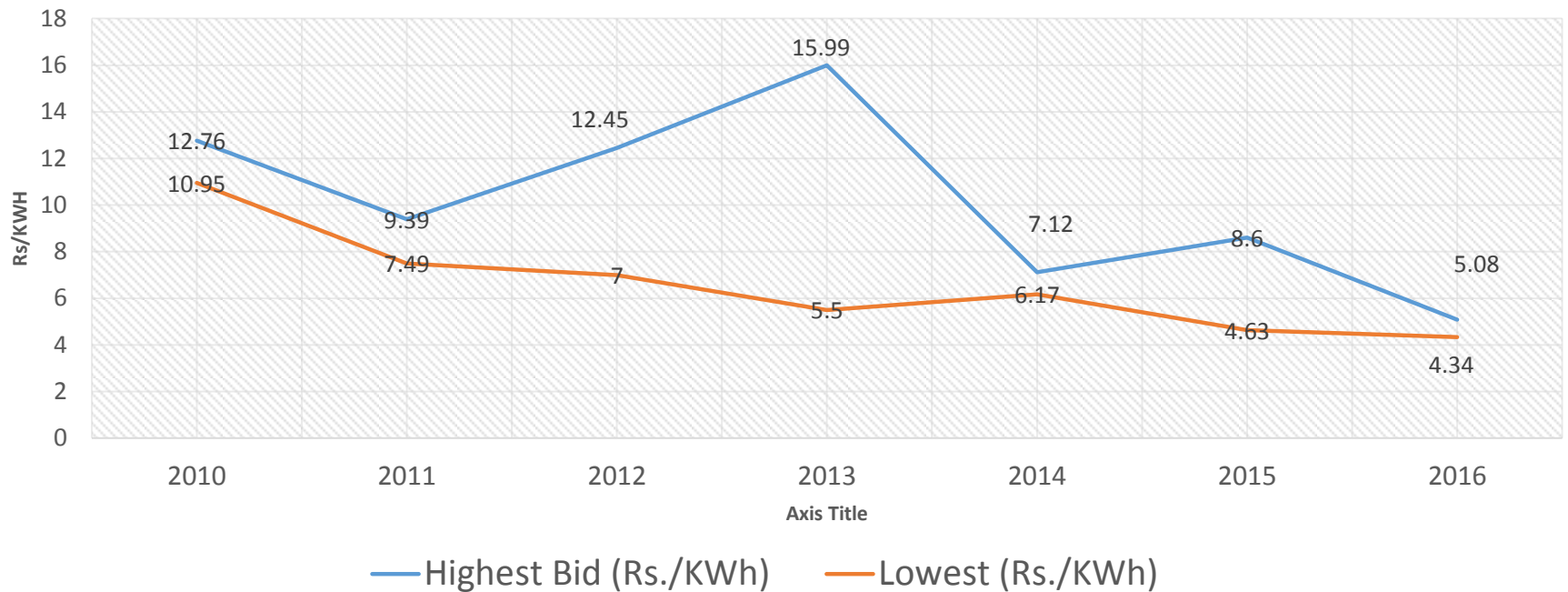
4,275

Source: MNRE

Price of utility scale solar has dropped 60% since 2010

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Trend Analysis for solar Bid results (2010-2016)



Source: MNRE

Institutional Structure of RE sector

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Utilities & Transmission

DISCOMS

PGCIL¹

Policy & Governing Institutions

MNRE

SNA²

State Govt

Regulator & Grid Operator

CERC & SERC³

NLDC, RLDC, SLDC⁴

Technical Authority

CEA⁵

SECI⁶
NIWE⁷

Funding Institutions

IREDA⁸,
National/
Privatised
Banks,
Multilateral
Institutions

Others

Solar
Developer &
Installer

Equipment
Manufacturer
& Supplier

Consumer

1: Power Grid Corporation of India Ltd

2: State Nodal Agency

3: State Electricity Regulatory Commission

4: National/Regional/State Load

Despatch Center

5: Central Electricity Authority

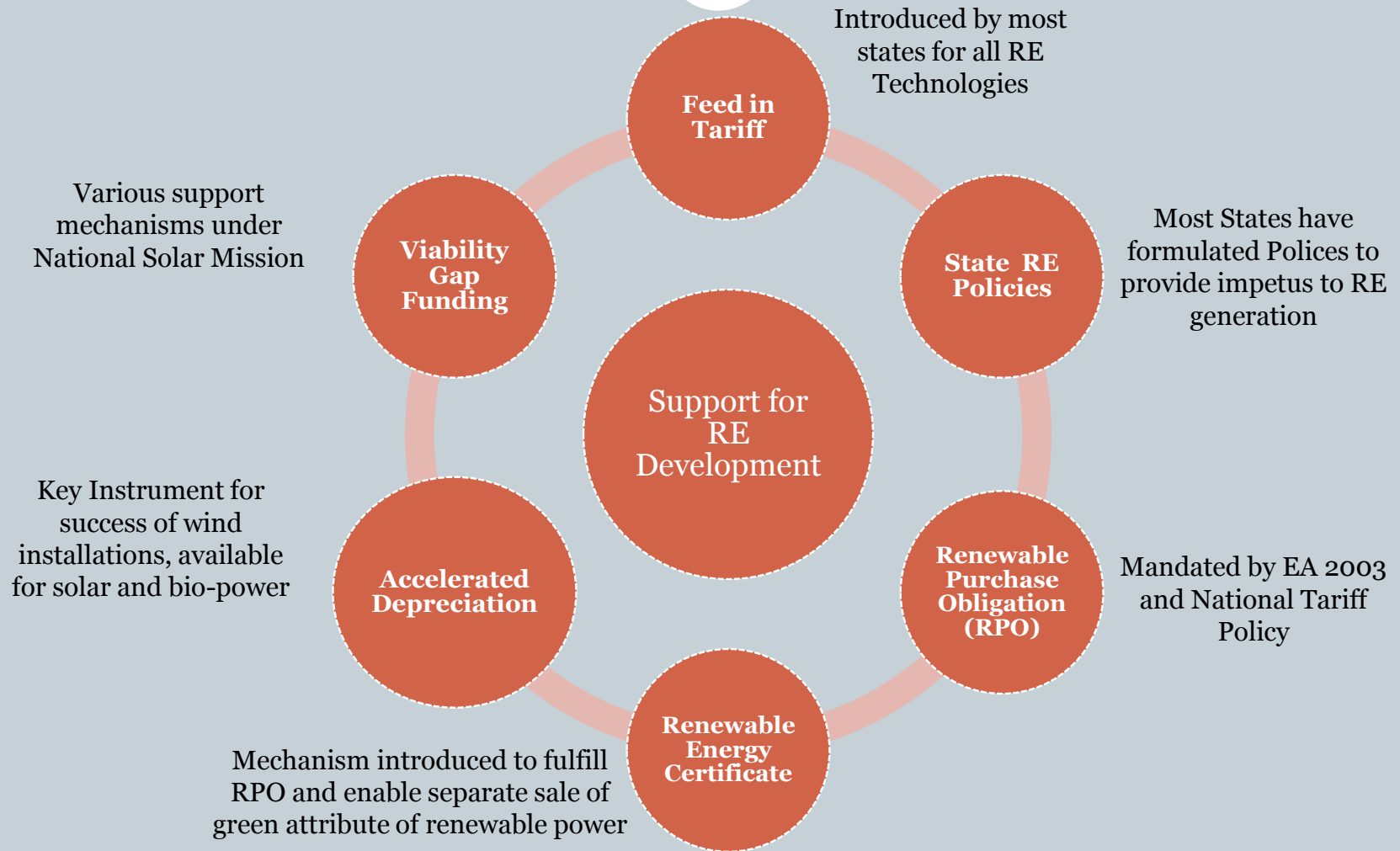
6: Solar Energy Corp. of India

7: National Institute of Wind Energy

8: Indian Renewable Energy Development Assoc

Policy Support for RE in India

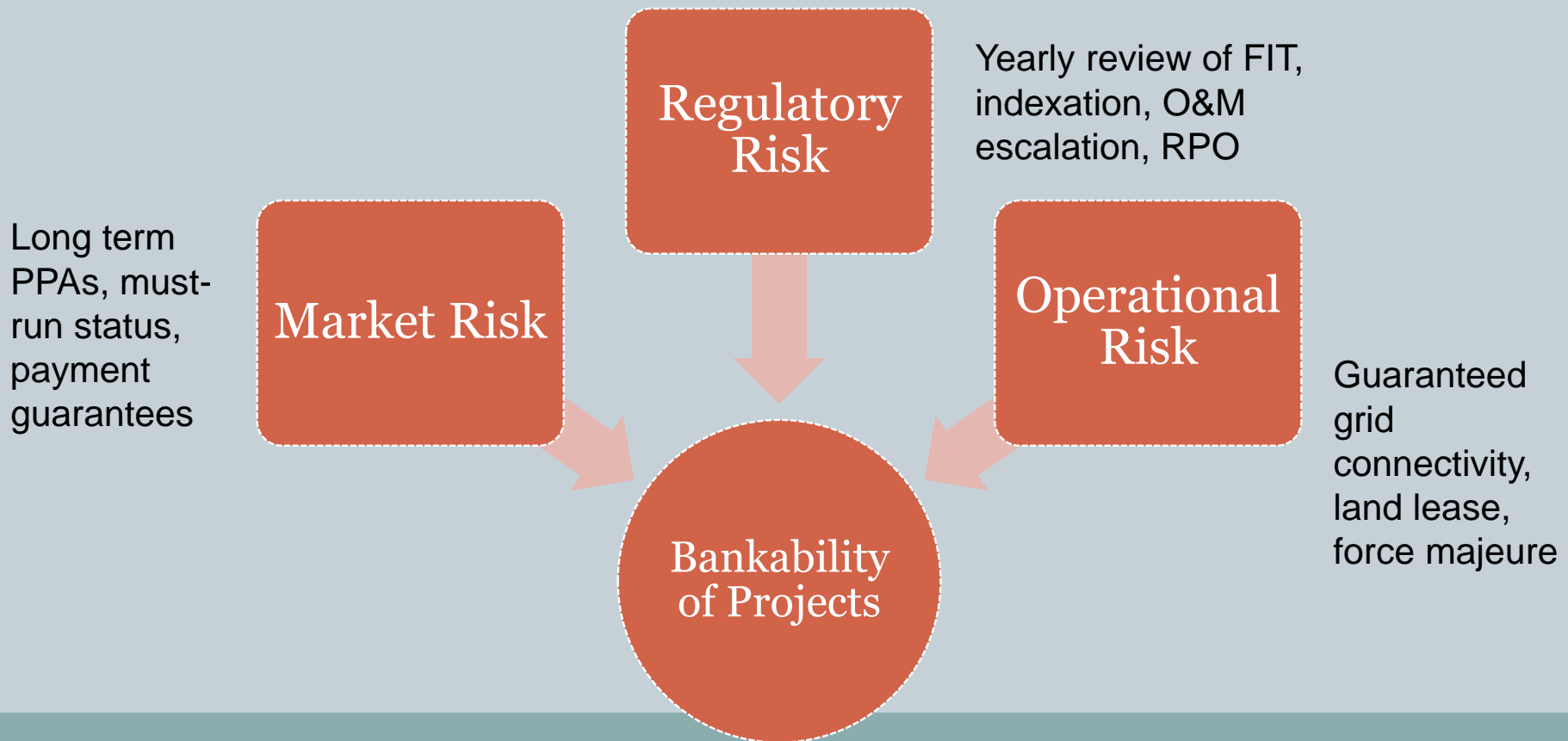
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Improving bankability of RE projects

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Indian Government & Regulators have worked hard to reduce risk for RE projects



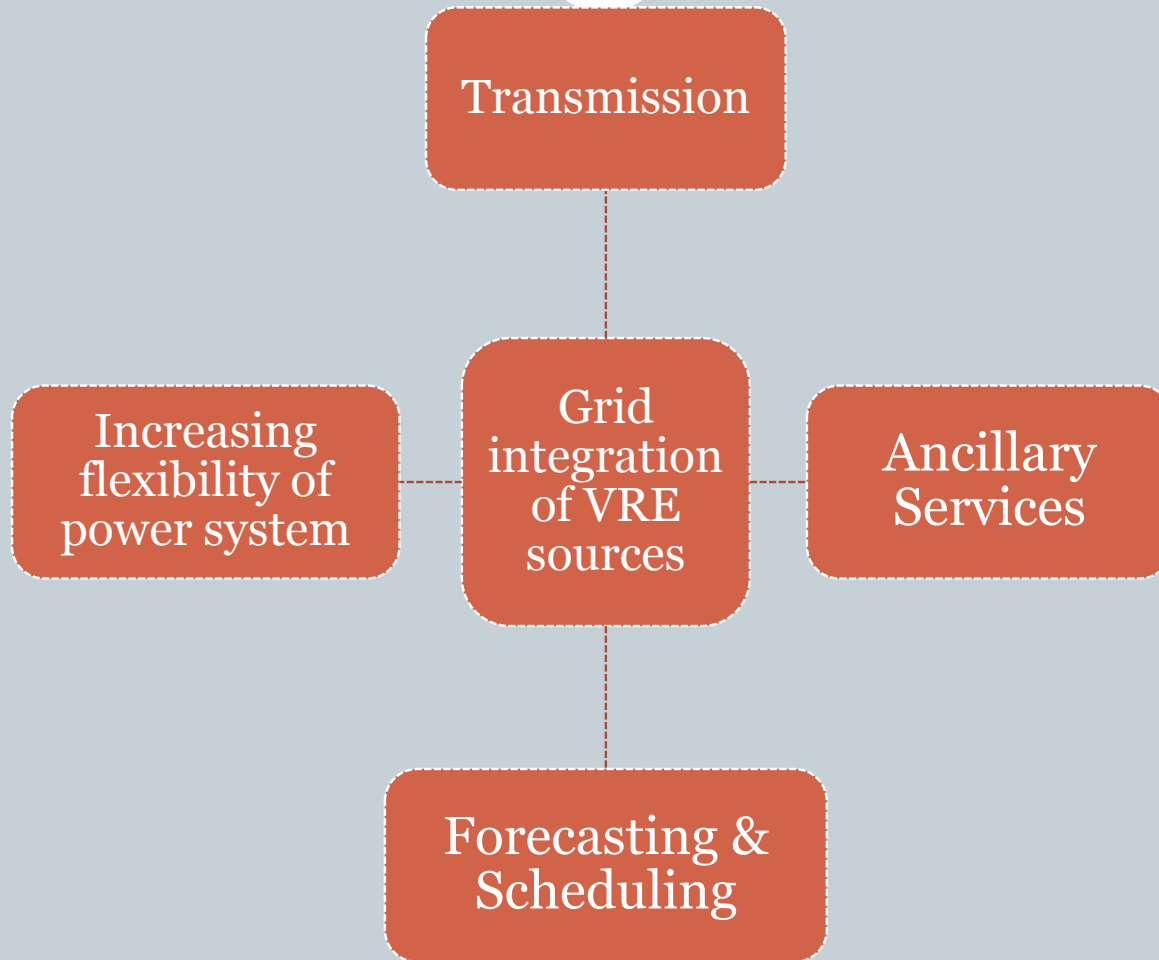
Grid Integration & Regulatory Interventions

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Grid Integration of Infirm RE sources

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Transmission Planning & Support

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- ADB is lending \$1 Billion to PowerGrid or the Central Transmission Utility (CTU) for strengthening transmission infrastructure between southern & western regional grids
- Green Energy Corridors (GEC)- Phase I & Phase II- conceptualized to strengthen transmission network
 - 765 kilovolt (kV) and 400 kV high voltage transmission lines, sub-stations, HVDC terminals, etc
- GEC I: RE Capacity envisaged - about 33 GW (in 12th plan) ; ~INR 40,000 crores (~USD 6 billion)
- GEC II: connectivity for solar parks ~8 GW already under planning
- In 13th Plan (2017-2022): investment of INR 120,000 crores envisaged
- Tariff Policy 2016: Inter-state transmission charges & losses to be waived for solar & wind projects commissioned by 2022

Scheduling, Forecasting & Commercial Settlement

(Framework for solar & wind generators)

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- Most renewable capacity connected to the State Transmission Network; must-run status
- All PPAs are single part tariff, based on actual generation => did not incentivize generators to invest in forecasting and submit schedules to SLDCs
- Framework issued by CERC in August 2015 lays the foundation for sustainable integration of RE sources
- System operators will now have visibility into how much solar & wind power is expected on the grid in a time-block*
- Model Regulations for States in October 2015 (six states in process of finalizing)

* Indian grid operates on 15-min despatch; 96 time-blocks in a day

Scheduling, Forecasting & Commercial Settlement

(Framework for solar & wind generators)

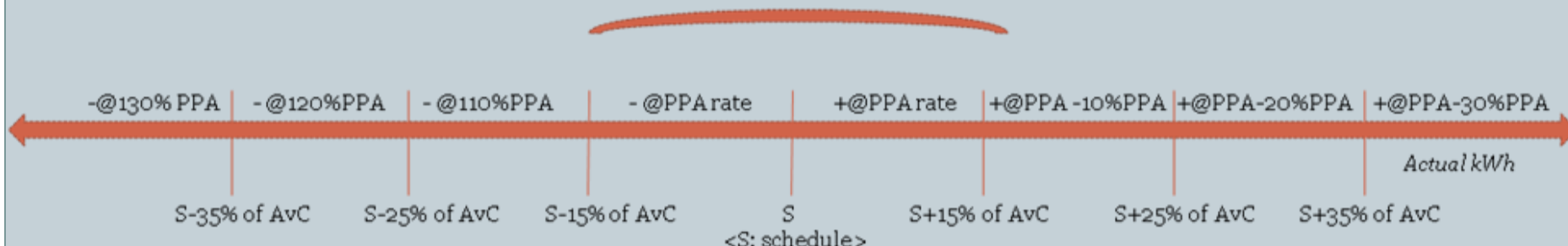
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- System Operator shall forecast from grid security perspective
- RE generators, independently or through Qualified Coordinating Agency (QCA)*, shall forecast & submit schedule which'll form the basis for commercial settlement, on a day-ahead basis
- Due to the infirm nature of these sources, more flexibility provided w.r.t schedule
- Incentive to improve forecasting- deviation charges outside a tolerance band, which could be tightened over time
- Bringing RE generators in alignment with existing commercial framework opens the entire country as a market for them

* Within States, forecasting & scheduling at the pooling station level

Deviation Settlement Framework for Regional Entities

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- Error definition: $[(\text{Actual generation} - \text{Scheduled generation}) / \text{Available Capacity}] \times 100$
- Payment as per schedule @PPA Rate
- Deviation Settlement within tolerance band (+/- 15%):
 - Receipt from/payment to pool @PPA rate (i.e. in effect, payment as per actuals)
- Beyond 15%, a gradient band for deviation charges is proposed as follows:

<i>Abs Error (% of AvC)</i>	<i>Deviation Charge</i>
15%-25%	10% of PPA rate
25%-35%	20% of PPA rate
>35%	30% of PPA rate

- 16 revisions allowed, one for every one-and-half-hour block, effective from 4th time-block.

Renewable Energy Management Centers (REMCs)

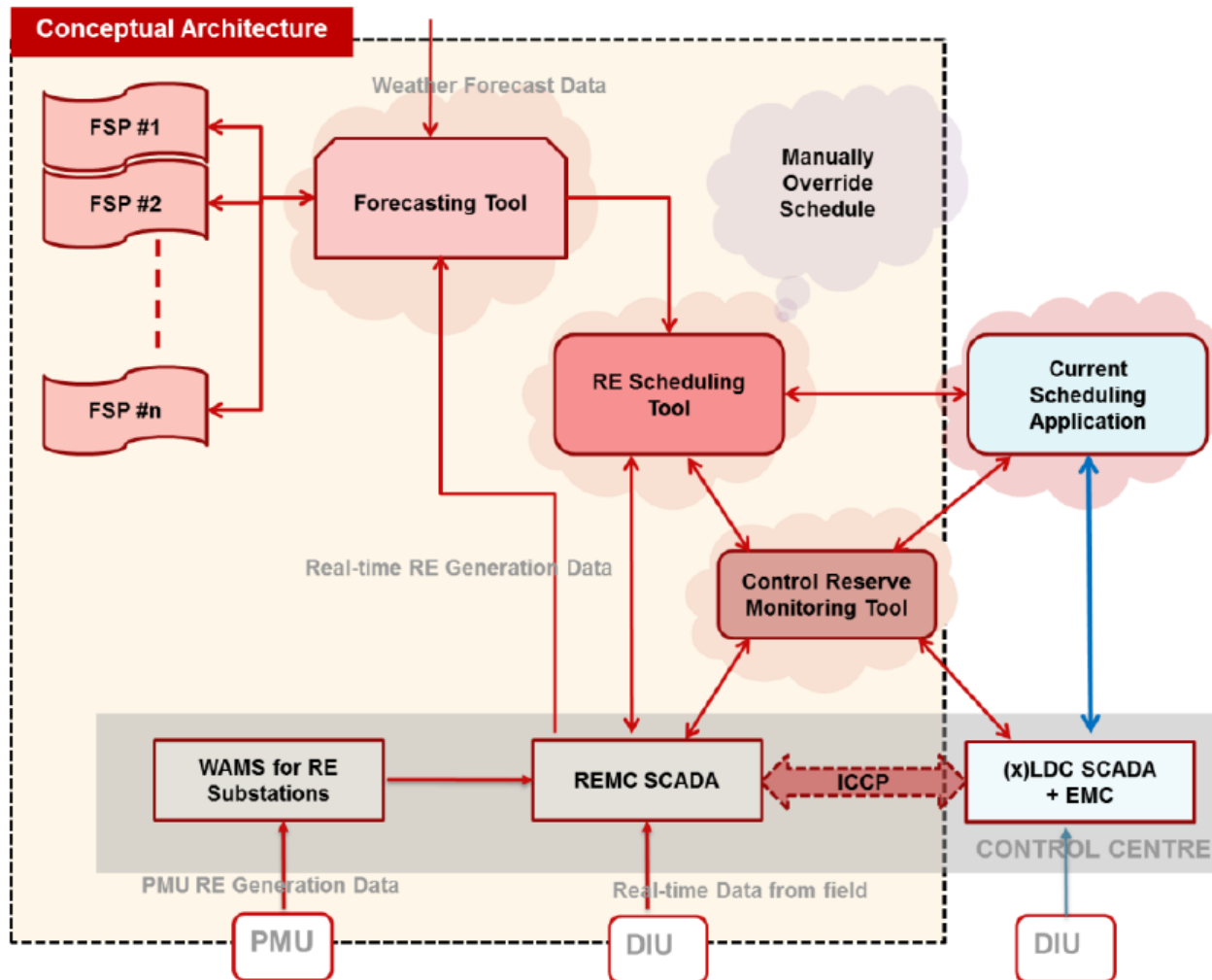
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Renewable Energy Management Centers (REMCs) to be established at Regional & State Load Despatch Centers

- Technical assistance by GIZ (€2 M) to PowerGrid (implementation lead) on Conceptual Design of REMCs, including network management
- Detailed Project Reports (DPRs) prepared for RLDCs and 7 States
- REMC Control Center comprises of following modules:
 - REMC SCADA
 - Forecasting Tool
 - RE Scheduling Tool
 - Control Reserve Monitoring Tool
 - WAMS for RE Substations

Conceptual Architecture of REMC

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Ancillary Services Regulation

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- Operationalized in April 2016*
- NLDC, through RLDCs, operates Ancillary Services
- Objective: to restore the grid frequency to desired level (tertiary frequency control) and to relieve congestion in the transmission network
- Triggering criteria:
 - Extreme weather forecasts and/or special day;
 - Generating unit or transmission line outages;
 - Trend of load met & frequency;
 - Excessive loop flows leading to congestion.

* For Inter-State Generating Stations, directly under purview of CERC & NLDC

Ancillary Services- Operations

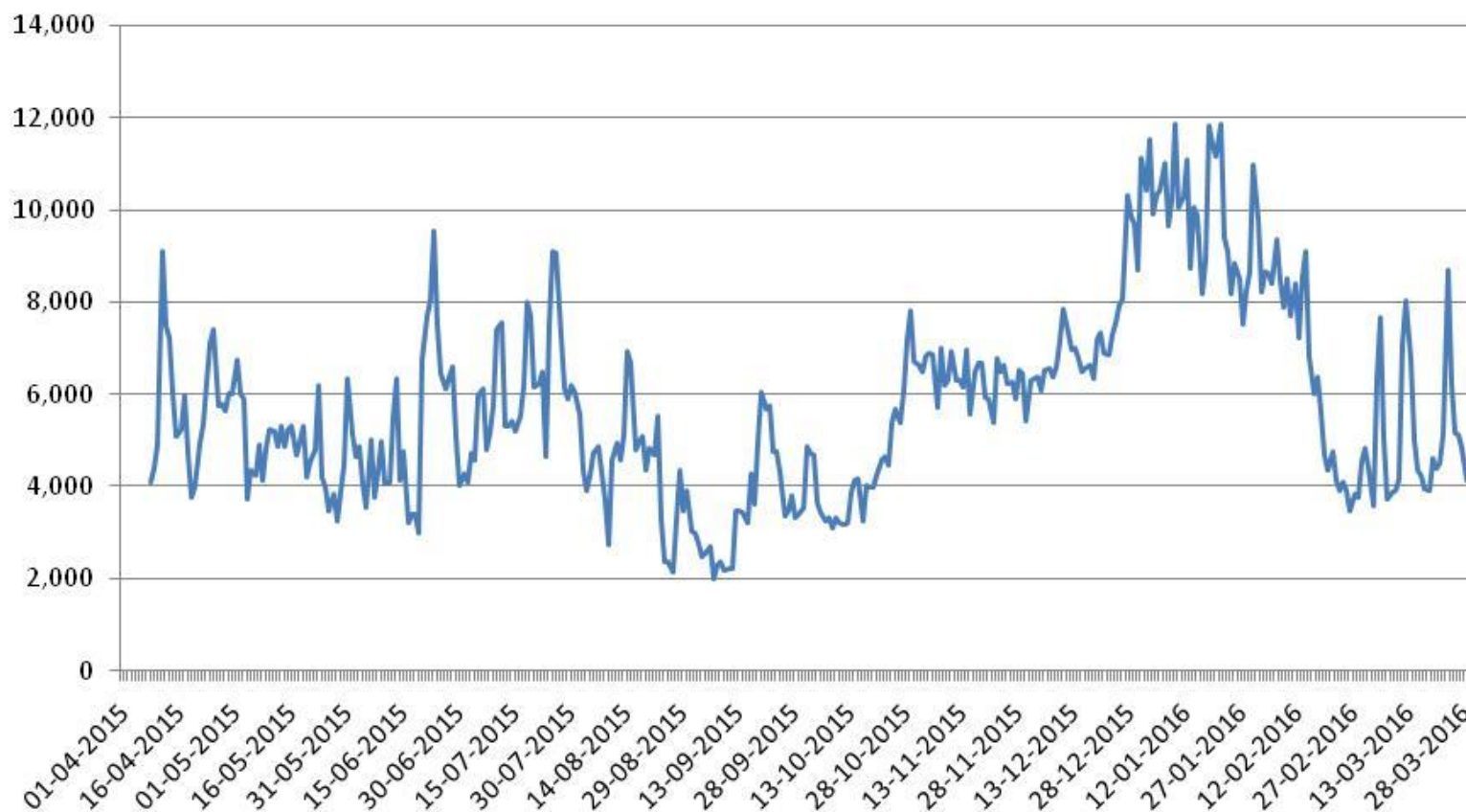
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- Regulation Up: utilize un-requisitioned surplus of regional generating stations to increase supply (e.g. generator outage or transmission congestion)
- Regulation Down: instructions to decrease generation if load is lower than expected (e.g. weather changes)
- Merit order stacking, based on variable cost
- Regulated incentive to generators for participating
 - Mark-up for Regulation Up;
 - a % of variable charges for Regulation Down

Un-requisitioned Surplus (URS) available with Inter-state Generating Stations

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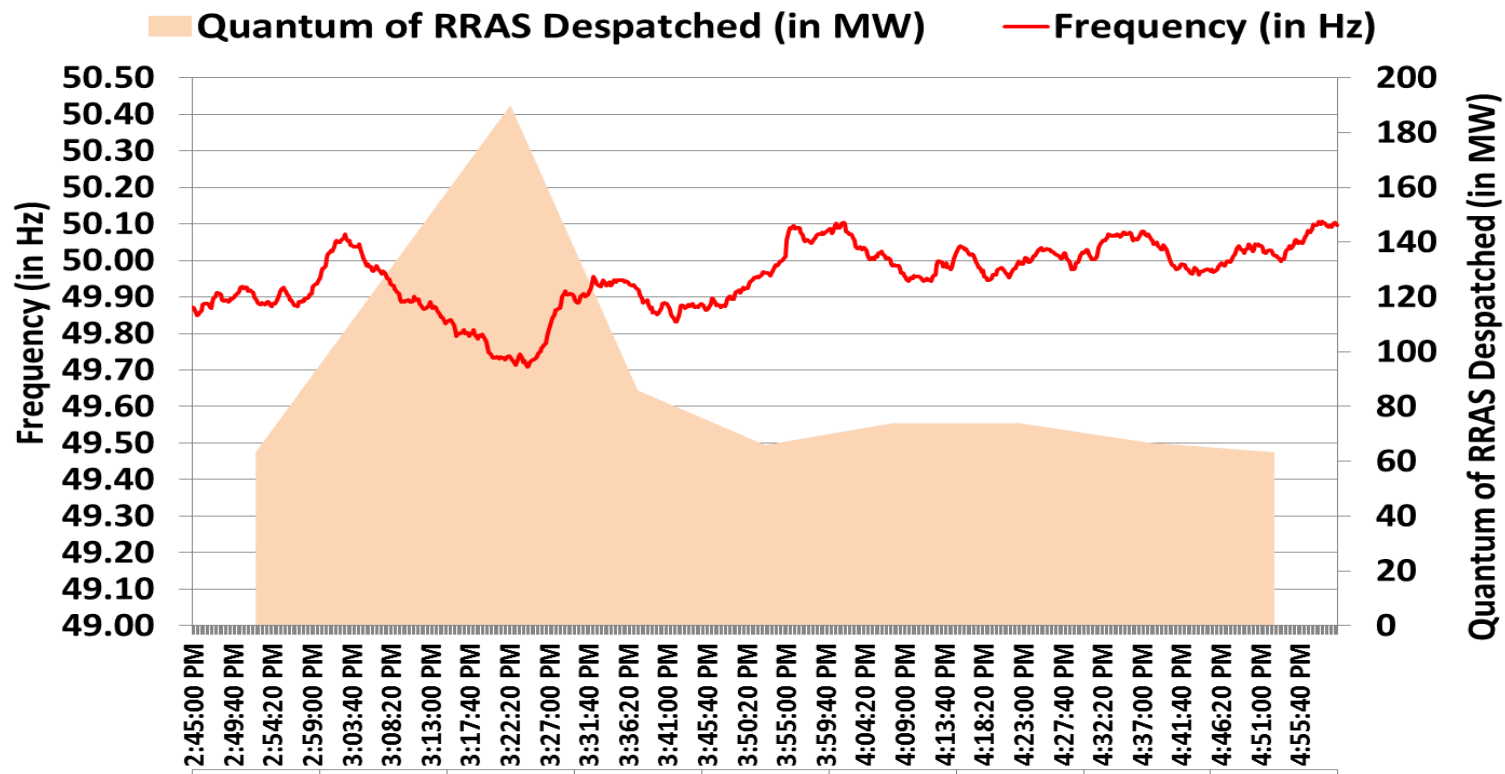
Hourly average All India URS 2015-16 (MW)



Average Un-requisitioned Surplus (URS) in a time-block: 6,175 MW

Example: Outage of HVDC Mundra – Mohindergarh Pole

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- Event Date: 28th April, 2016, Event Time: 1434 Hrs
- DM water leakage in valve hall, TTC/ATC of WR-NR corridor reduced from 7450 MW/6950 MW to 6200 MW/5700 MW
- RRAS despatch : 14:45 To 17:00 hrs, Regulation UP - 300 MW
- Effect of RRAS: Frequency improvement

Despatch of Ancillary Services

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- 2 months operational experience: April & May 2016

	Regulation Up		Regulation Down	
Data as of 18/5	No. of instances	Max power despatched	No. of instances	Max power despatched
	84	800 MW	17	1900 MW

During May 2016:

Regulation Up- on average ~3 / day; total MUs: 45

Regulation Down- on average ~1/day; total MUs: 27

(Daily total energy at national level ~3300 MUs)

Flexibility of Power System for Balancing

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- Flexing of coal plants: technical minimum now 55% (CERC Amendment to Grid Code in April 2016)
 - Generators are compensated for degradation in Station Heat Rate through increased energy charges
- Pumped storage present capacity: ~4800 MW
(only half is being operated in pumping mode)
- Gas plants installed capacity: ~24,500 MW
(Operating at very low PLF)

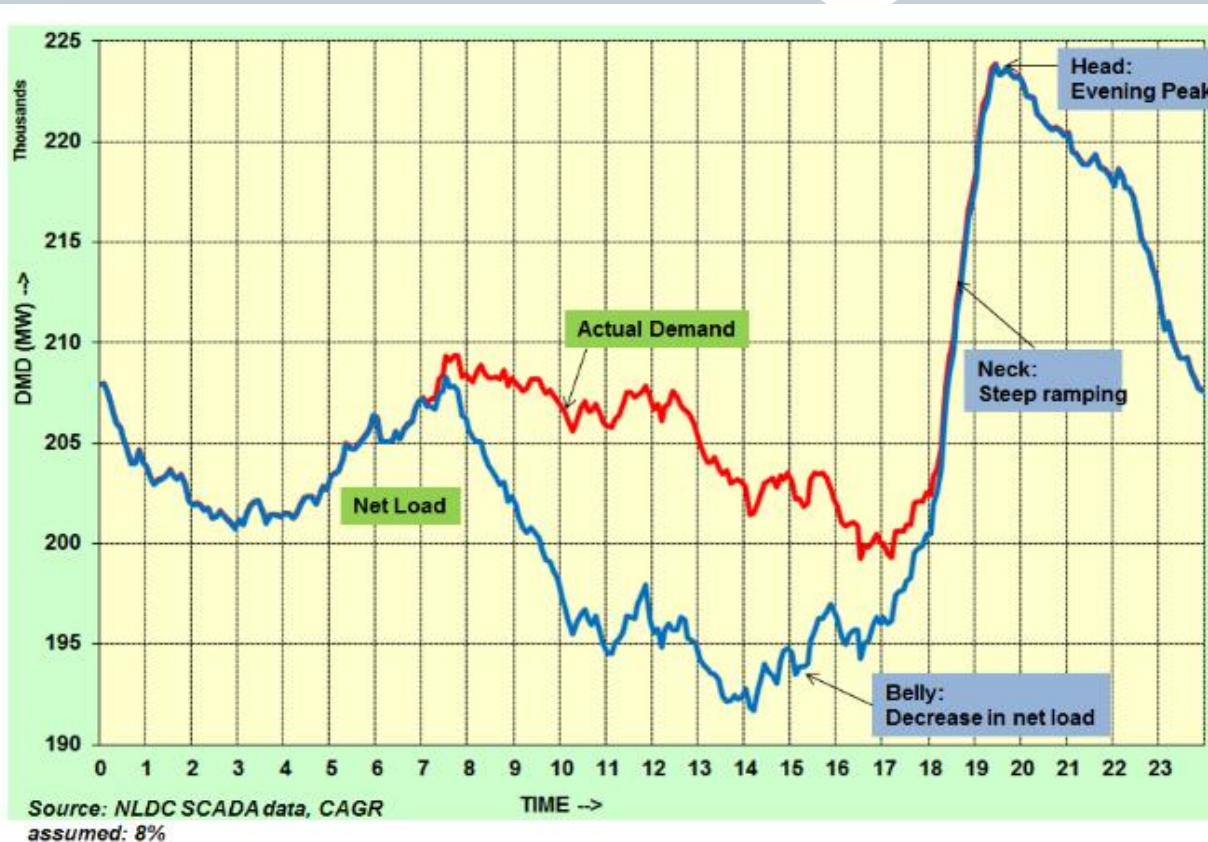
Other Regulatory measures

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- Roadmap on Spinning Reserves
 - Automatic Generator Control (AGC) for secondary frequency control to be operationalized in regional generators by 2017
 - POSOCO to create a market framework for Ancillary Services
 - States encouraged to align their Ancillary Services Regulations
- Power Markets: 24x7, intra-day trades
- Communication infrastructure: metering and telemetry upgrades in every State

Grid Operation Challenge: the Duck Curve

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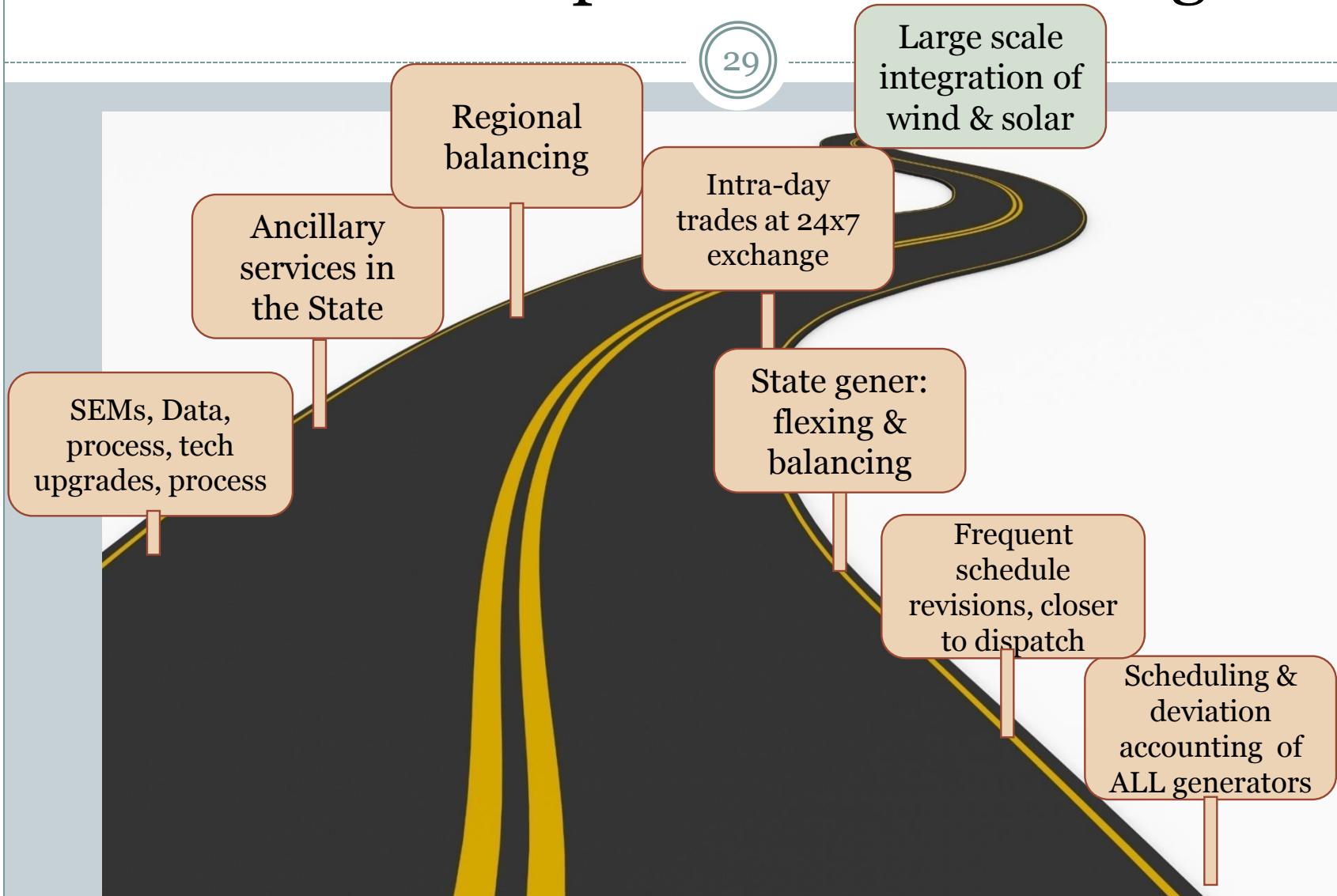


- Enhanced flexibility of coal plants
- Fast ramping gas plants
- Storage solutions such as pumped hydro

Greening the Grid: despatch modeling study to simulate grid operation in 2022
Participants: NREL, LBNL, NLDC, RLDCs, sponsored by USAID

The Roadmap to achieve RE Targets

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THANK YOU

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[http://powermin.nic.in/sites/default/files/uploads/Ujwal Bharat Brochure English.pdf](http://powermin.nic.in/sites/default/files/uploads/Ujwal%20Bharat%20Brochure%20English.pdf)

APPENDIX

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Yearly goals to reach 100,000 MW of Solar

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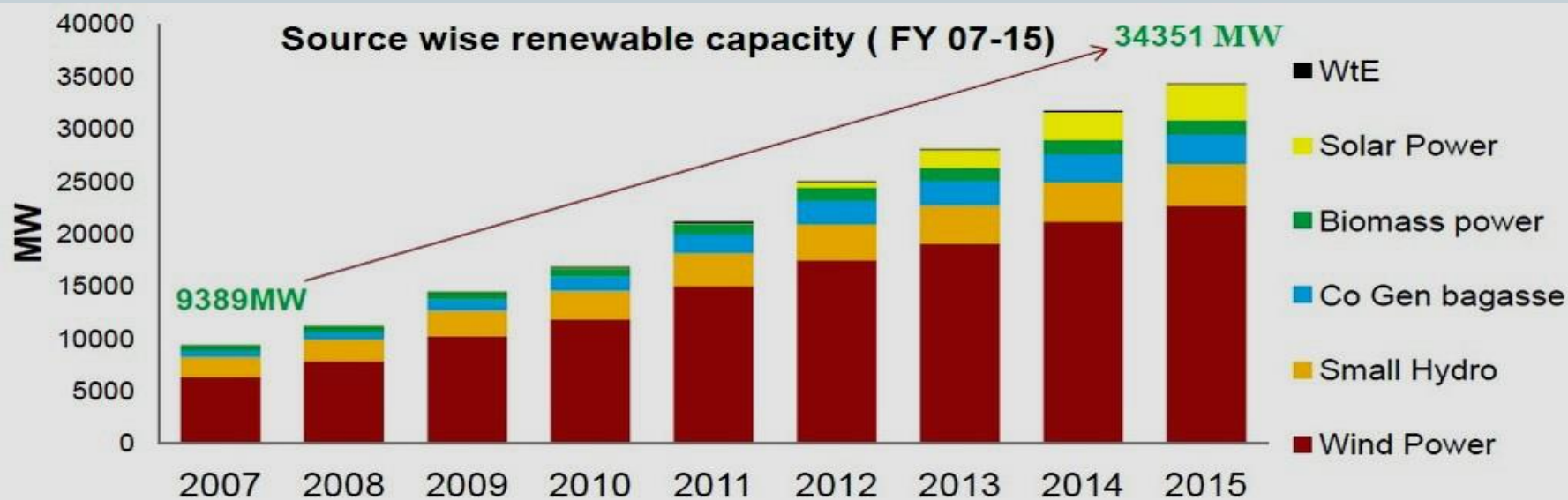
Year	Yearly Target (MW)	Cumulative Target (MW)
2015-16	2,000	5000
2016-17	12,000	17,000
2017-18	15,000	32,000
2018-19	16,000	48,000
2019-20	17,000	65,000
2020-21	17,500	82,500
2021-22	17,500	1,00,000

- Broken down into State level targets
- Each state will have an RPO of 8% for Solar by 2022

Progress so far - overview

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Technology	Target by 2022	Achievements as on April 30, 2016 (in MW)
Wind Power	60 GW	26,867
Solar Power	100 GW	6,998
Bio Power	10 GW	4,831
Small Hydro Power	5 GW	4,275



Renewable Energy Certificates (RECs)

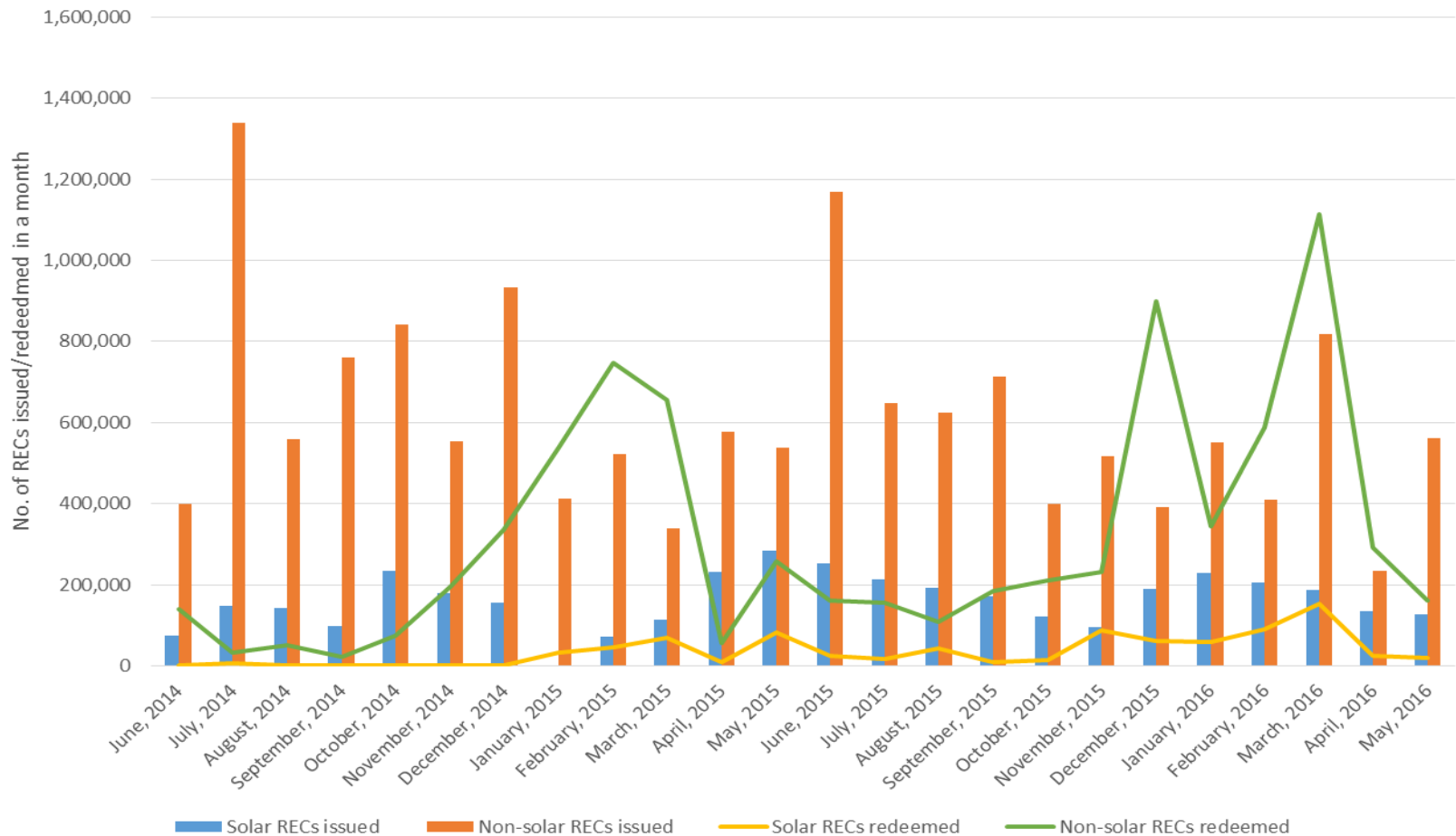
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- REC mechanism instituted to overcome resource variation across States- for RPO compliance.
- Recognizes the green attribute of renewable power; enables RE generator to sell at brown power rate and sell green attribute separately
- RECs issued by central agency NLDC based on actual metered generation of RE power
- RE generators can sell these certificates to obligated entities (utilities/open access consumers) who need to fulfil their RPO
- RECs compensated at a market determined price (@power exchanges) within a price band (floor and forbearance price) determined by CERC
- Floor & forbearance price move with the solar and non-solar tariffs and Average Power Purchase Cost (APPC) of the States

Enforcement of RPO has been challenging

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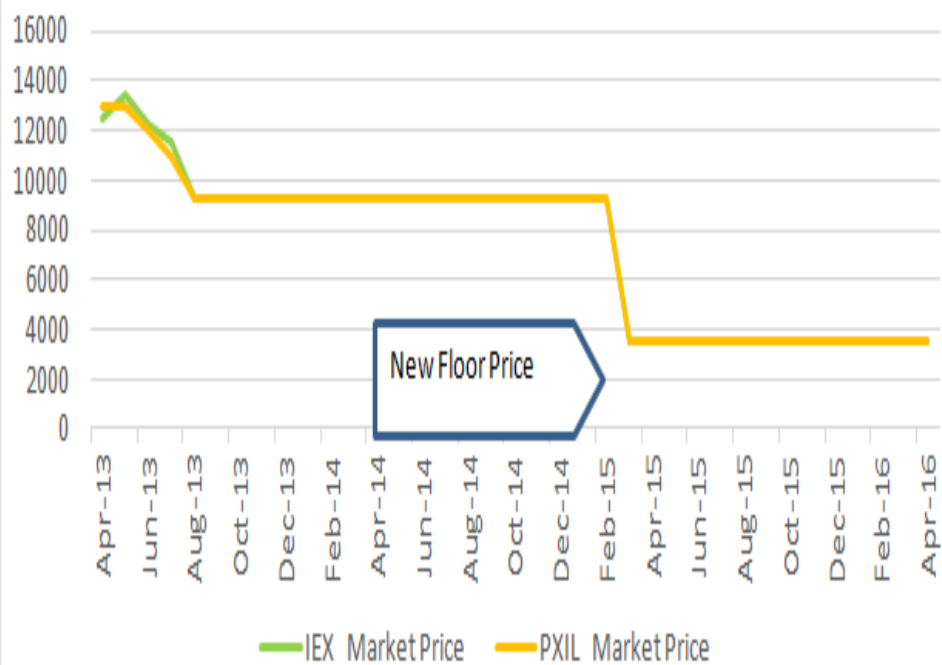
REC Market Trends: last 2 years



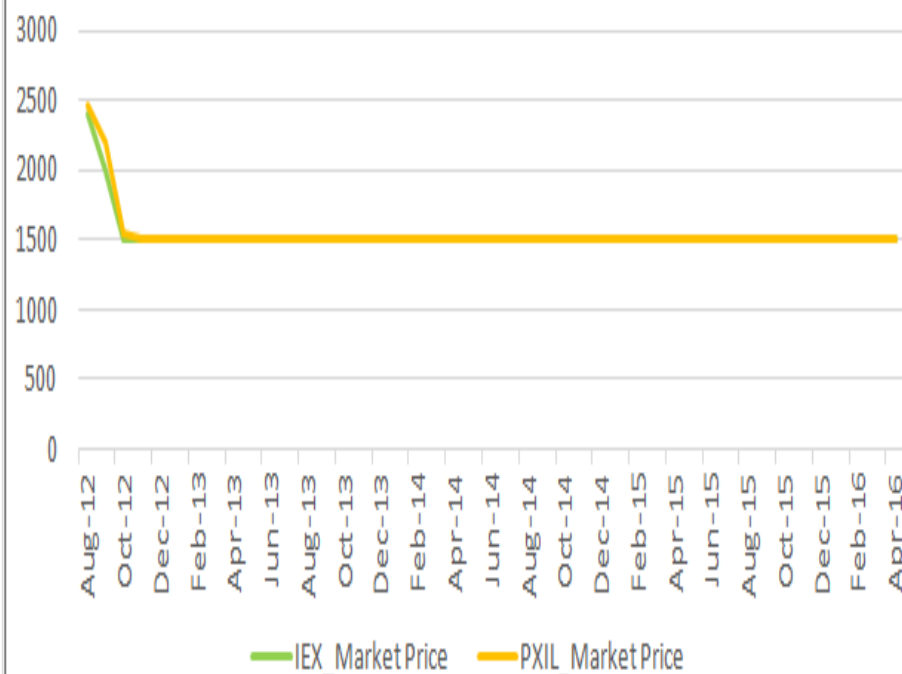
Market clearing happens at the floor price

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Solar Market Clearing Price



Non-Solar Market Clearing Price



Source: REConnect,
IEX, PXIL

With UDAY (Ujwal DISCOM Assurance Yojana)- power sector reform to revamp DISCOMs- RPO compliance to get a boost