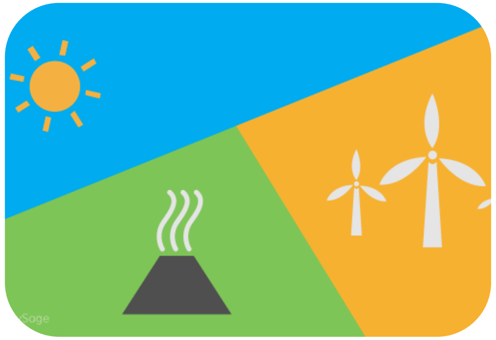
Best Practices in Planning New Transmission System

Central Transmission Utility of India Ltd.

BIMSTEC, 13.05.2026

Focus Areas – 5 E’s

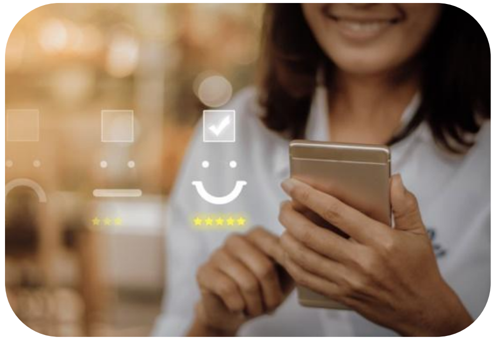


Energy

Environment

Efficiency

Economics



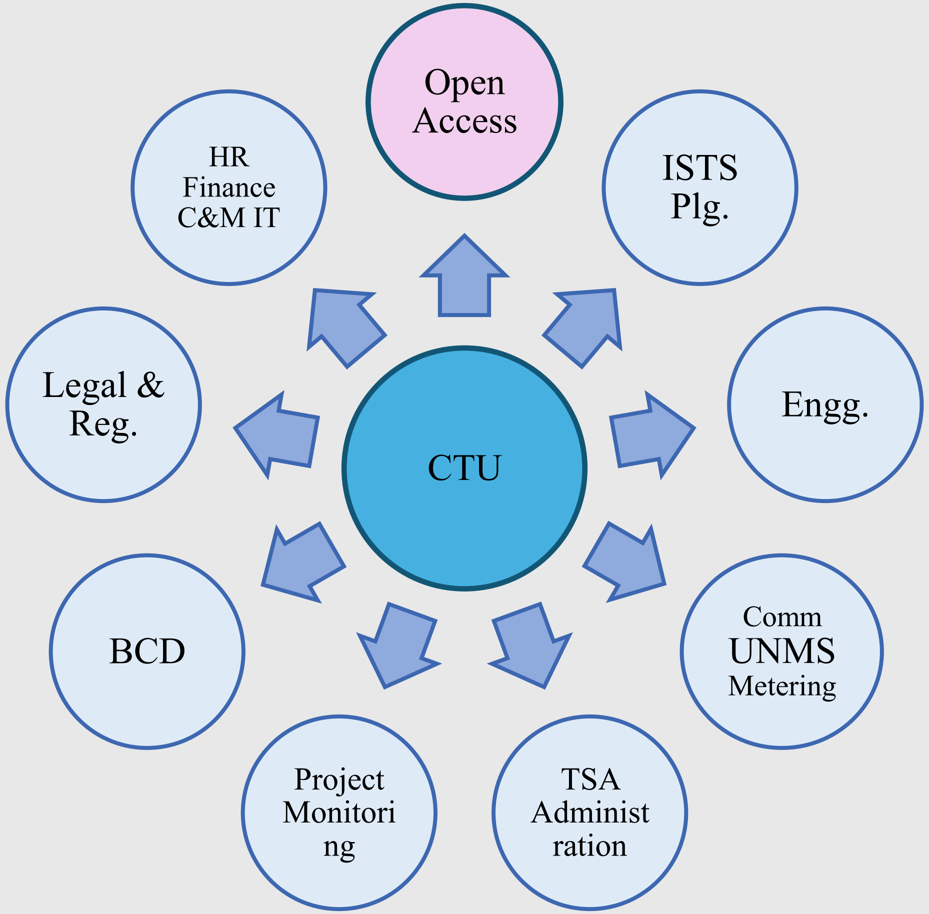
Empower

Central Transmission Utility (CTU) came into existence through "The Electricity Regulatory Commission Act, 1998". POWERGRID was designated as CTU by GoI on December 31, 1998 for five years.

ln line with provisions of the Electricity Act, 2003, POWERGRID, a CPSE, engaged in execution and maintenance of transmission system was notified by the MoP as the CTU vide Gazette notification dated 27.11.2003.

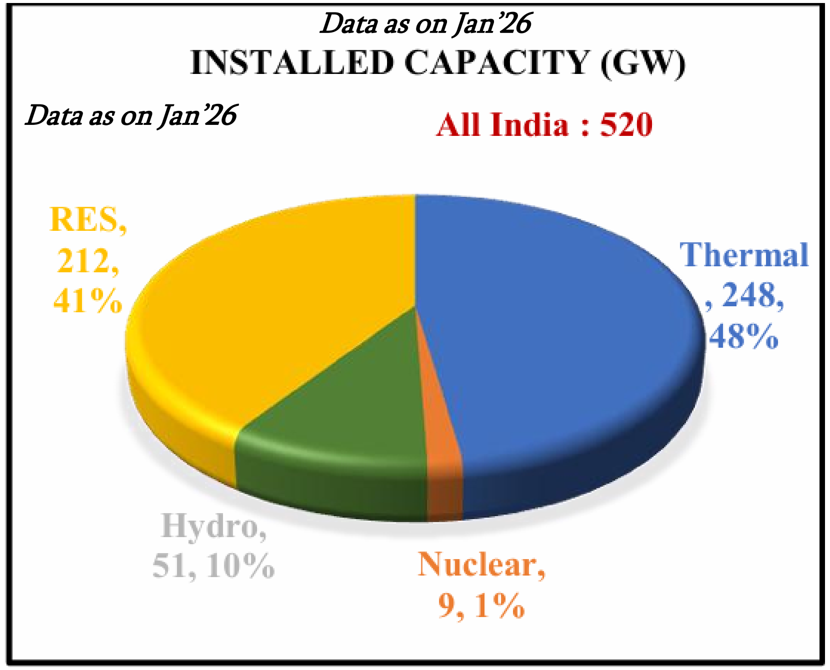
CTUIL was incorporated as a wholly owned subsidiary of POWERGRID on 28.12.2020. CTUIL started discharging CTU functions w.e.f 01.04.2021.

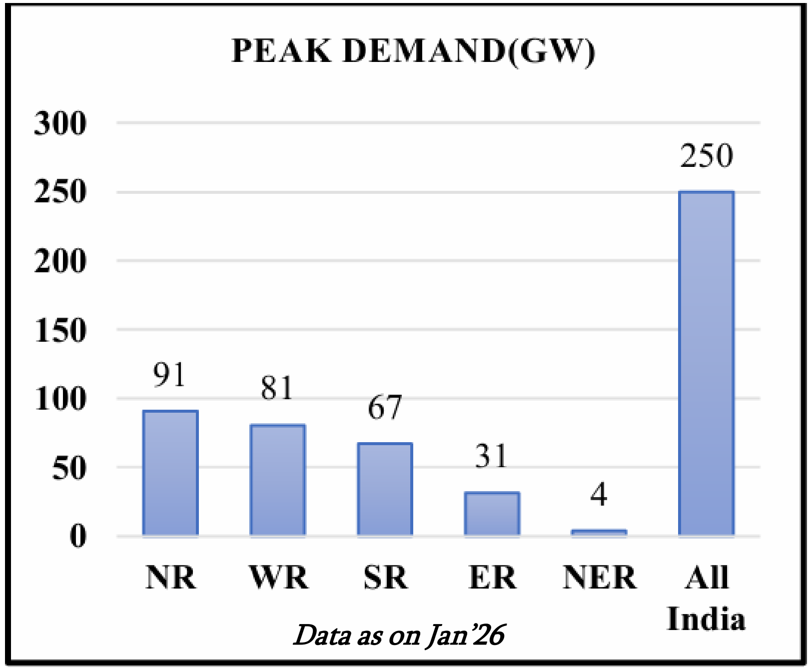
Key Functions of CTUIL



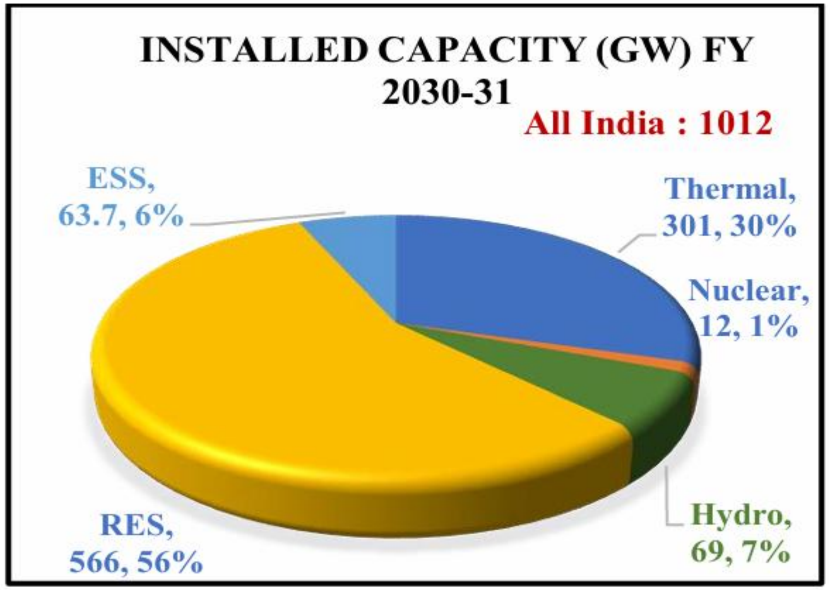
Power System Overview

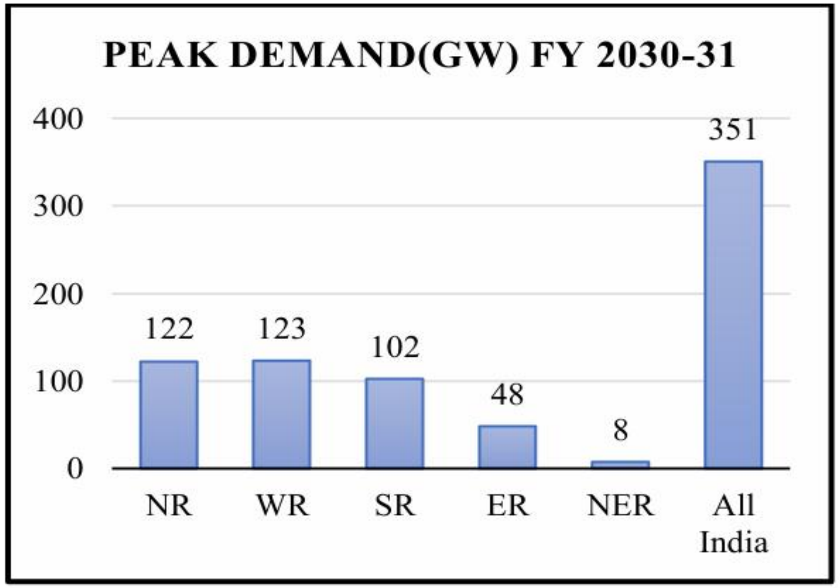
Indian Grid: Installed Capacity





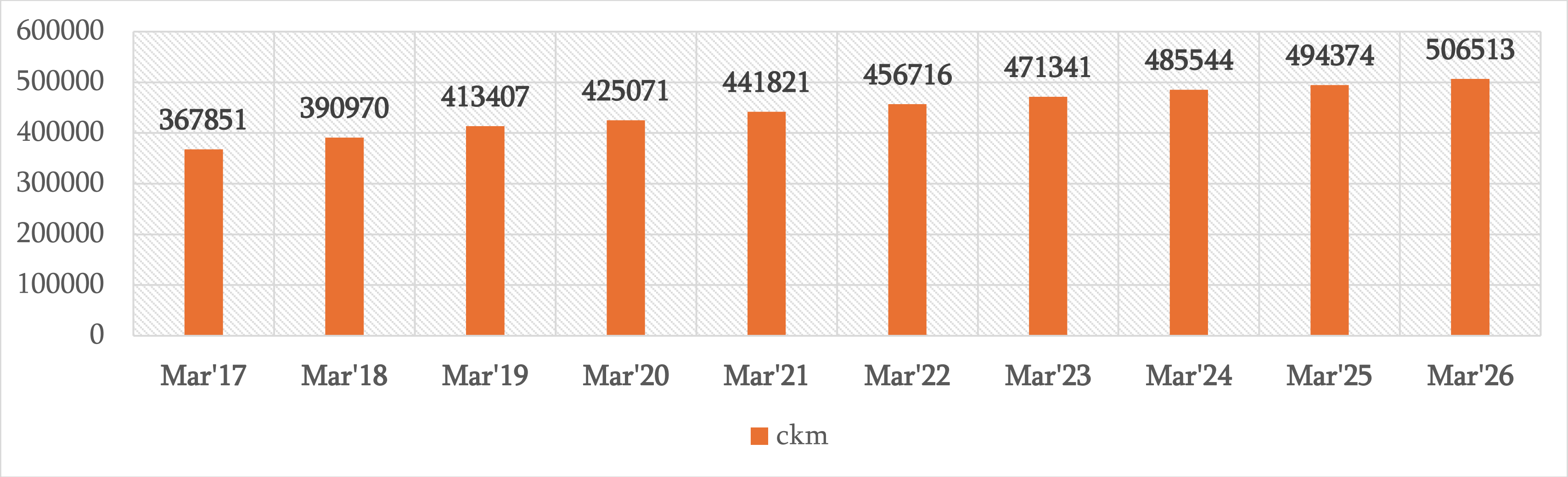
All India Peak Demand (till date):
256GW (in Apr'26)



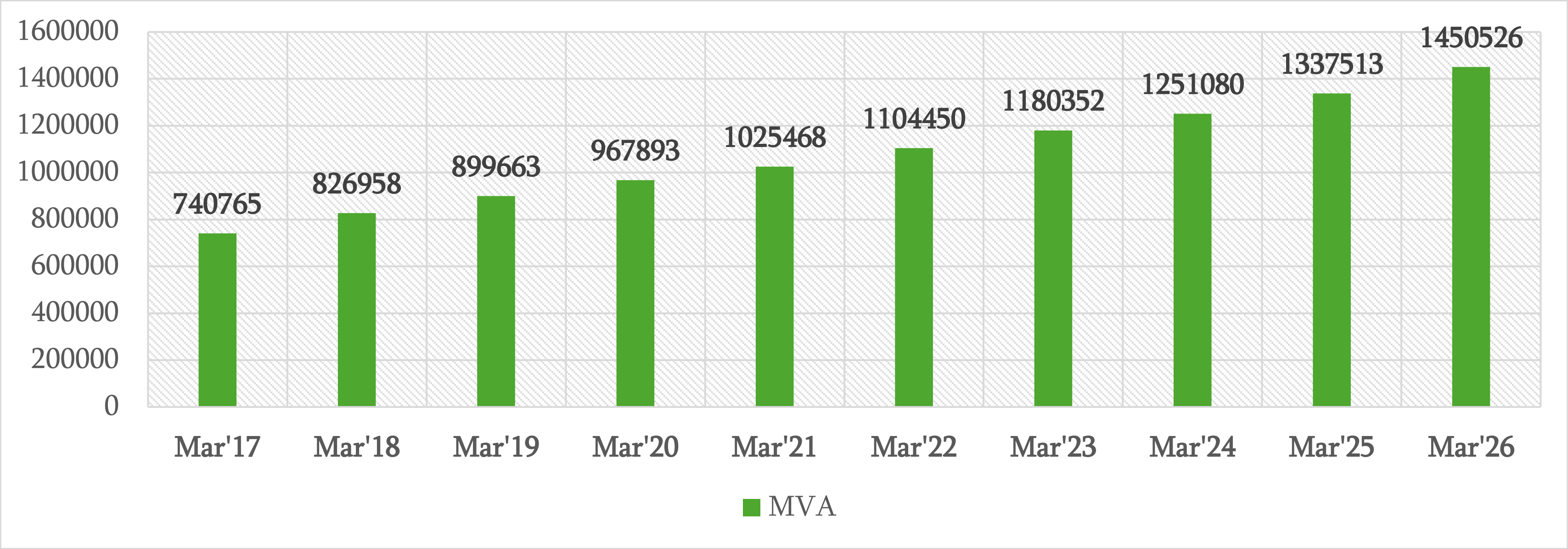


Source: As per CTUIL Rolling Plan ISTS for 2030-31

Indian Grid: Growth



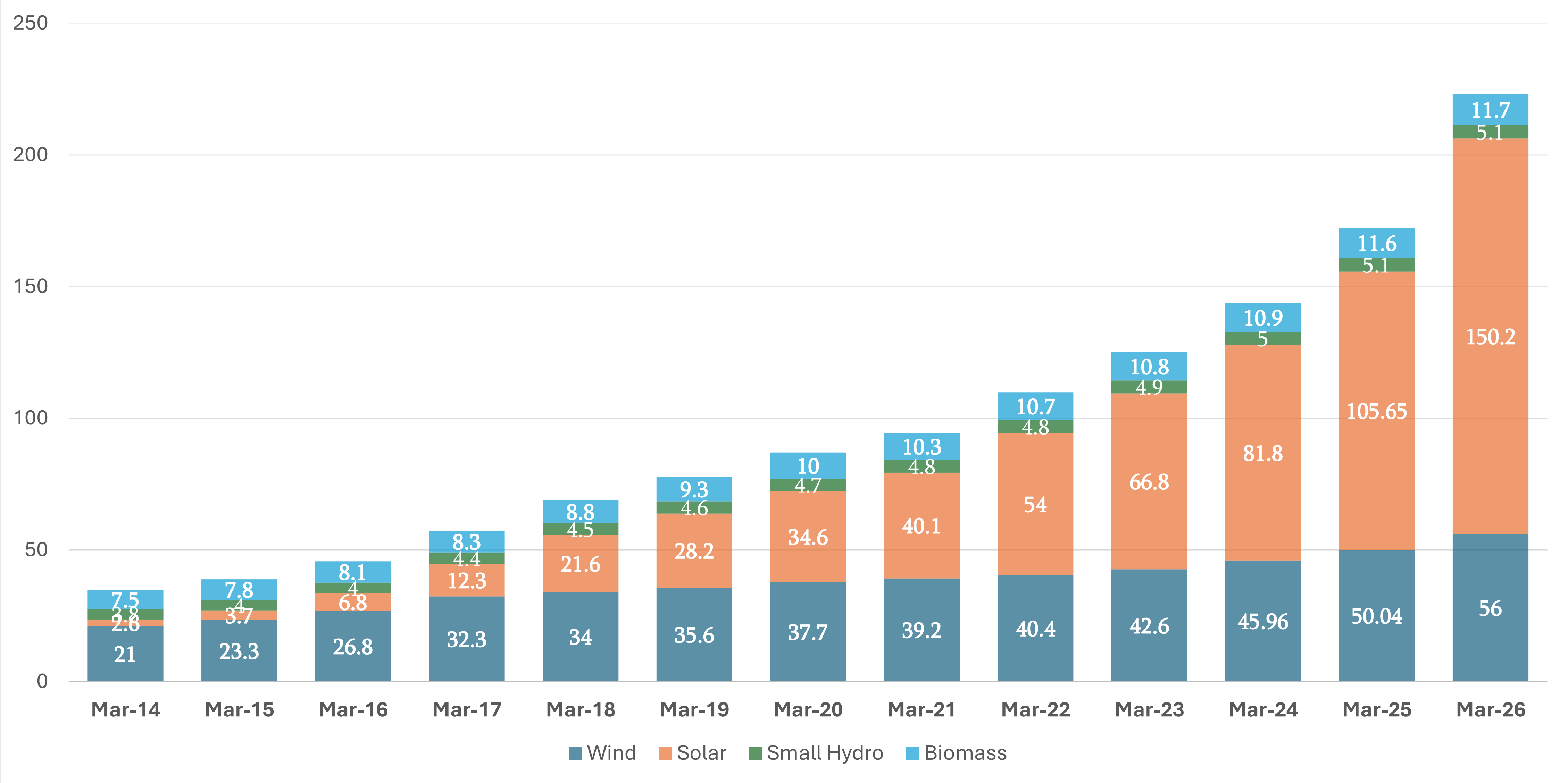
Growth in Transmission line (220kV & above)
CAGR: ~4%



Growth in Tranformation Capacity (220kV & above)
CAGR: ~8%

Source: As per CEA report

Indian Grid: RE Growth



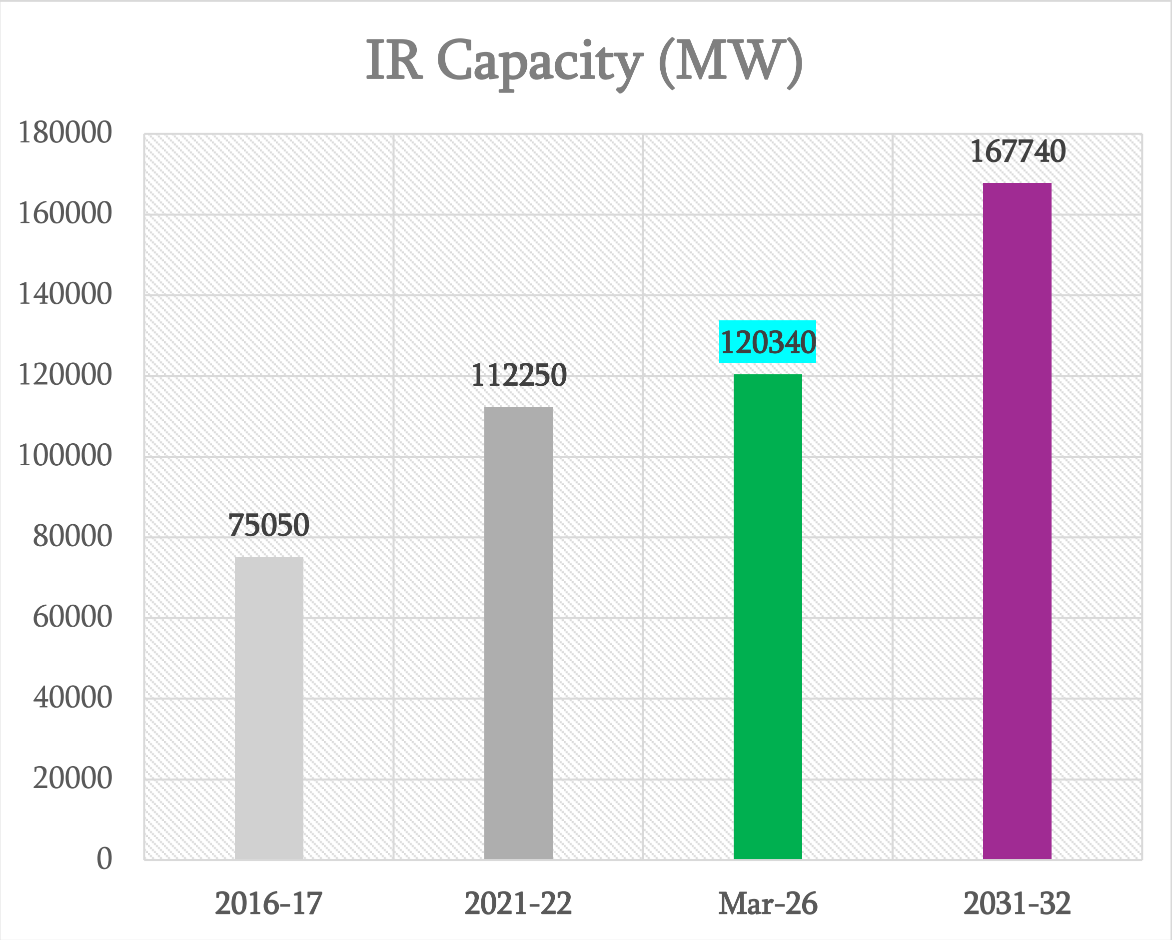
CAGR:

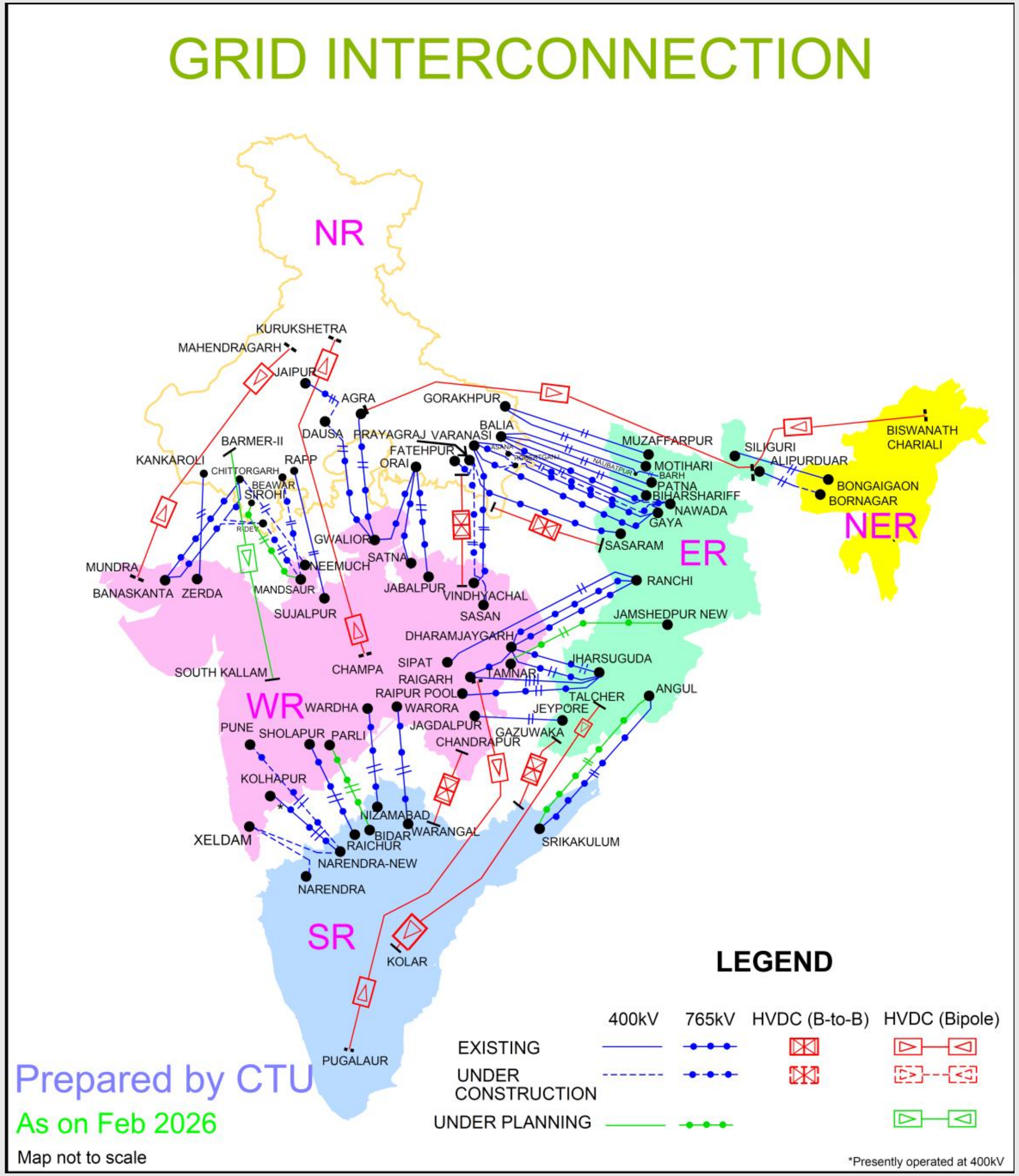
Wind: 9%

Solar: 45%

Source: As per CEA report

Indian Grid: Growth

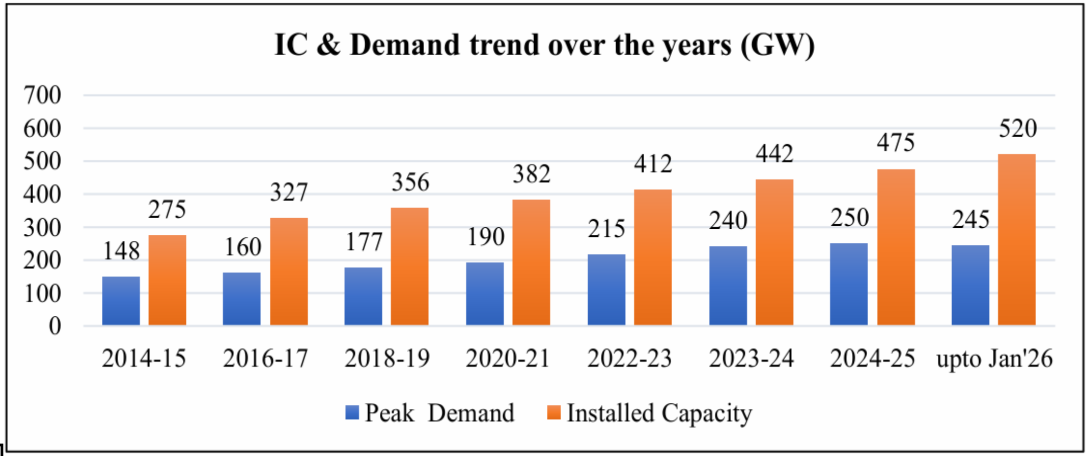


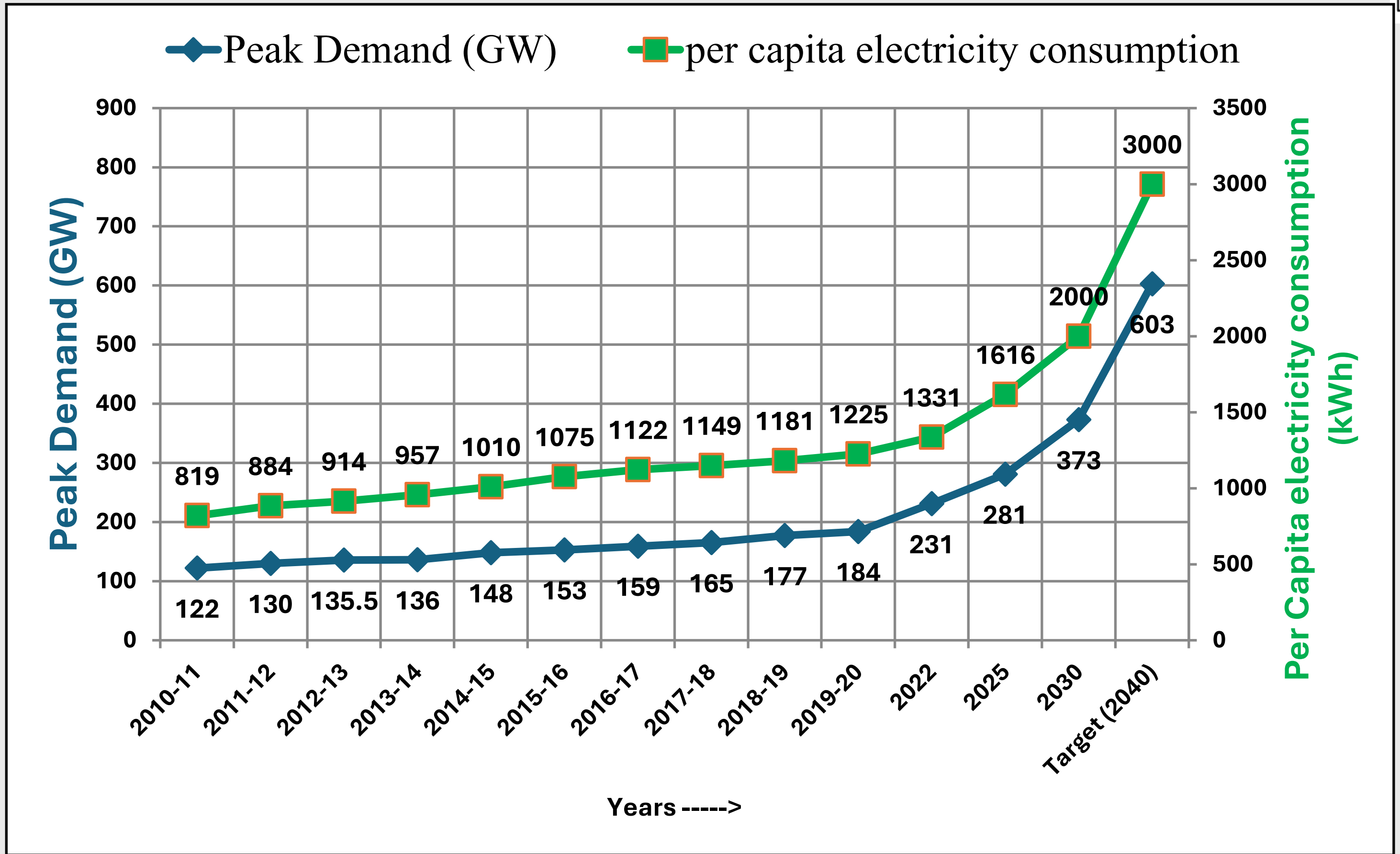


The National Grid facilitates seamless transfer of power from surplus region to deficit regions and has enabled a strong and vibrant power market along with integration of large scale Renewable Power generation capacity to Indian Grid.

Per Capita Consumption & Demand: Growth

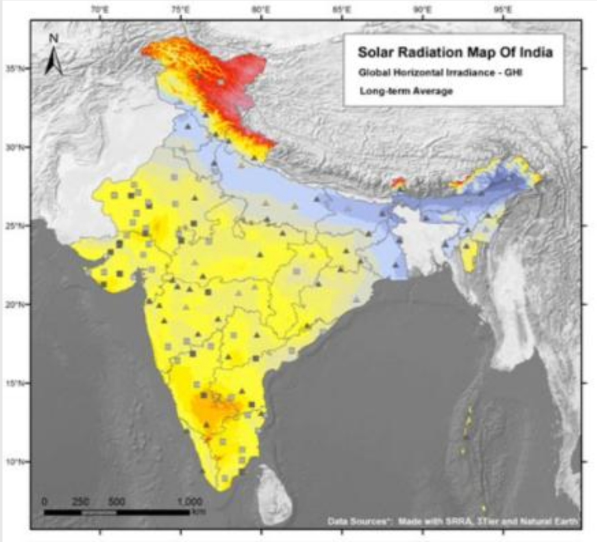
- *Per-capita electricity Consumption is computed as the ratio of estimated electricity consumption to estimated mid-year population*

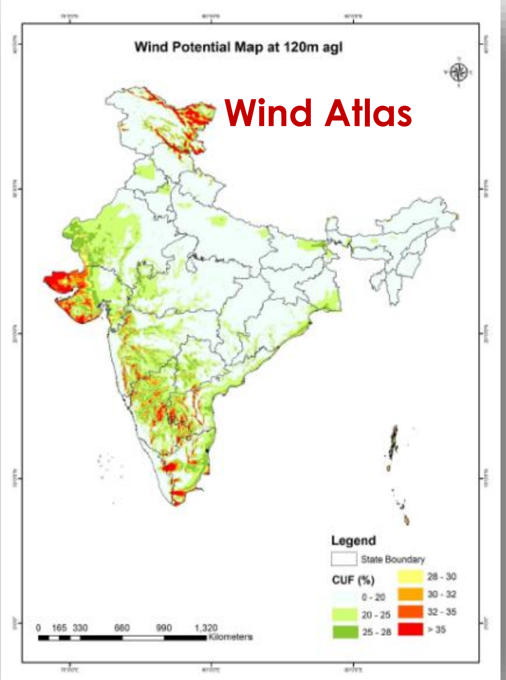




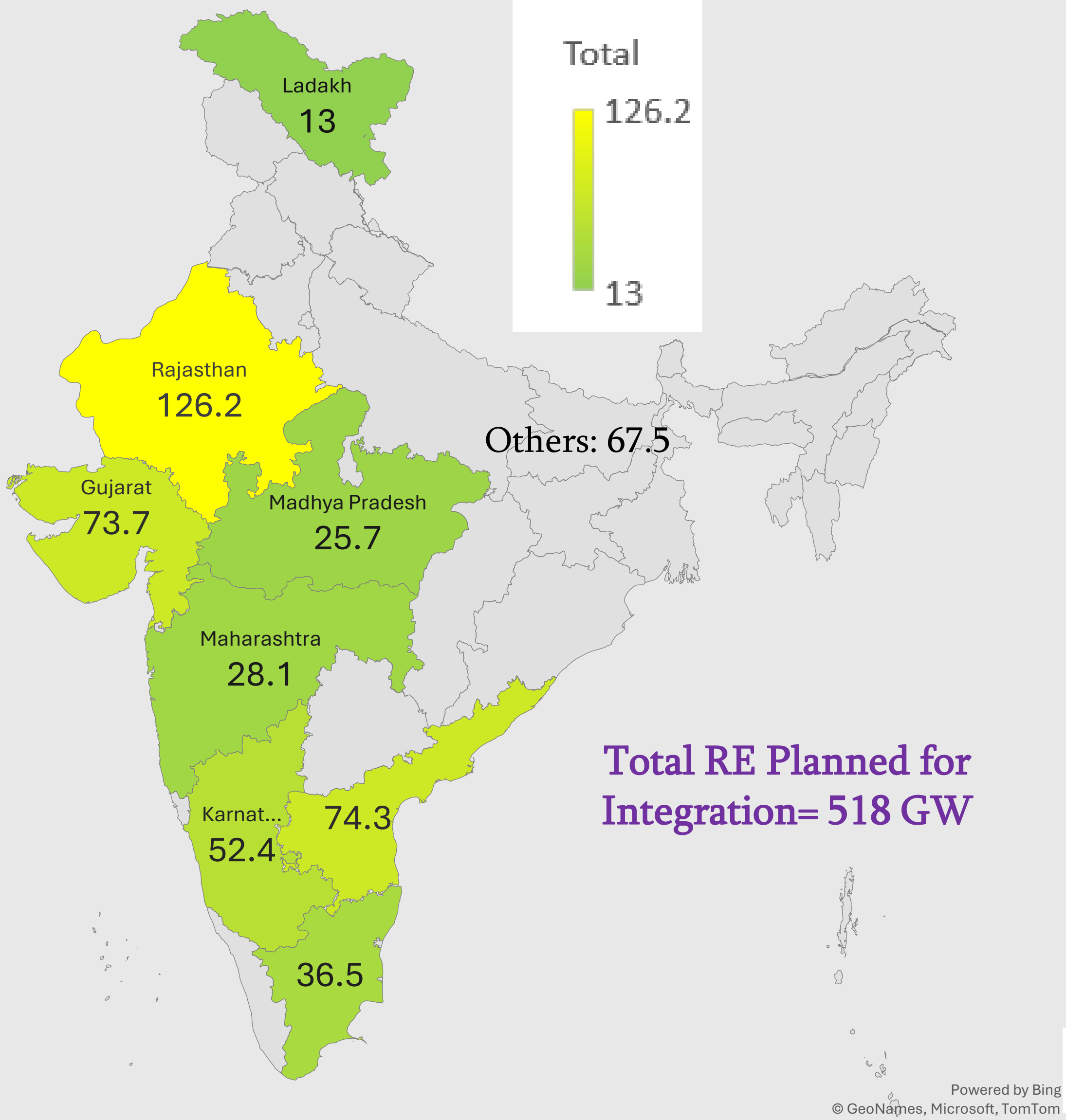
Distribution of Energy Resources

Solar Radiation Atlas

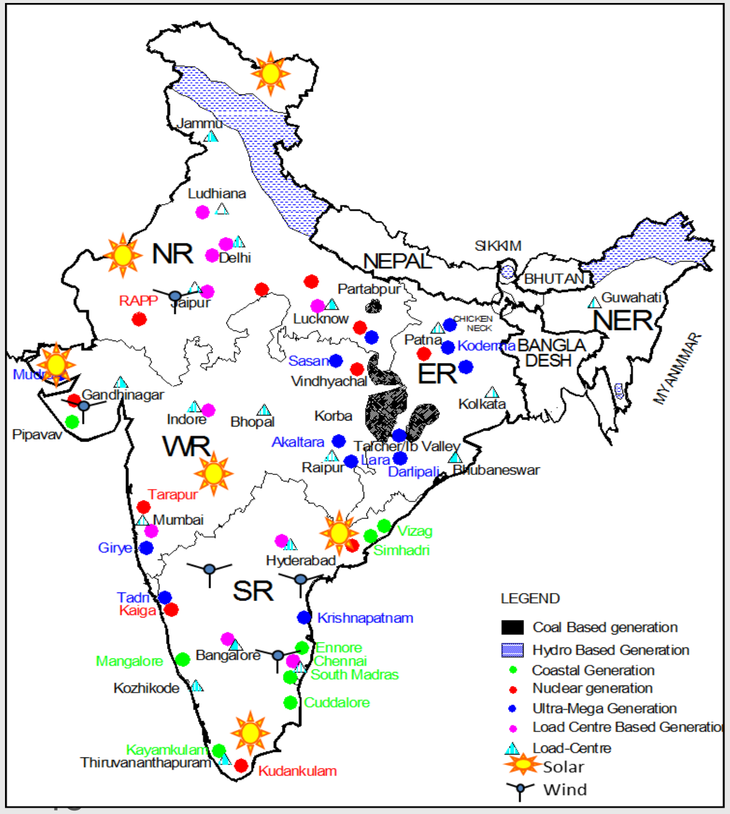


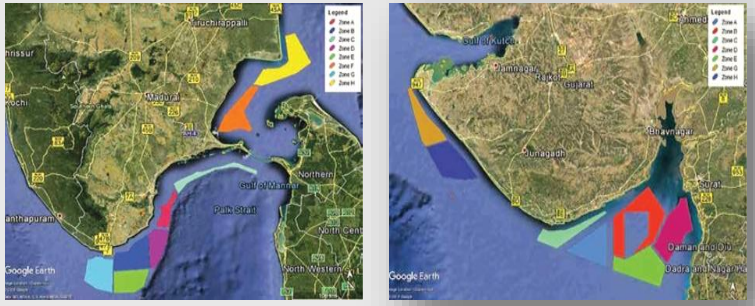


RE Potential Planned to be Integrated by 2030



Total RE Planned for Integration= 518 GW





Off Shore Wind Potential : 60 GW, Each at Gujarat & Tamil Nadu off Coast

Offshore Wind

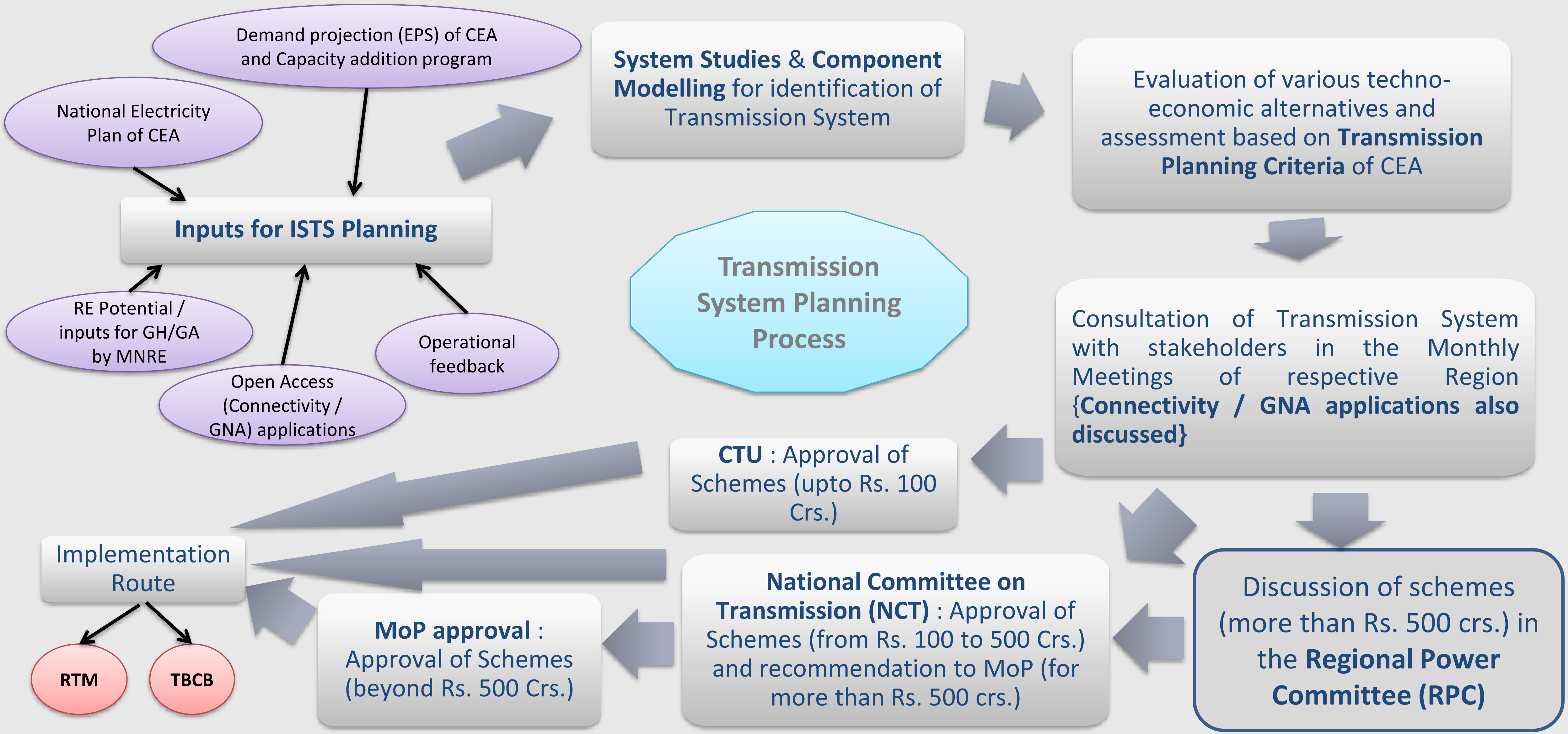
Transmission Planning Process

Transmission Planning Criteria 2023 by CEA

❖ **Guideline document for Transmission Planning purpose for Indian Grid**

The manual on transmission planning criteria published by CEA covers the planning philosophy, the information required from various entities, permissible limits, reliability criteria, broad scope of system studies, modelling and analysis and gives guidelines for transmission planning.

Transmission System Planning Process



Planning of Transmission System

Inputs

Demand

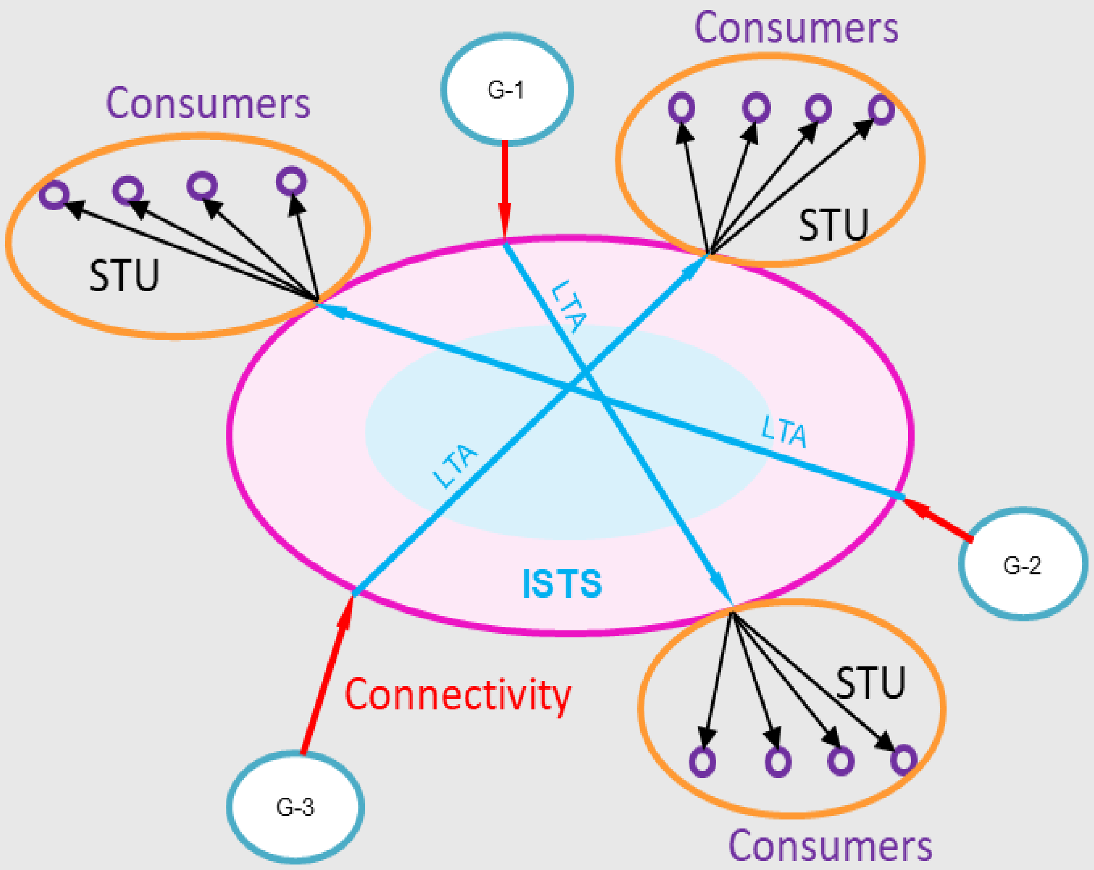
- Peak Demand as per EPS/Projected demand by States.
- GNA applications for Bulk consumer
- Demand of Green Hydrogen/Ammonia by MNRE
- Demand for Data Centers by MEITY
- Storage Demand during the day.
- Daily Load Curve for Summer, Monsoon, Winter
- Diversity of Demand across the region

Generation

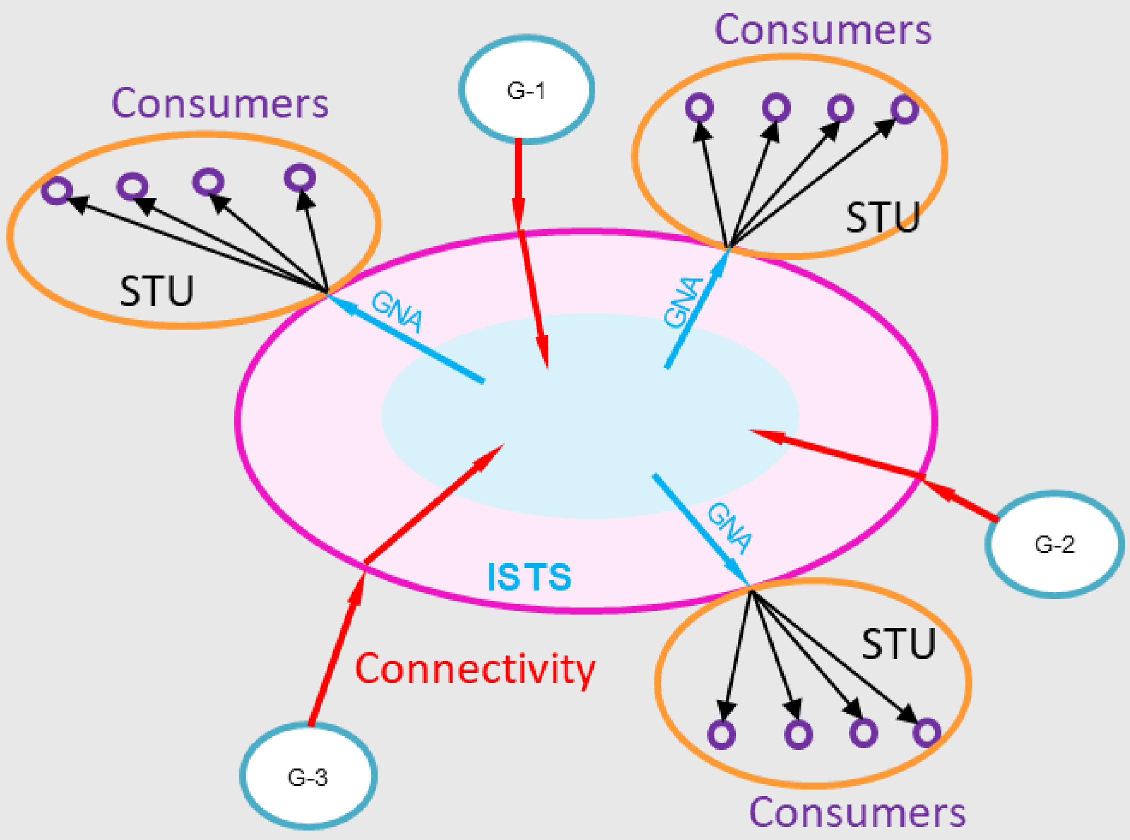
- Fuel-wise Installed Capacity.
- Dispatch Factor for '9' scenarios over '3' seasons.
- Dispatch priorities:
    - Thermal On-bar IC to meet Evening peak demand.
    - Must Run Dispatches.
    - Storage Dispatch.
    - Other Generation.
- During Solar Max scenario, the On-bar Thermal IC is dispatched @ Tech. min. of 40%.

Power System Planning

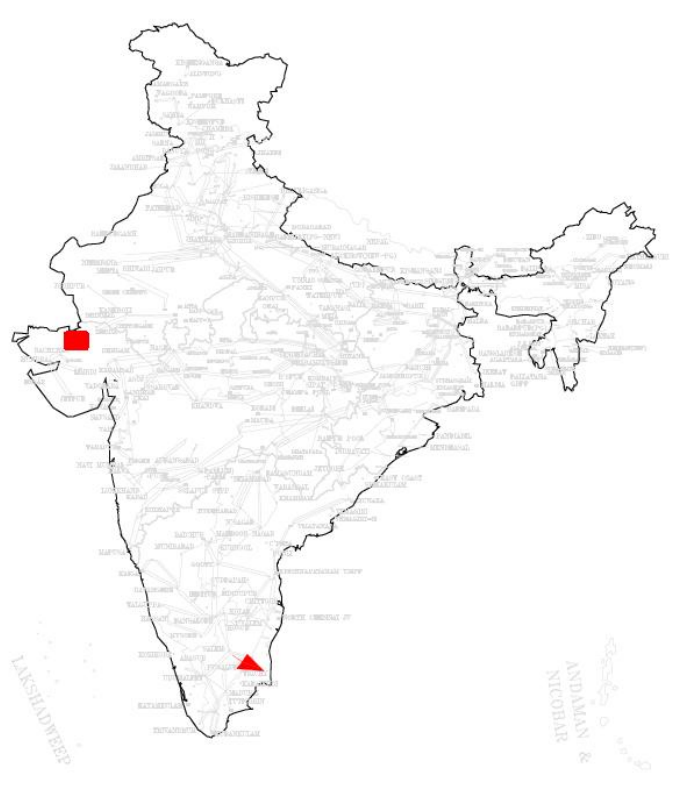
Connectivity Regulations 2009



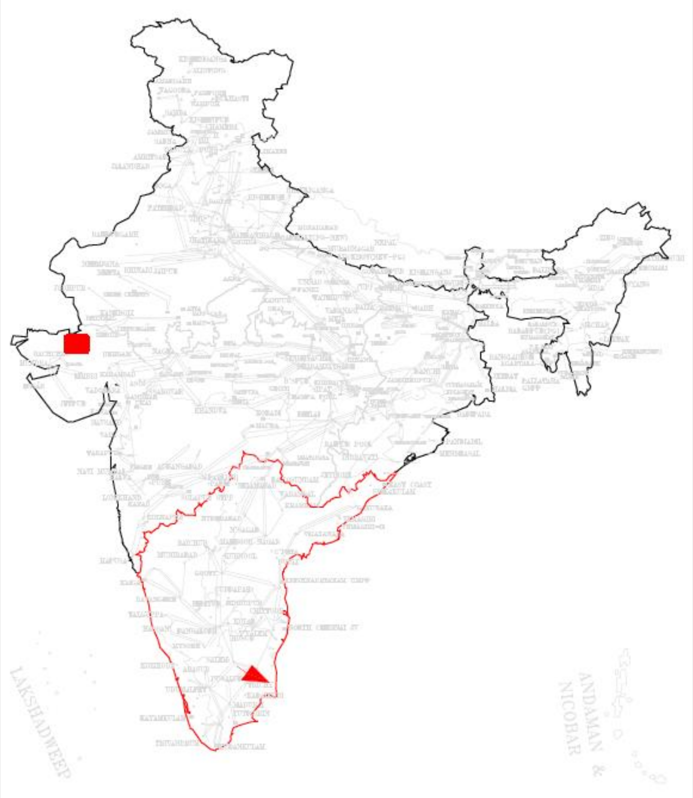
GNA Regulations 2022



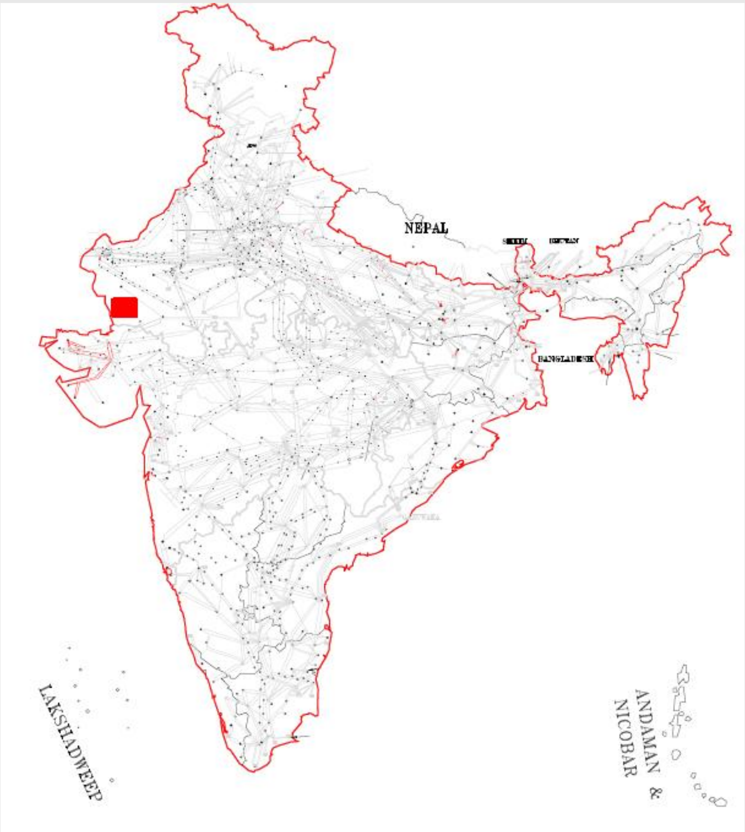
Power System Planning



Point to Point Transfer



Point to Region Transfer



Point to All India Transfer

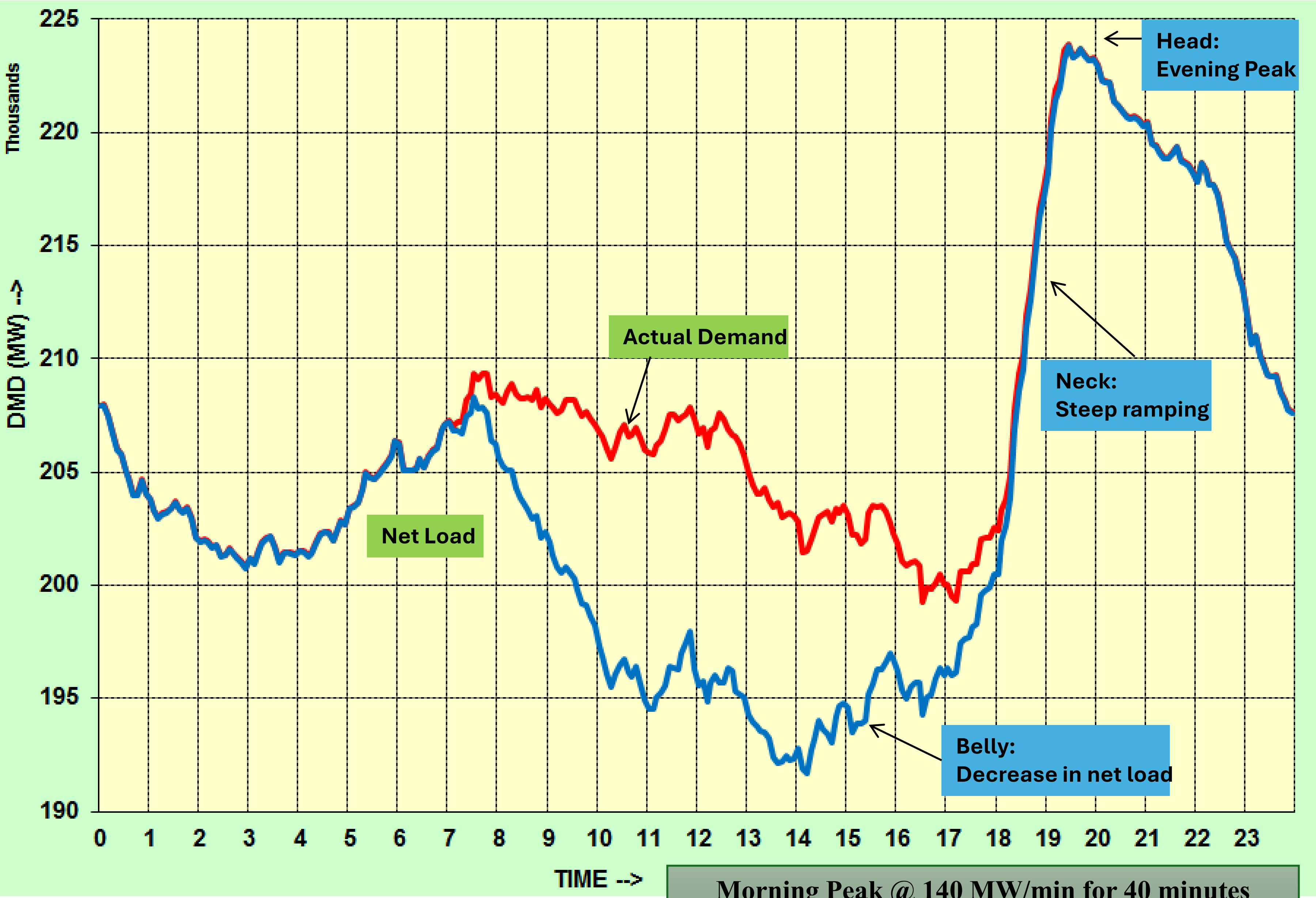
Integration of Renewable Energy New Technologies

Challenges : RE Integration

Challenge	Measures
Short Gestation period	• Planning & development of evacuation system based on potential renewable energy zones (Green Energy Corridors)
Intermittent	• Enlarging Balancing Area through transmission expansion • Ancillary Support Services • Forecasting of Renewable output
Variable Output	• Balancing resources • Dynamic reactive power compensators • Energy Storage System
Inertial Support	• Synthetic Inertia from Inverter/WTG • Energy Storage System • Synchronous Condenser

Compliance to Technical Standards; Standard Operating Procedure

Effect of Increased RE Penetration on Load Curve



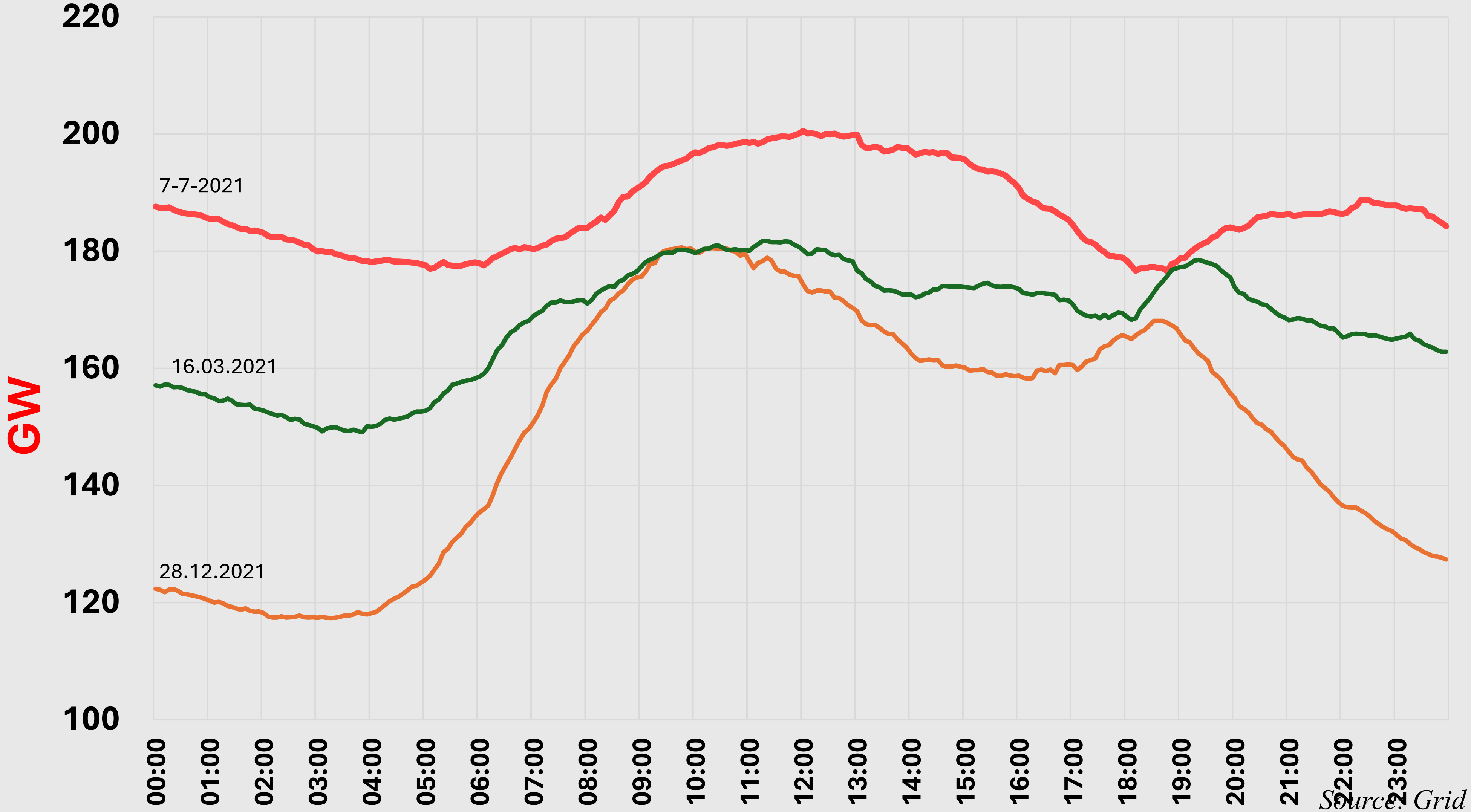
Morning Peak @ 140 MW/min for 40 minutes
Evening Peak @ 200 MW/min for 40 minutes

Source: NLDC SCADA data, CAGR assumed: 8%

Flexibility:

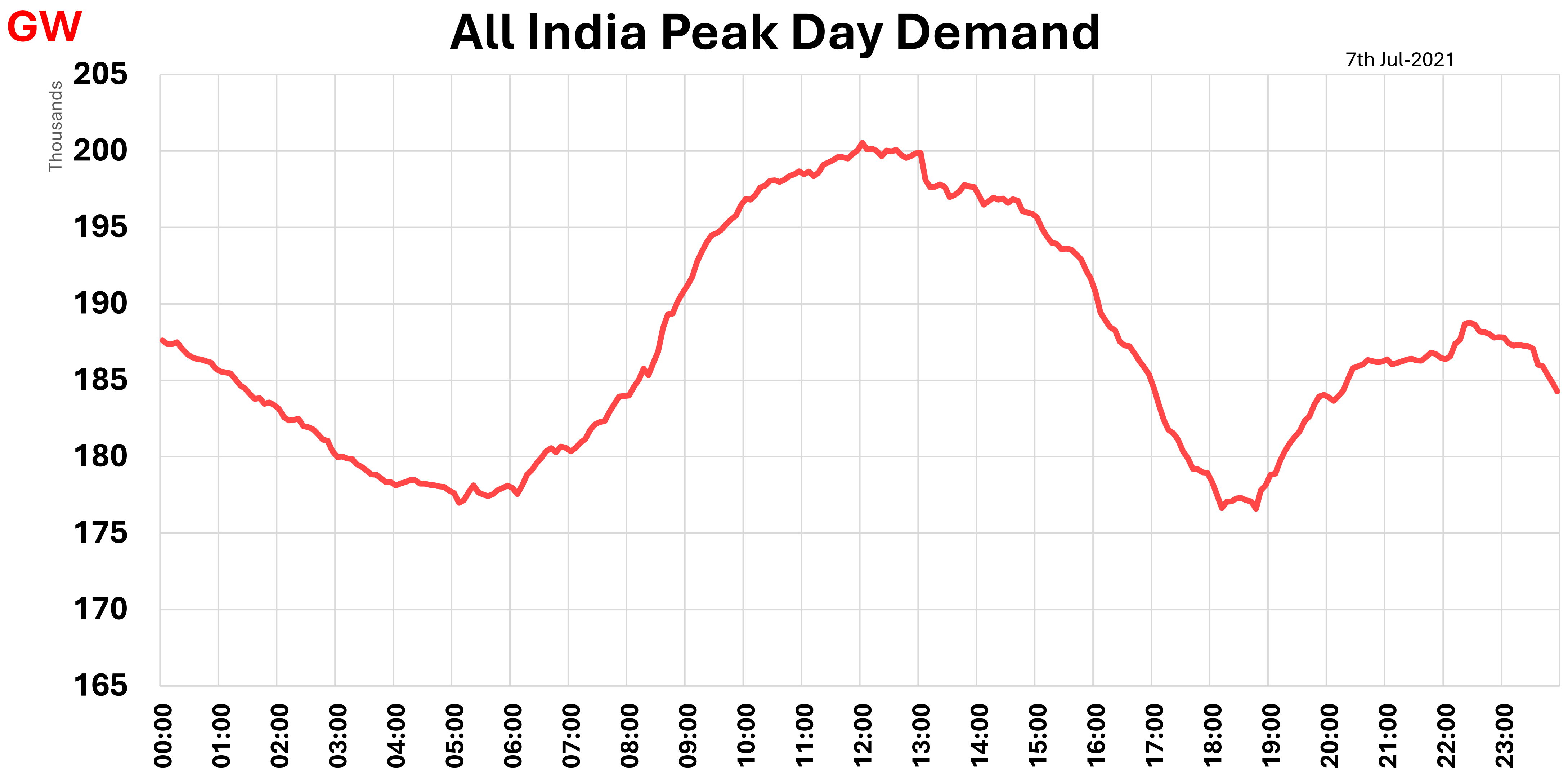
- High Ramp Rate Requirement
- Low Thermal Generation furing high RE Period
- Energy Storage
- Bidirectional Flow of Power
- Maintaining Grid Parameters, Stability and Grid Securitty

Typical Load Curve



Source: Grid India

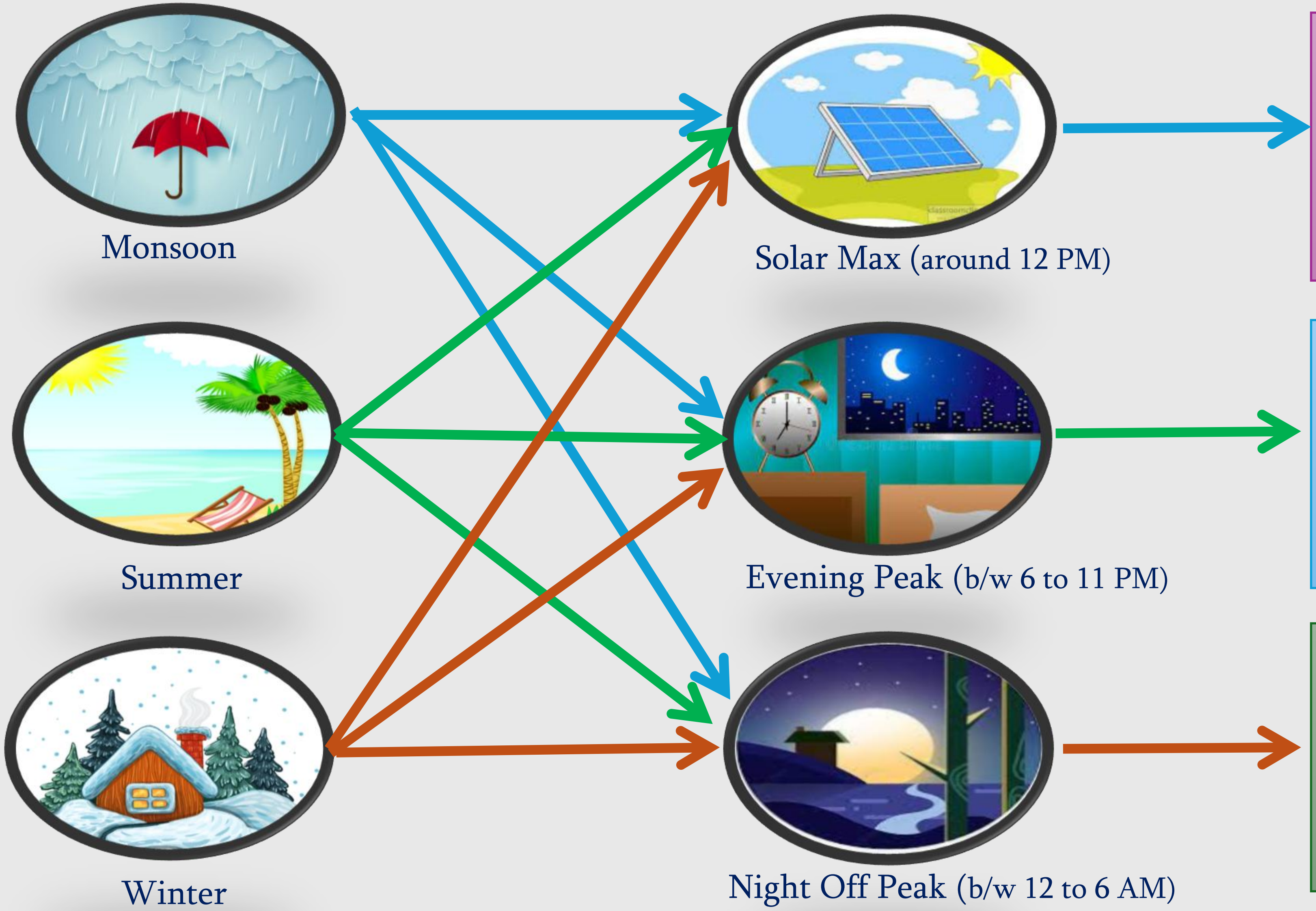
Typical Load Curve



Scenarios Considered

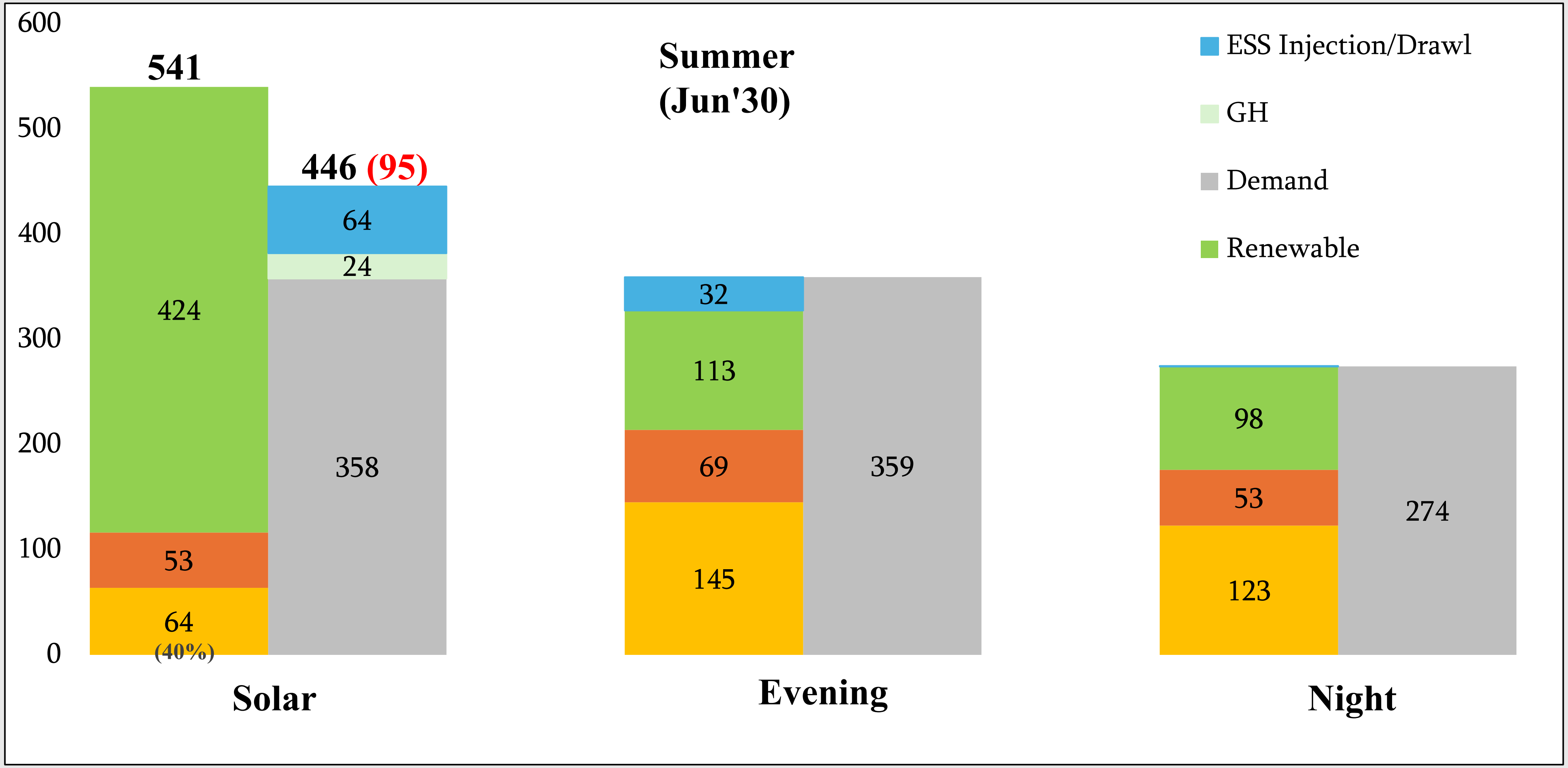
Seasons Considered

Diurnal & Nocturnal Cases



- Monsoon (Aug’27)
  - Solar max (Sc-1)
  - Evening peak (Sc-2)
  - Night off peak (Sc-3)
- Summer (Jun’27)
  - Solar max (Sc-4)
  - Evening peak (Sc-5)
  - Night off peak (Sc-6)
- Winter (Feb’28)
  - Solar max (Sc-7)
  - Evening peak (Sc-8)
  - Night off peak (Sc-9)

Load Generation Balance for FY 2030-31



All figures are in GW

Non-Fossil 2030 Generation

GW as of->	Mar 2014	Mar 2026	Mar 2030
Solar	3	118.7*	240*
Wind	21	56	100
VRE total	**24**	**174.7**	**340**
Rooftop & Off Grid Solar	-	31.5#	60#
Hydro incl. Small	44	56.6^	70^
Nuclear	5	8.7	15
Biomass & others	8	12	15
Total	**81**	**283.5**	**500**

*3.9 GW Hybrid solar

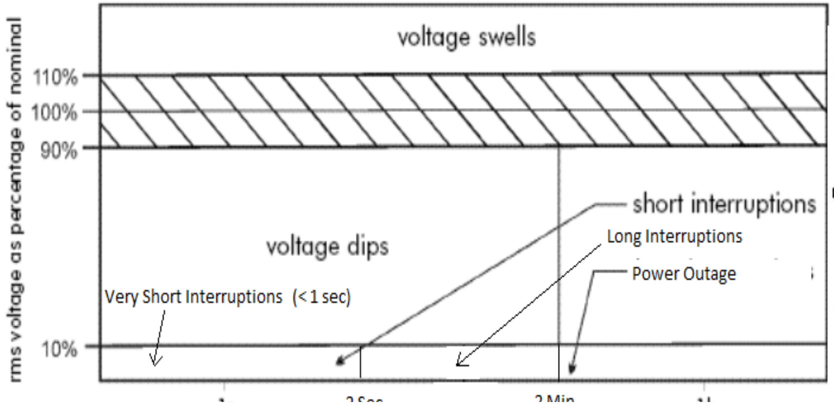
5.8 GW Off Grid Solar

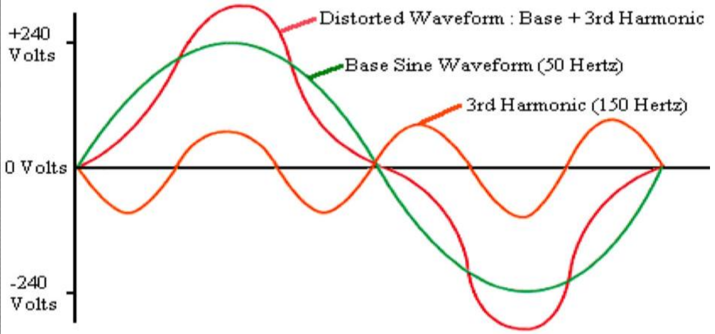
^5 GW Small Hydro

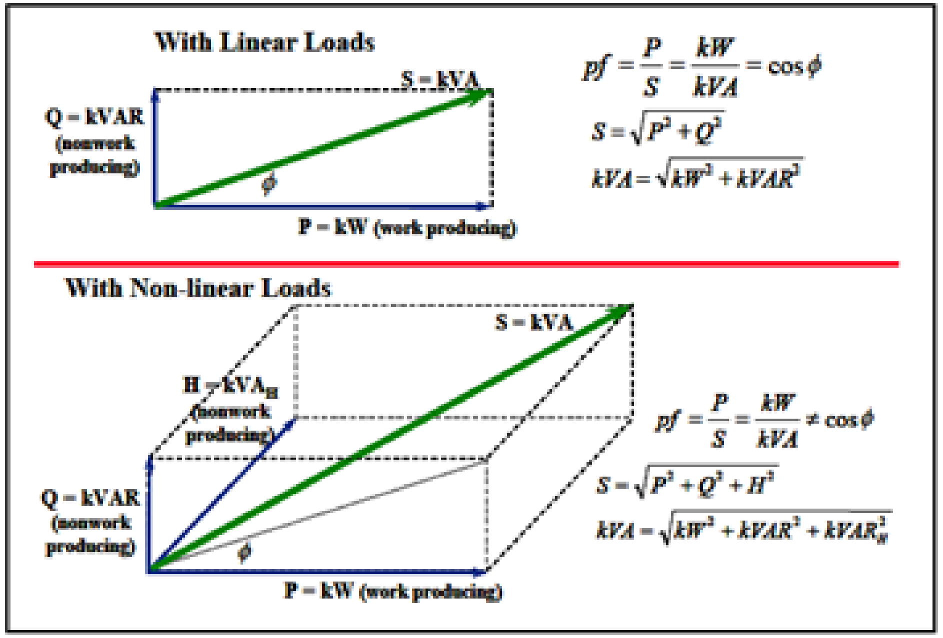
Power Supply Position in FY 2030-31

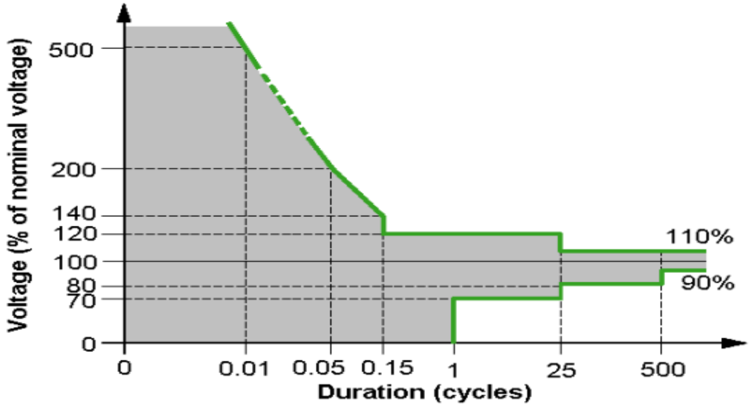
- Surplus of about **48-95 GW** across the seasons and dispatch scenarios requiring RE Curtailment even if there is no Transmission Constraint.
- The extent of Surplus/Curtailment shall further increase to
  - ❖ 72-119 GW - if 24 GW of Green Hydrogen considered in the demand is delayed.
  - ❖ 112-160 GW - if 64 GW of storage comprising 38 GW of PSP and 26 GW of BESS is delayed.
  - ❖ 68-115 GW - if Technical Minimum of Thermal On-Bar IC is considered as 55% instead of 40%
  - ❖ 102 - 149 GW - if 50% of each of the above three is not achieved.
- Looking into such a huge surplus :
  - Additional RE should be allowed injection during non-solar hours only for improvement in utilization of ISTS network.

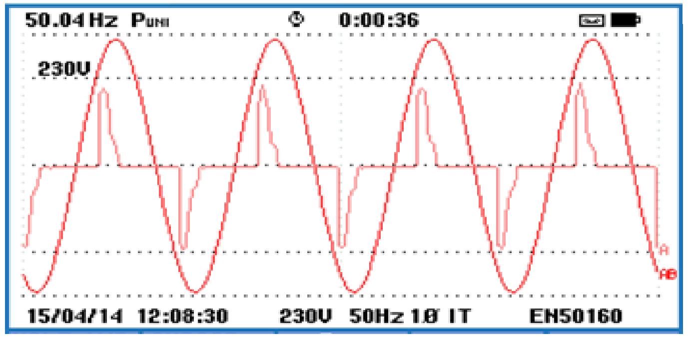
Power Quality

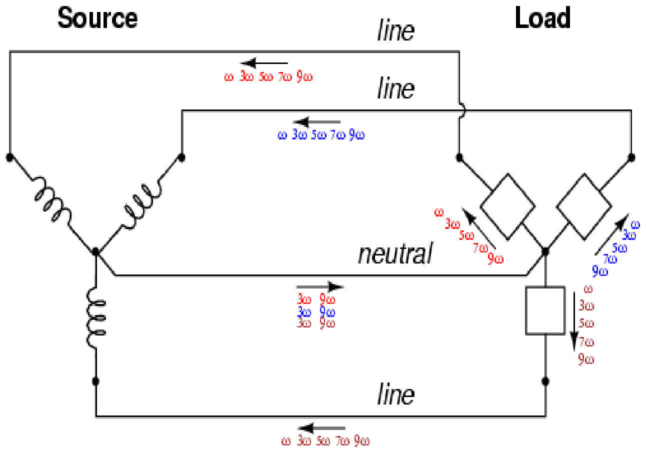


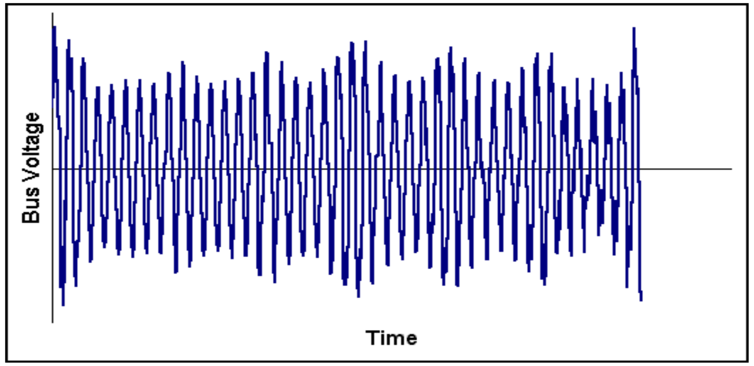












- Power Factor
- Harmonics
- Unbalance
- Interruptions
- Voltage Sag
- Voltage Swell
- Transients
- Flicker

National Green Hydrogen Mission

EXPECTED OUTCOMES OF THE MISSION BY 2030

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

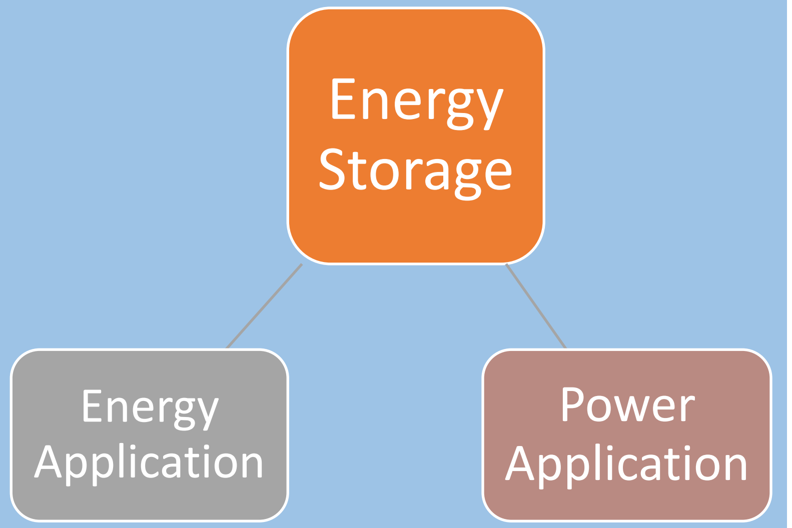
Renewable Energy Capacity Addition of
~125 GW

Over
₹8 lakh crore
in Total Investments

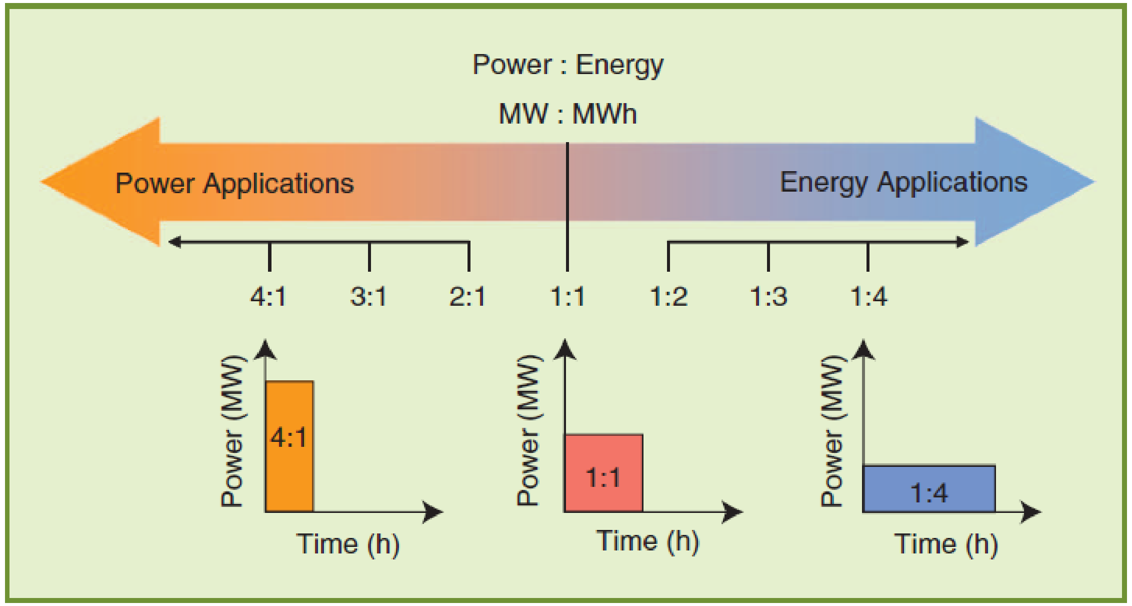
Create Over
6 lakh
Full Time Jobs

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

Energy Storage Applications



Energy storage mediates between variable sources and variable loads.



Power- Energy Continuum of energy storage Technologies and applications

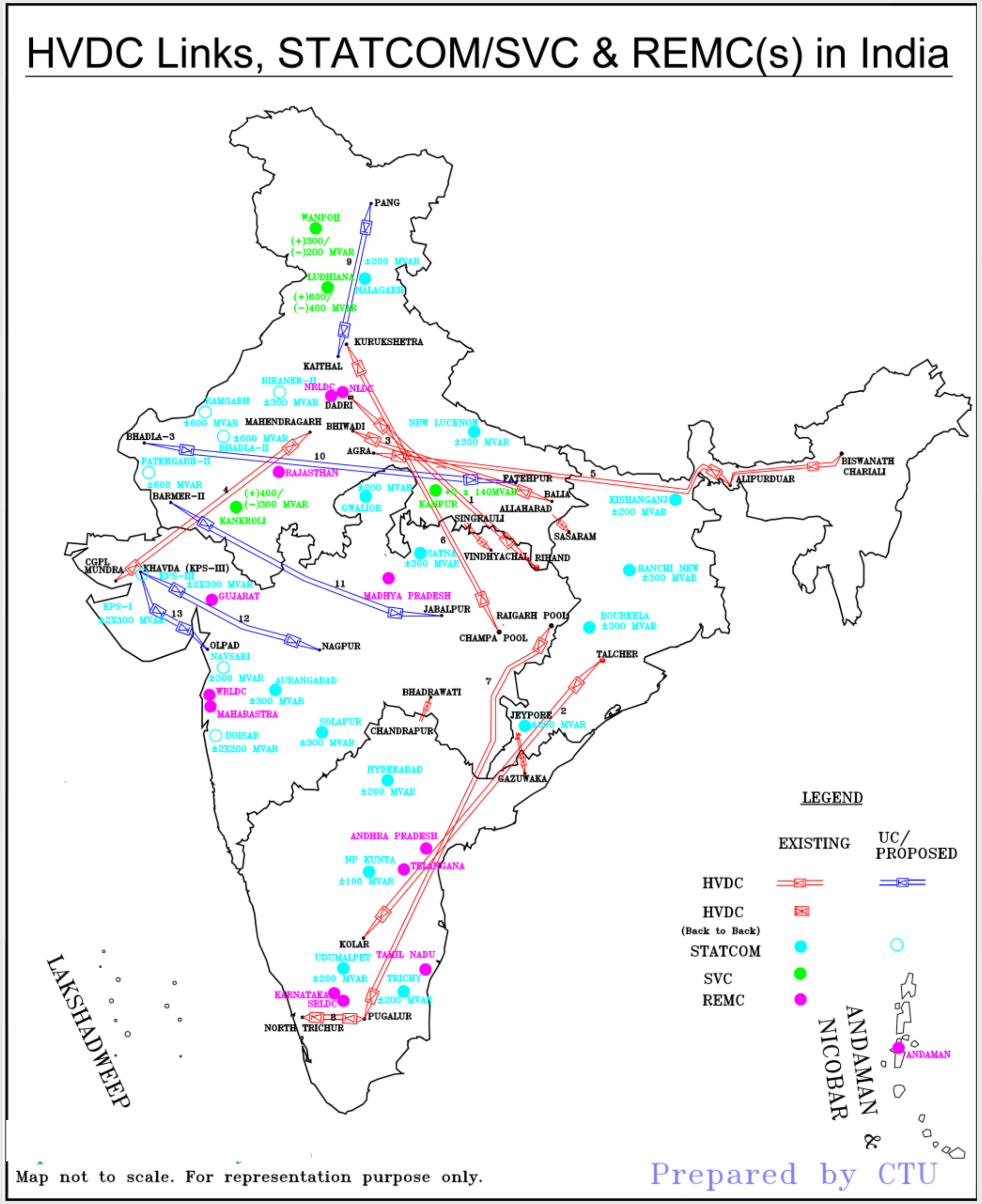
Generator
- RE firming & smoothening
- Energy time shift

Transmission
- Investment Deferral
- Dynamic Support

Distribution
- Peak Shaving
- Reliability
- Power Quality
- Micro Grid Enabler

Grid Operator
- Flexible Generation
- Black Start
- Ancillary Services
- Balancing

Transmission Infrastructure: RE Integration



System Stability

- 17 no. of Hybrid STATCOMs
- 4 no. of SVC (2500MVAr)
- 48 nos. FSC/TCSC

Bulk Power Transfer

- 3 no of ±800kV HVDC Bipole (18GW)
- 5 no of ±500kV HVDC Bipole (10.5GW)
- 1 no of ±320kV VSC HVDC (2GW)
- 4 no of HVDC Back to Back (3 GW)

Optimized ROW through New Tower & Conductor Designs

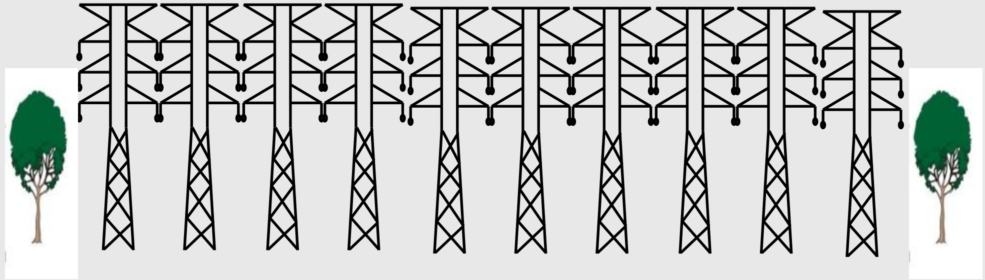
Advantages of using higher voltage level

- Higher power carrying capacity and minimized losses.
- Saving forest area, tree/vegetation cover, loss of agricultural production.
- Saving quantity of steel and conductor material used.

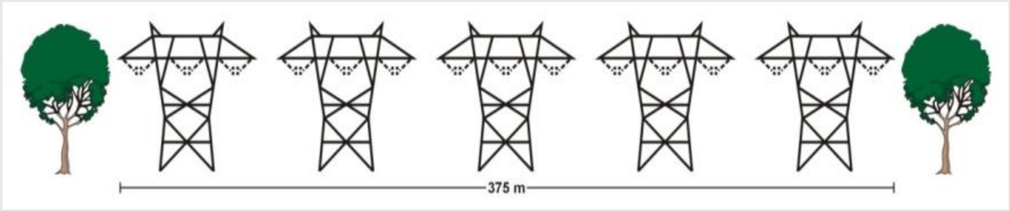
	ROW (m)	Capacity (MW)	MW/m-RoW
400kV (D/c)	46	1000	22
765kV (S/c)	64	2100	33
765kV (D/c)	69	4200	61
±500kV HVDC	52	2500	48
±800kV HVDC	70	6000	90
1200 kV UHVAC	100	8000	80

HVAC vs. HVDC (for 10GW)

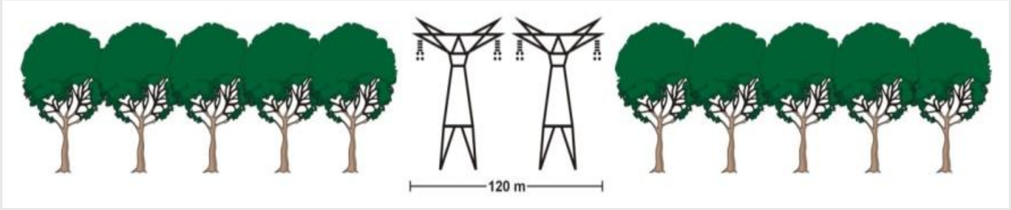
HVAC 400 kV



HVAC 765 kV

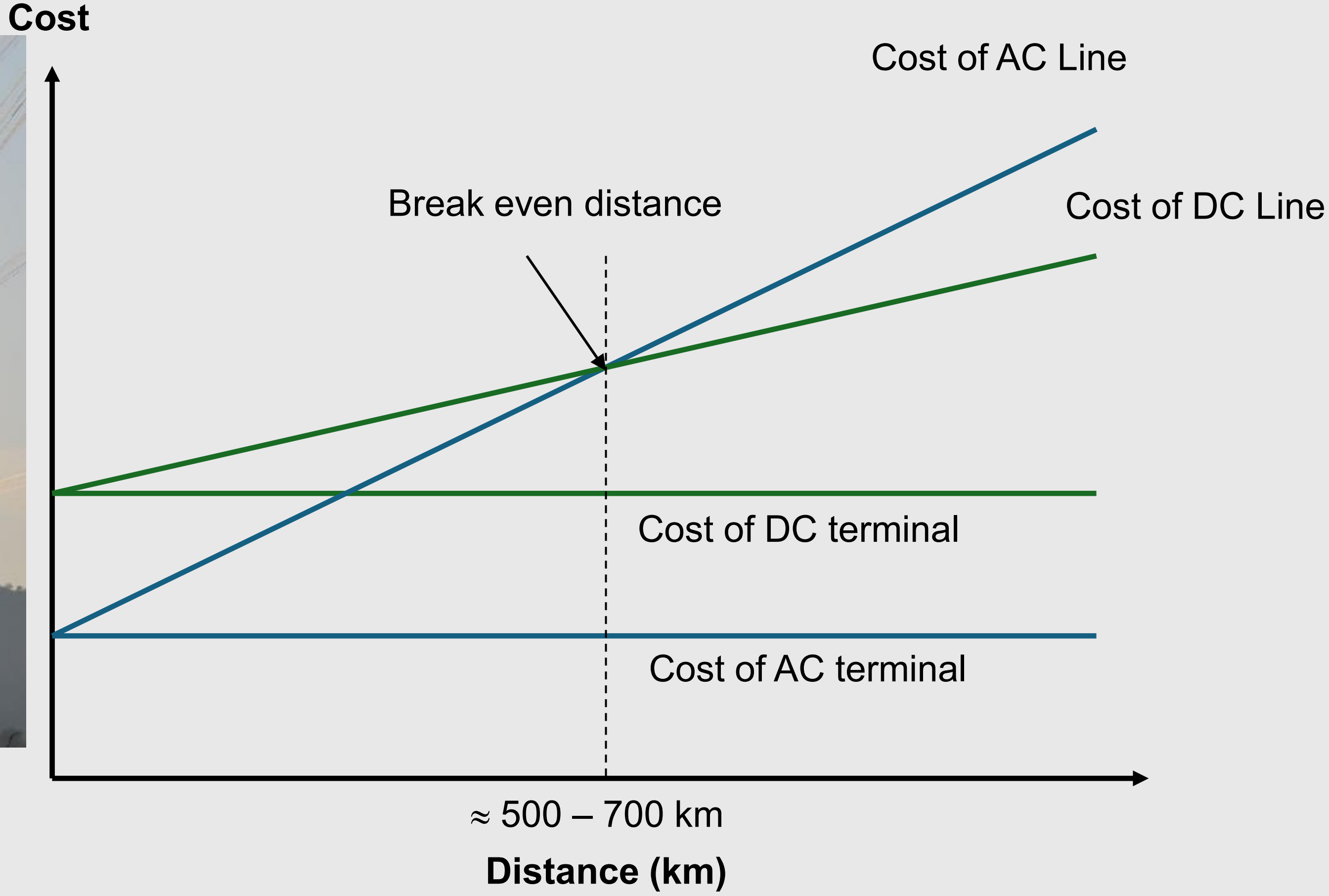


HVDC ±800 kV



Transmission using HVAC vs HVDC

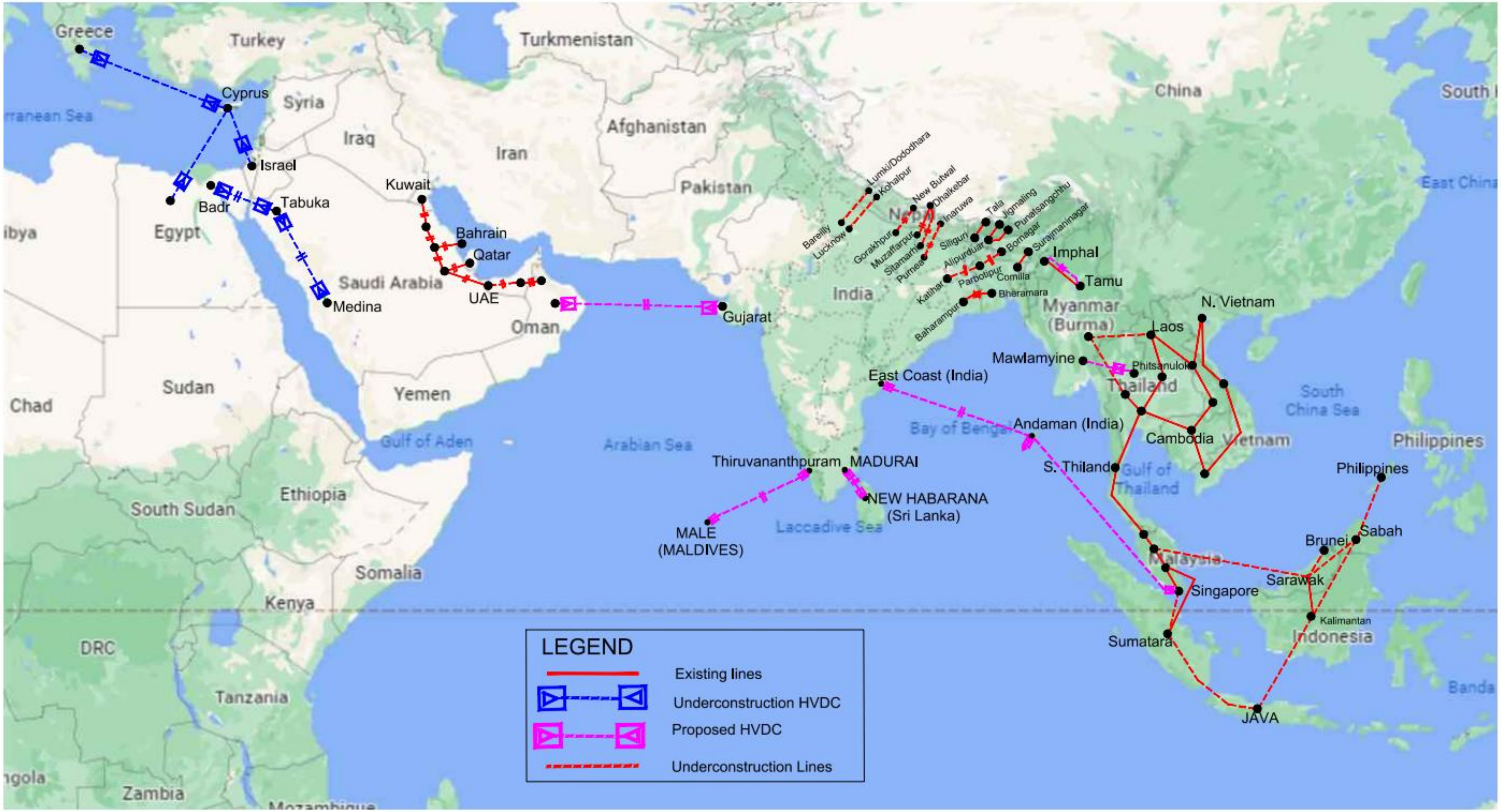
765kV D/C



±800kV HVDC

Cross Border Interconnections under Consideration

OSOWOG



New Technologies in Power Sector

- Condition monitoring & Predictive maintenance using AI/ML algorithms
- Process Bus Technology
- Dynamic Line Loading (DLL)
- BESS as transmission infrastructure
-  Synchronous Condenser
- Grid Forming Inverters

THANK YOU…!!!