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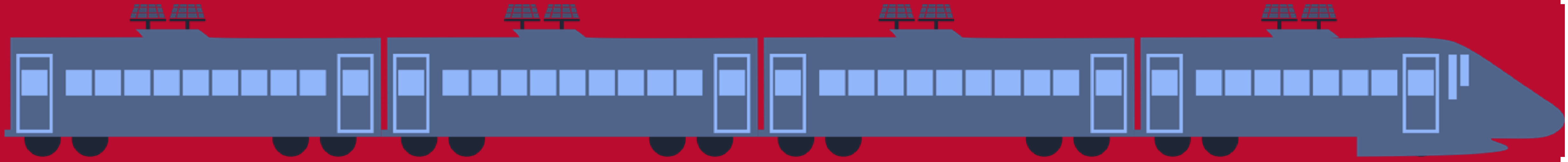
GOVERNMENT OF INDIA
MINISTRY OF NEW AND RENEWABLE ENERGY

USAID MNRE Partnership to Advance Clean Energy - Deployment 2.0 Technical Assistance Program

Designing a new Renewable Energy Procurement Model for Indian Railway’s Traction Loads – An analysis for Haryana

May 01, 2020



Indian Railways is 2nd largest rail network in the world, carries the most passengers in the world, is the 9th largest employer in the world, employing 1.6 million people and not surprisingly is an energy guzzler

Indian Railways Power Demand to double by 2022 from 2 GW to 4 GW

Largest Consumer of Electricity in India

18.5

Billion Units of electricity used annually

16 Billion for Traction, 2.5 Billion for non-traction

- Electrify 100% of all Rail Routes by 2022
- Carbon Neutrality by 2030
- 1 GW of solar power by 2022
- 200 MW of Wind by 2022
- 10% of IR's energy from RE by 2022
- Help meet India's NAPCC targets

The Indian Railways is uniquely positioned for the adoption of Renewable Energy and solar due to its diverse energy needs, pan India network and distributed load centres

- **Large number of load centers**:
  - Traction loads for freight and passenger traffic operations
  - Non-traction loads for railway stations, factories & workshops (7500 stations and counting)

- **Diverse and distributed load profile**: small buildings to large factories to railway stations to varying traction load

- **Wide visibility of rooftop projects**: railway stations, reservation centers, etc.

- **High electricity expenditure** due to high tariffs (our socialistic genesis) and increasing demand for electricity

- **Go Green:** the ambition to be a green and sustainable railways

USAID PACE-D 2.0 RE's engagement with IR goes back to 2014 when it began working with the Railway Board on the Deployment of Solar Rooftop

- ✓ Making Indian Railways Greener
- ✓ Reducing costs of power procurement
- ✓ Fulfilling government mandate of RE

PACE-D
PARTNERSHIP TO ADVANCE CLEAN ENERGY - DEPLOYMENT
Technical Assistance Program

Targeting solar rooftop projects

Exploring large-scale solar ground-mounted & wind to meet RPO

Identifying Challenges

Design
- Zero Investment
- Cost competitive
- Risk vs Benefits of RE
- Replication and scale

Procurement Framework
- Framework for site survey
- Model PPA, RFQ, RFP
- Execution strategy

Sign Off
- Training Key IR Staff
- Pre-bid Assistance
- Assistance in conducting bidding
- Issuing LOA

Expanding RE Scope
- Power procurement strategy
- Leverage deemed distribution licensee

PACE-D TA Programs journey with the Indian Railways continued till the beginning of 2018 by which time ~ 250 MW of solar rooftop had been bid and NZEB principles integrated into the New Station Design Plans

2014

- Recognizing challenges of scaling rooftop solar, PACE-D and Railways initiate collaboration discussions.
- PACE-D begins work with Northern Railways to implement solar under SECI's Rooftop Program.

2015

- 50 MW rooftop solar procurement launched by Railways.
- 32 MW awarded to 19 developers under existing railways procurement approach by zones.

2016

- 100 MW rooftop solar procurement launched by Railways.
- 48 MW awarded to 2 developers.
- Tariffs ranging between INR 4.58 – INR 4.98 per unit achieved under long term contracts.

2017

- 67 MW unallocated capacity from previous rounds awarded to 5 bidders.
- Tariffs ranging between INR 2.68 – INR 4.49 per unit achieved under long term contracts.
- 4.8 MW capacity for small plants (less than 25 kWp) to be deployed under Capital Expenditure (CAPEX) model for 800 stations.

Key Learnings

- 2015: The need to centralize bidding process to bring in efficiency of procurement & provide scale
- 2016: Small rooftop capacities not preferred; Simultaneous tenders constrained the bandwidth of developers
- 2017: CAPEX model for small rooftop

USAID PACE-D TA Program's engagement with REMCL started in the 2nd half of 2019 – to identify areas where PACE-D 2.0 RE could help REMCL and IR scale up utilization of RE

- USAID and REMCL's initial discussions focussed in evaluating 1) system friendly RTC procurement & 2) streamlining solar rooftop deployment.
- REMCL suggested a few areas of cooperation, which PACE-D accepted
- REMCL shared traction load data for two states in January and then for a third in March
- System friendly RTC Procurement - demand curve (Haryana & Rajasthan), rudimentary Cost Benefit Analysis undertaken in January, 2020

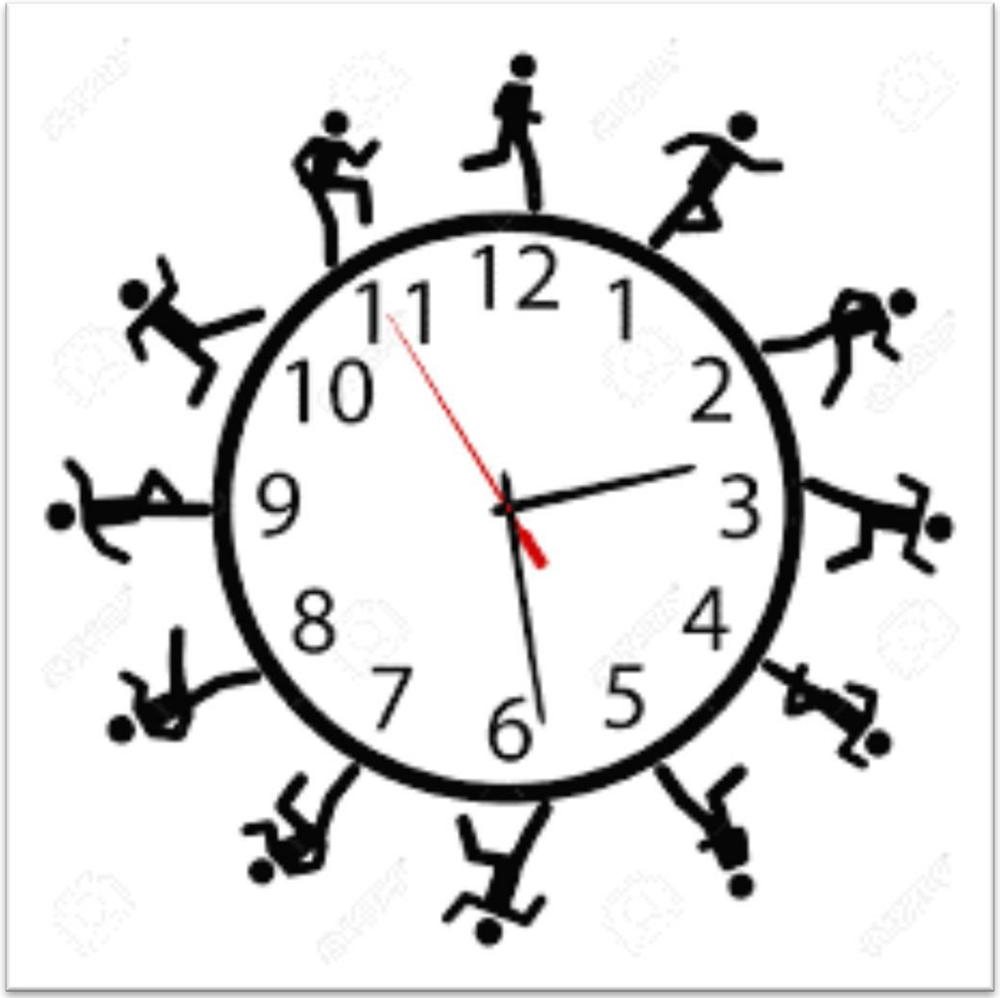
Background to the discussions was the increasing focus on energy independence/ security & the need to reduce energy procurement costs by transitioning to a deemed distribution licensee

- In order to cut costs, IR became a Distribution Licensee
- This required it meet its need for 24*7 Power supply across states to feed varying demand curve(s)
- REMCL, acting on behalf of IR had three objectives:
  - Maximizing & optimizing on-site energy production for non-traction load
  - Meeting IR's Renewable Purchase Obligation (RPO) &
  - Substituting conventional supply with lower cost RE for traction load (wherever possible and to whatever extent)

It was agreed that the PACE-D 2.0 RE Program would analyze demand for a state and develop a strategy for System Friendly Round the Clock Power

Problem Statement: IR, in order to optimize power procurement, IR wants to integrate RE into its power mix. However, RE power is infirm power, would need to be supplemented by thermal power and/ or distribution company supply – leading to increase in costs. RTC procurement can help it address this issue

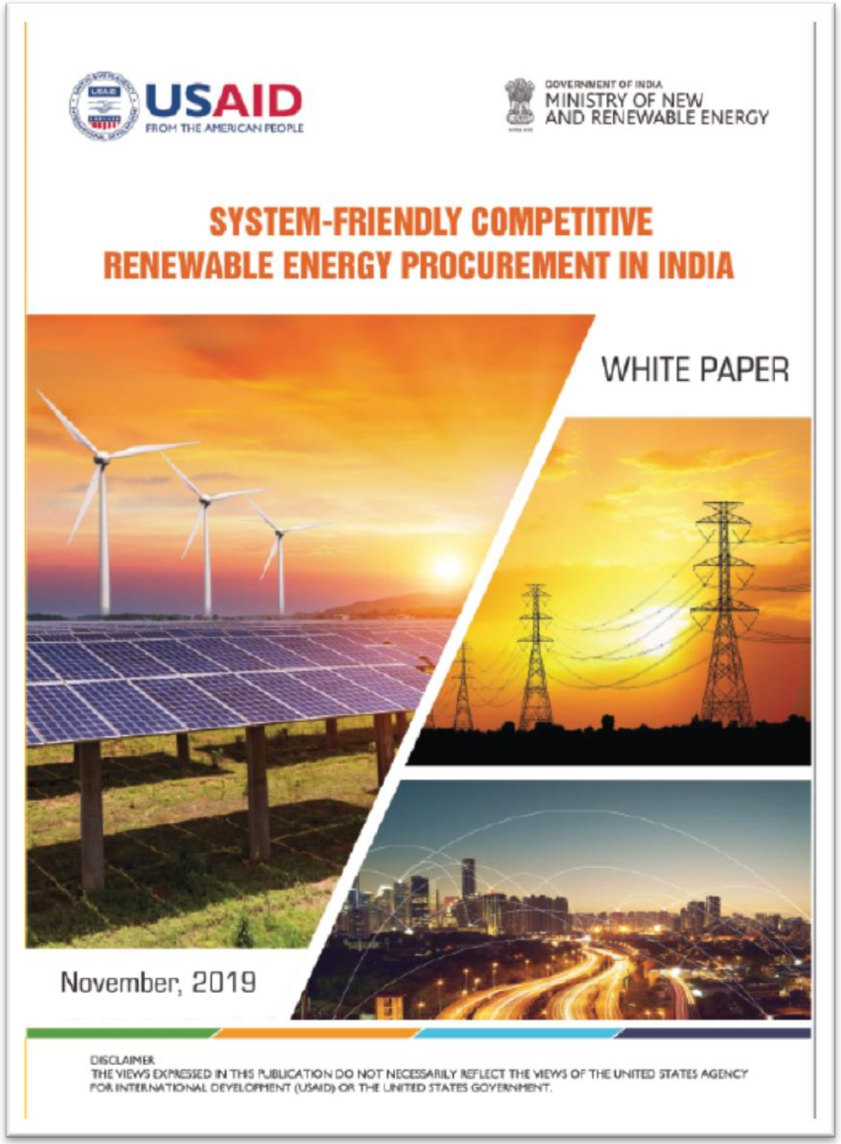
- IR, with its deemed licensee status, can procure electricity for traction load cheaper than through DISCOMs.
- IR, currently, has a number of PPAs with thermal power suppliers which reduced its cost of power supply
- However, IR, as these PPA's have a capacity charge, utilizing RE power becomes more expensive
- IR is unable to take advantage of cheaper green power due to the dynamic and independent nature of supply contracts
- This brings to the concept of round the clock power with green energy
- Green energy can be combined with battery storage and/or thermal to make it firm power and supply as per the dynamic demand

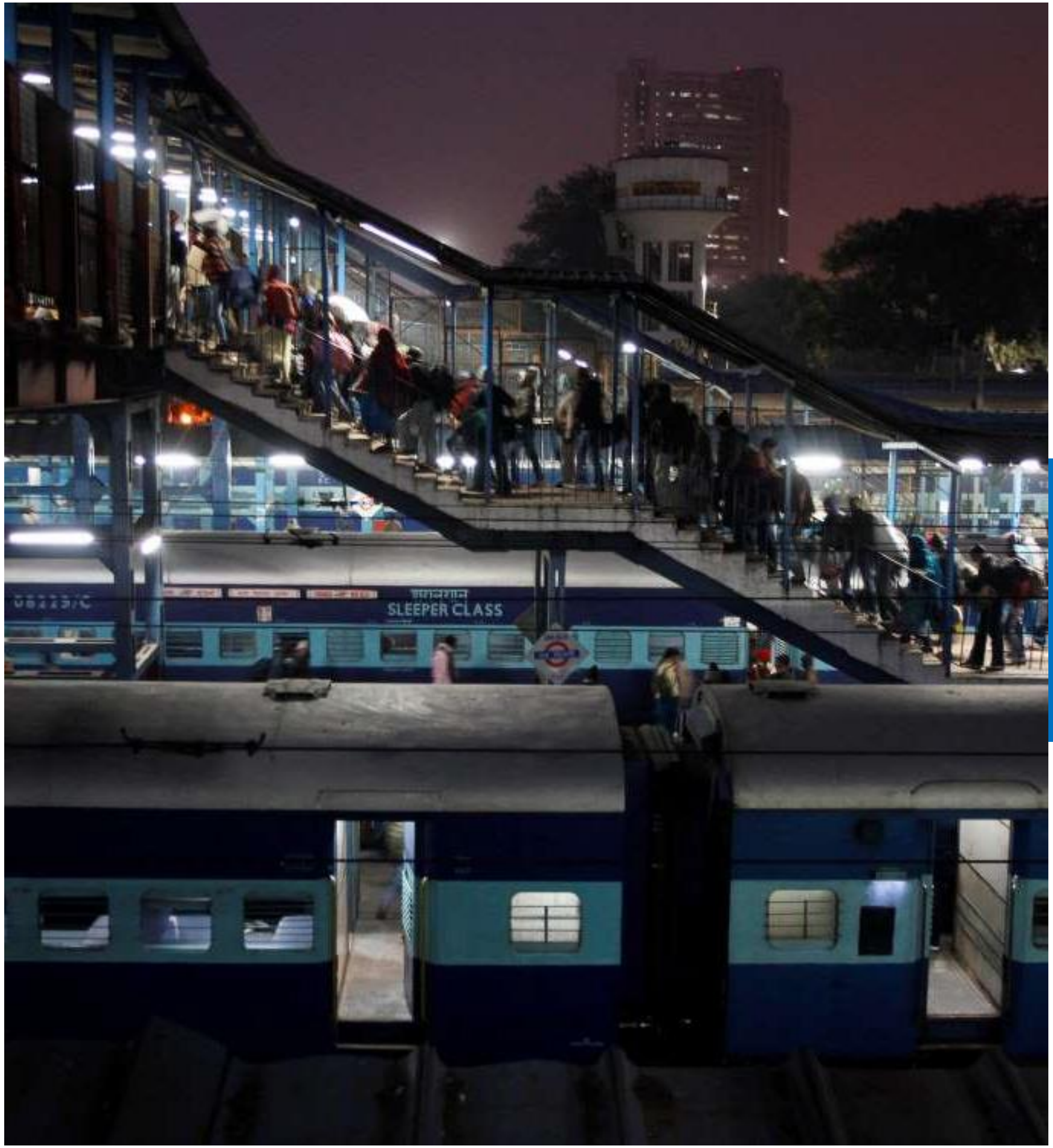


A Whitepaper developed by the PACE-D 2.0 RE Program team provided a theoretical basis on which the PACE-D 2.0 RE Team developed the strategy for System Friendly Round the Clock RE Power Procurement

This paper discusses:

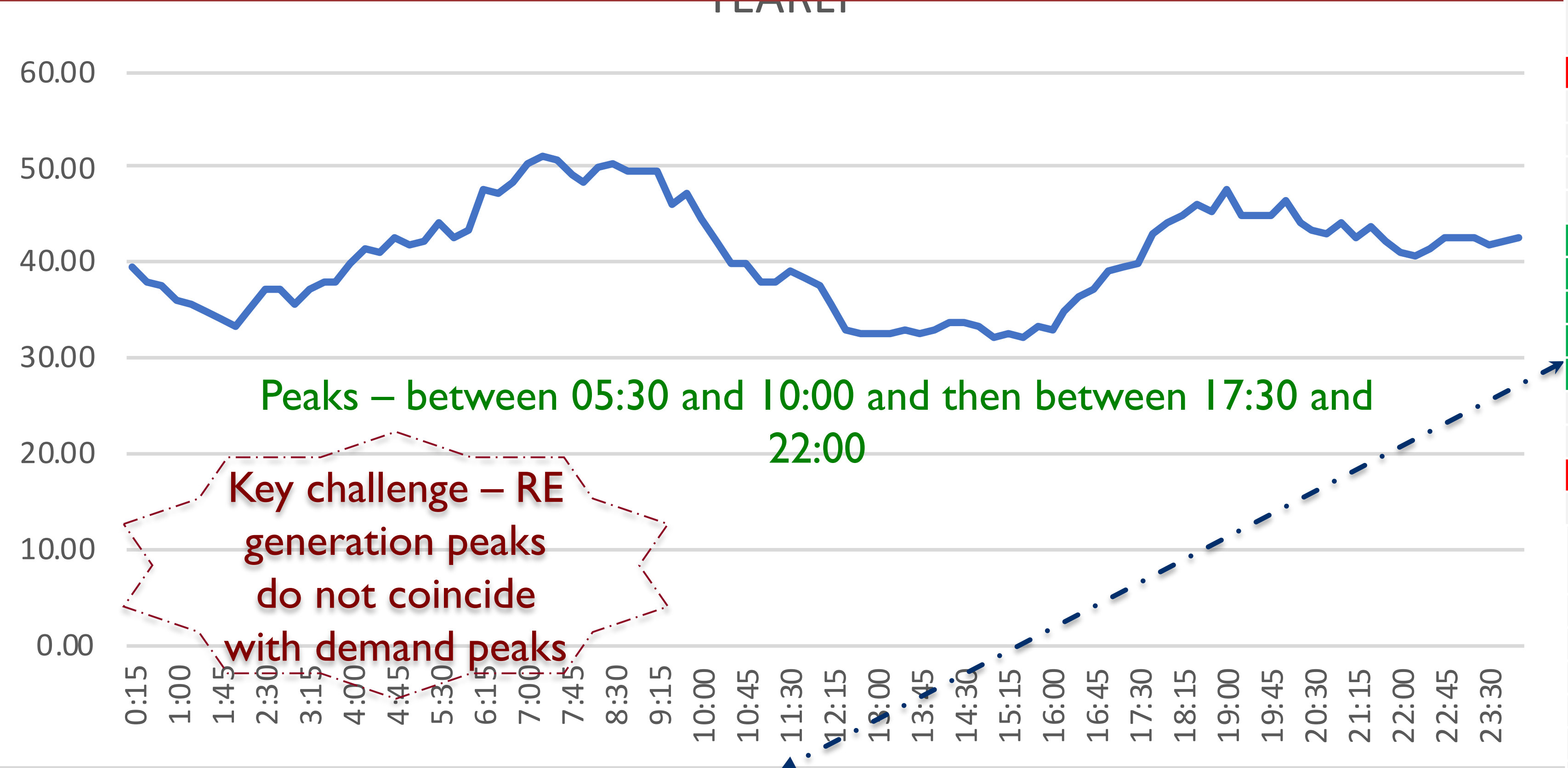
- The relevance of system-friendly RE competitive procurement in India.
- Analyses experience with RE hybrid procurement and other system system-friendly approaches implemented in India.
- Four international trends on innovative RE procurement (time-based incentives) and penalties, aggregators (virtual hybrids), competitive procurement of physical hybrid solutions, and locational signals are presented.
- Initial considerations for application in India.
- Recommendations and an outlook on future work for energy policy authorities.





Cost Benefit Analysis for System Friendly Round the Clock Power for Haryana

Haryana, is a small state by IR electricity demand requirements, hits its peaks between 5:30 AM – 10: 00 AM in the morning and then between 5:30 PM – 10:00 PM in the evening. This creates some challenges in the procurement of RE



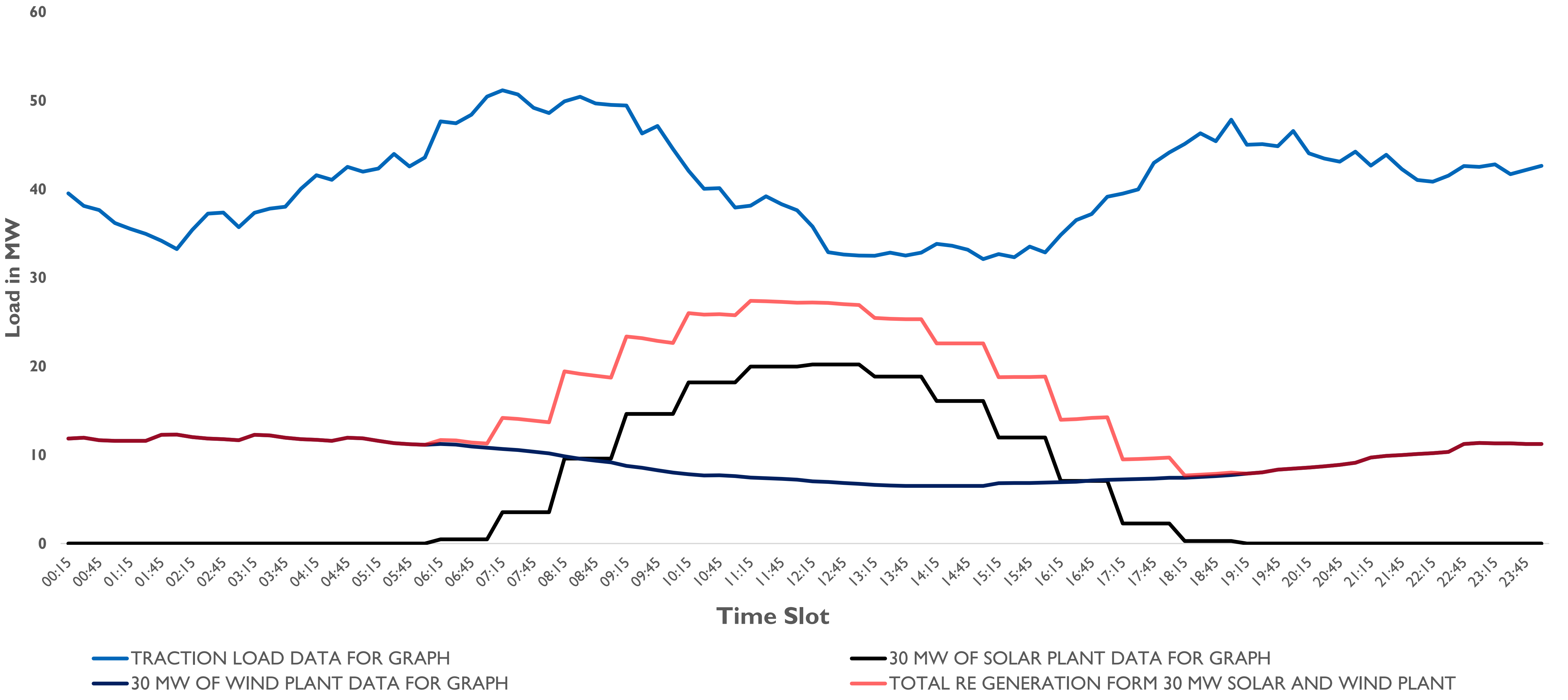
Demand (MW)	Number of instances (15 Min slots)	No of Instances (%)	Cumulative
10	1	0.00%	0.00%
20	93	0.27%	0.27%
30	2,886	8.24%	8.50%
32.5	2,421	6.91%	15.41%
35	2,967	8.47%	23.88%
37.5	3,687	10.52%	34.40%
40	4,140	11.82%	46.22%
42.5	4,287	12.23%	58.45%
45	4,017	11.46%	69.92%
47.5	3,586	10.23%	80.15%
50	2,713	7.74%	87.89%
60	4,052	11.56%	99.46%
70	190	0.54%	100.00%
Total	**35,040**		

Demand (MW)	Demand (MWh)	Total % of the demand met
10	87,600	25%
20	1,75,151	49%
30	2,60,382	73%
32.5	2,79,718	78%
35	2,97,341	83%
37.5	3,12,898	88%
40	3,25,978	91%
42.5	3,36,433	94%
45	3,44,252	96%
47.5	3,49,698	98%
50	3,53,135	99%
60	3,56,854	100%
70	3,56,953	100%
Total	**3,56,953**	

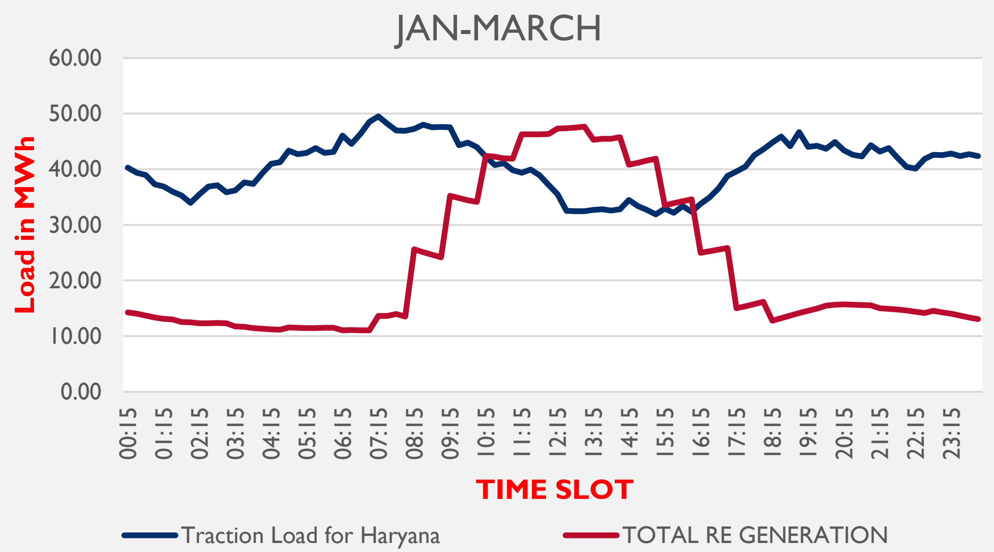
The 1st table on the right highlights the demand distribution across slots – majority of the demand lies between 37.5 & 47.5 MW

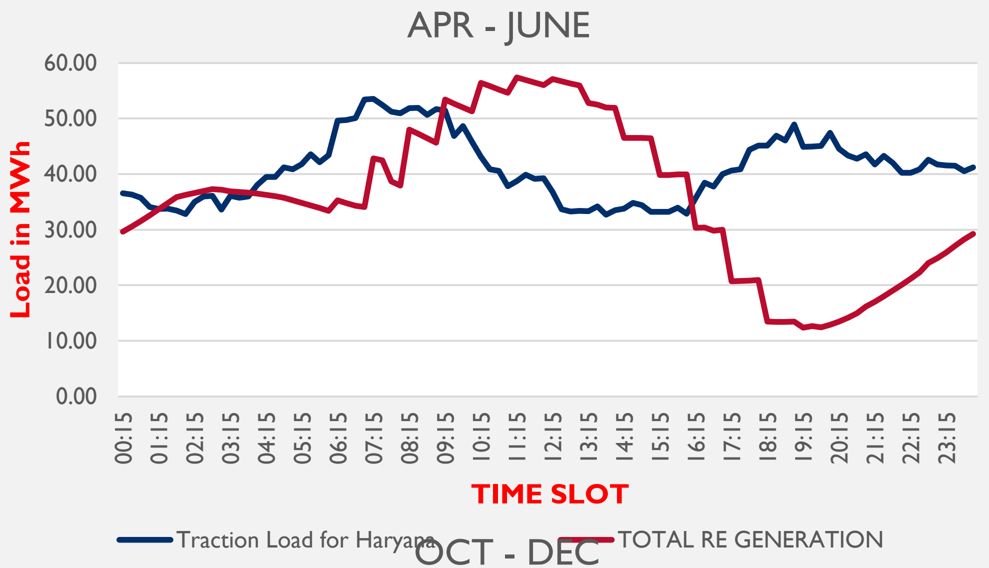
The 2nd table on the right highlights the % of the annual demand (for Haryana) that can be met at varying levels of fixed procurement. We see that 40 MW allows IR to meet 91% of its annual demand

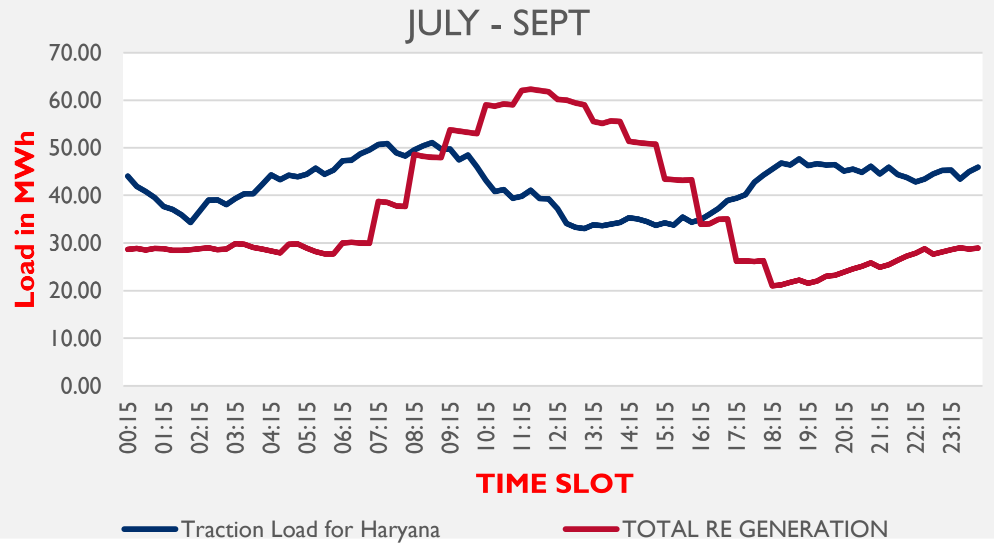
With decreasing cost of RE, it makes sense to procure as much RE as possible to meet the demand. However, as the demand curve and the RE supply curve are quite divergent, this creates a challenge for the utilization of RE and the availability of energy for IR

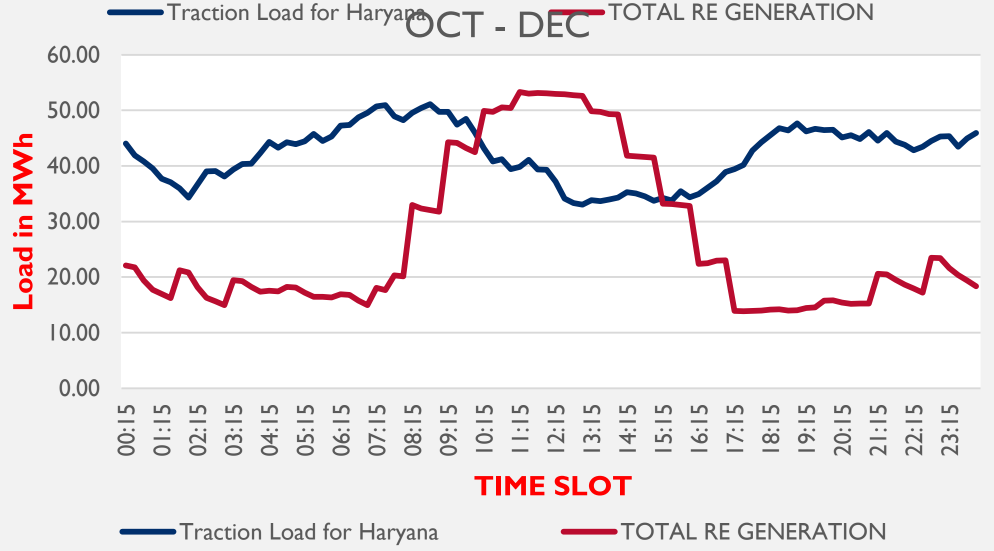


This variation in the RE generation curve and the demand curve makes matching RE supply and demand a very challenging exercise, especially as demand shifts seasonally









The initial aim of the Program was to evaluate whether a state could be converted into a completely RE (Green) Powered Zone – we tried doing this with Haryana – leading to quire outrageous results

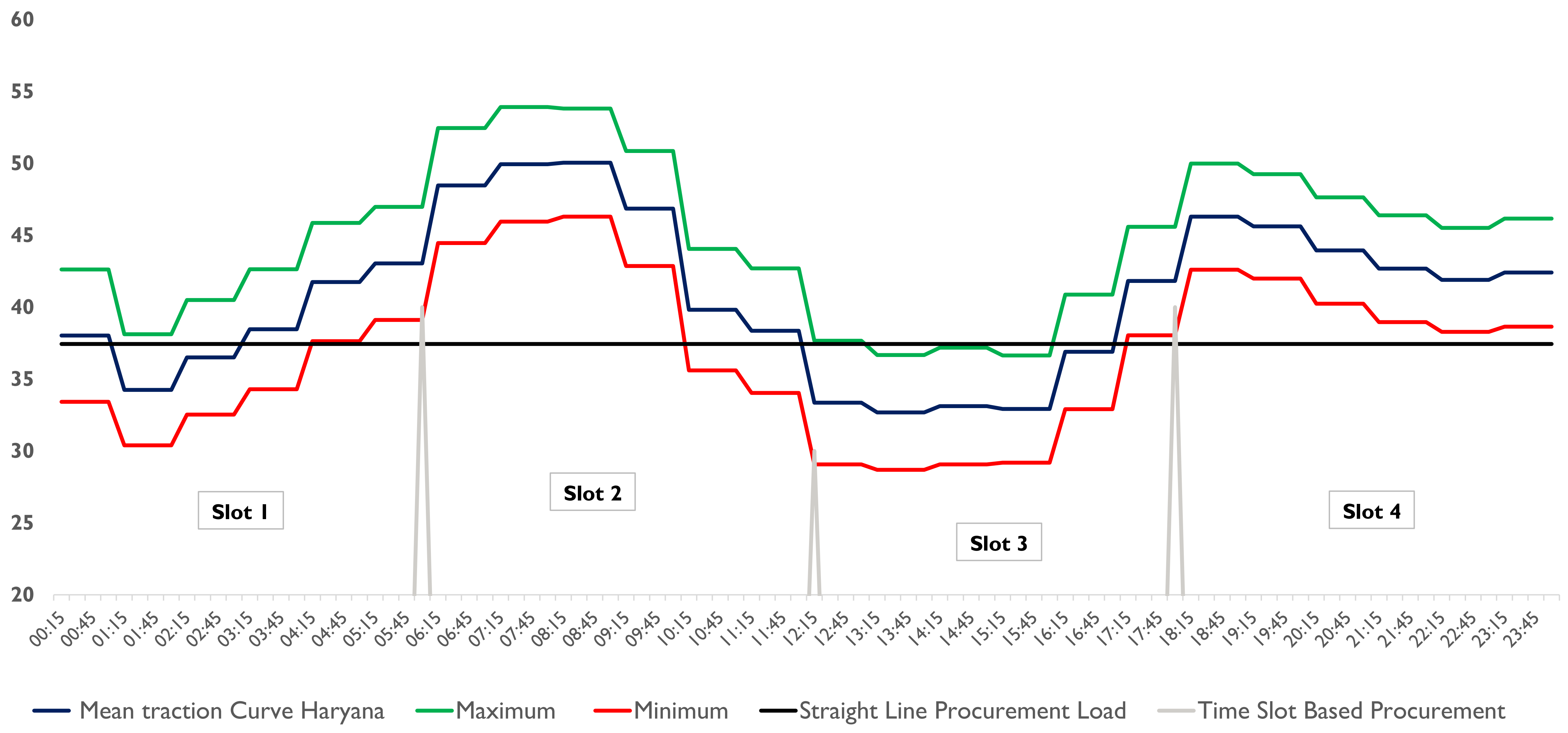
S. No.	Solar (MW)	Wind (MW)	Percentage of total power met through RE	Cost of RE Power Procured (INR/kWh)
1	50	50	54	4.50
2	100	100	75	4.72
3	150	150	83	5.52
4	200	200	88	6.51

Maximizing RE as a % of the total energy demand leads to huge overdesign and very high cost of RE procurement

Then in order to analyse how we can meet the requirements of IR – lowest cost power with as much RE component as possible, the Program identified 3 models for procuring power – 1) Fixed demand RTC procurement; 2) Slot wise fixed demand RTC procurement; and 3) Real time demand RTC procurement

Model	Summary	Benefits	Challenges
Fixed Demand procurement	IR procures fixed load across the day	Simple procurement model for the suppliers. Expected to receive high response from suppliers	• Limits the procurement to the fixed demand • IR will need to find other avenues for procuring power beyond the fixed demand
Slot wise Fixed Demand procurement	IR procures different fixed demands for different time slots of day	Support IR meet peak demand	• Limits the procurement to the fixed demand per slot
Real time demand procurement	IR procures as per the real time demand	IR sources entire power from single supplier which simplifies the procurement process for IR	• Meeting real time demand would need additional generation capacity reserves making power more expensive • Difficult to monitor contracts in case of increase in traffic in future

These three models have been highlighted here with the help of the demand curve.

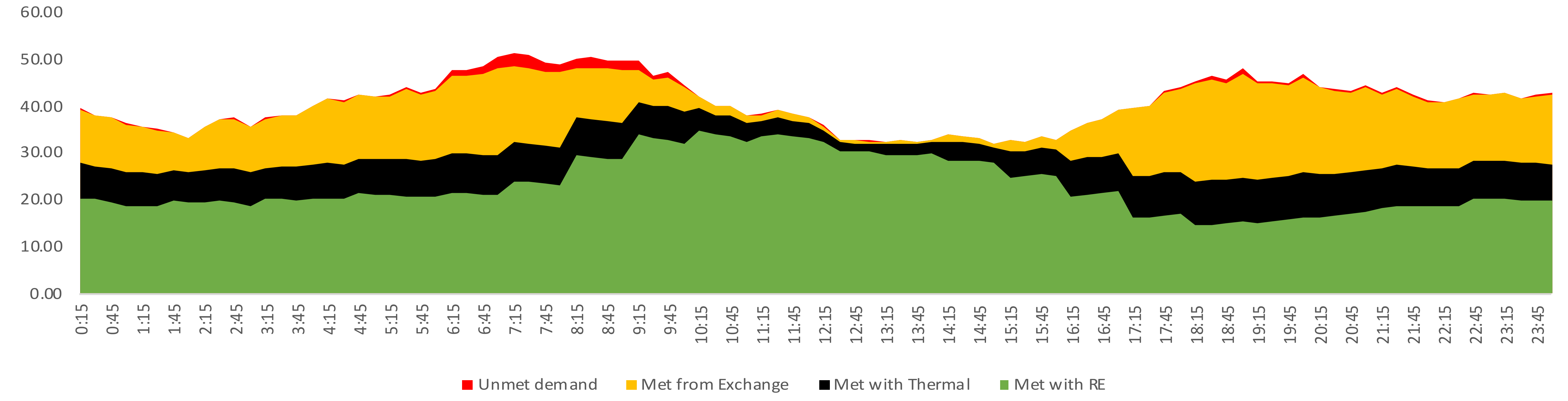


Based on discussions (with REMCL, developers and internally) we came up with the view that the fixed line method would be the most efficient form of RTC power procurement, given the conditions of the market and the demand from REMC (Assumptions)

Base Load (MW) Scenarios	Thermal (MW)	Solar (MW)	Wind (MW)	% of Energy Demand Fulfilled	% of RE share in Energy Demand Fulfilled	Unit Cost (INR per KWh)	% of Surplus RE	Savings (INR Crore)
30	10	30	40	73	56	4.24	8	21.0
35	10	30	50	83	56	4.27	10	23.2
40	10	30	60	91	57	4.31	12	24.2
45	10	40	60	96	58	4.34	13	24.6
50	10	40	60	99	57	4.35	12	24.6
100% demand	10	40	60	100	56	4.36	12	24.6

The results of the Simulation for System Friendly Round the Clock Power for Haryana

Scenario 1: Results for the least cost analysis for 50 MW Flat Demand based procurement (Minimum 50% RE) – slightly higher cost, higher % of energy demand met, 57% of RE

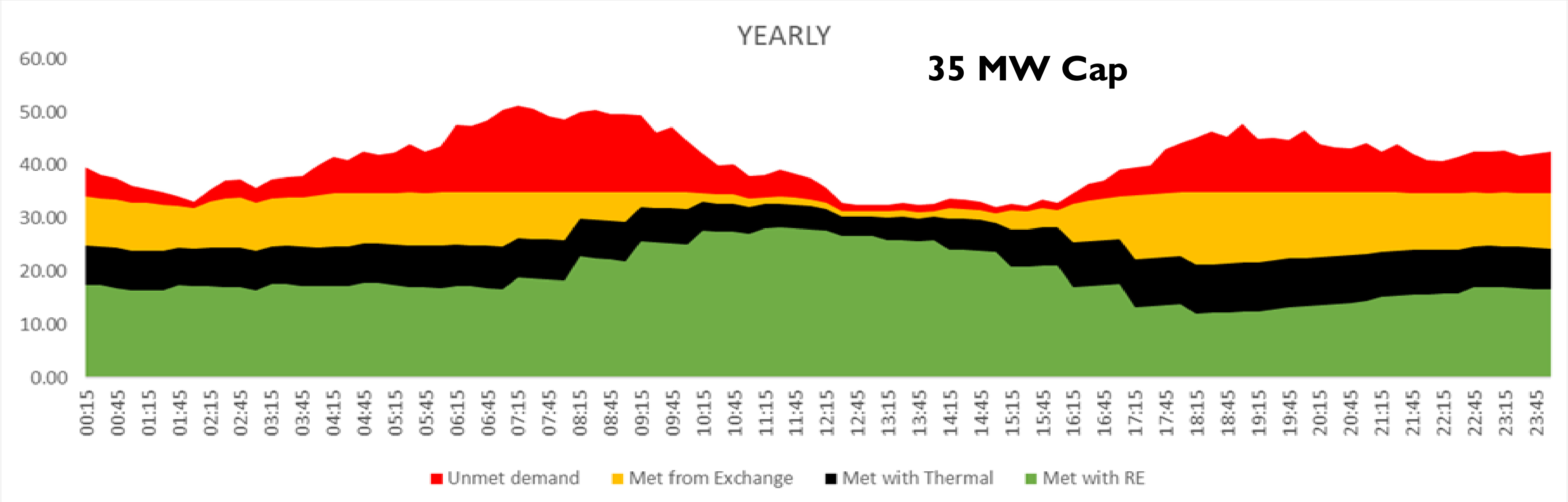


Results		
Net cost of RE	65.9	INR Crore
Average cost of RE	**3.28**	**INR/kWh**
Total cost of thermal power	32.4	INR Crore
Average Cost of thermal	**5.41**	**INR/kWh**
Total cost of exchange power	55.3	INR Crore
Total energy cost	153.73	INR Crore
Average cost of portfolio	**4.35**	**INR/kWh**

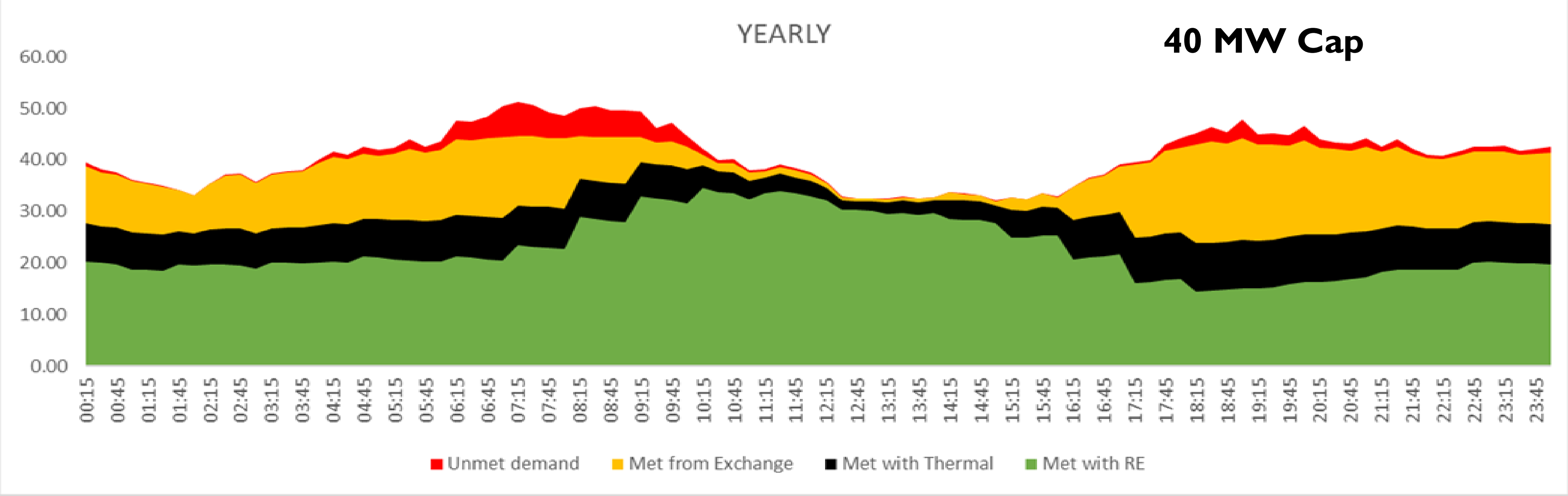
Generation & Consumption	
Consumed Power from RE	57%
Surplus Power from RE	12%
Thermal consumption	17%
Procured from exchange	26%

Solar	40	MW
Wind	60	MW
Thermal	10	MW

Scenario 2 & 3: Results for the least cost analysis for 35/40 MW Flat Demand based procurement (Minimum 50% RE) – slightly lower cost, higher unmet demand, lower % of RE vis a vis 50 MW

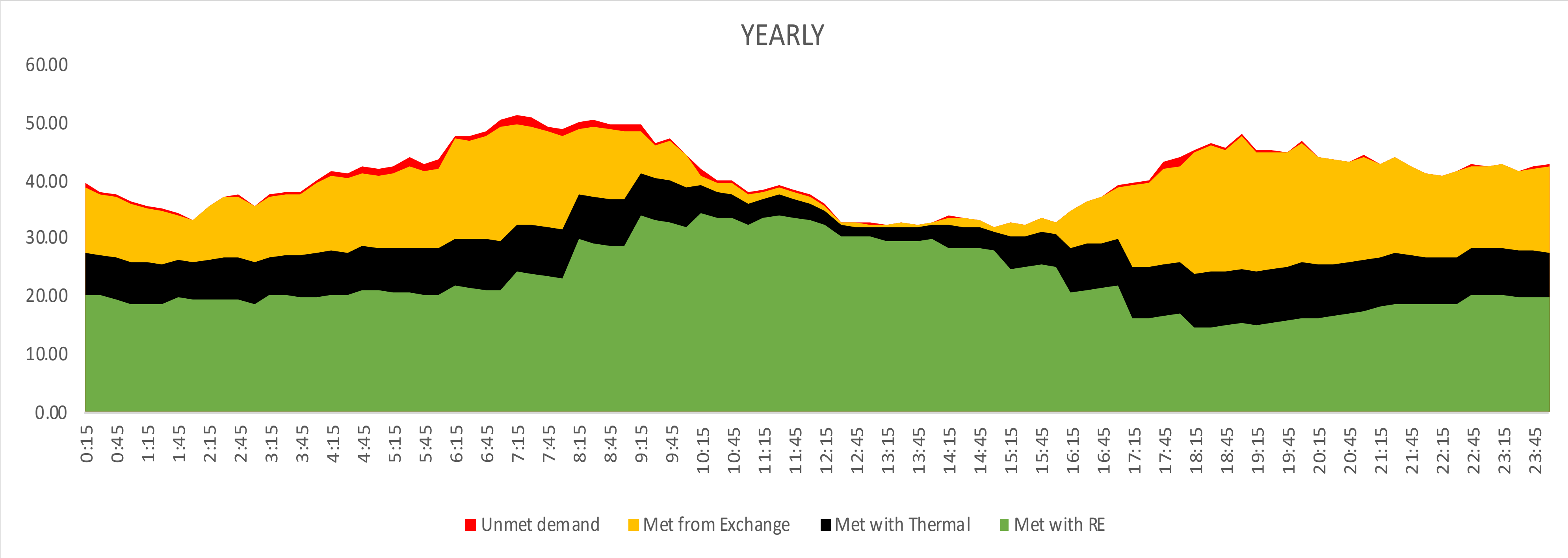


Generation & Consumption	
Consumed Power from RE	58%
Surplus Power from RE	13%
Thermal consumption	21%
Procured from exchange	22%
Solar	30 MW
Wind	50 MW
Thermal	10 MW
Avg cost	INR 4.27/kWh



Generation & Consumption	
Consumed Power from RE	58%
Surplus Power from RE	13%
Thermal consumption	17%
Procured from exchange	25%
Solar	40 MW
Wind	60 MW
Thermal	10 MW
Avg cost	INR 4.34/kWh

Scenario 4: 45 MW Base Demand + 7.5 MW Additional Demand for 10 hours (Minimum 50% RE) – low unmet demand; not much difference in price; 57% of power from RE



- Base load (24 hours supply – 45 MW
- Additional load – 7.5 MW
  - 6:00 AM to 10 AM
  - 6 PM to Midnight
- Equivalent to 50 MW flat demand in energy terms
- Average cost of supply is similar to that of 50 MW flat demand

Results			**Generation & Consumption**		
Net cost of RE	65.9	INR Crore	Consumed Power from RE		57%
Average cost of RE	**3.28**	**INR/kWh**	Surplus Power from RE		12%
Total cost of thermal power	32.4	INR Crore	Thermal consumption		17%
Average Cost of thermal	**5.42**	**INR/kWh**	Procured from exchange		26%
Total cost of exchange power	55.3	INR Crore	Solar	40	MW
Total energy cost	153.7	INR Crore	Wind	60	MW
Average cost of portfolio	**4.35**	**INR/kWh**	Thermal	10	MW

Key results and inferences

Results

- 100% RE procurement becomes prohibitively expensive
- Ability of RE to meet demand diminishes significantly as RE cross the 60% mark
- The least cost procurement option for Thermal+RE is around 30 MW

Inferences

- Under fixed demand procurement, excess power will be procured by IR from the exchange or Discom
- In the fixed demand analysis, cost differential between 40 & 50 MW is marginal – we recommend a higher MW procurement
- We suggest a fixed demand procurement with minimum 50% of energy coming from RE

The Next Steps

- Selection of States
  - Single state (State with high demand requirement recommended)
  - Clubbing multiple states
- Procurement Parameter
  - Least tariff option for minimum 50% (or some other %) RE
  - Highest % RE for a set tariff
  - Combination of above two
- Choose Procurement Model
  - Meet entire demand
  - Meet a certain fixed load/ base load
  - Meet base load plus additional load in few time slots

Thank You

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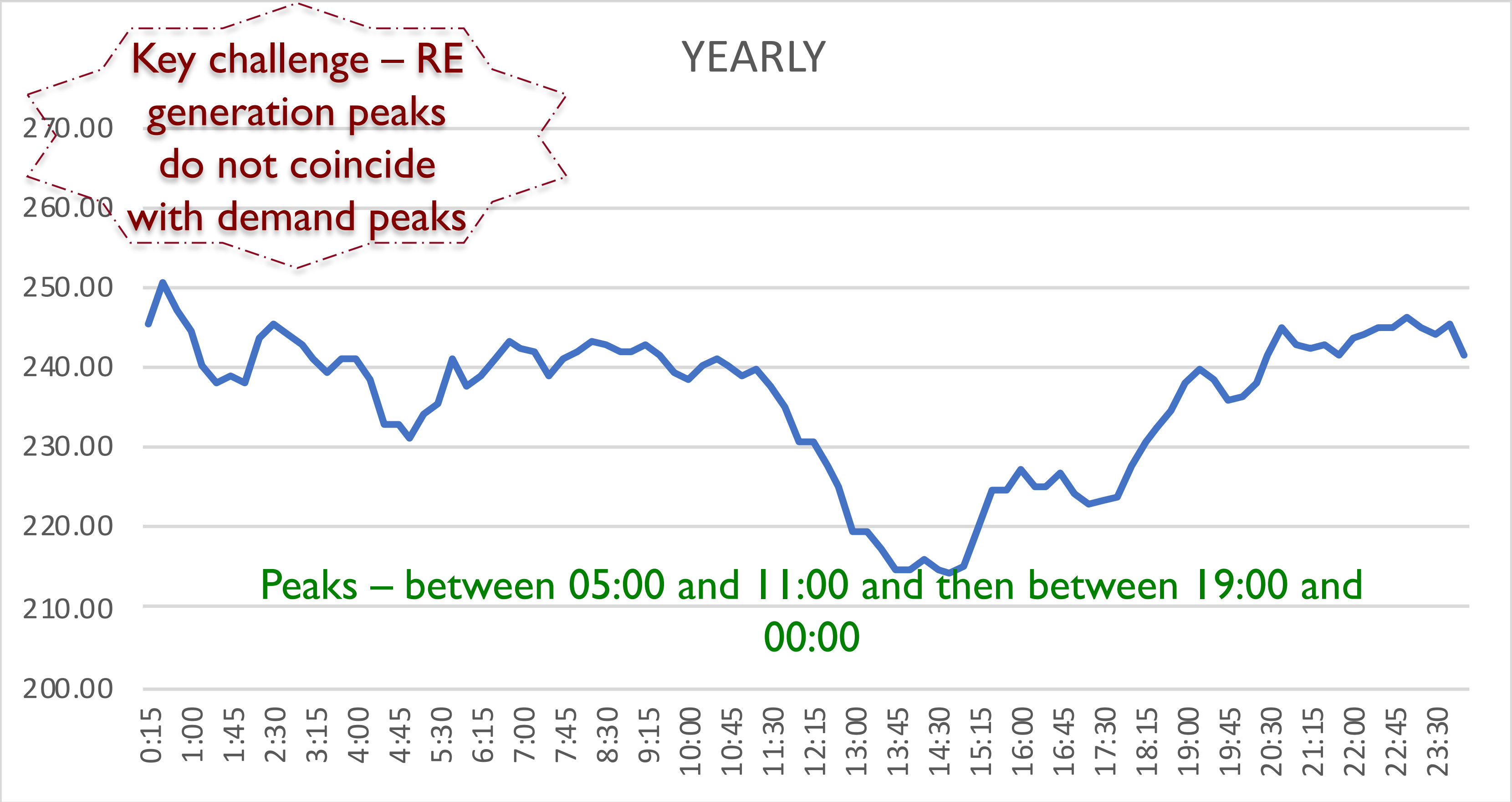
Key Assumptions

	JITPL		BRBCL	
	Angul, Odisha		Navi Nagar, Bihar	
Haryana		38 MW		15 MW
	Fixed Cost	₹ 1.45	Fixed Cost	₹ 2.81
	Var. Cost	₹ 1.45	Var. Cost	₹ 1.90
	Period	Oct. 2020	Period	25 YEARS

Cost of solar power	2.88	INR/kWh
Cost of wind power	3	INR/kWh
Sales price of RE surplus power	1	INR/kWh
Fixed charges (PLF<85%)	2.81	INR/kWh
Fixed charges (PLF>85%)	1.124	INR/kWh
Variable charges	1.9	INR/kWh
Purchase price of power from exchange	6	INR/kWh

100% Thermal scenario		
Thermal capacity	53	MW
Thermal consumption	3,55,404 (99.6%)	MWh
Fixed charges	1,10,89,32,780	INR
Variable charges	67,52,67,205	INR
Total cost of thermal power	1,78,41,99,985	INR
Average Cost of thermal	**5.02**	**INR/kWh**
Procured from exchange	1,549 (0.4%)	MWh
Cost of procurement from exchange	92,96,026	INR
Total cost	1,79,34,96,010	INR
Average Cost	**5.02**	**INR/kWh**

For Madhya Pradesh, peaks occur during 5:00 AM – 11: 00 AM and 7:00 PM – 12:00 AM. Data from 2018-19 was used.



Demand (MW)	No of Instances (%)	Cumulative	Total % of the demand met
165	0.05%	0.05%	70%
170	0.06%	0.11%	72%
175	0.14%	0.25%	74%
180	0.23%	0.47%	76%
185	0.46%	0.93%	78%
190	0.78%	1.71%	81%
195	1.25%	2.96%	83%
200	1.85%	4.81%	85%
205	2.58%	7.39%	87%
210	3.51%	10.90%	89%
215	4.51%	15.41%	90%
220	5.96%	21.37%	92%
225	7.50%	28.87%	94%
230	8.42%	37.29%	95%
235	9.52%	46.81%	96%
240	9.81%	56.62%	97%
250	18.53%	75.15%	99%
310	24.85%	100.00%	100%

From the table, we see that 215 MW allows IR to meet 91% of its annual demand

This can also be seen in the cumulative supply curve – here shown as a Demand Vs RE Generation Pattern (Solar 60 MW + Wind 60 MW)