Centre for Energy Regulation

Department of Industrial and Management Engineering
Indian Institute of Technology Kanpur- 208016

Capacity Building Programme for Officers of CERC & JERCs
"Regulatory Perspectives on Network, Renewable Energy and Market Development"

Prospects for Green Energy Market and Green Hydrogen policy in India

04 Feb 2023

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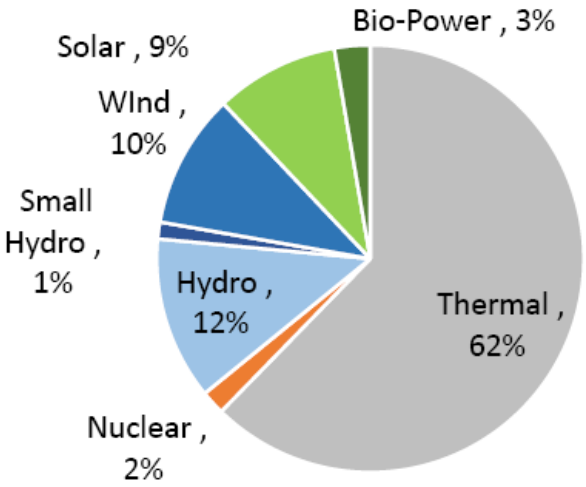
  - CAISO market – Market Surveillance mechanism
- Independent System & Market Operator
  - CAISO example
- Green Hydrogen

India – Changing Fuel Mix

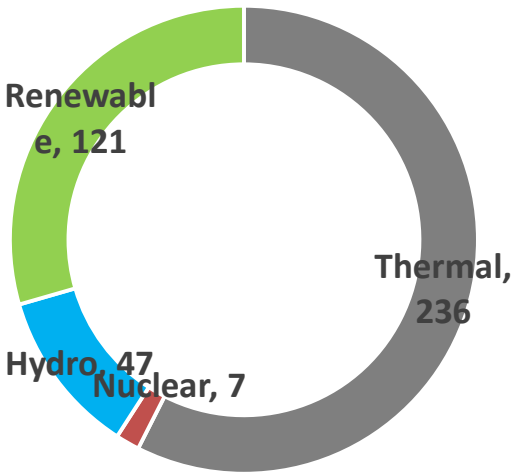
Total Installed Capacity >>

~370 GW

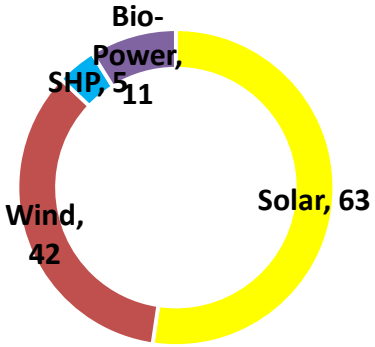


2020

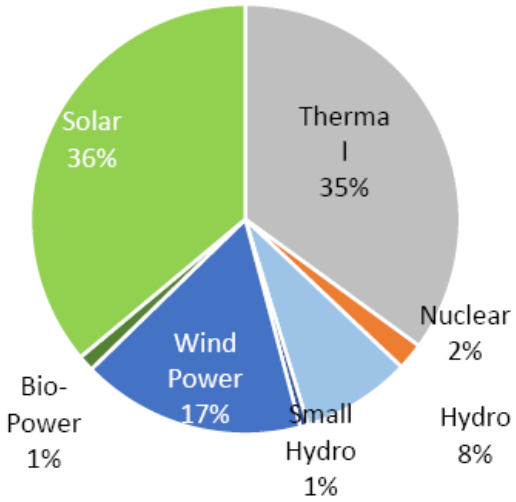
411 GW



Dec 2022



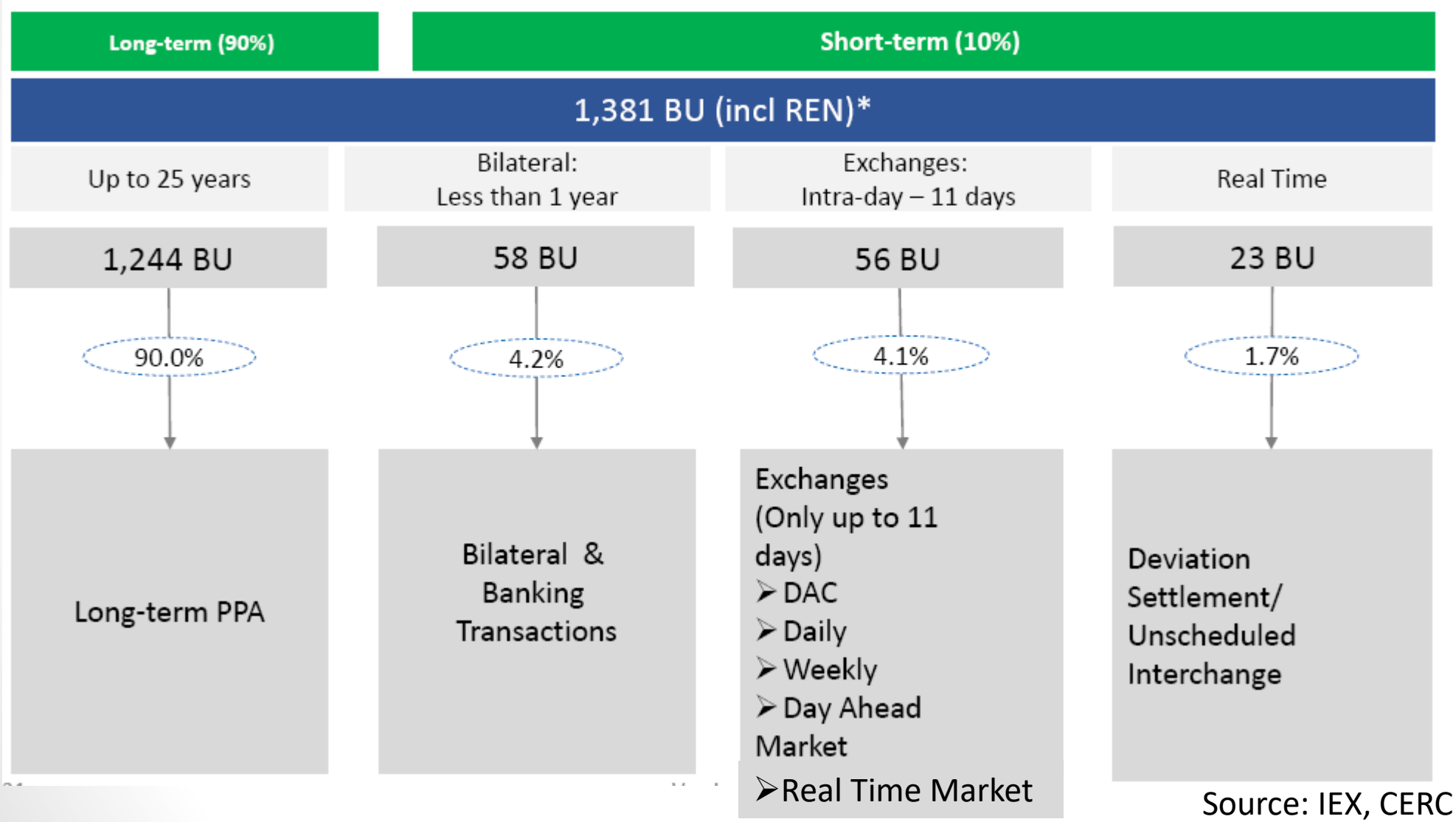
~800 GW



2030

Source: CEA , IEX

India – How Electricity is transacted (FY '21)



Source: IEX, CERC

Power Exchange Products

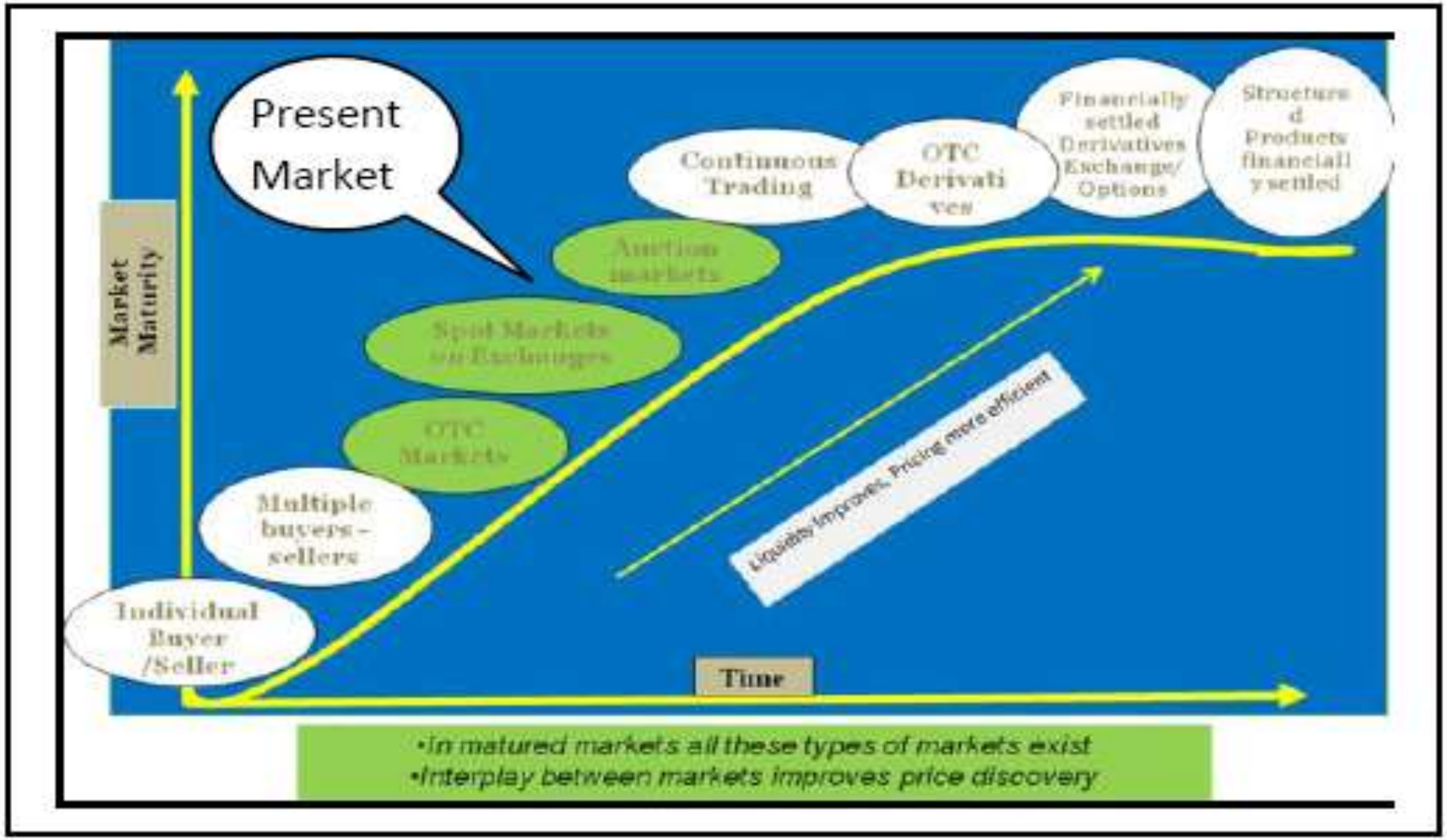
Day-Ahead Market since Jun 2008	➢ Delivery for next day; Includes cross border trade launched on 21st April 2021 ➢ Price discovery: Closed, Double-sided Auction
Term-Ahead Contracts since Sep 2009	➢ For delivery up to 11 days ➢ Intra-day, Day-ahead Contingency, Daily Contracts, Weekly Contracts
Real-Time Market since Jun, 2020	➢ Delivery in an hour ➢ Price discovery: Closed, Double-sided Auction
Green Market G-DAM since Oct'21 G-TAM since Aug'20	➢ GTAM - Intra-day, DAC , Daily and Weekly ➢ GDAM - Green Power Delivery for next day
Renewable Energy Certificates since Feb 2011	➢ Green Attributes as Certificates: ➢ Sellers: RE generators not under feed in tariffs ➢ Buyers: Obligated entities; 1MWh equivalent to 1 REC
Energy Saving Certificates since Sep, 2017	➢ 1 ESCert= 1 Mtoe(Metric Tonne Oil Equivalent) ➢ Trading session every Tuesday | Trading time 13:00 hrs. to 15:00 hrs.

Continuous

DAM vs RTM

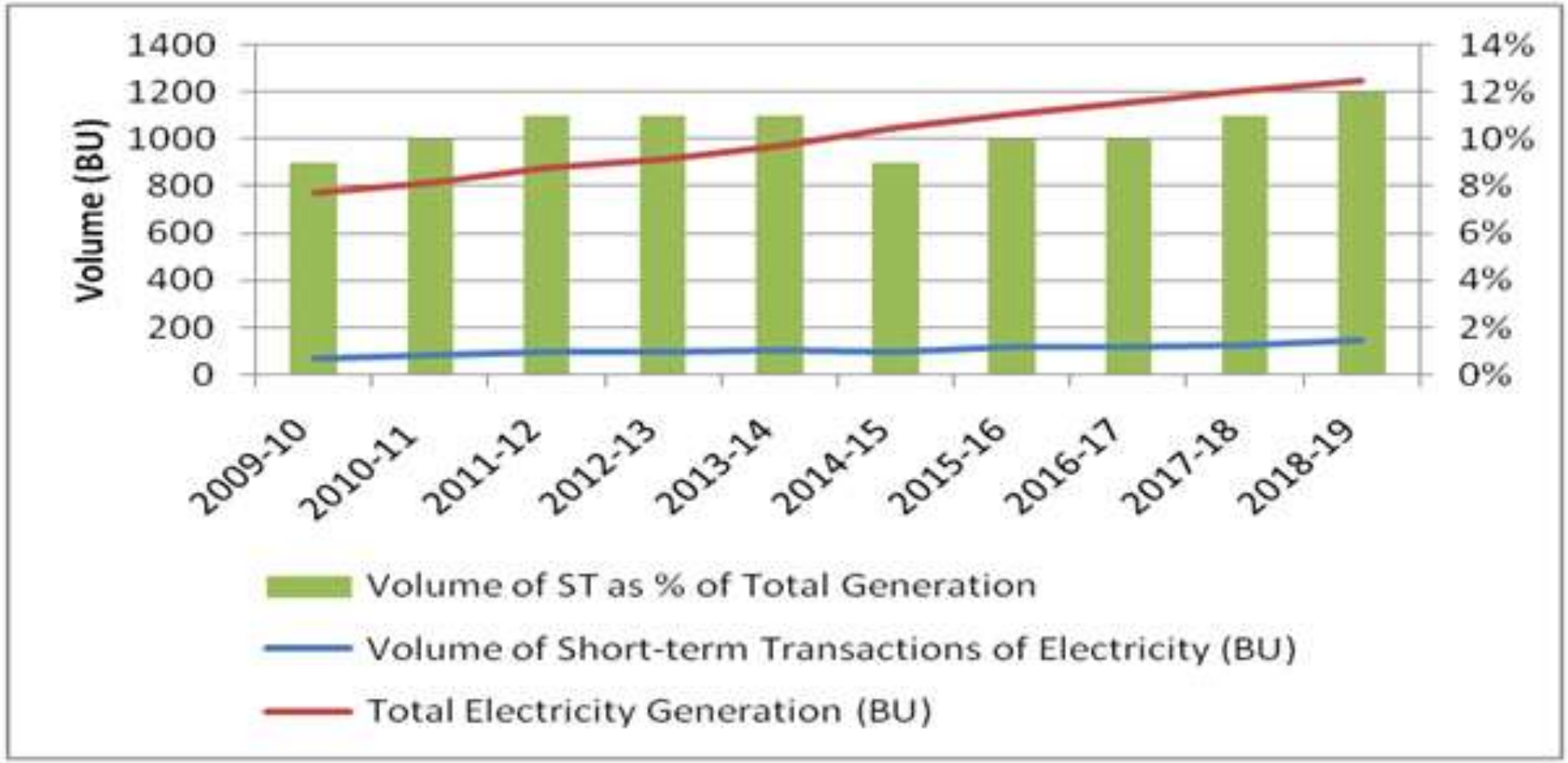
Sl.	Details/Function	Day/Term Ahead Market (DAM/TAM)	Real Time Market (RTM)
1	**Trading Period**	Previous Day from 10:00 to 12:00 Hrs. (1 Session only)	Every Alternate 15 Minutes (48 RTM sessions)
2	**Delivery Time**	Next day ***(After 12 Hrs from Bid Closure)***	Same day ***(After 1 Hour from Bid Closure)***
3	**Contingency Feed**	Not for Contingency requirement	**Always available as a backup Source during Emergency**
3	**Bid approach**	- Bid Planning required one day in advance - Advance planning required - Unable to cover Incidental Risks	- Based on Real time scenario (More accuracy can be planned) - Captures sudden demand from surplus power/ available - Bid strategy can be changed as per the past session price trends For better economy/Sales realization
4	**URS Power**	Least Participation of URS/ Surrendered power (for ISGS)	- URS power can be traded in RTM (Beneficiary consent not required) **- URS power comparatively Cheaper than other sources will result into lower Price discovery in RTM**
5	**Curtailment**	Day Ahead Power will be curtailed prior to RTM	**Curtailment Risk very low** (DAM Power will be curtailed first, RTM later)
6	**Supply Commitment** *(during Outage of captive Units)*	- No schedule revision possible once bid is clear - Heavy DSM Charges in case of Unit Outage	- Participation in upcoming bid session can be discontinued. ***(Hence, no bid, no-commitment/DSM/Under Injection penalty)*** - Also Generators may buy power under RTM under tripping/ reduced generation to avoid DSM penalty

Market Maturity Model



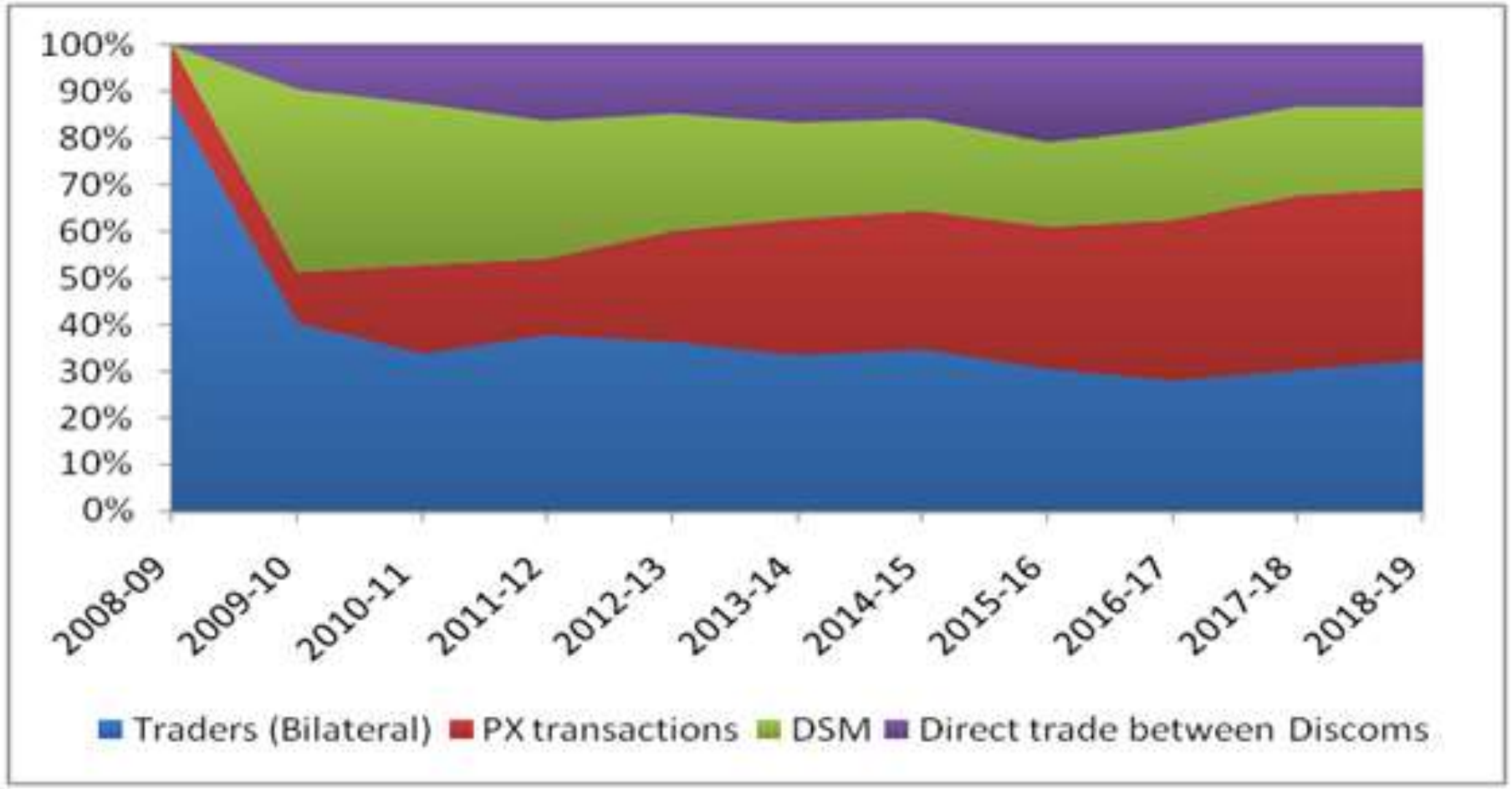
Source: IITK workshop

Power Market Growth in India



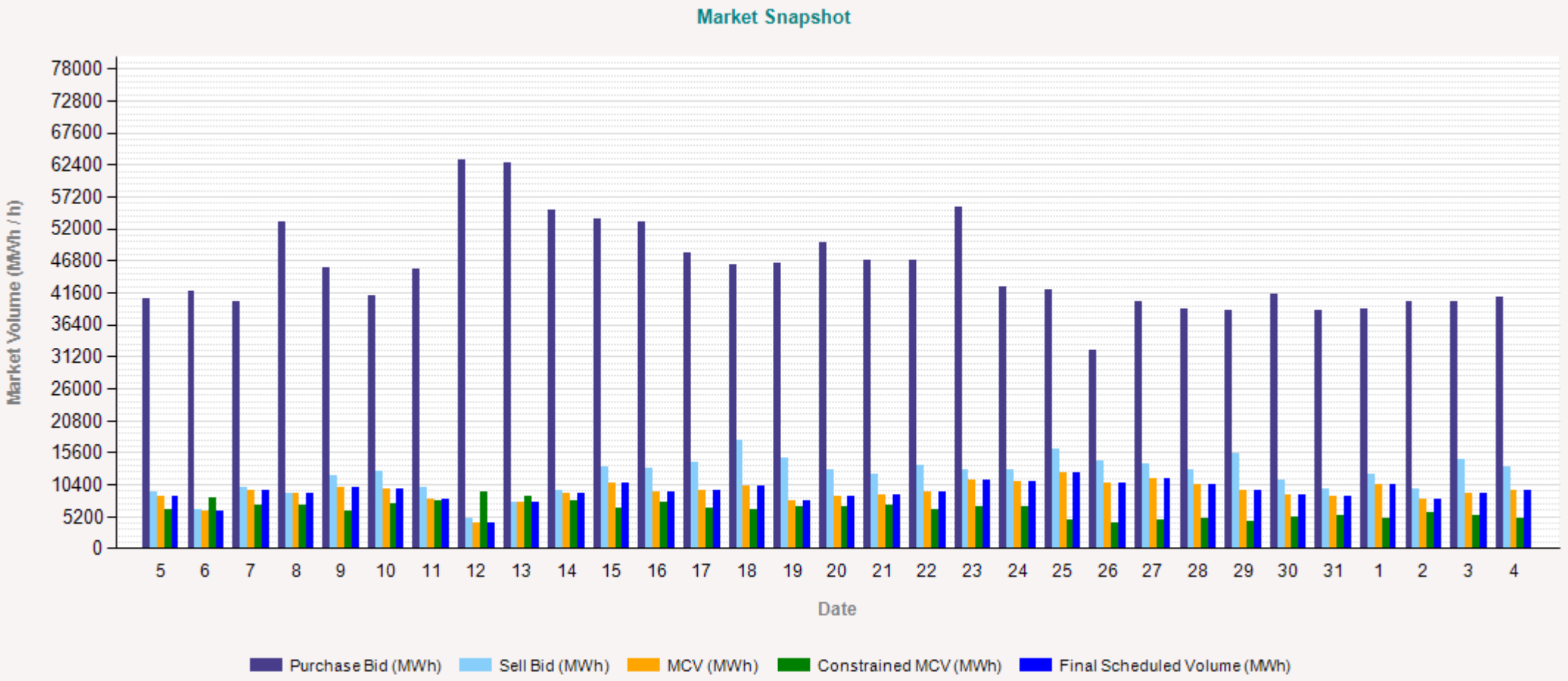
Source: CERC (www.cercind.gov.in)

Composition of short term power txn in India



Source: CERC (www.cercind.gov.in)

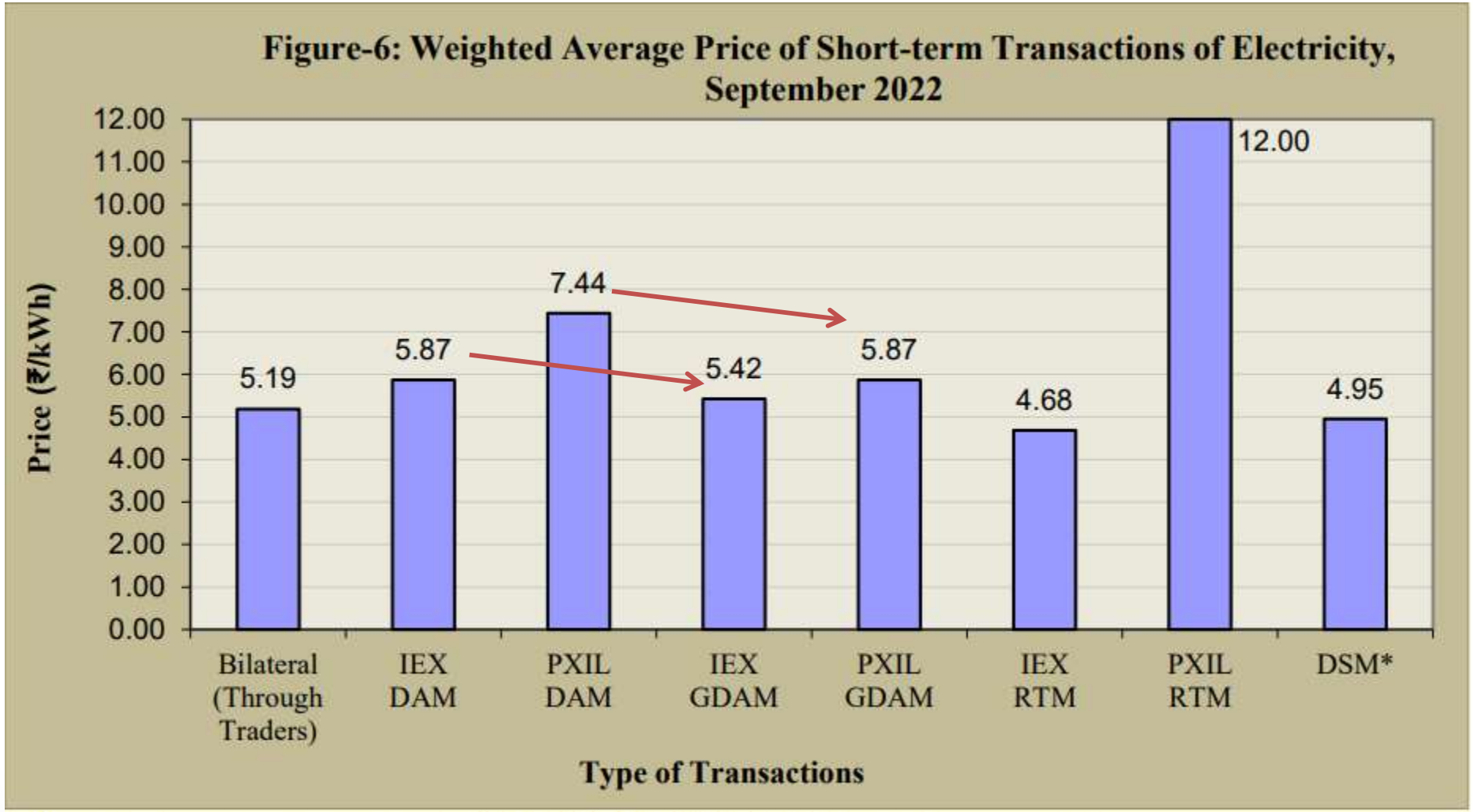
GDAM – Supply is constrained



Source: IEX

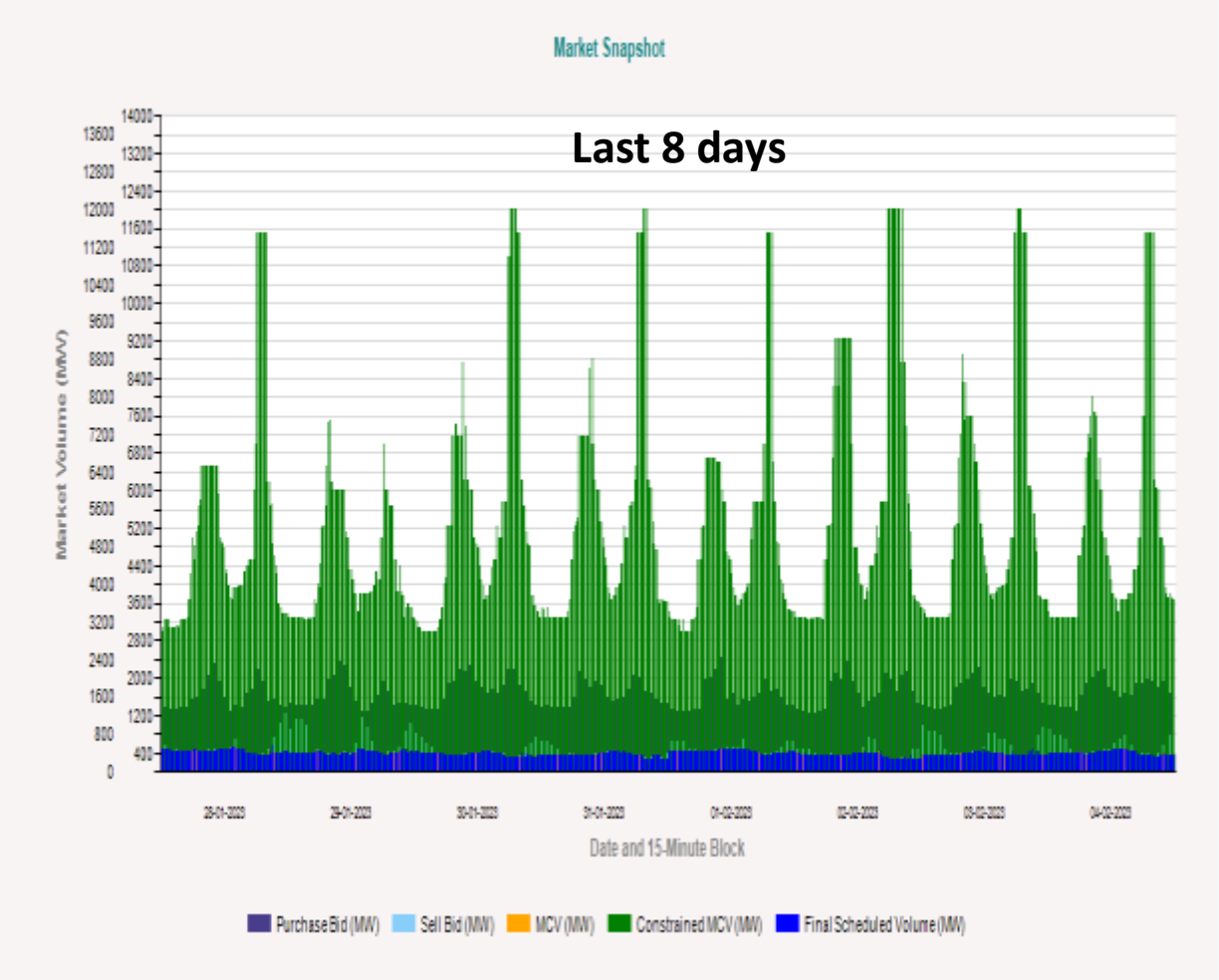
Wt. Avg. rates – Sep '22

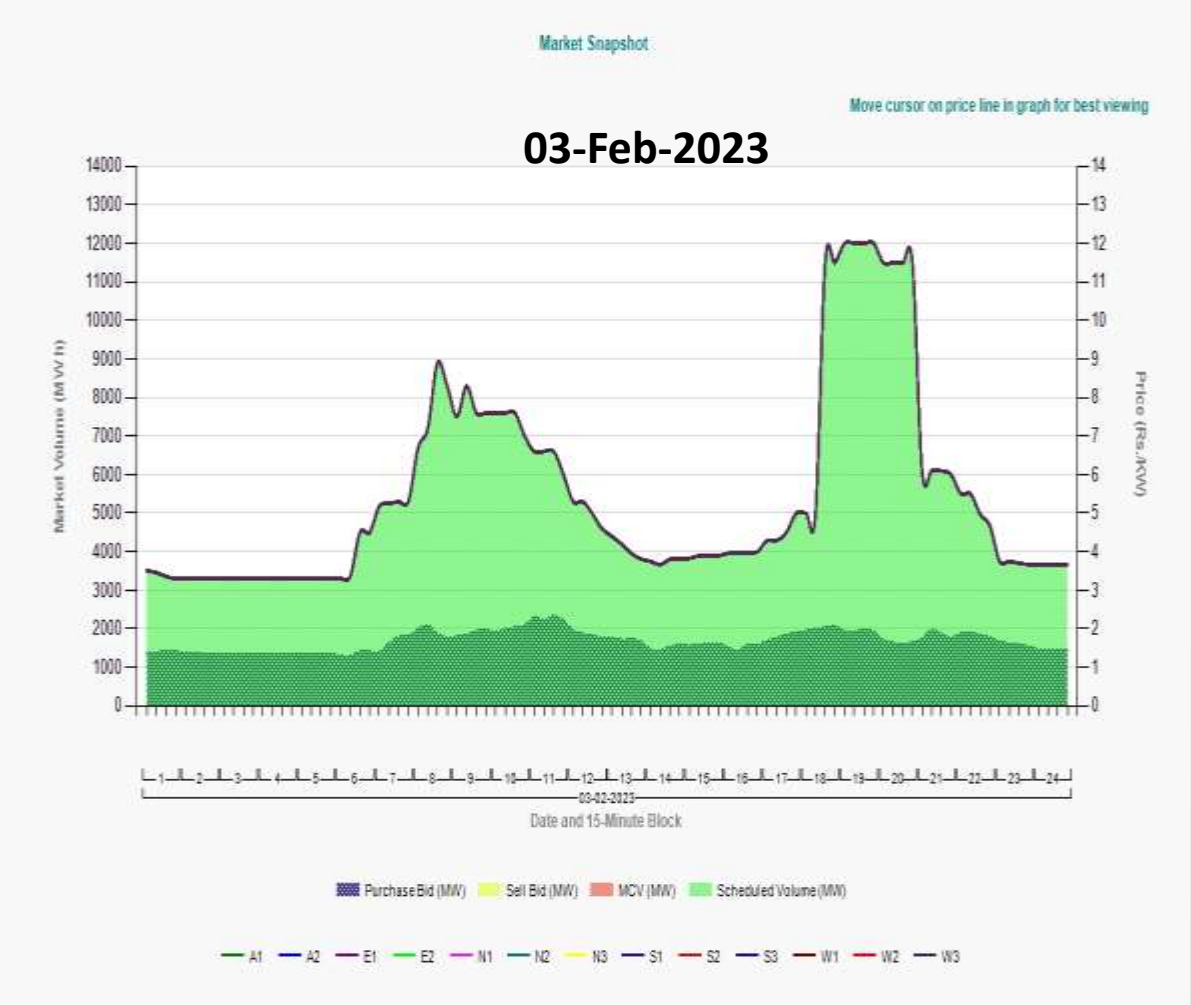
Source: CERC Market Report



Note: *No electricity was transacted in DAM, G-DAM & RTM of HPX during September 2022.*
** Simple average price of DSM of the month*

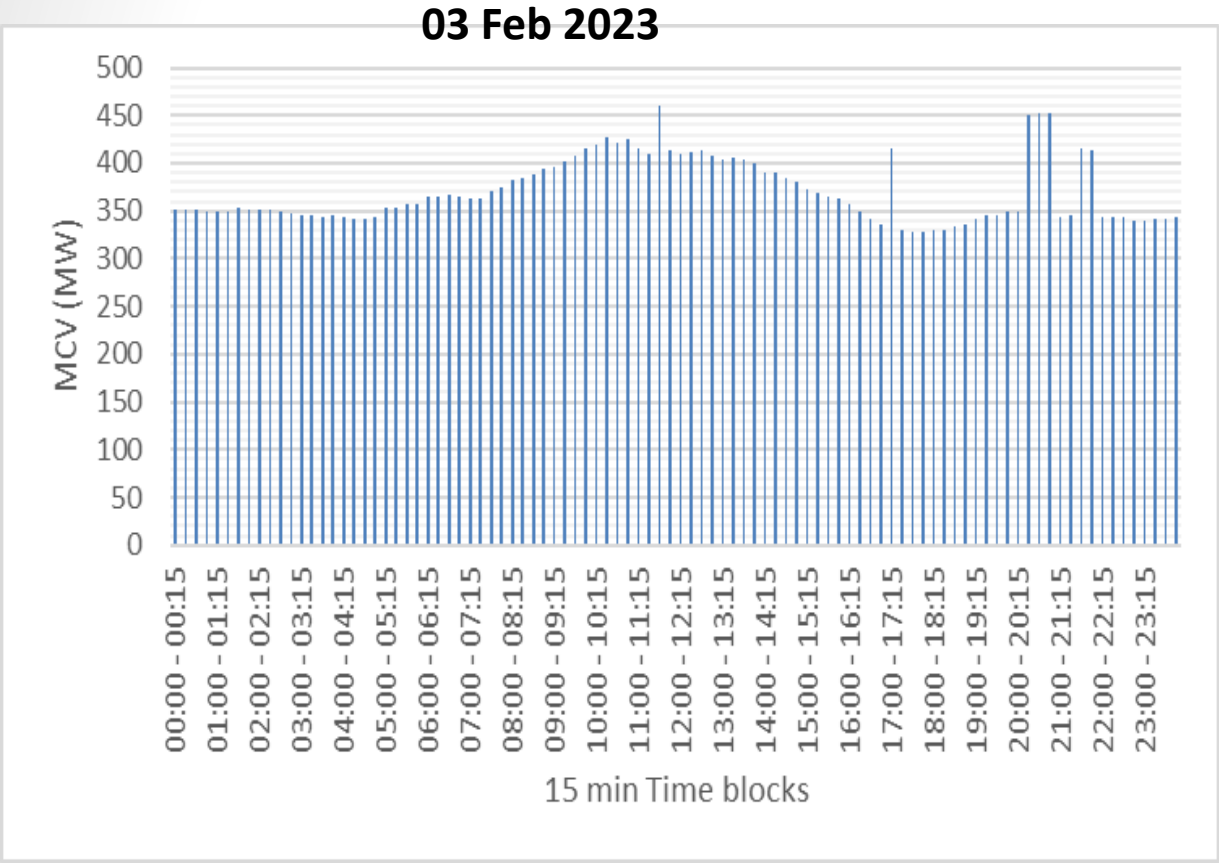
GDAM Snapshot





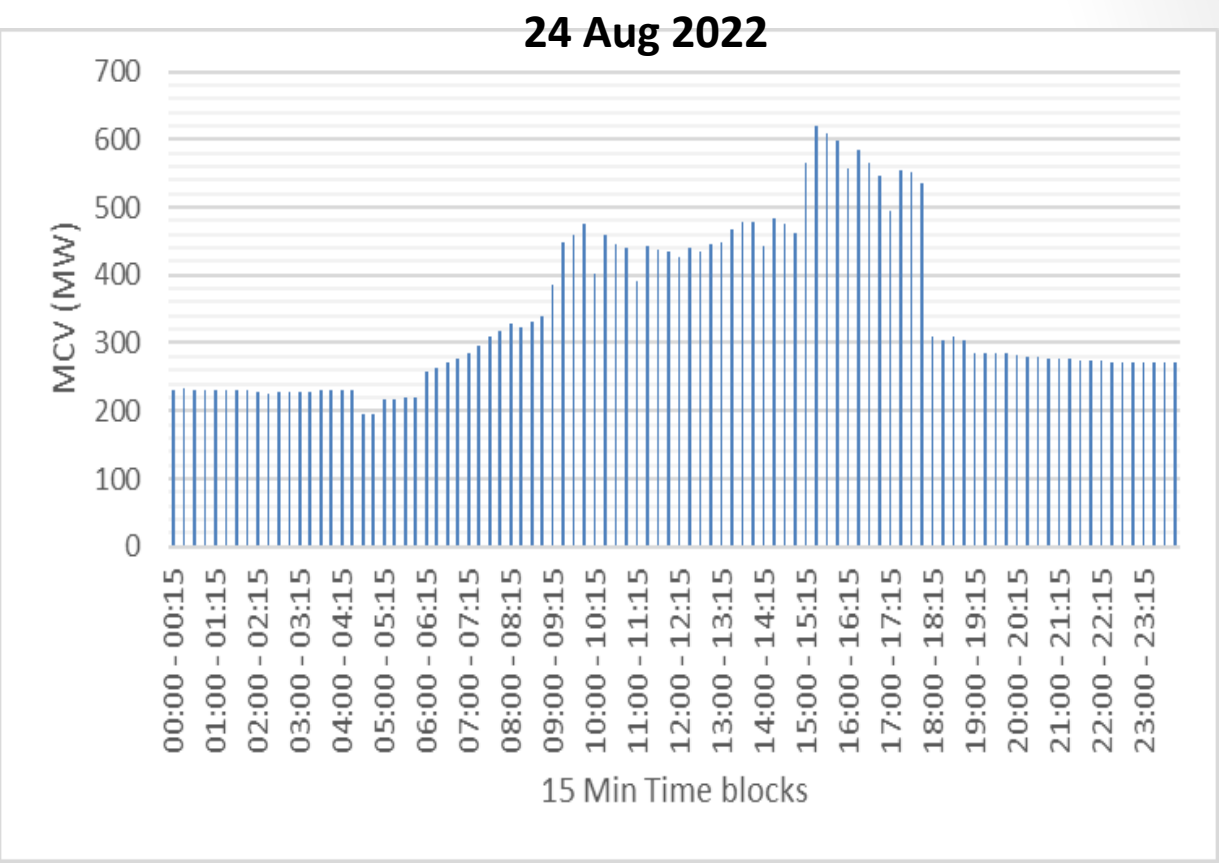
GDAM – ACP Comparison

GDAM – MCV illustrations – Winter & Monsoon



IC: Wind – 41.9 GW; Solar: 63.3 GW

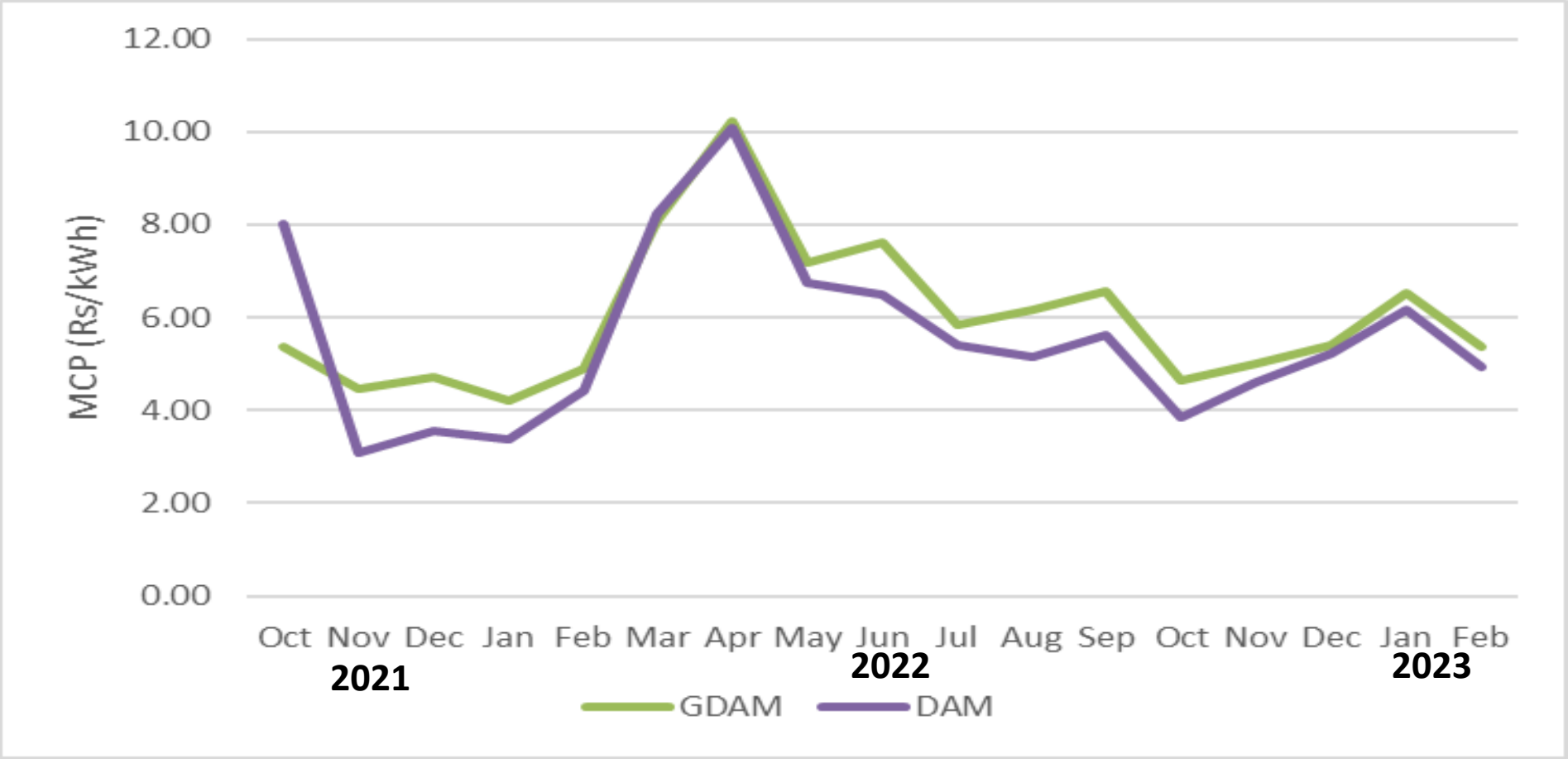
(As on 31.12.22)



IC: Wind – 41.2 GW; Solar: 59.3 GW

(As on 31.08.22)

Monthly MCP Trends (GDAM vs DAM)

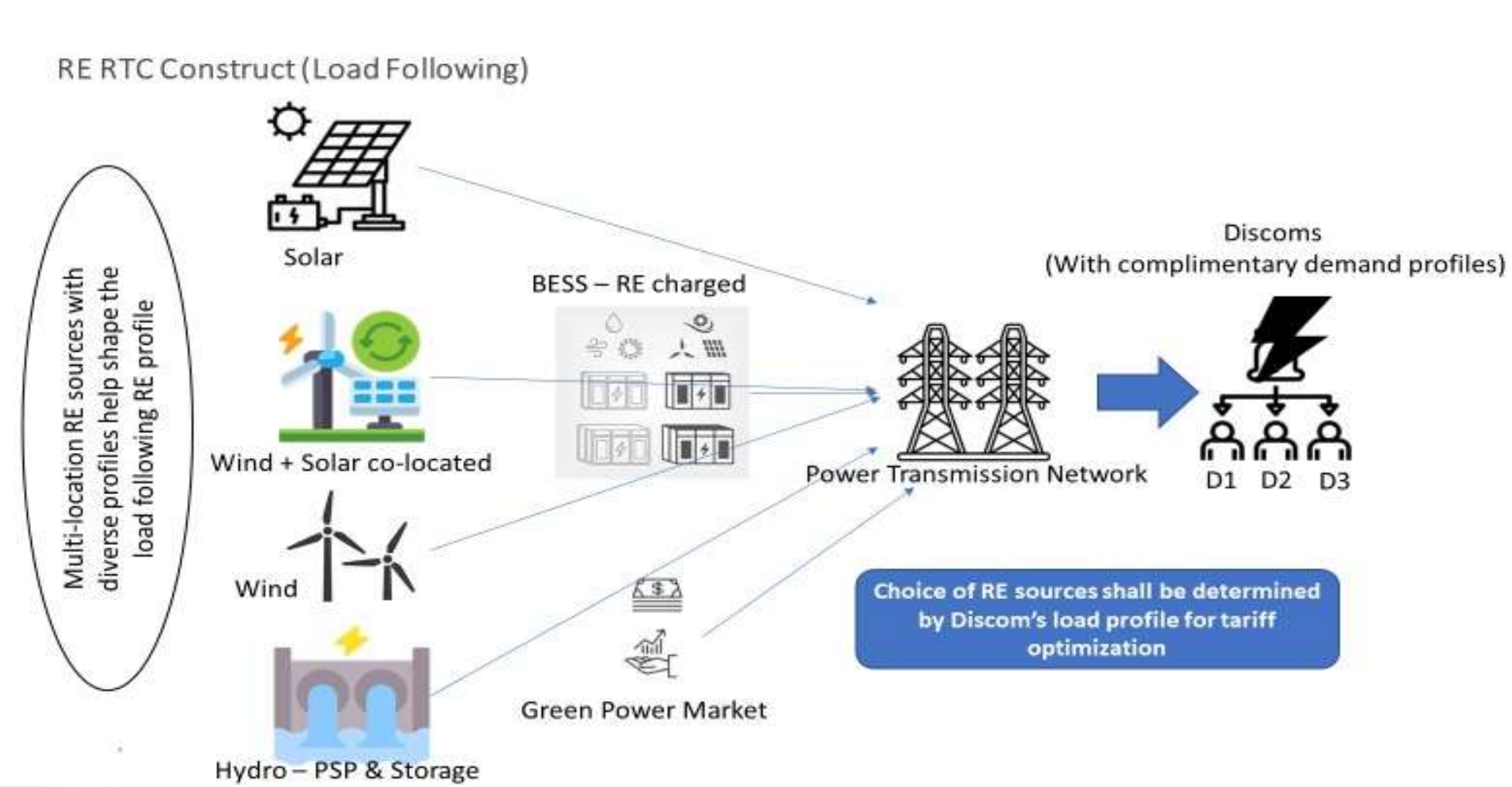


Source: IEX

Increased liquidity (GDAM)– Key enablers

- Discom’s procurement beyond RPO compliance
- Increased merchant capacity
- Green Energy Open Access
- New Long term 100% RE construct – Load following
- Market Based Economic Despatch

Load following 100% RE – RTC construct

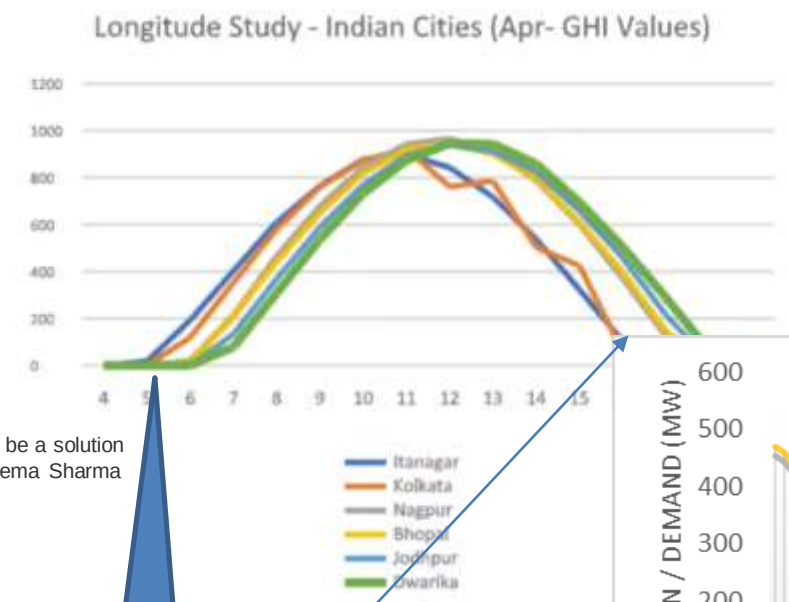


RE based RTC power profiles (Load following)

- Multi location wind and solar power stations together with balancing hydro power and/or BESS can create load following & firm generation profile in MW (15 min time block).
- The day ahead & intra –day variability can be minimized by using assets as above
- State's existing Hydro resources can be used to create RE-RTC profile with firm 25 yr tariff within (Rs 3-3.5 per kWh or less)
- Any residual variability can be met from Real Time Markets or Ancillary Services
- Customizable RE profiles can be created as per needs of States
- Flexibility & variability of RE can be turned into its strength of providing firm generation profile (with minimal variability managed from PX/AS)

RE-RTC power has a commercial case to replace coal stations – load centre or pit-head

RE based RTC generation profile – An Example

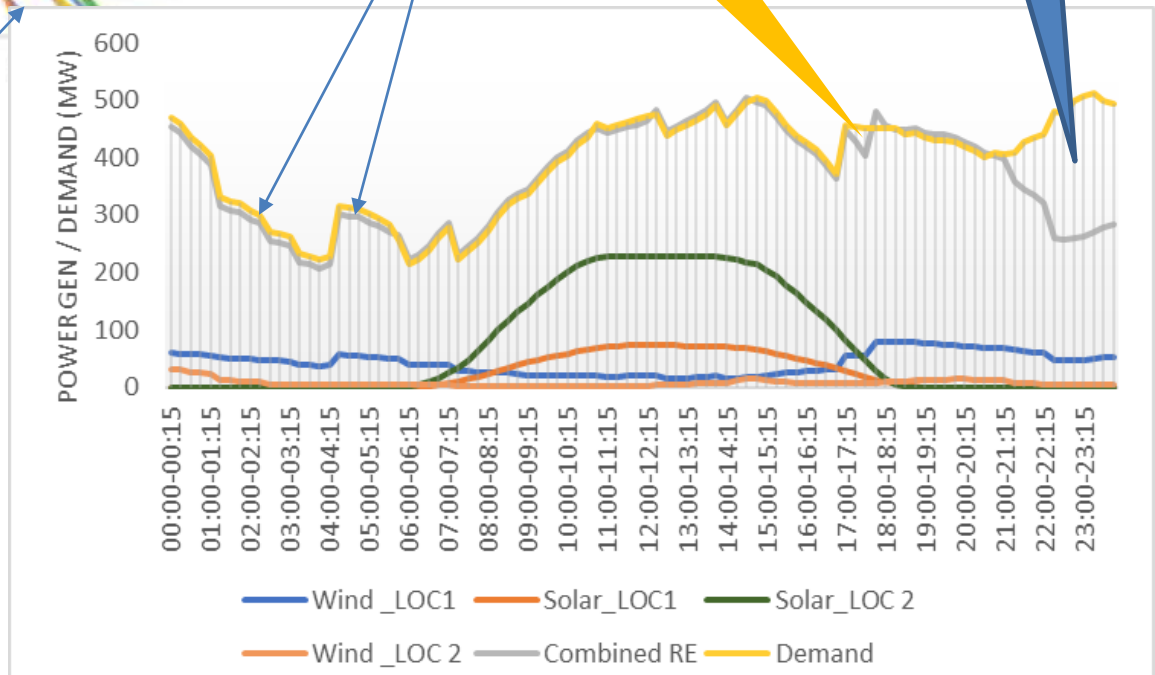


Source:How regional solar cooperation could be a solution for India's energy crisis, Sapan Thapar & Seema Sharma

Up to 1 hr gap

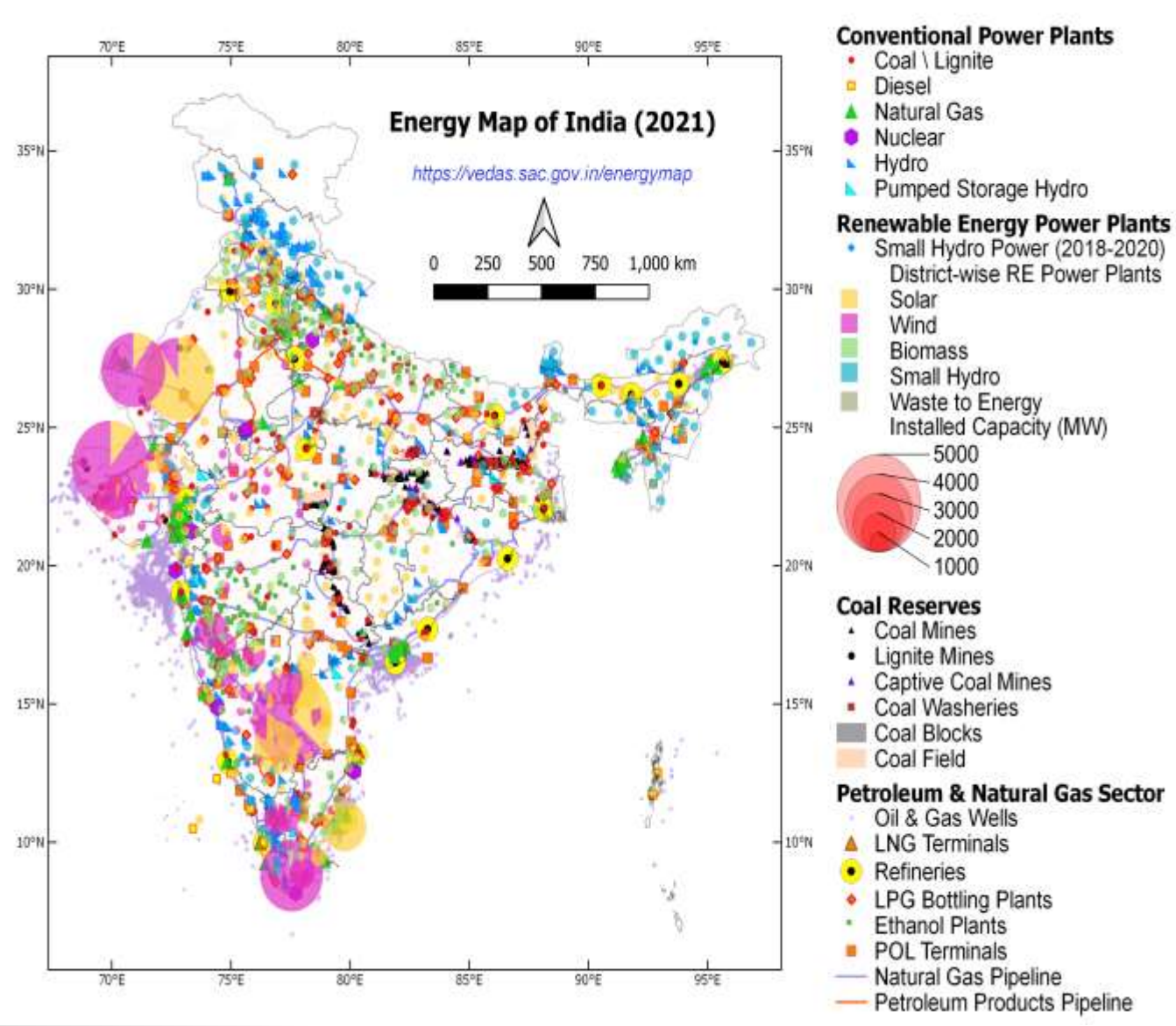
Minor variation managed thru' PX/AS

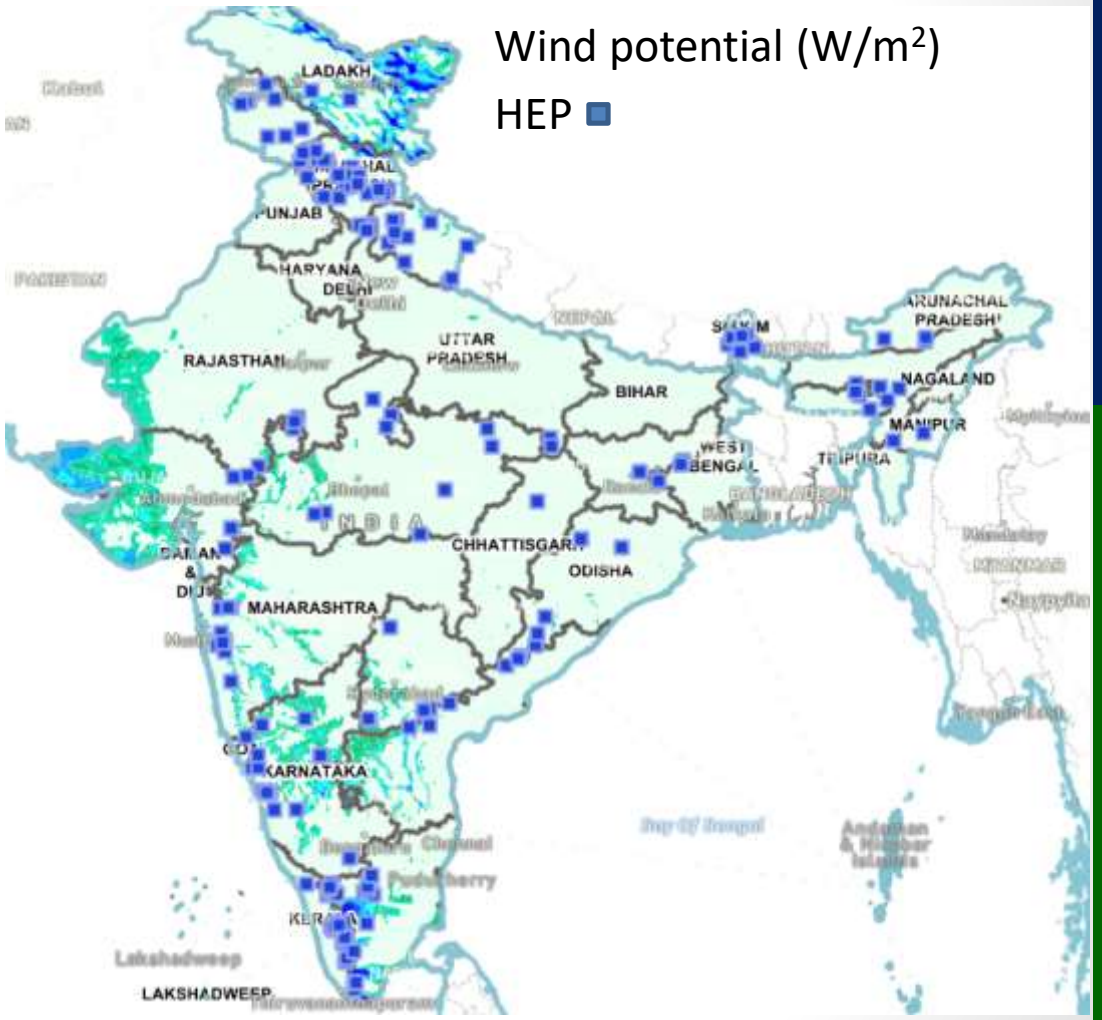
Storage Hydro can be used for peaking support to match demand



Similar Slot Wise analysis for entire year basis historical data and improved F&S of RE enable RE – RTC profile creation with lowest tariff

Energy Resource Map



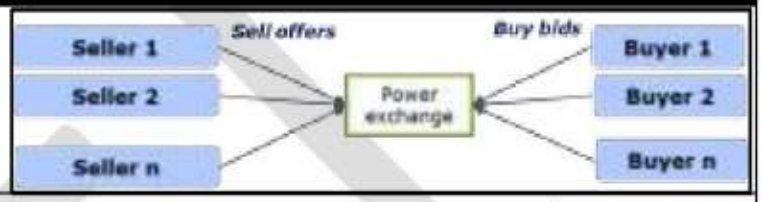


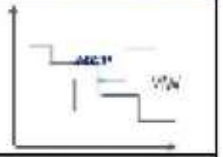
Enablers for Mega Aggregated RE stations

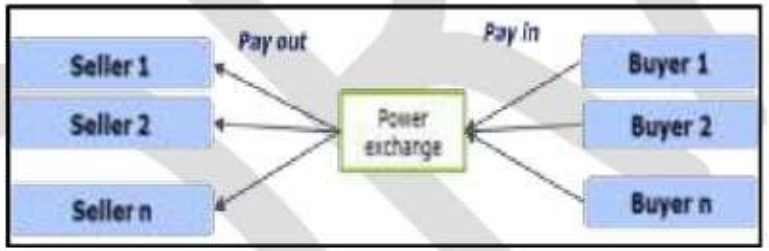
- Portfolio approach to evaluate CUF and not site specific
- Increase in balancing area through regional pooling (proposed in Draft IEGC)
- General Network Access Regulations (GNA) – Copperplate transmission system
- Demand response as a resource (proposed in draft IEGC regulations and AS regulations 2022)
- RE stations to provide ancillary services (proposed in draft IEGC – primary reserves)
- Suitable market mechanism for AS (notified in AS Regulations ‘22)
- Guidelines for Load following RE based RTC power station – Aggregated stations (MOP guidelines likely soon)

Market Based Economic Despatch

Details	Particulars
Pooling of buy / sell bids	• Sellers and buyers submit their offers and bids on a day ahead basis • Offers and bids (quantum and price) are pooled
Price discovery, scheduling & dispatch	• National merit order stack is prepared • Market Clearing Price (MCP) is discovered as per common merit order for each time block of upcoming day
Payments and settlement	• Cleared buyers would pay MCP to the Power exchange which will in turn pay the MCP to the cleared sellers • Final settlement would be as per contract for the portion of demand cleared in relation to contracted MW. Gains realized due to URS sale will be shared with beneficiaries as stipulated by the Commission • The buyers would still continue to pay the fixed costs outside the market.







Particular
Discoms
Generator
Others

- The proposed mechanism would be a key step in enabling uniform clearing price for procurement of power and transitioning towards the concept of **"One Nation, One Grid, One Price"**

Phase 1 of MBED – Applicable to NTPC stations only

Source: MOP Draft paper, Jun '21

PX (RTM) rate discovery curves

Time period	Clearing price (MCP)	MCV	Seller bid price before sharp move	Seller bid volume before sharp move	Shape of curve	% seller bid volume before sharp move against MCV
	Rs/Mwh	MW	Rs/Mwh	MW		%
	A	B	C	D	E	F = D/C
18:30 - 18:45	20000	2164.1	6000	2100	Vertical	97%
18:45 - 19:00	20000	2269.1	9000	2100	Vertical	93%
19:00 - 19:15	20000	2448.4	9000	2350	Vertical	96%
19:15 - 19:30	20000	2743.4	9000	2600	Vertical	95%
19:30 - 19:45	20000	3066.6	9000	2900	Vertical	95%
19:45 - 20:00	20000	3091.6	9000	2900	Vertical	94%

Rate Discovery curves

Rate Discovery Curve

01/02/2021, 08:45-09:00 hr

Independent Market Surveillance Mechanism

- In India, CERC has a market monitoring cell
- The Cell publishes analysis of rates and volumes, players through monthly & yearly reports
- However, given the recent very high prices discovered on RTM & DAM since Oct'21, there is a need to go beyond the surface and identify root cause
- Pattern in high purchase or sell bids by players
- Resource Adequacy and prediction of unnecessary high dependence on energy markets (PX) with capacity on bar not monitored (due to various reasons)
- **There is a need for independent market surveillance mechanism.**
- Example can be seen from California ISO, which established independent market surveillance committee comprising of 3 or more independent & recognized experts.
- ISO staff to provide data & admin support

Source: http://www.caiso.com/Documents/MarketSurveillanceCommitteeCharter.pdf

Independent Market Surveillance Mechanism

- The functions of the Market Surveillance Committee include:
  - Provide independent review of market performance and market power problems
  - Develop a record of structural problems and propose corrective action
  - Review rule changes, penalties, and sanctions
- Current members in CAISO MSC include
  - James Bushnell - email: jbbushnell@ucdavis.edu
  - Scott Harvey - email: scott.harvey@fticonsulting.com
  - Benjamin Hobbs, Chair - email: bhobbs@jhu.edu

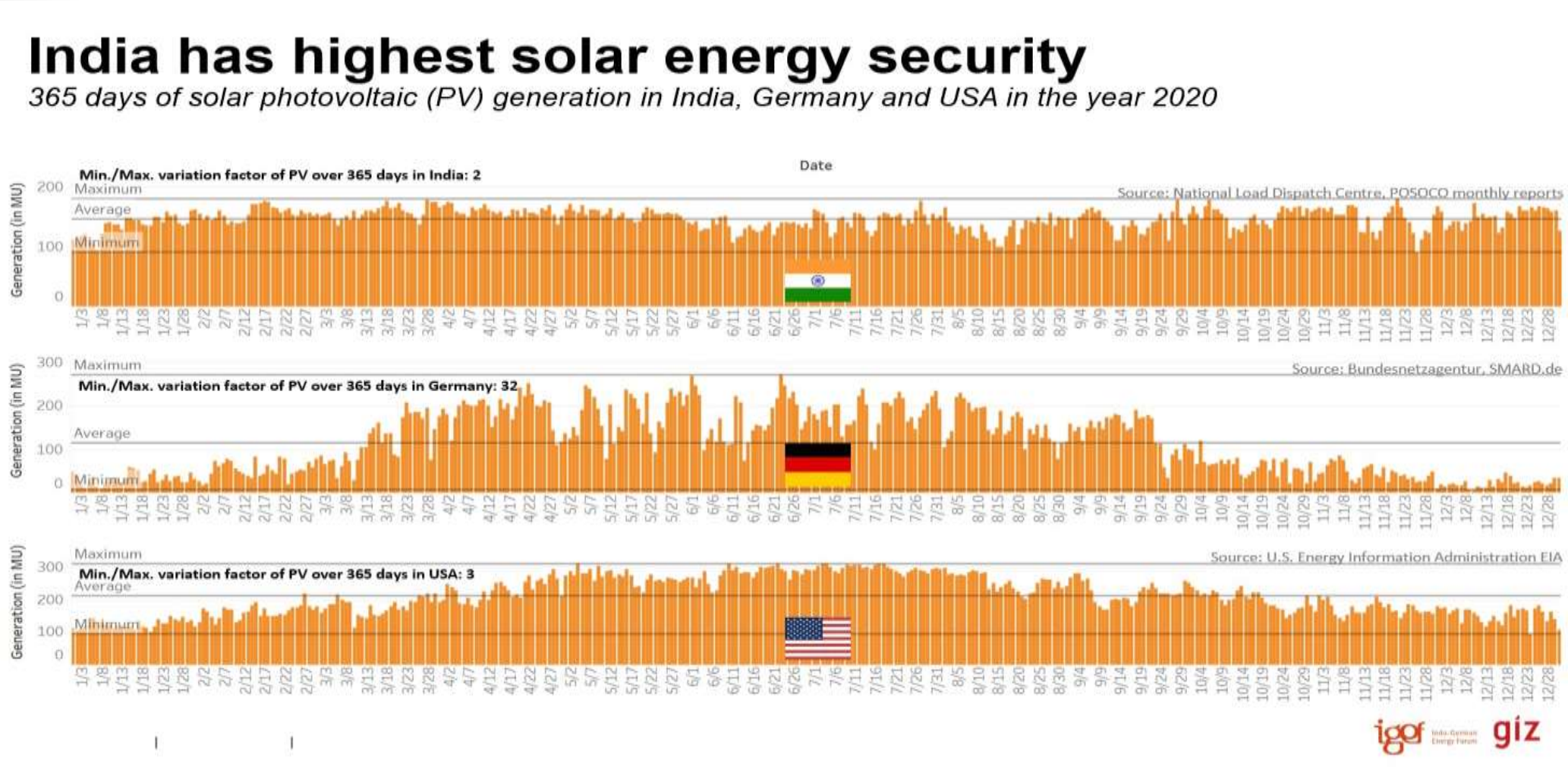
Source:
http://www.caiso.com/informed/Pages/BoardCommittees/MarketSurveillanceCommittee/MarketSurveillanceCommitteeDescription.aspx
http://www.caiso.com/informed/Pages/BoardCommittees/MarketSurveillanceCommittee/Default.aspx

Need for Non-profit Market Operator

- With increasing penetration of ST markets and the proposed move to MBED mechanism, it is imperative to ensure robustness of PX platform as well its independence
- The current PX mechanism ensures earning of the PX by means of trading margin.
- There may be conflict of interest between the market participants and promoters of PX which may result into inefficient market operation.
- The transition to single combined system + market operator with non-profit objectives shall serve the objective.
- Example is California Independent System Operator (CAISO) market.
- Suitable study and thought in this regard as applicable to Indian scenario shall be helpful in ensuring a robust and reliable market (energy, capacity, ancillary etc)

Green Hydrogen - Overview

Solar potential – Key to Green H2

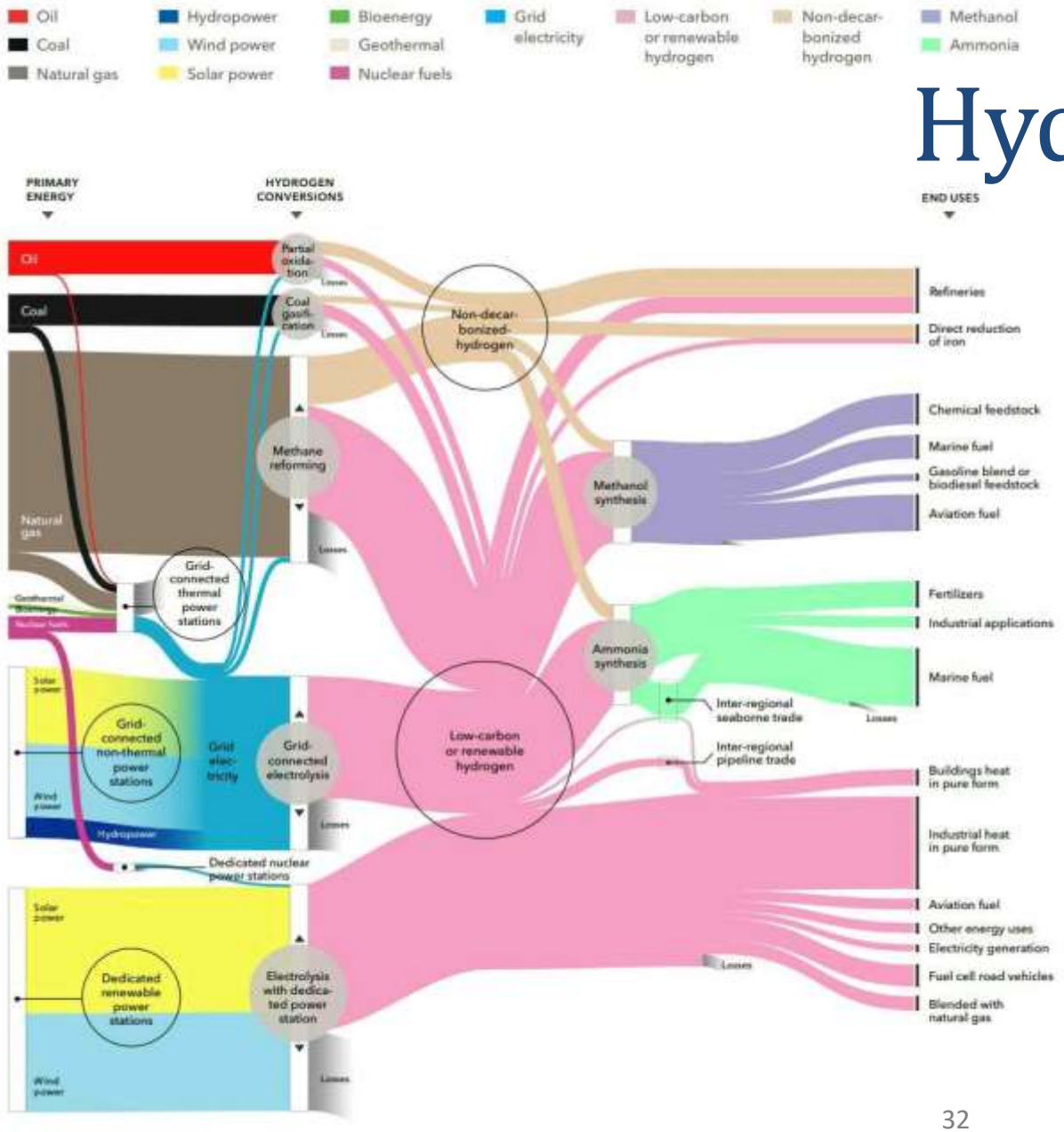


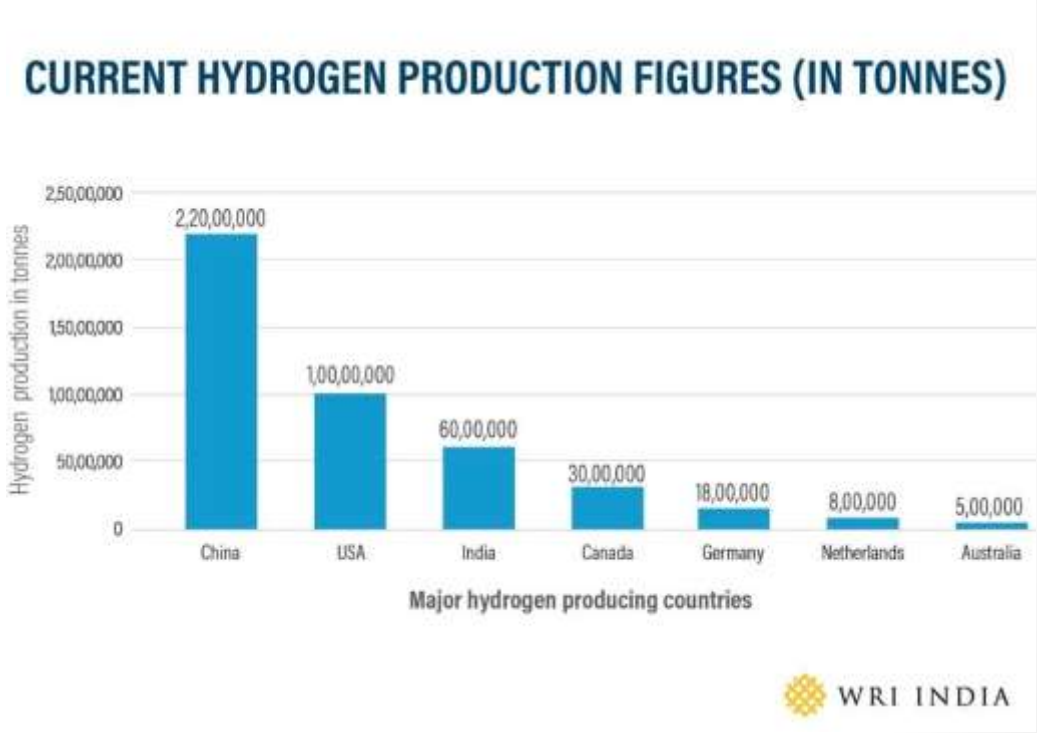
The Hydrogen Colour Spectrum

© Bruno G. Pollet

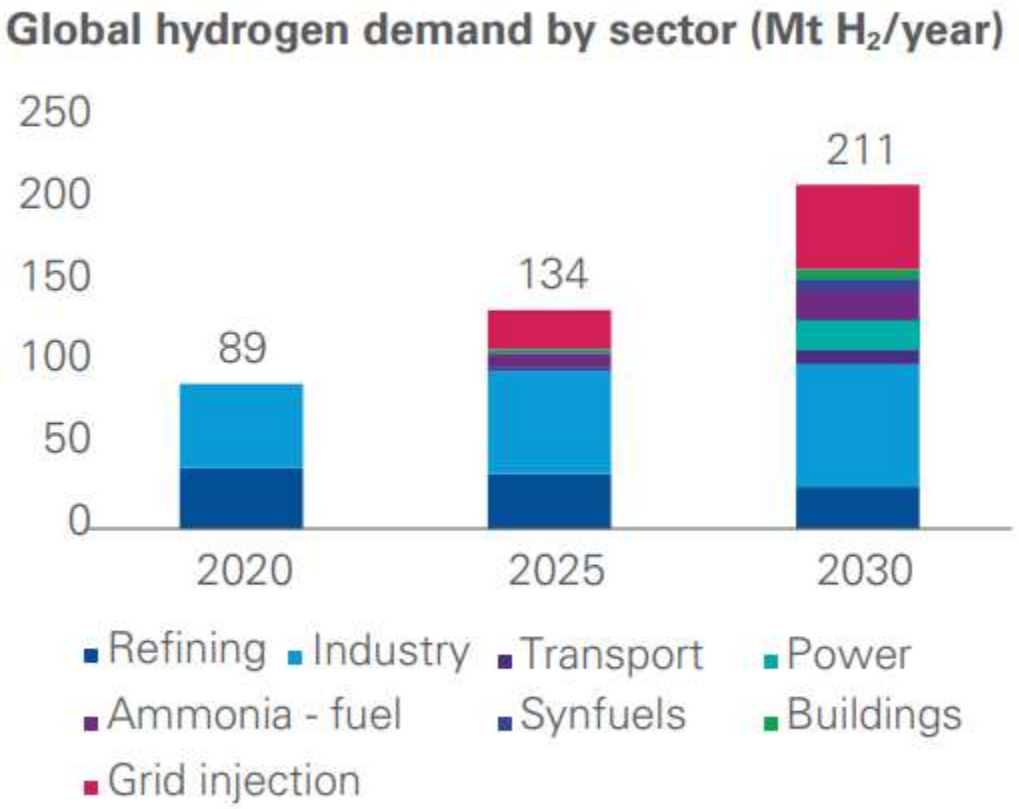
	Colour	Technology	Primary Energy / Source of Electricity	Carbon Footprint	Terminology
Production -Biomass-	Green Hydrogen	Thermolysis	Biomass	Low < 3 kg CO_2eq / kg H_2	Renewable Hydrogen
		Steam Reforming	Biomethane	Low < 3 kg CO_2eq / kg H_2	Renewable Hydrogen
Production -Electricity-		Water Electrolysis	Renewable Energies (Solar, Wind, Hydro etc)	Minimal < 2 kg CO_2eq / kg H_2	Renewable Hydrogen
	Pink Hydrogen		Nuclear	Minimal < 2 kg CO_2eq / kg H_2	Low-carbon Hydrogen
	Yellow Hydrogen		Electrical Network	Low Depending on source for producing electricity	Low-carbon Hydrogen
Production -Fossil Fuels-	Blue Hydrogen	Steam Reforming Gasification	Natural Gas, Coal + Carbon Capture Sequestration (CCS)	Low < 3 kg CO_2eq / kg H_2	Low-carbon Hydrogen
	Turquoise Hydrogen	Pyrolysis	Natural Gas	Low < 3 kg CO_2eq / kg H_2 + Carbon Black (CB)	–
	Grey Hydrogen	Steam Reforming		High ~ 11 kg CO_2eq / kg H_2	High-carbon Hydrogen
	Brown Hydrogen	Gasification	Lignite	Very High > 20 kg CO_2eq / kg H_2	High-carbon Hydrogen
	Black Hydrogen		Bituminous Coal	Very High > 20 kg CO_2eq / kg H_2	High-carbon Hydrogen
Naturally Occurring	White Hydrogen				

Hydrogen – Supply chain

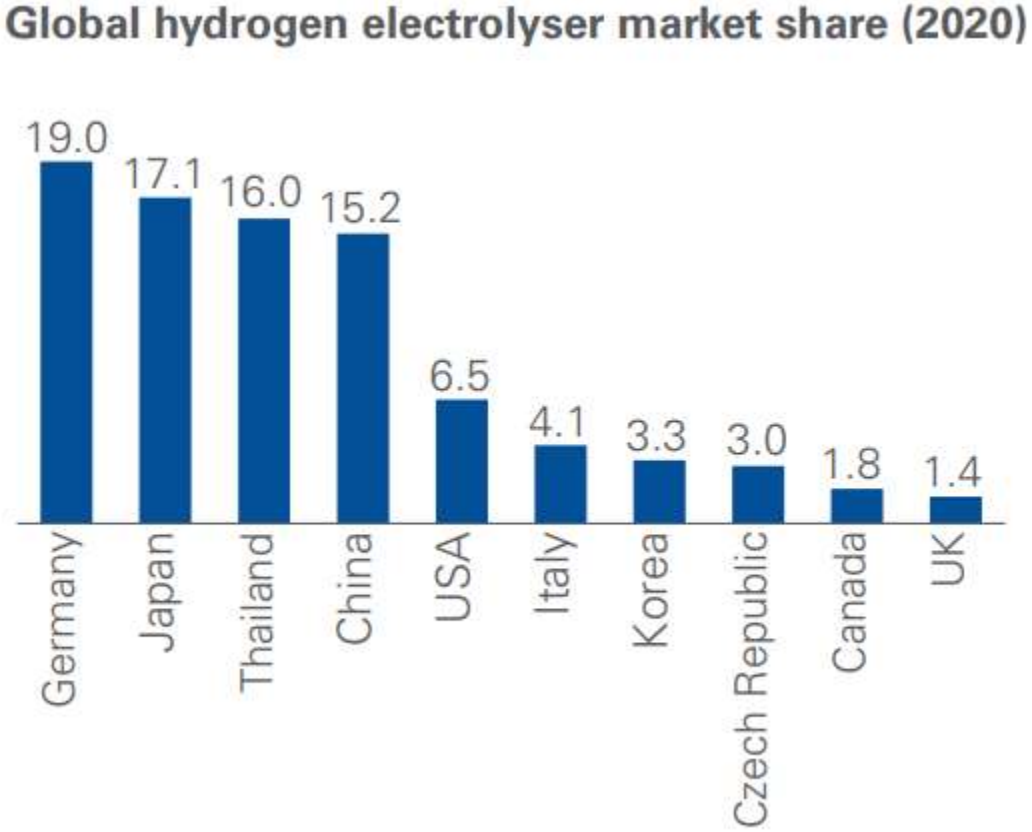




Global Hydrogen Demand



Source: IEA, 2020



Source: Clean Energy Wire 2020

METHANOL AS A HYDROGEN CARRIER

Methanol → Hydrogen → Electricity

1
- Carbon intensity of the grid determines the carbon intensity of electrified applications
- Most grids have low integration of renewable energy capacity

Country					
Carbon intensity of Grid $kgCO_2eq/kWh$	0.40	0.20	0.42	>0.70	0.70

2
- Renewable energy generation has to be **X3 or X4** larger than electricity demand to address intermittency
- Cost to integrate fully renewable grids:
  - >USD 4.5 trillion
  - >USD 3.6 trillion
  - >USD 11 trillion

3
- Rising cost of electricity brings cost of H2 to **>USD 3.5/kg** (based on price of US industrial electricity)

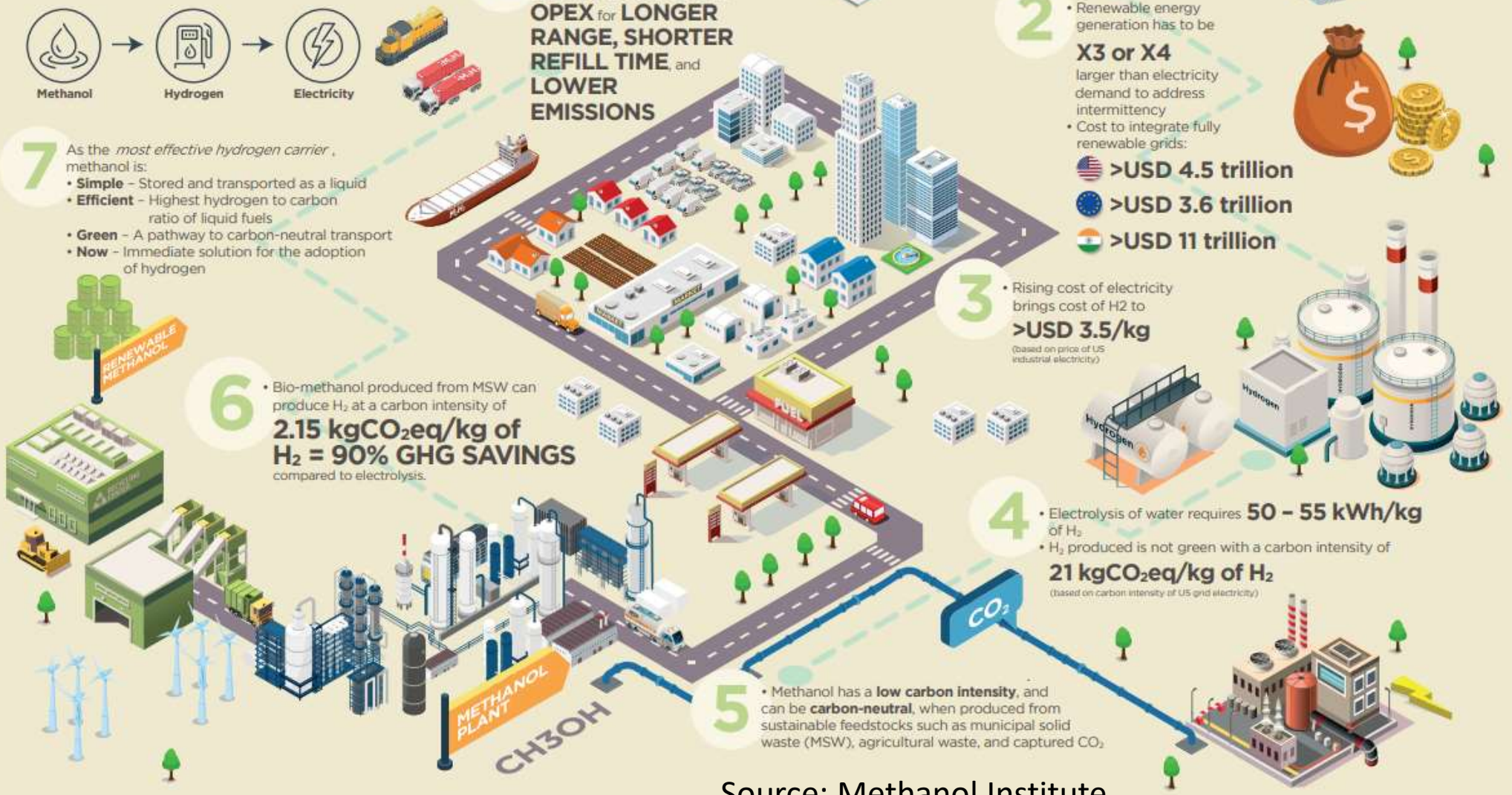
4
- Electrolysis of water requires **50 – 55 kWh/kg** of H_2
- H_2 produced is not green with a carbon intensity of **21 $kgCO_2eq/kg$ of H_2** (based on carbon intensity of US grid electricity)

5
- Methanol has a **low carbon intensity**, and can be **carbon-neutral**, when produced from sustainable feedstocks such as municipal solid waste (MSW), agricultural waste, and captured CO_2

6
- Bio-methanol produced from MSW can produce H_2 at a carbon intensity of **2.15 $kgCO_2eq/kg$ of H_2 = 90% GHG SAVINGS** compared to electrolysis.

7 As the *most effective hydrogen carrier*, methanol is:
- **Simple** – Stored and transported as a liquid
- **Efficient** – Highest hydrogen to carbon ratio of liquid fuels
- **Green** – A pathway to carbon-neutral transport
- **Now** – Immediate solution for the adoption of hydrogen

8 Vehicles with onboard methanol reformation incur **LOWER CAPEX** and **OPEX** for **LONGER RANGE, SHORTER REFILL TIME**, and **LOWER EMISSIONS**



Source: Methanol Institute

Gas turbine experience with Hydrogen

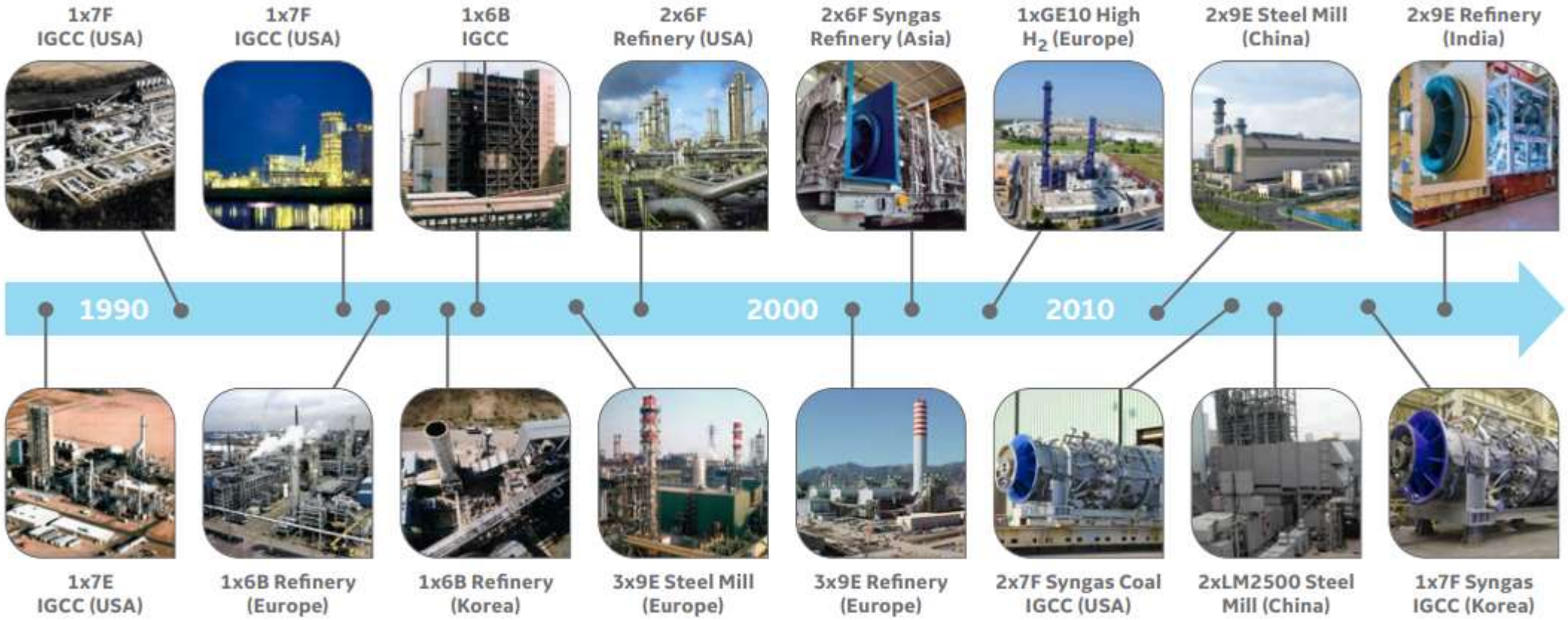


Figure 10: Timeline of selected projects with hydrogen fuels.

Source: GE

Gas turbine experience with Hydrogen

Sep 26, 2022
by Sonal Patel

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September 26, 2022

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by Sonal Patel

T&D | Sep 29, 2022

More Than 2.5 Million Without Power in Florida Due to

NYPA, GE Successfully Pilot Hydrogen Retrofit at Aeroderivative Gas Turbine

A pioneering GE aeroderivative gas turbine project to demonstrate hydrogen combustion as part of a retrofit at an existing U.S. natural gas power plant has successfully utilized blends of 5% to 44% hydrogen with natural gas—some of the highest volumes of hydrogen blended into a commercially operating gas turbine.

[NYPA, GE Successfully Pilot Hydrogen Retrofit at Aeroderivative Gas Turbine (powermag.com)]

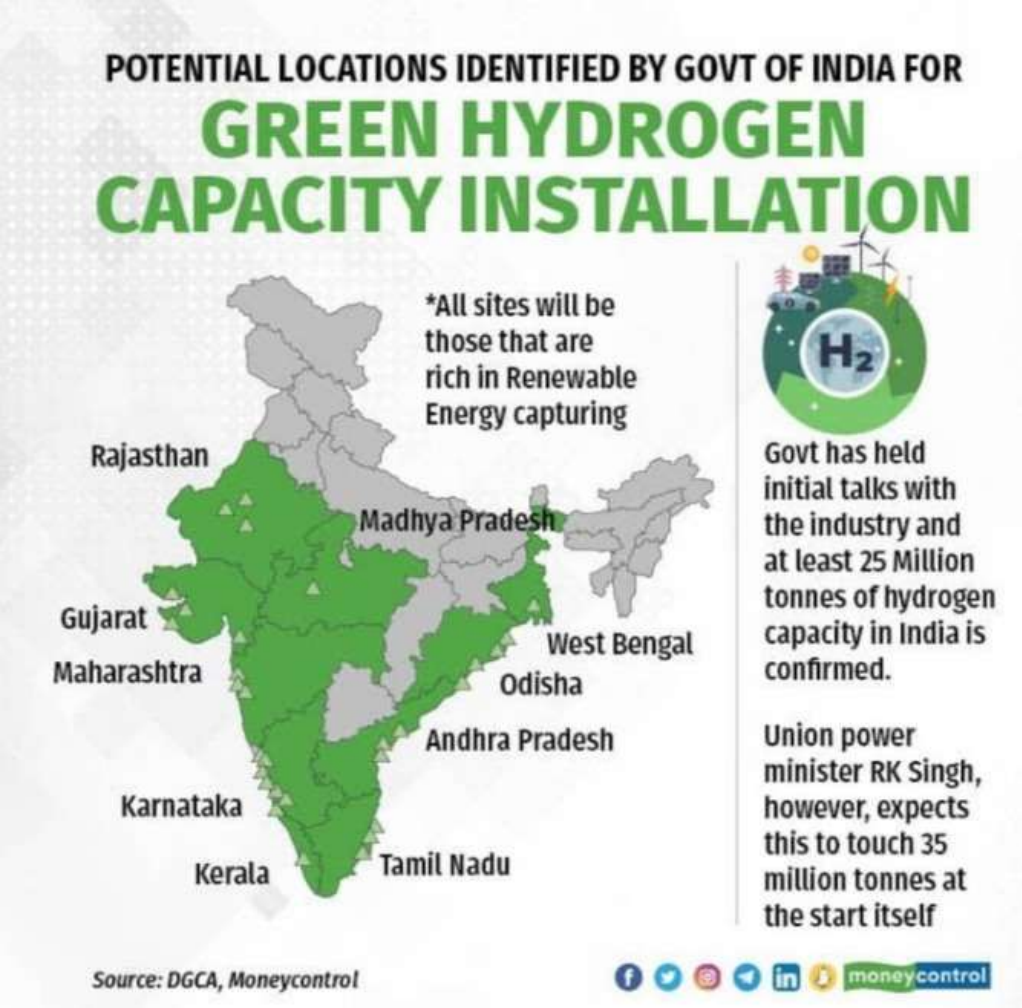
DOE, US's target 1:1:1 for GH

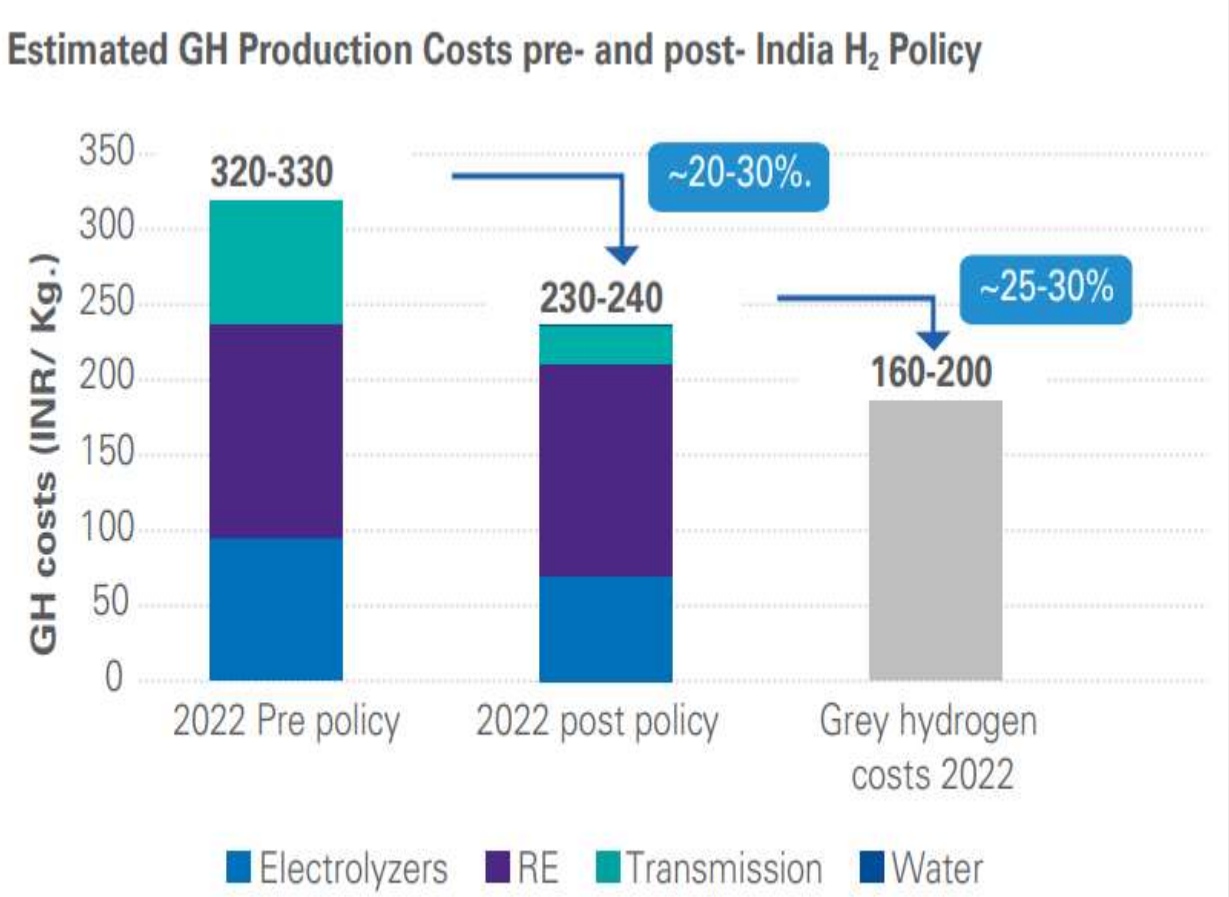
Hydrogen Shot

In June 2021, the DOE launched the first in a series of Energy Earthshots to accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade. This "Hydrogen Shot" – "111" – aims to reduce the cost of clean hydrogen to $1 per kilogram in just a decade

DOE is also working closely with industry to expand low-carbon hydrogen production capacity, including through grants, loans, and other tools and incentives. We will support multiple production routes with potential to achieve the Hydrogen Shot, to stimulate competition, innovation, investment, and commercialization, to catalyze sharp declines in cost, across the value chain.

India – Hydrogen story



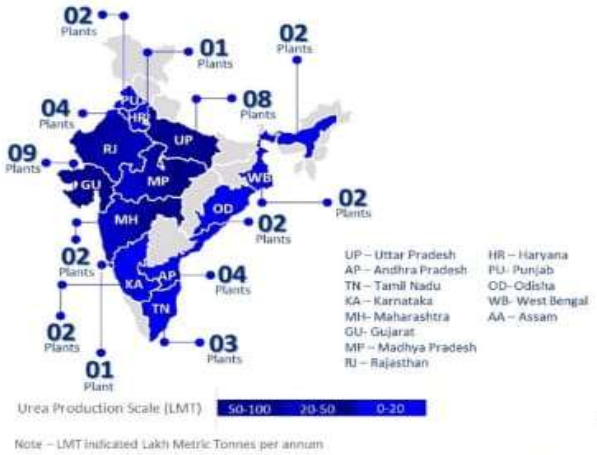


Source: KPMG India Analysis

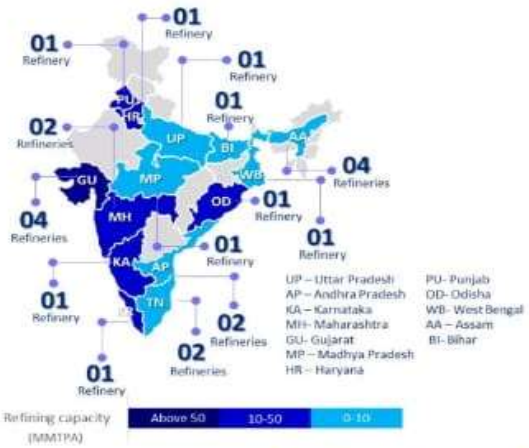
Opportunity for Hydrogen Intake in India –

Refineries & Fertilizer Plants

Spread of number of Urea Plants in India as of March'2022

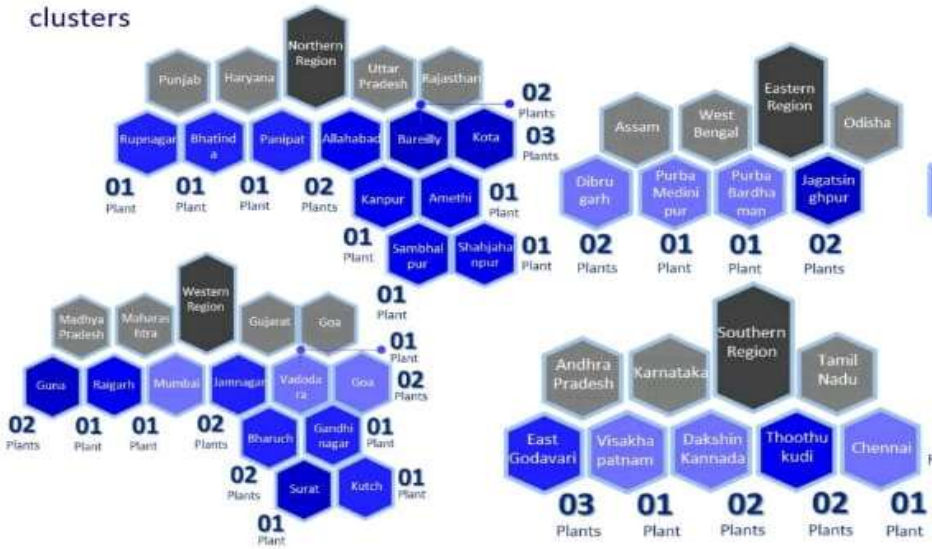


Spread of number of Refineries in India as of March'2022

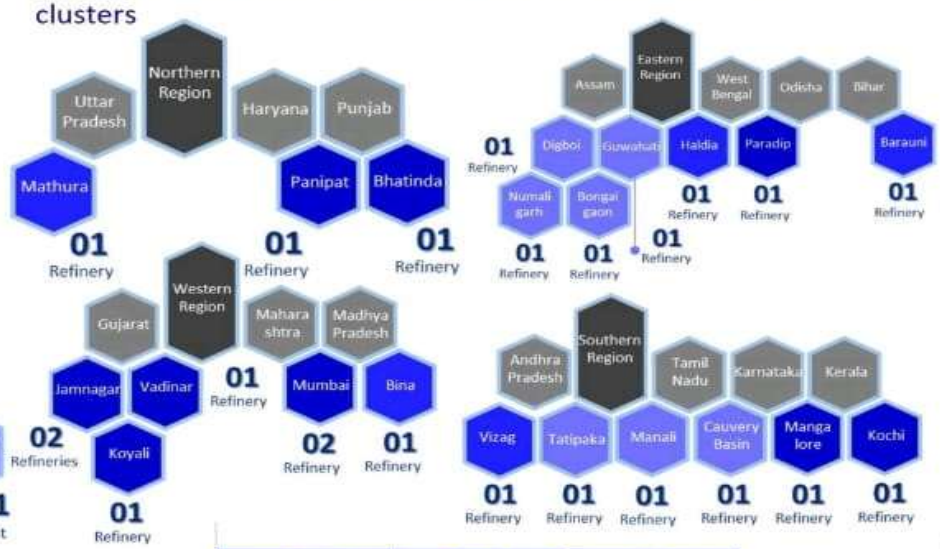


Spread of number of Chemical & Chemical Products in India as of March'2022

Potential demand hubs for hydrogen across the urea producing clusters



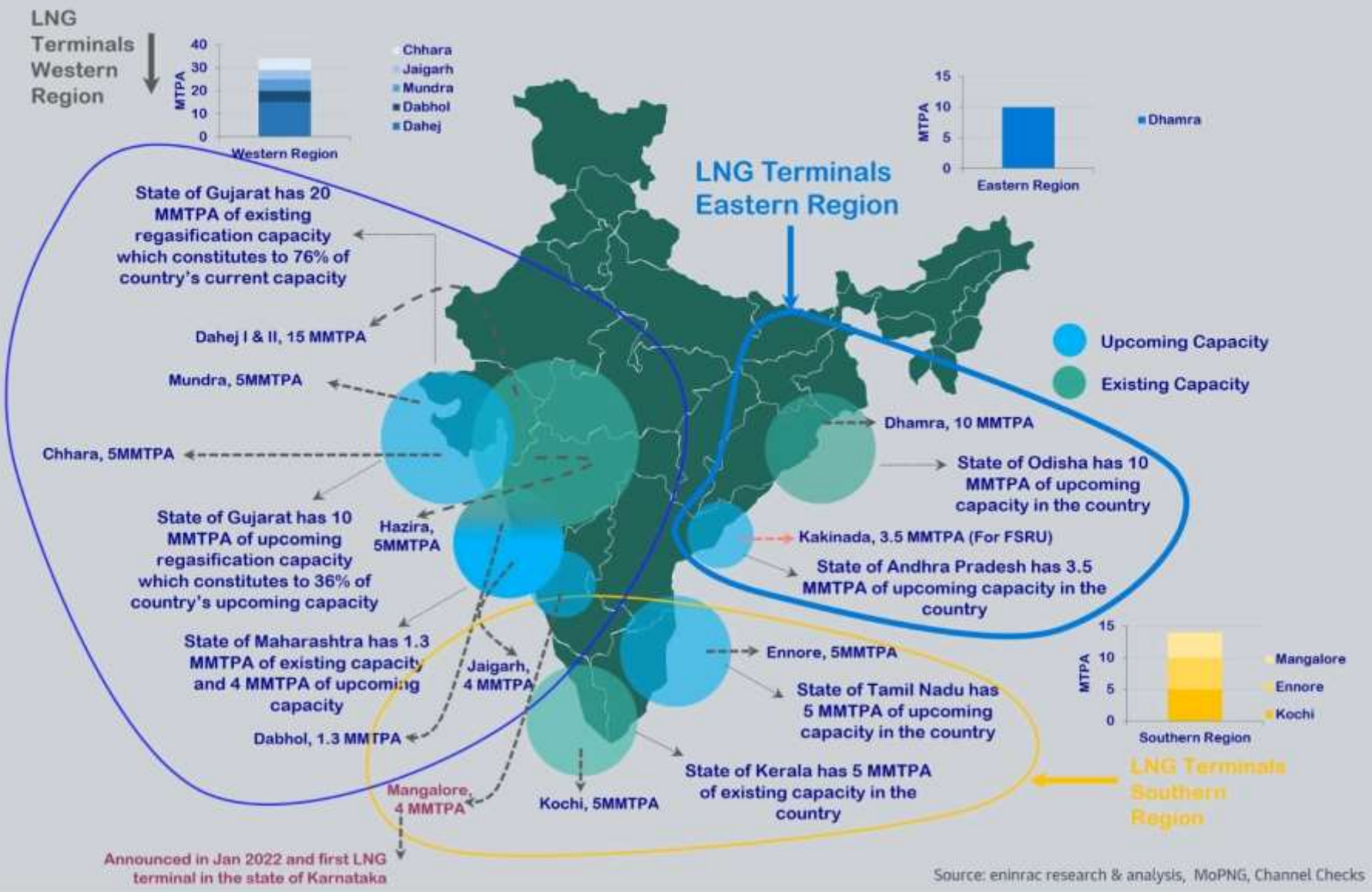
Potential demand hubs for hydrogen across the refineries clusters



Source: Eninrac Report on Hydrogen Market & Opportunity in India, MoPNG, MoC&F, Channel Checks

eninrac consulting, 2022

Region wise both existing and upcoming LNG terminals in India- First mover advantage for hydrogen and ammonia bunkering facilities



Source: eninrac research & analysis, MoPNG, Channel Checks

National Green Hydrogen Mission

DEMAND CREATION

Export Markets
Capturing Global Demand

Substituting imports
Fossil Fuels and Fertilizers

Domestic demand
Multiple Sectors

INCENTIVISING SUPPLY

Strategic Interventions for GH2 Transition

Direct Financial Incentives for:
- Electrolyzer Manufacturing
- Green Hydrogen Production

KEY ENABLERS

Resources
Finance, renewable energy - banking & storage, transmission, land, water

R&D
Result oriented, time-bound, including through PPP, grand challenges

Ease of doing business
Simpler procedures, taxation, SEZ, commercial issues

Infrastructure & Supply Chain
Ports, Re-fueling, Hydrogen Hubs, pipelines

Regulations & Standards
Testing facilities, standards, regulations, safety & certification

Skill Development, Public awareness
Coordinated Skilling programme, online portal

Source: MNRE, Govt of India

NGHM 2023 – Expected outcomes

EXPECTED OUTCOMES OF THE MISSION BY 2030

India's Green Hydrogen Production Capacity will Reach at Least
5 MMT Per Annum

Renewable Energy Capacity Addition of
~125 GW

Over
₹8 lakh crore
in Total Investments

Create Over
6 lakh
Full Time Jobs

50 MMT per annum
of CO2 Emissions are Expected to be Averted

Summary

- PLI supported Electrolyser manufacturing in India – Key to target $1/kg GH
- Massive deployment of RE a must (Load following RE RTC a key)
- Demand mandates for key sectors in a phased manner
- Carbon Market – Domestic & Global
- Mechanism for M&V of green Hydrogen – Active role to be played by India in Global discussions

Thank You

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Energy Analytics Lab

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