Minutes of the 5th meeting (virtual) of SAFIR Joint Working Group (JWG) "To study, formulate and recommend for facilitating Power trade development in South Asia"

Date :3rd September 2021 at 04:30 PM IST

List of participants : At Appendix-I

Deputy Chief (Regulatory Affairs) Central Electricity Regulatory Commission (CERC), India welcomed all members to the fifth meeting (virtual) of SAFIR Joint Working Group (JWG) on the said subject and provided a brief on the agenda of the meeting.

Agenda 1: Confirmation of minutes of 4thmeeting held on 21.05.2021

Deputy Chief (RA), CERC apprised the members about the agenda items which were discussed and the action points identified in the 4thmeeting of the JWG held on 21.05.2021.She also informed the JWG that while inputs from Bangladesh ERC were received, SAFIR Sectt was yet to receive inputs from other members . It was discussed that other members may also send their feedback to the SAFIR Sectt at the earliest and accordingly, , the minutes of the 4thmeeting of JWG were confirmed.

Agenda 2:Harmonization of Rules and Common Minimum Grid Code - Presentation by IRADe

Project Director and Technical Head of SARI/EI, IRADemade a presentation on Harmonization of Rules and the Common Minimum Grid Code ***(Annexure – I)***. The presentationhighlighted the recommendations made by the Bhutan Electricity Authority(BEA) on the Common Minimum Grid Code.

The following emerged after the presentation as made :

a) The term " largest country " may be replaced with the features and details of the Scheduling and Despatch code as an Annexure b) IRADe to have discussions with system operators or similarly placed institutions in member countries tohave the Common Minimum Grid Code elaborately assessed by the experts in each country.

c) IRADe to have focused discussion with officials of POSOCO and CERC on the Common Grid Code regulatory framework along with one to one discussion with similarly placed institutions within respective member countries.

Agenda 3:Electricity market design – International perspectives- Status update by World Bank w.r.t. synthesizing the same with studies conducted by IRADe

Senior Energy specialist, World Bank, briefed the members regarding support of World Bank in the form of interventions and studies and its benefits for the member countries. He added that the World Bank in association with Deloitte had carried out a study as suggested by JWG. Representatives of Deloitte made a presentation (***Annexure-II)*** where they presented two models (i) Sequential Market Clearing (ii) Unified Market Clearing for Market operations for Cross Border Trade of Electricity. It also presented a case of system cost savings as a result of regional trade.

The following emerged after the presentation as made :

a) The study should reveal the benefits that CBT would bring to allpartnering countries.
b) The study should cover aspects such as objective and scope of market design , salient features of the model suggested and economic benefit analysis and sensitivity analysis for 5 and 10 years to assess the benefits for the partnering nations.
c) Study of the existing policy and regulatory framework in SAFIR member countries should be undertaken with an aim to assess the extent to which these policy and regulatory framework supports/ facilitates regional market structure evolution and the mechanism that needs to be placed for the development of Regional Electricity Market.
d) EIM model of California should be studied and the possibility of replicating the model in the SAFIR member countries may be explored.

Decision Points & Way forward

1. The members of JWG shall provide their comments/ suggestions on the Common Minimum Grid Code and the Electricity market models and the Annexure therein to SAFIR Secretariat.

2. SAFIR Secretariat shall compile the comments/suggestions received from members of JWG and inform IRADe and the World Bank to compile and incorporate the same in both the reports.

3. IRADe to hold discussions with POSOCO and CERC officials on the Common Grid Code regulatory framework and other similarly placed institutions across member countries. SAFIR Secretariat will help in coordinating these discussions.

4. The World Bank to study the EIM model of California and the explore the possibility of replicating the model in SAFIR member countries .

5. IRADe and the World Bank to factor in various suggestions made during the meeting, into their documents

6. The date of the next meeting will be mutually decided.

The meeting concluded with vote of thanks to Chair.

Appendix - I

Listofparticipantsofthe5th meeting (virtual) of SAFIR Joint Working Group (JWG) "To study, formulate and recommend for facilitating Power trade development in South Asia" held on 3rd September 2021 at 04:30 PM IST

S. No.	Name & Designation	Organisation
	MEMBERS	
01	Mr. Samdrup Thinley, Chairperson/CEO,	JWG/ BEA, Bhutan
02	Mr. Mohammad Bazlur Rahman, Member	BERC, Bangladesh
03	Dr. S K Chatterjee, Chief (Regulatory Affairs) and Convenor	CERC, India
	SPECIAL INVITEES	
04	Mr. Ram P Dhital,	Member, ERC Nepal
05	Mr. RV Shahi, Sr. Energy Advisor	World Bank, Europe
06	Mr. Pankaj Batra, Project Director	SARI/EI, IRADe, India
	OTHER PARTICIPANTS	
07	Ms. Bhagirathi Bhattarai	Member, ERC of Nepal
08	Mr. GaminiHerath, Deputy DG	PUCSL, Sri Lanka
09	Mr. Sonam Darjay, Chief, Licensing & Technical Division	BEA, Bhutan
10	Mr. Chalith Pasindu	PUCSL, Sri Lanka
11	Mr. Kanchana Siriwardena, Director Tariffs & Economic Affairs	PUCSL, Sri Lanka
12	Mr. Ather	NEPRA Pakistan
13	Mr Gul Hassan Bhutto	NEPRA Pakistan
14	Mr Debabrata Chattopadhyay, Senior Energy Specialist	World Bank
15	Mr Salman	World Bank
16	Mr. Yuge Ma	World Bank
17	Mr. Anish Mandal, Partner	Deloitte
18	Mr. Utkarsh Kumar	Deloitte
19	Mr. Nirmal Shaju	Deloitte
20	Ms. Rashmi Nair, Deputy Chief (Regulatory Affairs)	CERC, India
21	Mr. Ravindra Kadam, Advisor (RE)	CERC, India
22	Mr. Ankit Gupta, Research Officer	CERC, India
23	Mr. Manvendra Pratap, Research Officer	CERC, India
24	Ms. Anuradha Das, Program Coordinator	SARI/EI, IRADe, India
25	Ms. Maitreyi Karthik	SARI/EI, IRADe, India

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South Asia Regional Initiative for Energy Integration

Presentation

on

Harmonisation of Rules and Common Minimum Grid Code (CMGC) for South Asia

Presented by
Mr. Pankaj Batra
SARI/EI/IRADe

4th meeting of the Joint Working Group(JWG) of SAFIR "To study, formulate and recommend for facilitating Power trade development in South Asia" (Virtual Meeting), 4.30 PM IST onwards , through Video conferencing, Thursday , 3rd September 2021, New Delhi, India

Contents

01 Need for Harmonisation Rules and SARI/EI Past Work

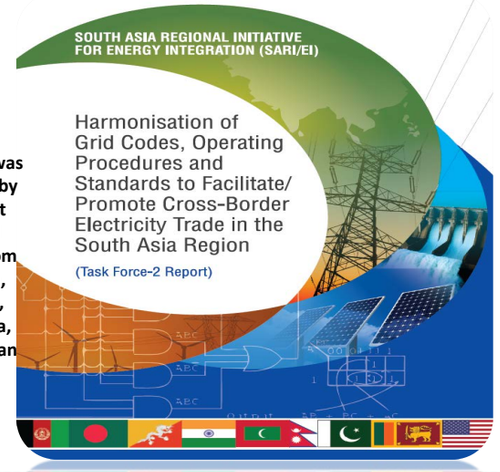
02 Provisions of Common Minimum Grid Code (CMGC) for South Asia after incorporating comments

Need for Harmonisation Rules and SARI/EI Past Work

Need for Harmonization of Rules, Grid Codes and SARI/EI Past Work

- South Asia (SA) countries are at different stage of power sector evolution in terms policy, regulatory and legal frameworks.
- Any regional market design will need to have some basic **technical rules** to be commonly followed by the SA countries for market to function smoothly in a transparent , fair and competitive manner.
- SARI/EI has recognized this need a long time back, worked on many areas to related harmonization of policy, legal and regulatory framework among SA countries over last 8 years.
- Earlier published **regional regulatory guidelines** and as well as comprehensive report on **Harmonization of Grid codes, Operating Procedures and Standards to facilitate/promote Cross-Border Electricity Trade** in the South Asia Region-Framework Grid Code Guidelines.
- By building upon the past work and taking forward various initiatives, we have developed The **Common Minimum Grid Code for South Asia**.

Task Force-2 Report on Harmonisation of Grid codes, Operating Procedures & Standards to facilitate/promote CBET in South Asia Region



Task Force-2 was represented by Government Nominated Members from Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan & Srilanka.

Provisions of Common Minimum Grid Code (CMGC) for South Asia after incorporating comments

4. Objective and Structure of the Common Minimum Grid Code for South Asia

(a) Facilitation of cross border trading of power, in a fair and non-discriminatory manner for all South Asian nations, while ensuring secure, reliable, economic and efficient operation of the grid.

(b) Facilitation of the coordinated optimal operation of the South Asian Grid.

(c) Facilitation of coordinated and optimal maintenance planning of generation and transmission facilities in the South Asian grid.

5.1 Objective

a) To ensure the safe operation, integrity and reliability of the connected South Asia grid.

b) Any new country getting connected to the South Asia grid shall neither suffer unacceptable effects due to its connectivity nor impose unacceptable effects on the South Asia grid.

c) Any new country seeking connection to the South Asia grid is required to be aware, in advance, of the requirements for connectivity to the South Asian grid and also the standards and conditions its system has to meet for being integrated into the grid.

This term “new country” would be replaced by “applicant”, and the term “applicant” defined as the transmission utility of the new country getting connected to the South Asian grid. This will be done after the definitions are put, after agreement by all the SA countries.

5.3 Important Technical Requirements for Connectivity to the Grid

a) The minimum technical requirements for connectivity to the South Asian grid are as given below. ~~The SAFTU shall give the minimum requirements of additional transmission infrastructure/modifications in the transmission infrastructure necessary to integrate the new country into the South Asian grid.~~

5.3 Important Technical Requirements for Connectivity to the Grid

f)The new country would have to ensure robust~~, redundant~~ and reliable communication between countries, through two different modes of communication, so that voice and data communication takes place instantly and seamlessly across countries. This would be mutually decided by the points of contacts of the South Asian countries. The associated communication system to facilitate data flow up to appropriate data collection point at the interface sub-station, shall also be established by the concerned country system operators as specified by the SAFTU in the Connection Agreement.

g) The relevant international standards on cyber security of power systems may be followed by all the countries.

6. OPERATING CODE:

6.5 Restoration plan to be done in coordination in case of tripping

All connected countries would have to furnish the required data to the concerned country System Operators whose grid is likely to be affected, and South Asia Forum of planning bodies from disturbance recorders and sequence-of-events recorder within 48 hours of the ~~tripping~~ restoration. Restoration procedures, including black start would have to be laid out by the South Asia Forum of planning bodies for the South Asian Grid as a whole, to facilitate quick restoration of the system after tripping.

6. OPERATING CODE:

6.6 Periodic reports

The monthly reports shall contain the following:-

(a) Frequency profile

(b) Voltage profile of interconnecting ~~important~~ sub-stations. ~~and sub-stations normally having low /high voltages~~

(c) Major Generation and Transmission Outages

(d) Transmission Constraints

6. OPERATING CODE:

B. For an asynchronous (HVDC) connection, the following technical requirements hold :

For HVDC connection, the provisions 6.1, 6.2, 6.3 will not apply. However, the reliability of the control and protection of the HVDC link has to be ensured, and testing would have to be done periodically.

7. SCHEDULING AND DISPATCH CODE

7.2 The system operator of each country shall regulate their generation and/or consumers' load so as to maintain their actual drawal from the South Asia grid close to the above schedule. If regional entities deviate from the drawal schedule, such deviations from net drawal schedule shall be priced through a pre-decided Unscheduled Interchange (UI) mechanism. Till the time a mechanism for UI is mutually decided at the level of single point of contact of the South Asian countries, the Deviation Settlement mechanism of the largest country in South Asia shall prevail.

All entities connected to the grid are jointly responsible for ensuring that the grid operates securely and smoothly. Some penalty for deviation from schedule needs to be there, for the purpose of grid discipline. So, all nations need to arrive at some mechanism. This sentence may be replaced with the agreed mechanism, as and when the same is agreed to.

7. SCHEDULING AND DISPATCH CODE

b) Scheduling of collective transaction:

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Power Exchange(s) shall furnish the interchange on the boundaries of various countries, as intimated by NLDC. Power Exchange(s) shall also furnish the information of total drawal and injection in each of the countries. Based on the information furnished by the Power Exchanges, NLDC (National Load Despatch Centre), the National System Operator of India, dealing with the subject, shall check for congestion. In case of international transactions, the NLDC shall ask the system operator of the respective country for internal congestion within the grid of that country relating to the transmission corridor on which power would flow across the border, and along with congestion on the Indian side of the transmission corridor, shall assess the congestion on the complete transmission corridor to the respective country.

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DECISION IN THE 3RD MEETING OF THE JWG

Decision Points & Way forward

1. The members of JWG shall provide their comments/ suggestions on the Report including the Terms of Reference therein to the SAFIR Secretariat.
2. SAFIR Secretariat shall compile the comments/suggestions received from members of JWG and inform IRADe and World Bank to compile and incorporate the same in both the reports .

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USAID FROM THE AMERICAN PEOPLE

SARI/EI

IRADe Integrated Research and Action for Development

Common Minimum Grid Code (CMGC): Progress

SARI/EI Drafted CMGC and shared with all Regulators & stakeholders of SA countries

Conducted Stakeholder Consultation in Bangladesh, Bhutan, Nepal

Presented CMGC in the 2nd meeting of SAFIR Working Group (Dhaka, 4th Dec,2020)

& in the 18th ECM Meeting (5th December 2019)

18th ECM recommended that each member country may form a Grid Code Review Committee consisting of all the stakeholders to discuss various features of the draft CMGC

SARI/EI/IRADe were requested to do more detailed consultation with the grid code review committee of each country as well as with all stakeholders (utilities, system operators, planners, regulators and policy makers etc.)

Suggestions received from BEA.
Suggestions from others awaited.

Next Step

→ First Consultation with grid code review committees

→ More Detailed Consultation with utilities, system operators, planners, regulators and policy makers etc

→ Second Consultation with grid code review committees and Finalisation of Draft

→ Submission of Revised CMGC to the Chairperson of Regulatory Commissions of SA Countries

Thank You

Deloitte.

Annexure - II

Electricity Market Modeling and Spot Price Projection Analysis

May 2021

Background and Scope of Work

The South Asian Forum for Infrastructure Regulation (SAFIR) Joint Working Group - a subgroup of national electricity regulatory entities from Bangladesh, Bhutan, India, Nepal and Sri Lanka - has requested the World Bank to provide technical assistance and analysis for the design of a regional electricity market

The objective of this analysis is to assess the impact of regional trade on prices under different market evolution regimes (i.e., low liquidity in 2021 vis-à-vis Market Based Economic Dispatch in 2025) as well as alternative forms of designing the regional wholesale market.

Designs for the regional wholesale market include:

i. Unified market wherein the Indian and the rest of the BBNS markets clear simultaneously; and
ii. Sequential market clearing wherein the Indian market clears independently to set prices for India that then forms the basis for trade.

The key findings of interest are the extent trade volume that is expected to grow over the years would influence prices in India under the MBED regime in the medium (2025).

The market modeling study includes:

- ***inter alia simulation of market prices in the region*** *including prices that may reasonably be expected on the Indian Power Exchanges*
- *analysis on how these* ***prices might be influenced under different regional trade scenarios*** *that were envisaged as part of the South Asian Regional Electricity Market (SAREM) analysis in 2019/2020.*

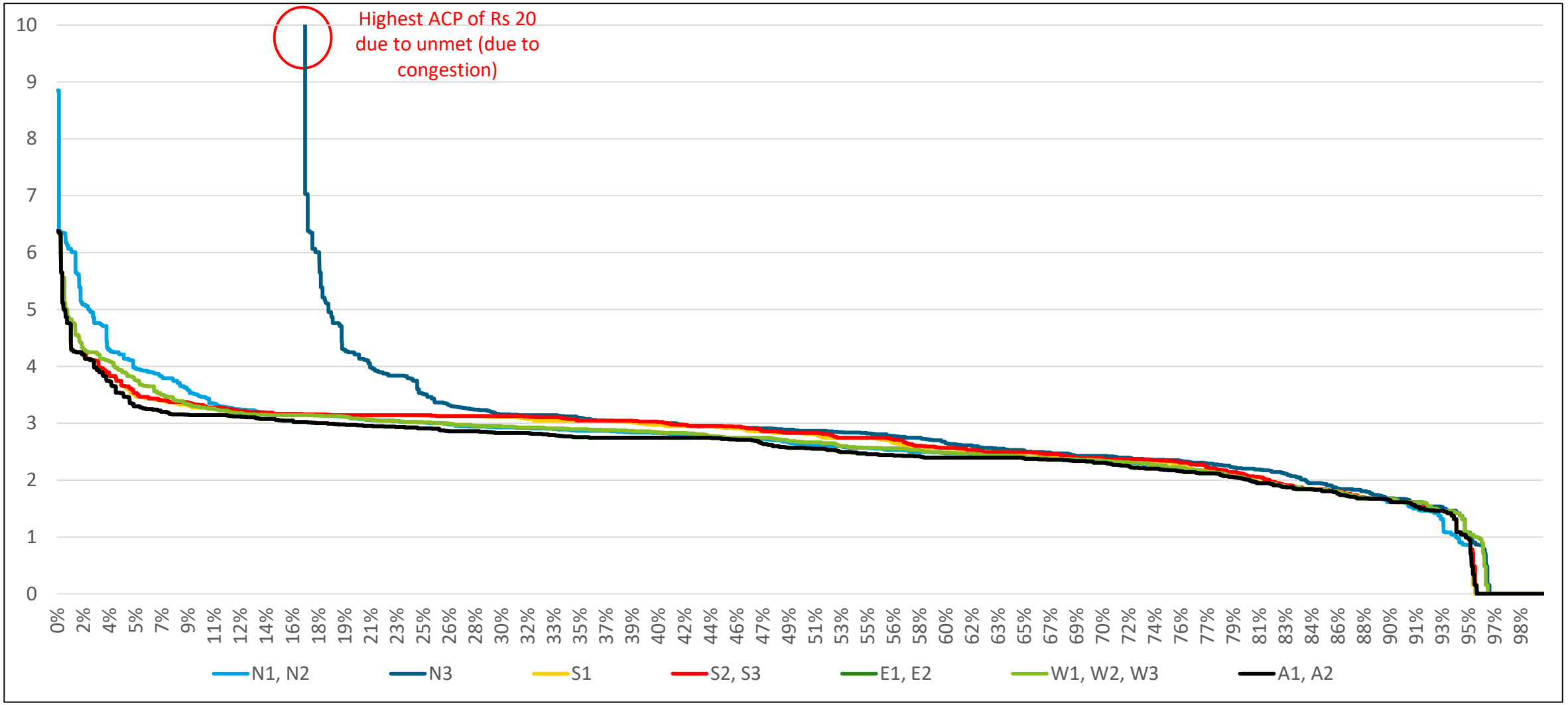
Analysis for 2024-25 – Indian scenario

Analysis for 2024-25 – Indian scenario

Results

Price Duration Curves (2024-25)

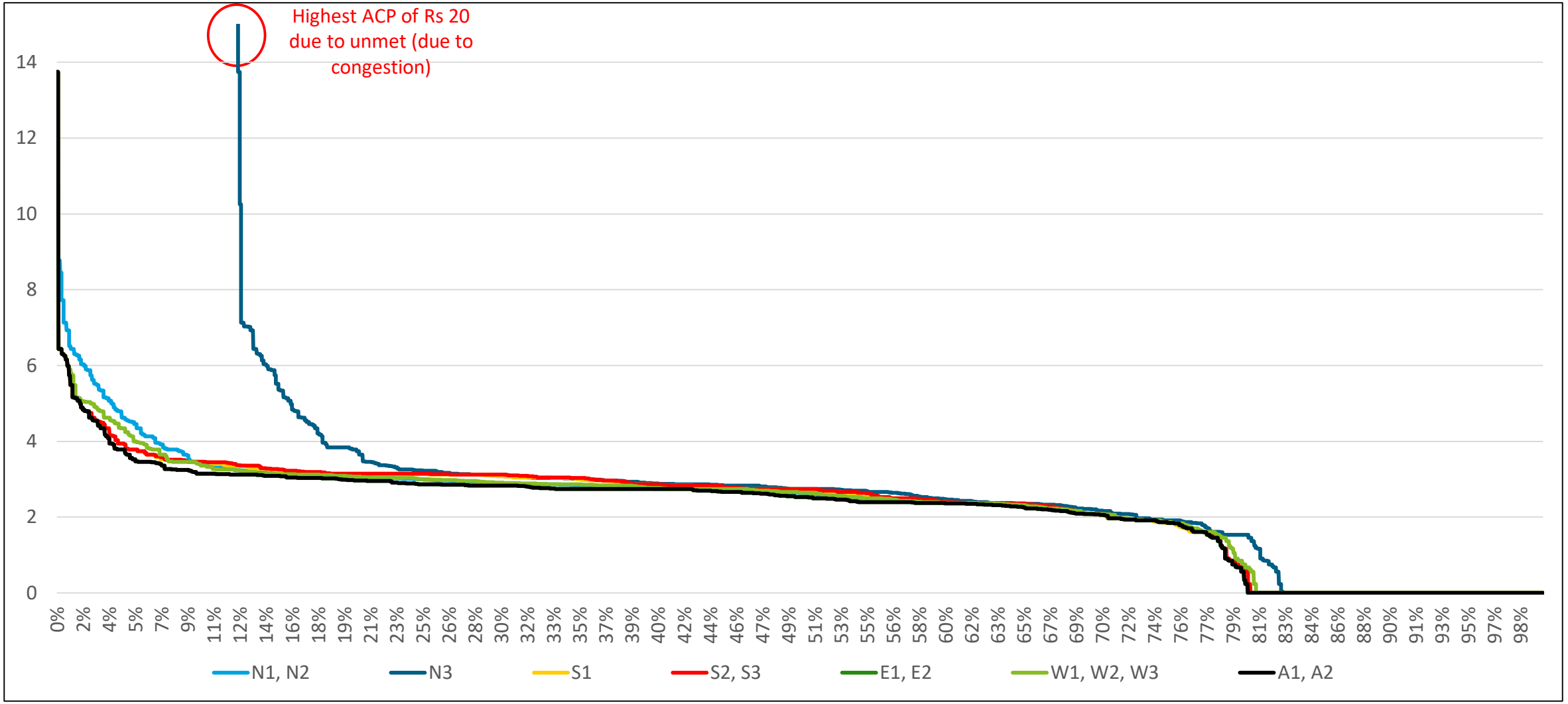
Scenario 1: 75% of 2025 Solar and Wind Targets Met



Maximum prices limited to Rs 20/kWh (Graph y-axis capped to Rs 10)

Price Duration Curves (2024-25)

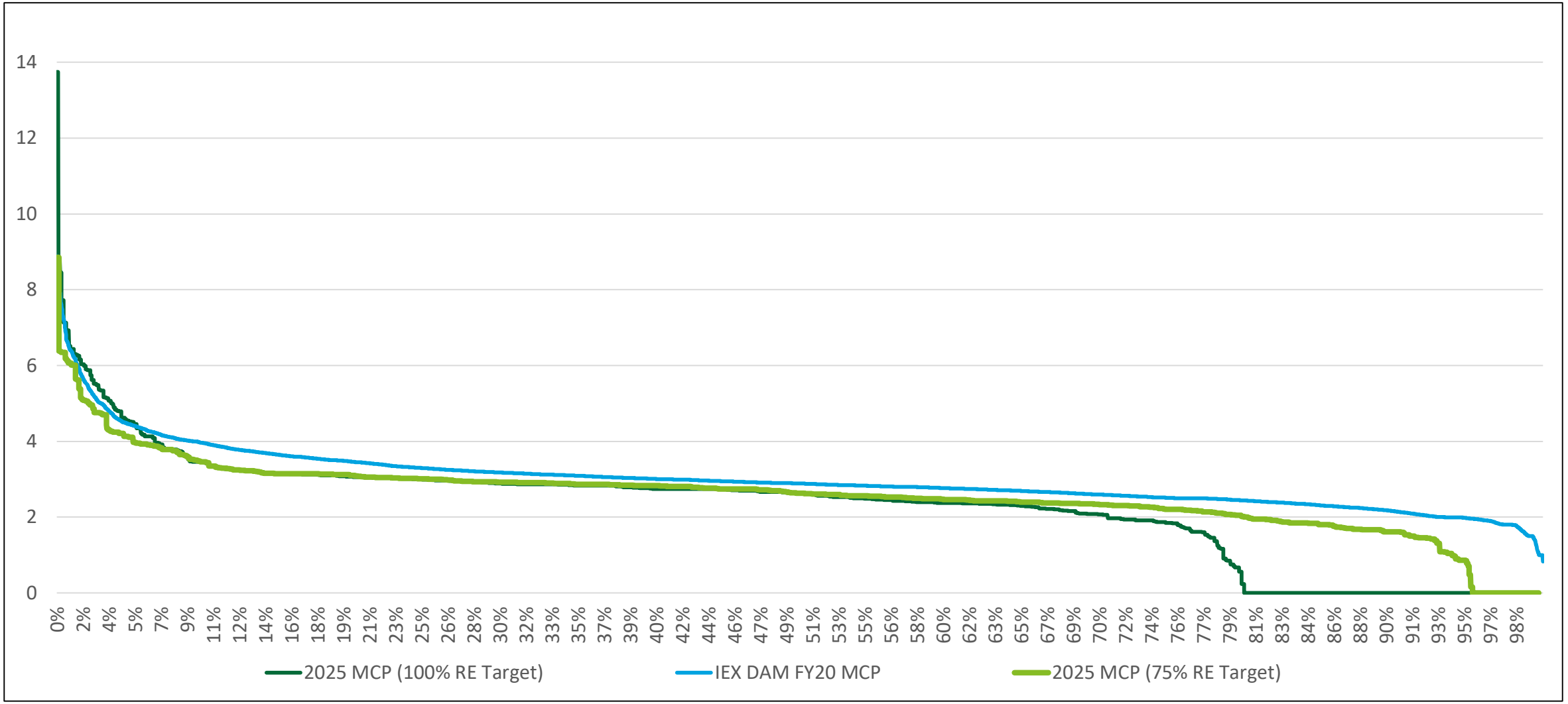
Scenario 2: 100% of 2025 Solar and Wind Targets Met



Maximum prices limited to Rs 20/kWh (Graph y-axis capped to Rs 15)

Marginal Prices Analysis

Comparison of FY 25 with FY 20



Maximum prices limited to Rs 20/kWh (Graph y-axis capped to Rs 15)

Analysis for 2024-25 – With cross border trading

Analysis for 2024-25 – With cross border trading

Results and analysis

Results - Regional Market Simulation

System Costs

Scenario 1: 75% of 2025 Solar and Wind Targets are Met	
Total Energy to be Met: *(calculated as per Net Demand)*	**1188.68 BU**
Indian System Cost without Cross Border Trade:	**Rs. 293157 crore**, or *Rs 2.466 / kWh*
System Cost with Cross Border Trade:	**Rs. 282234 crore**, or *Rs 2.374 / kWh*
Benefits:	**Rs. 10993 crore**, or ***Rs 0.092 / kWh***
System costs have reduced by 3.75%	
Total Cross Border Trade Volume *(Import + Export)*	**36.39 BU**
Per Unit Impact of Cross Border Trade	*Rs 3.004 /kWh*

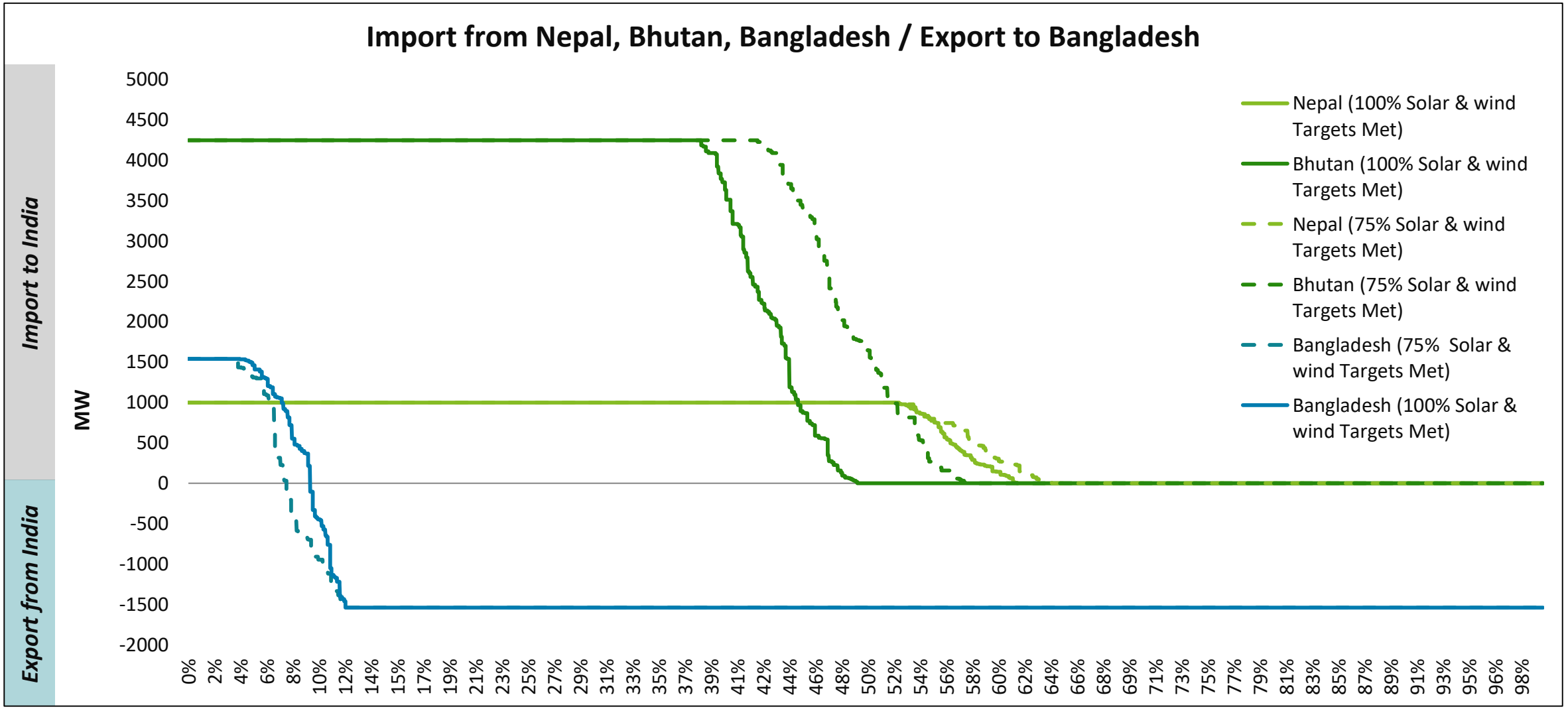
Scenario 2: 100% of 2025 Solar and Wind Targets are Met	
Total Energy to be Met: *(calculated as per Net Demand)*	**1065.44 BU**
Indian System Cost without Cross Border Trade:	**Rs. 265664 crore**, or *Rs 2.493 / kWh*
System Cost with Cross Border Trade:	**Rs. 255242 crore**, or *Rs 2.395 / kWh*
Benefits:	**Rs. 10422 crore**, or ***Rs 0.098 / kWh***
System costs have reduced by 3.92%	
Total Cross Border Trade Volume *(Import + Export)*	**34.04 BU**
Per Unit Impact of Cross Border Trade	*Rs 3.061 /kWh*

Note:

- *Cost of must run is not considered*
- *Fixed cost of thermal stations are not considered*
- *Cost of hydro import from Nepal and Bhutan is considered as zero*
- *Cost / Revenue of import / export from Bangladesh is determined based on hourly marginal costs of Bangladesh*

Unified Clearing

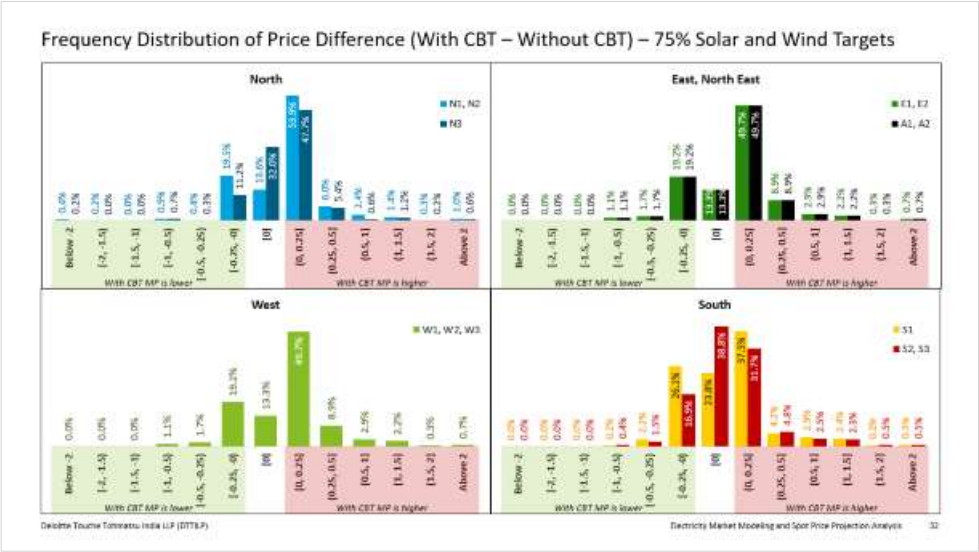
Import – Export Duration Curves



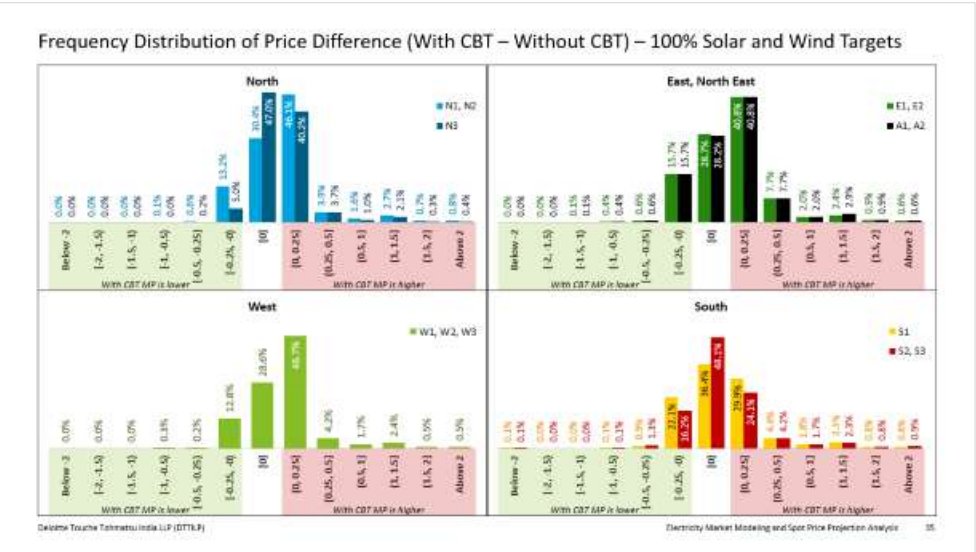
Unified Clearing

Impact on Market Prices

Scenario 1



Scenario 2



Conclusion

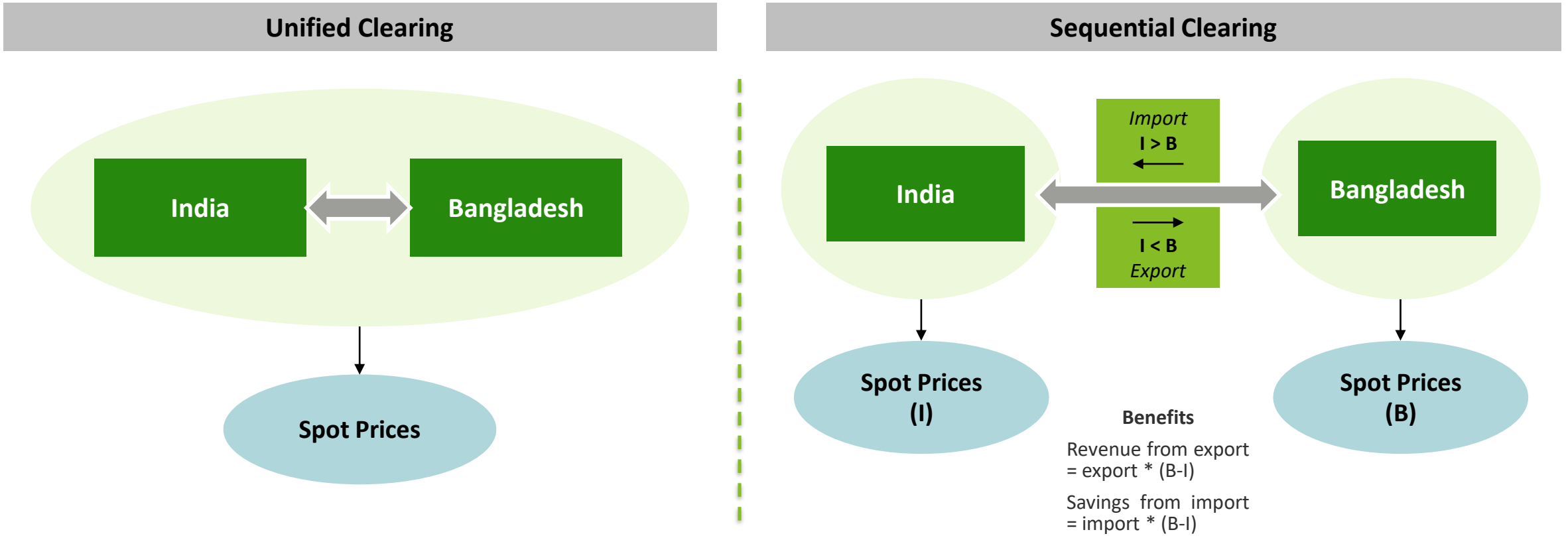
- System costs are reduced by more than 3.5% with cross border trading for both the scenarios.
- With cross border trade volume of 34-36 BUs, India is getting benefits of around 10-11K Cr.
- Import from Bhutan and Nepal is happening more than 60% of the time and also India is exporting to Bangladesh for about 90% of the time to reduce overall system costs.

Unified vs Sequential clearing (India-Bangladesh)

Methodology

Methodology - Regional Market Simulation

Unified clearing vs Sequential Clearing



- *In **Unified clearing,** India and Bangladesh are considered as one system(Bangladesh connected to ER and NER regions) and spot prices are determined.*
- *In **Sequential clearing,** spot prices of India is first determined and then the **spot prices of E and NER are compared with spot prices of Bangladesh*** to determine the direction of power flow between Bangladesh and the two regions of India.*

Unified vs Sequential clearing (India-Bangladesh)

Results and analysis

Unified vs Sequential clearing

System Costs

Scenario 1: 75% of 2025 Solar and Wind Targets are Met	
Indian System Cost without Cross Border Trade:	**Rs. 2,93,157 crore**, or *Rs 2.466 / kWh*
System Cost with Sequential Cross Border Trade with BD:	**Rs. 2,91,395 crore**, or *Rs 2.451 / kWh*
System Cost with unified Cross Border Trade with BD:	**Rs. 2,89,809 crore**, or *Rs 2.438 / kWh*
Benefits with Sequential Cross Border Trade:	**Rs. 1,763 crore**, *(0.6%)* or ***Rs 1.300 /kWh per unit of CBT***
Benefits with Unified Cross Border Trade:	**Rs. 3,349 crore**, *(1.14%)* or ***Rs 2.531/kWh per unit of CBT***

Scenario 2: 100% of 2025 Solar and Wind Targets are Met	
Indian System Cost without Cross Border Trade:	**Rs. 2,65,664 crore**, or *Rs 2.493 / kWh*
System Cost with Sequential Cross Border Trade with BD:	**Rs. 2,63,463 crore**, or *Rs 2.472/ kWh*
System Cost with unified Cross Border Trade with BD:	**Rs. 2,62,997 crore**, or *Rs 2.469 / kWh*
Benefits with Sequential Cross Border Trade:	**Rs. 2,201 crore**, *(0.8%)* or ***Rs 1.631 /kWh per unit of CBT***
Benefits with Unified Cross Border Trade:	**Rs. 2,666 crore**, *(1%)* or ***Rs 2.000 /kWh per unit of CBT***

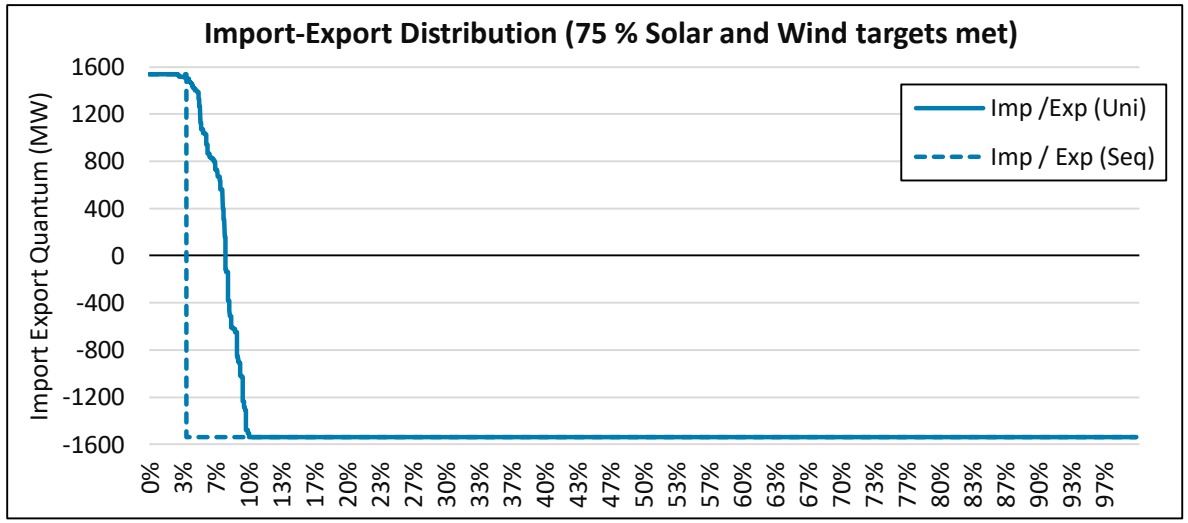
In both scenarios, Unified clearing is more beneficial in terms of system cost

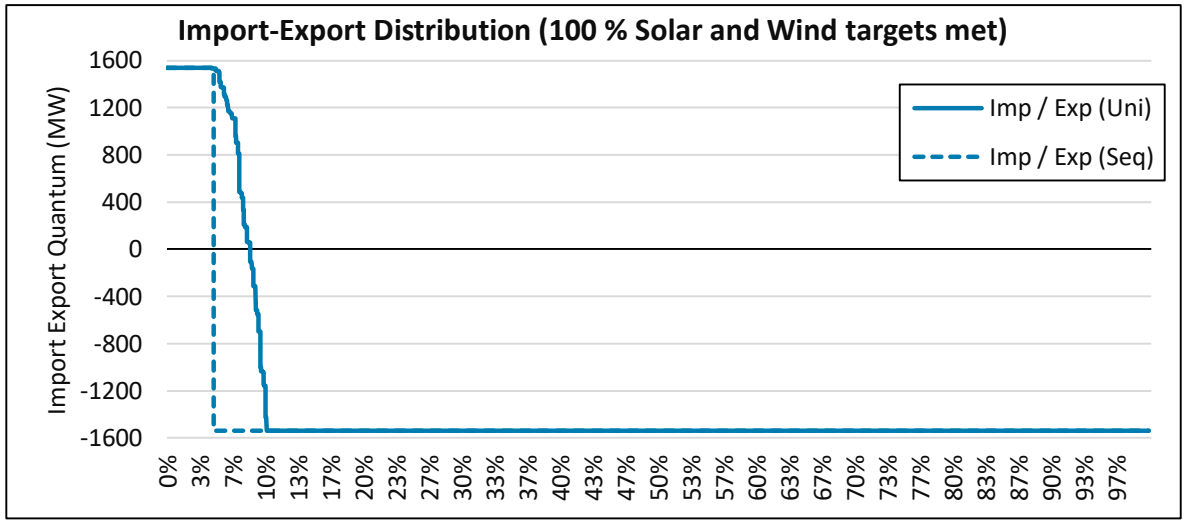
Note:

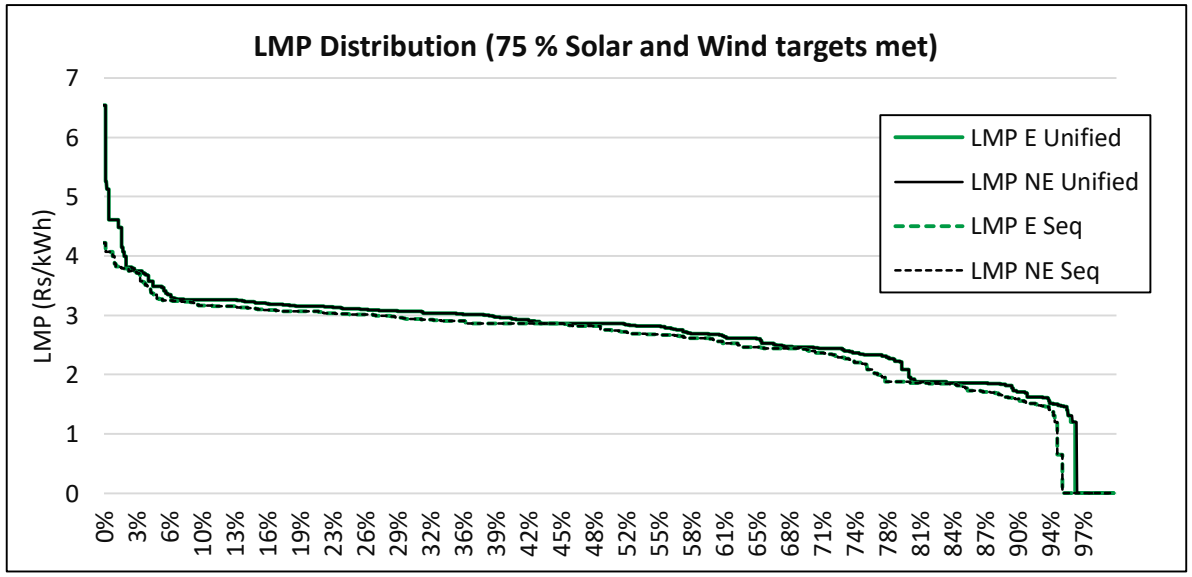
- *Cost of must run is not considered.*
- *Fixed cost of thermal stations are not considered.*
- *Hydro import from Nepal and Bhutan is not considered.*
- *Cost / Revenue of import / export from Bangladesh is determined based on hourly marginal costs of Bangladesh.*

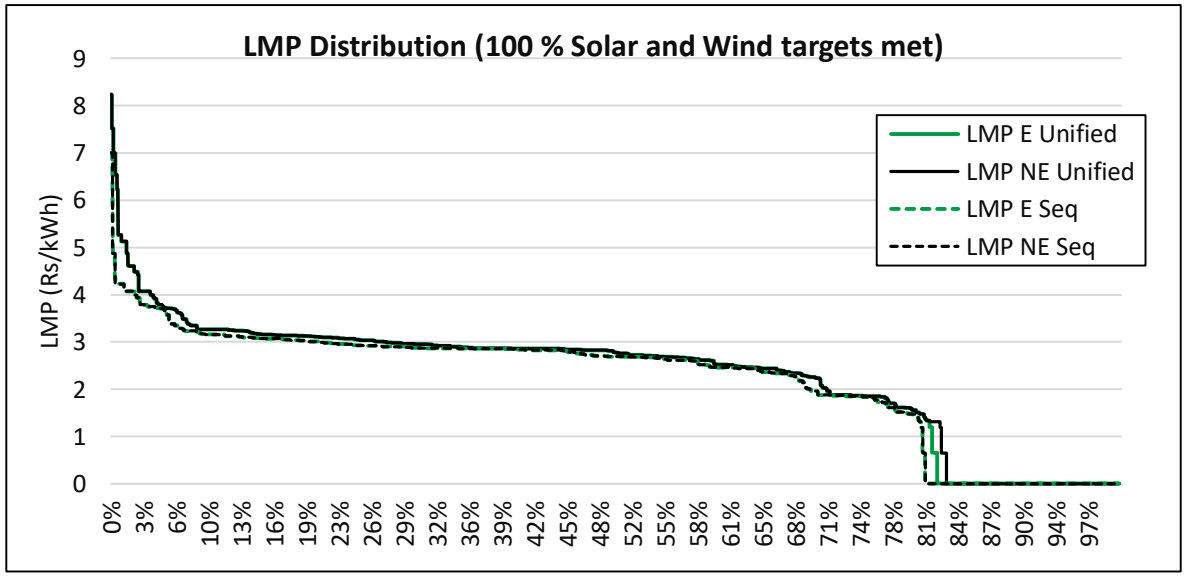
Unified vs Sequential clearing

Import/Export Quantum & Price Duration curves









Export quantum is greater in Sequential Clearing CBT case compared to Unified CBT case. There is also a marginal increase in clearing prices in Unified Clearing

Unified vs Sequential clearing

Observations

- With Unified Regional Market clearing, there is a marginal increase in the clearing prices compared to the Sequential scenario (where the Indian prices are insulated) for both RE scenarios.

- However, though there is an increase in the marginal clearing prices in the Unified clearing scenario, India achieves higher benefits, from a system cost perspective, through Unified clearing compared to Sequential clearing
    - In RE Scenario 1, the benefits from unified clearing is **Rs. 3348 crore** and is **Rs 1762 crore** in sequential clearing. Unified clearing is around 90% more beneficial in this scenario
    - In RE Scenario 2, the benefits from unified clearing is **Rs. 2666 crore** and is **Rs 2201 crore** in sequential clearing. Unified clearing is around 20% more beneficial in this scenario

Conclusion

Conclusions

Cross-border trading of *India* with *Nepal*, *Bhutan* and *Bangladesh* is analysed in this study for the year 2024-25 with two scenarios of renewable integration:

- Scenario 1: 75% of 2025 Solar and Wind target met
- Scenario 2: 100% of 2025 Solar and Wind target met

The benefits brought about by cross border trade are significant, even though there is a marginal increase in clearing prices – increase in average prices by **Rs 0.107/kWh** for Scenario 1 (75% of 2025 Solar and Wind target met) and by **Rs 0.116/kWh** for Scenario 2 (100% of 2025 Solar and Wind target met)

The benefits in Scenario 1 is **around Rs 11,000 crore** and in Scenario 2 **around Rs 10,500 crore.** The savings in system costs is around **4%**

An analysis on Unified and Sequential clearing regimes for trade between *India* and *Bangladesh* were also undertaken:

- For Scenario 1, sequential clearing yielded **Rs 1763 Cr.** of benefits ***(Rs 1.3/kWh** per unit of trade)* compared to **Rs 2658 Cr.** ***(Rs 2.53/kWh** per unit of trade)* for unified clearing
- For Scenario 2, sequential clearing yielded **Rs 2201 Cr.** of benefits ***(Rs 1.63/kWh** per unit of trade)* compared to **Rs 3348 Cr.** for unified clearing ***(Rs 2/kWh** per unit of trade)*

Thank You!

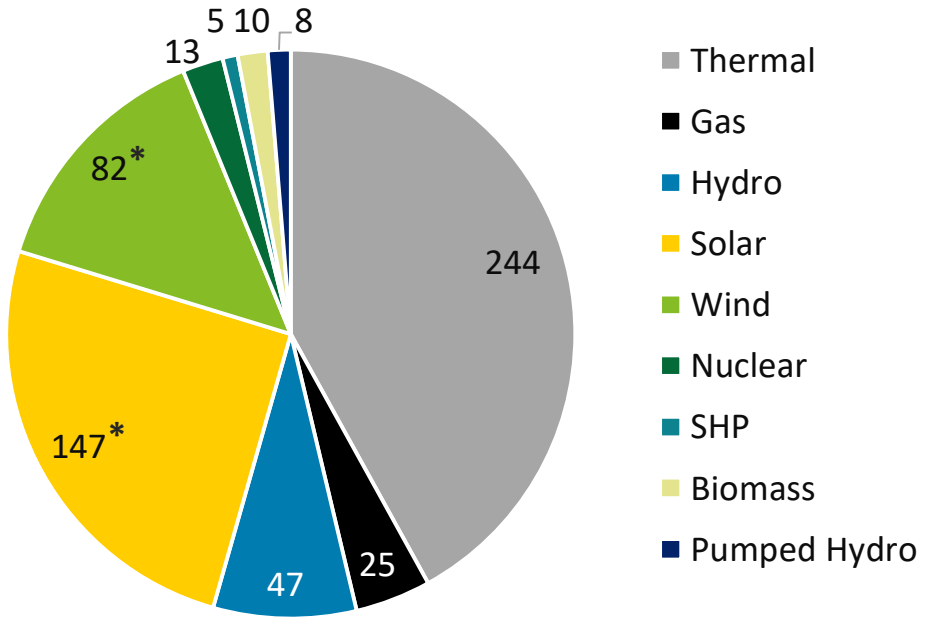
Annexures

Analysis for 2024-25 – Indian scenario

Data and Assumptions

Data Used and Assumptions taken

2024-25



** RE at 100% capacity for 2025. Another scenario considering 75% RE capacity is also considered*

Installed Capacity has been taken according to CEA's *Report On Optimal Generation Capacity Mix For 2029-30*.

Generation addition have been taken according to NEP and CEA broad status report. In the absence of data, generation addition has been linearly assumed between 2021-22 and 2029-30

Energy Requirement (2024-25)	**17,03,410 MU** *(Base corrected EPS 19th figure)*

Assumptions Used		
	Thermal (Coal)	**Gas**
Variable Costs	from Merit India website, CERC report; wherever unavailable, the weighted average of the VCs of all plants of that state have been taken.	
	escalated at 3.45% yoy	kept constant
Tech Min	55% of IC	40% IC
Aux Consum	taken as 9%. DC = IC * (1 – aux)	
Ramp Rate	1%/min	3% /min
Min Up/Down time	6 hr (up) / 4 hr (down)	4 hr (up) / 3hr (down)
Solar, Wind, Nuclear, Hydro and other RE taken as must run and do not contribute to MCP		

Two scenarios for RE have been considered, one where 75% of the Solar & Wind targets are met and one where 100% of Solar & Wind targets are met

Analysis for 2024-25 – With cross border trading

Data and Assumptions

Cross Border Interconnections Assumptions

2024-25

Nepal to India	1000 MW Capacity	**To NR**	255 MW Capacity	Hydro Capacity: 255 MW
		To ER	745 MW Capacity	Hydro Capacity: 745 MW
Bhutan to India	4250 MW Capacity	**To ER**	4092 MW Capacity	Hydro Capacity: 4092 MW
		To NER	158 MW Capacity	Hydro Capacity: 158 MW
Bangladesh to India	1540 MW Capacity	**To ER**	1000 MW Capacity	–
		To NER	540 MW Capacity	–

Assumptions:

- Hydro imports from Nepal and Bhutan are assumed to have zero cost.
- No export is considered from India to Nepal and Bhutan
- For Bangladesh, the spot prices of West Bangladesh are considered for simulation. An exchange rate of 0.85 is considered for converting Taka to INR.
- Import cost from Bangladesh is calculated based on spot prices of Bangladesh i.e. ***Import Quantum * Spot price Bangladesh***
- Export revenue for export from India to Bangladesh is calculated based on spot prices of Bangladesh i.e. ***Export Quantum * Spot price Bangladesh***

Approach and Methodology

Approach and Methodology

1

Data collection and processing

Demand, generator, transmission capacity data was collected from various sources and processed

Demand and generation data are prepared according to load growth projections and generation profiles for each state

2

Selection of Representative days

Representative days are chosen using k-means clustering performed on the net-demand of each region to consider the variabilities of demand, solar and wind.

Representative days are given as inputs to the MILP model

3

Determination of Area Clearing Prices for the bid areas

A centralised dispatch mechanism using Security Constrained Unit Commitment with Economic Dispatch with calculation of Marginal Costs using the dual formulation was used to determine the Area Clearing Prices

Market Model

Objective Function and Constraints

The Objective function is to minimize the total system cost while ensuring that the total system demand is met

Penalties are kept for unmet demand and excess generation

Thermal Constraints:

- **Maximum Generation Constraint:** DC of the station is taken as the maximum generation
- **Minimum Generation Constraint:** Technical Minimum of the Station
- **Ramping Constraints:** Based on Ramp up and Ramp down rates
- **Start-up constraints and Start-up Cost**
- **Minimum up time:** Time duration for which the generator must be in generating state after turning on
- **Minimum down time:** Time duration for which the generator must be shut down for after turning off

Must Run to Generate based on profile at zero cost

Pumped Storage Constraints:

- **Total Charging possible =** IC * no. of hours of storage / efficiency
- **Total Discharging possible** <= Total Charge / efficiency
- **Max Charge / Discharge in a slot** = IC

Transmission Constraints:

- **DC OPF constraints**
- **Line flow limits constraints:** ATC of the lines taken as the limits

Marginal Prices:

- The dual (marginal price) of the demand-balance equation for each region and slot is extracted

Data Used and Assumptions taken

2024-25

Lines	ATC	ATC (Reverse Flow)
N1, N2 to **W1, W2, W3**	2000	-24500
N1, N2 to **E1, E2**	1800	-6600
E1, E2 to **W1, W2, W3**	*No limit specified*	*No limit specified*
W1, W2, W3 to **S1**	15500	-4200
E1, E2 to **S1**	5400	*No limit specified*
A1, A2 to **E1, E2**	3245	-1960
N1, N2 to **N3**	7000*	-7000*
S1 to **S2, S3**	7950	-7950

ATC as per TTC-ATC for Apr, 2023 Apr-23 TTC_R0.pdf (powergrid.in)

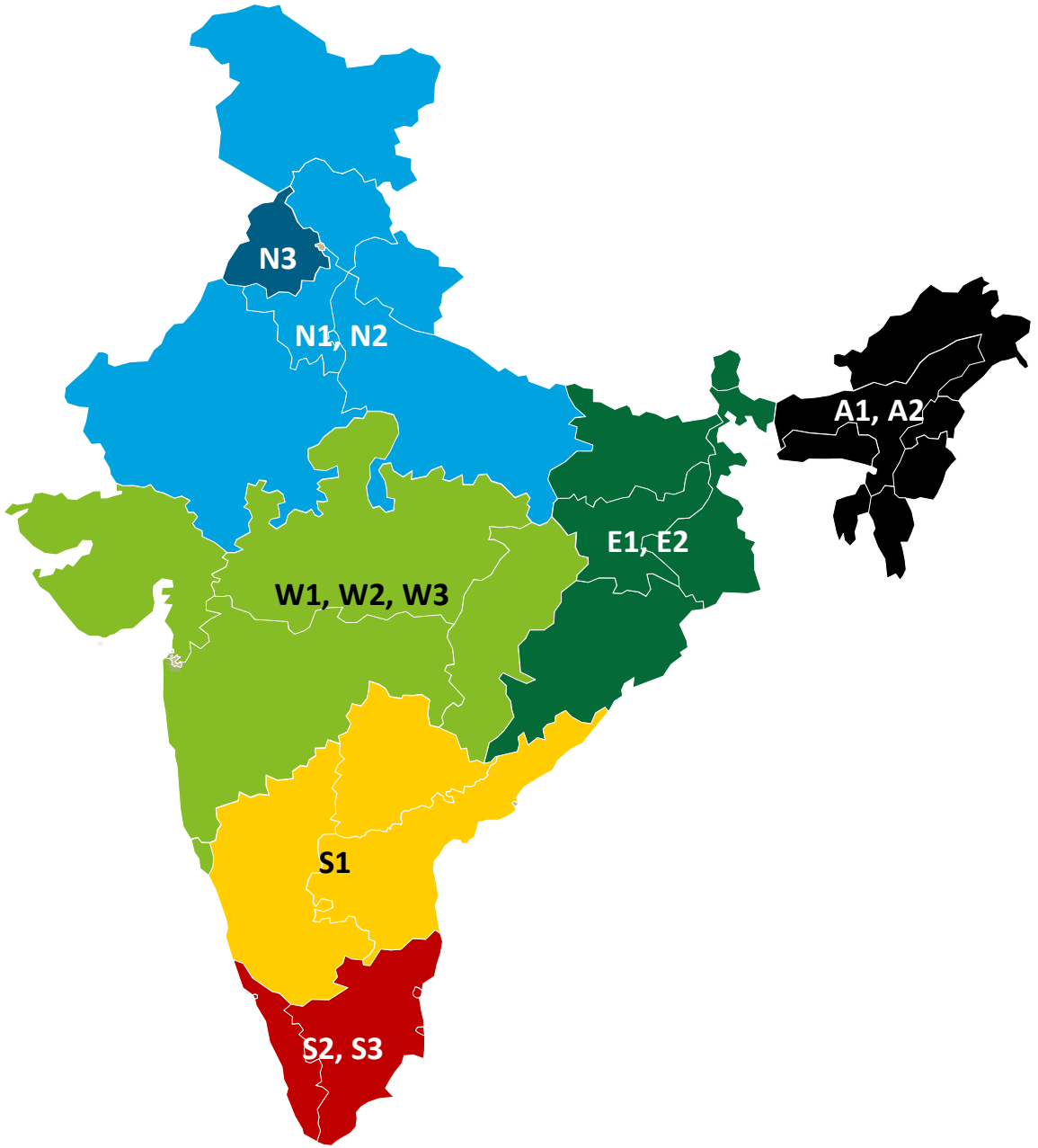
ATC as per TTC-ATC for Apr/July, 2021

https://posoco.in/download/atc_nldc_apr21_rev24/?wpdmdl=36546

https://posoco.in/download/import-of-punjab_atc_july21_rev0/?wpdmdl=36086

(TTC instead of ATC taken for Punjab due to high level of congestions)*

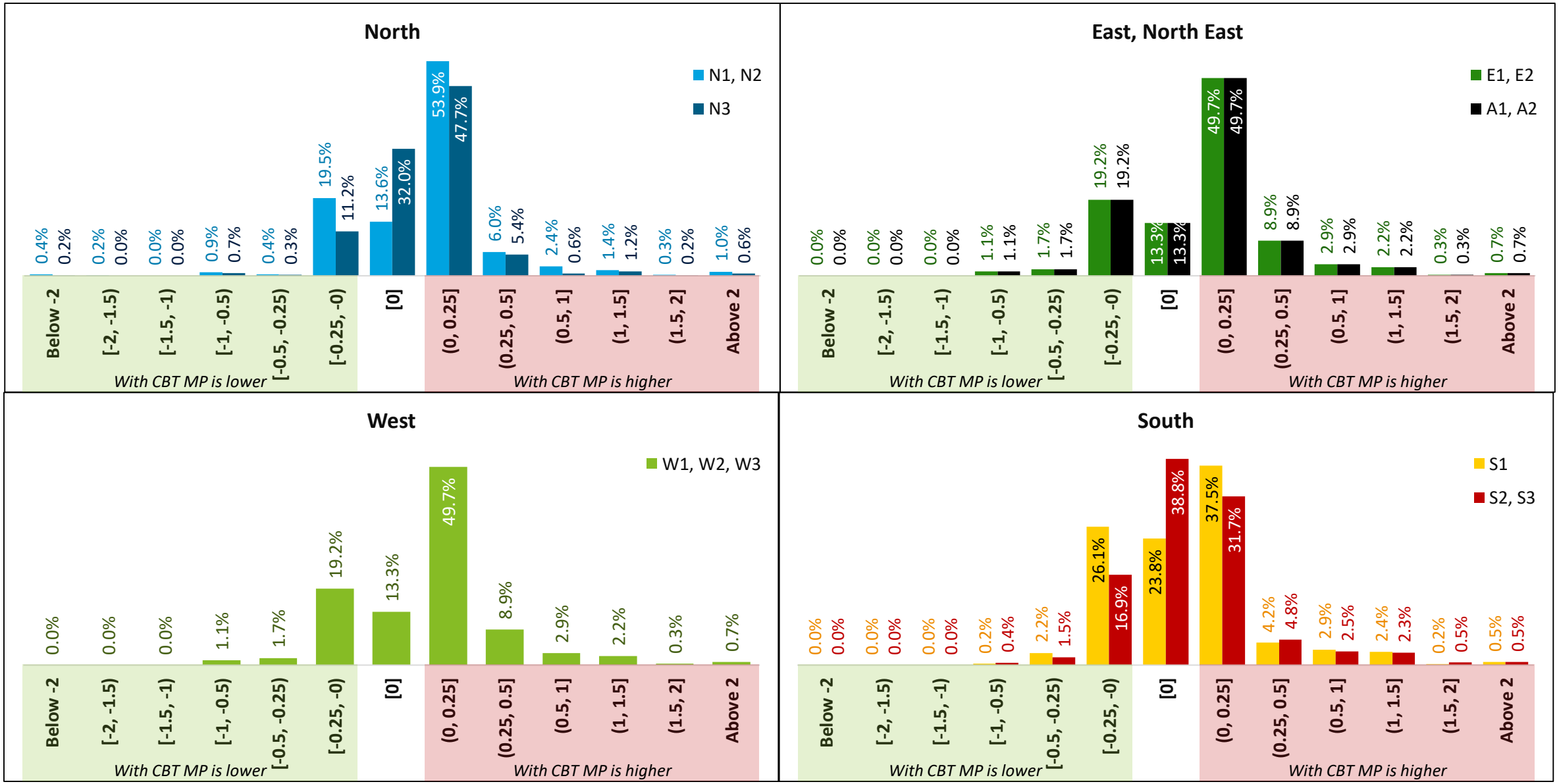
https://posoco.in/download/s1-s2s3_ttc_atc_apr21_rev1_31-03-2021/?wpdmdl=36162



Analysis of Scenario 1

75% of 2025 Solar and Wind Targets Met

Frequency Distribution of Price Difference (With CBT – Without CBT) – 75% Solar and Wind Targets



Frequency Distribution of Price Difference (With CBT – Without CBT) – 75% RE Targets

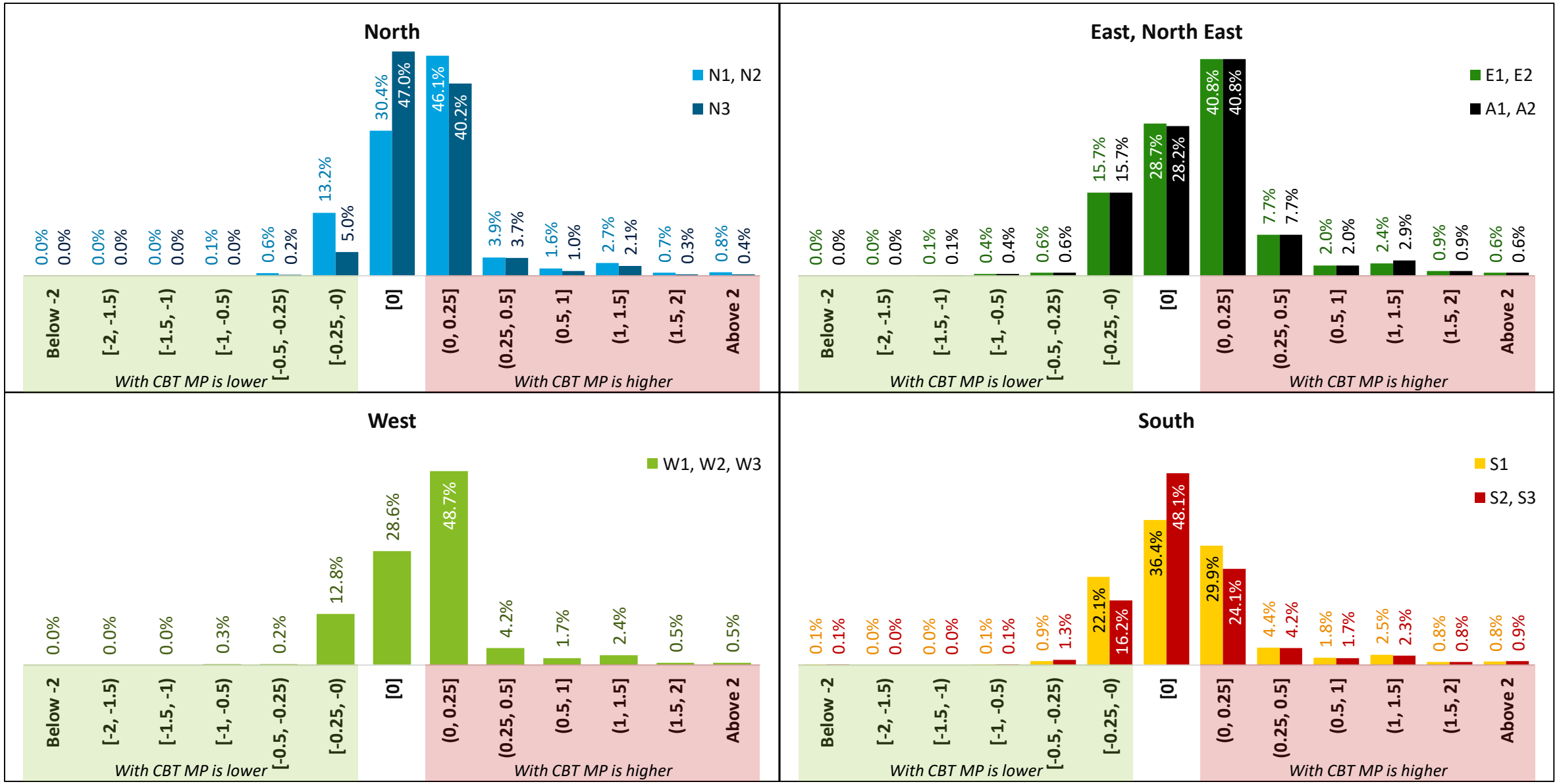
Observations

- For N1, N2, E1, E2, A1, A2, W1, W2 and W3 regions, the prices remain same as that of without cross-border trading scenario for around 13% of the time.
- Except for the Southern regions, all regions have a marginal price increase of up to Rs 0.25/kWh for about 50% of the time. For Southern region, the increase of up to Rs 0.25/kWh is for less than 40% of the time
- For around 20-30% of the total hours, the prices are reduced with cross border trading
- On a broader sense, the marginal prices of India are slightly higher with cross border trade. A major reason for this is lesser units are being committed in Eastern region because of the availability of hydro power from Nepal and Bhutan. Illustrations highlighting the same are included in the following slides.
- Southern region prices are comparatively less impacted with this price increase. This is because the E-S1 line gets congested for about 50% of the time, therefore, the prices of southern region are not dependent much on eastern generators.

Analysis of Scenario 2

100% of 2025 Solar and Wind Targets Met

Frequency Distribution of Price Difference (With CBT – Without CBT) – 100% Solar and Wind Targets



Frequency Distribution of Price Difference (With CBT – Without CBT) – 100% RE Targets

Observations

- For N1, N2, E1, E2, A1, A2, W1, W2 and W3 regions, the price remains same as that of without cross-border trading scenario for around 30% of the time
- All regions (except for Southern) are observed to have price increase of up to Rs 0.25/kWh for about 40-50% of the time. This number is lesser in case of southern region (less than 30% of the time)
- All regions see a price reduction for 10-15% of the total hours (16% - 20% of the hours for Southern regions) with cross border trading.
- On a broader sense, the marginal prices of India are slightly higher with cross border trade. A major reason for this is lesser units are being committed in Eastern region because of the availability of hydro power from Nepal and Bhutan. Illustrations highlighting the same are included in the following slides.
- Southern region prices are comparatively less impacted with this price increase. This is because the E-S1 line gets congested for about 50% of the time, therefore, the prices of southern region are not dependent much on eastern generators.

Unified vs Sequential clearing

Calculation of Sequential Clearing Benefits

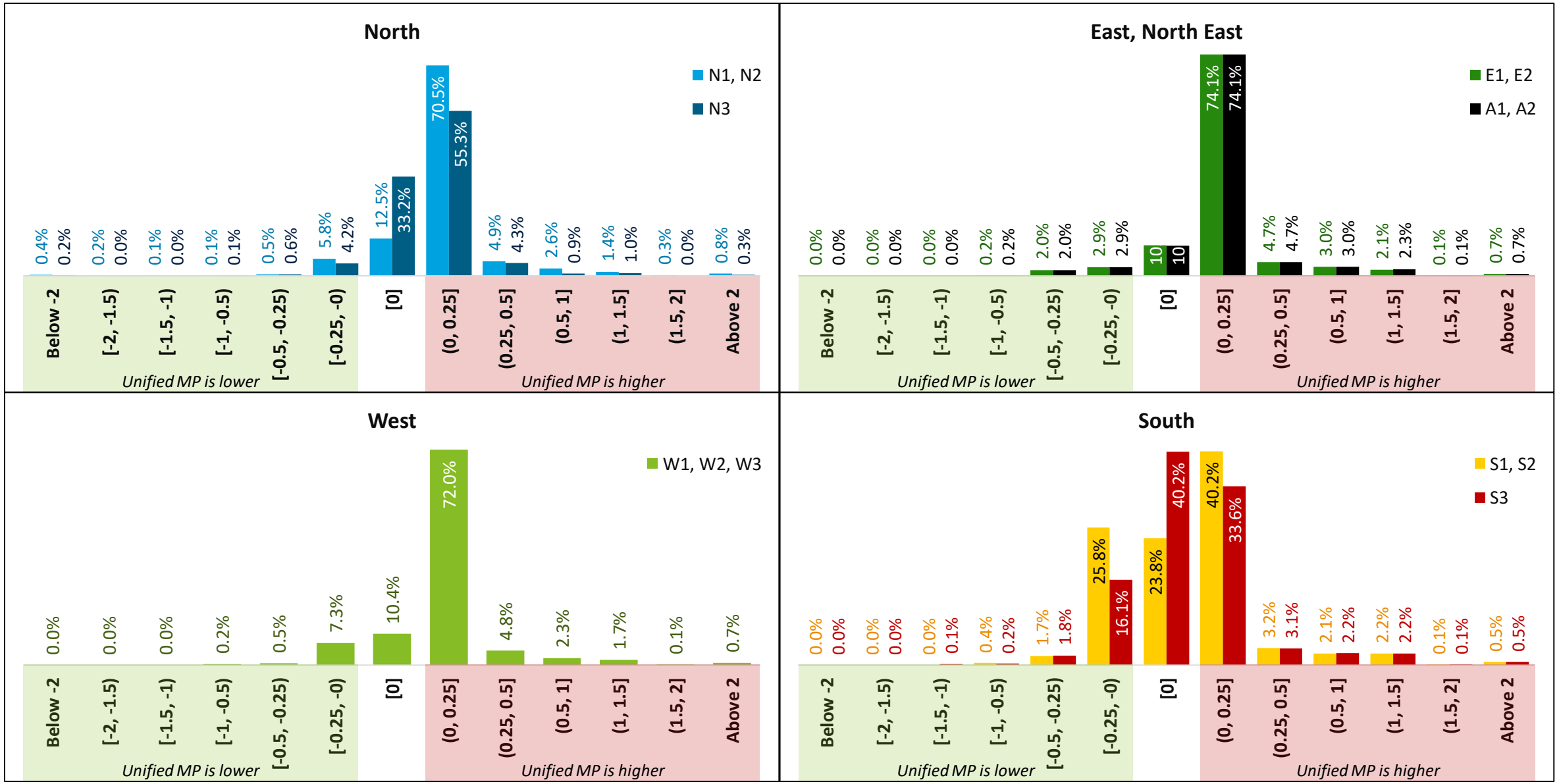
	Sequential Clearing Benefits		Illustration for a slot	Scenario 1: 75% Solar and Wind Target (Annual)	Scenario 2: 100% Solar and Wind Target (Annual)
Export	Bangladesh Spot price	*[A]*	Rs 3.265/kWh	–	–
	Eastern region Spot Price	*[B]*	Rs 2.683/kWh	–	–
	North-Eastern region Spot price	*[C]*	Rs 2.683/kWh	–	–
	Export from Eastern region	*[D]*	1000 MWh	8432 GWh	8340 GWh
	Export from North-Eastern region	*[E]*	540 MWh	4553 GWh	4503.6 GWh
	Revenue from Export	***[(A – B)*D + (A – C)*E]***	**Rs 8.97 lacs**	**Rs 1741.51 Cr**	**Rs 2160.8 Cr**
Import	Bangladesh Spot price	*[A]*	Rs 3.265/kWh	–	–
	Eastern region Spot Price	*[B]*	Rs 3.749/kWh	–	–
	North-Eastern region Spot price	*[C]*	Rs 3.749/kWh	–	–
	Import to Eastern region	*[D]*	1000 MWh	328 GWh	420 GWh
	Import to North-Eastern region	*[E]*	540 MWh	177 GWh	226.8 GWh
	Savings from Import	***[(A – B)*D + (A – C)*E]***	**Rs 7.45 lacs**	**Rs 21.4 Cr**	**Rs 39.9 Cr**
Total Benefits				**Rs 1762.9 Cr**	**Rs 2200.7 Cr**
Per Unit Impact of Cross Border Trade				***Rs 1.300 /kWh***	***Rs 1.631 /kWh***

Unified vs Sequential clearing

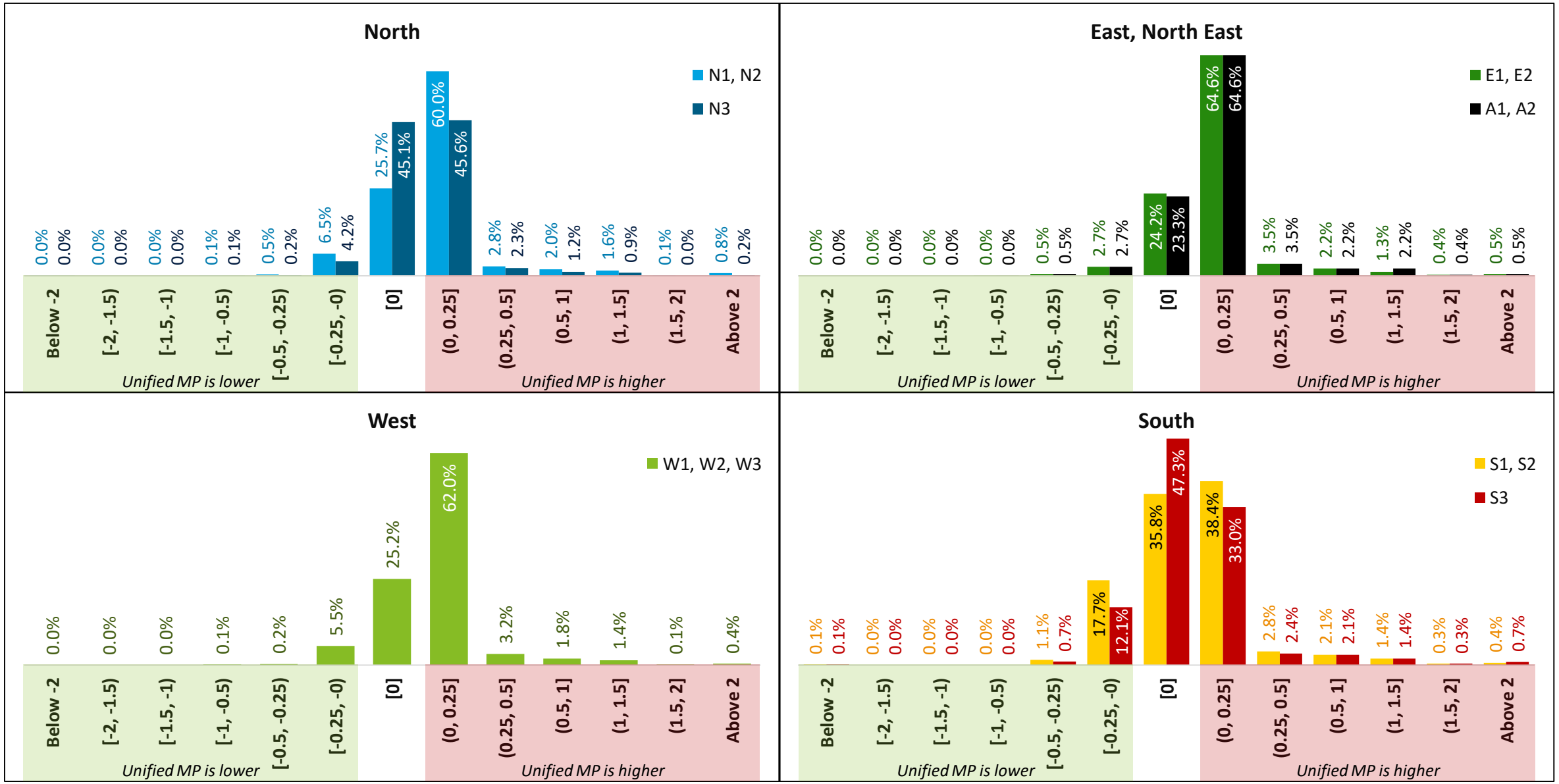
Calculation of Unified Clearing Benefits

Unified Clearing Benefits			Scenario 1: 75% Solar and Wind Target	Scenario 2: 100% Solar and Wind Target
Export Quantum to Bangladesh	*From ER*	*(a)*	*8034.7 GWh*	*7951.8 GWh*
	From NER	*(b)*	*4331.8 GWh*	*4338.0 GWh*
Revenue from export to Bangladesh		*[A]*	*Rs 4813.9 crore*	*Rs 4666.9 crore*
Import Quantum from Bangladesh	*To ER*	*(c)*	*571.2 GWh*	*670.8 GWh*
	To NER	*(d)*	*342.6 GWh*	*355.5 GWh*
Cost of import from Bangladesh		*[B]*	*Rs 328.3 cr*	*Rs 386.3 crore*
Increase in thermal costs due to export - Savings in thermal costs due to import		*[C]*	*Rs 1136.9*	Rs 1614.9 GWh
Net Benefits from Unified Clearing		*[D] = [A - (B + C)]*	**Rs 3348.7 crore**	**Rs 2665.6 crore**
Per Unit Impact of Cross Border Trade		*[D / (a + b + c + d)]*	***Rs 2.531 /kWh***	***Rs 2.000 /kWh***

Frequency Distribution of Price Difference (Unified – Sequential) – 75% Solar and Wind Targets



Frequency Distribution of Price Difference (Unified – Sequential) – 100% Solar and Wind Targets met



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