

Load Forecasting and Generation Optimization

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Load Forecasting

Electric Power Survey (EPS)

Methodology

Partial End Use Method (PEUM)

- Time Series Regression Analysis based on Past Electricity Consumption data.
- New emerging aspects are also considered.

Econometric Method

- Based on economic indicators also.
- New emerging aspects are also considered.

20th Electric Power Survey

- Covers electricity demand projection for Discoms/States/UTs/Regions/Country by Partial End Use Method for the years 2021-22 to 2031-32.
- Perspective demand projection has also been done for the years 2036-37 and 2041-42.
- Factors like reduction in T&D losses, energy efficiency measures, green hydrogen production, EVs, roof-top solar etc. have appropriately been factored.
- Forecast has been prepared with mutual consensus with all the concerned power utilities.

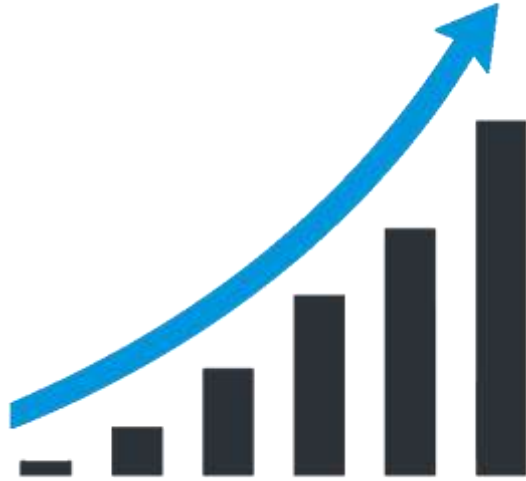
Partial End Use-Methodology

- Bottom Up Approach
- A time series analysis applied at end-user consumption level.
- Time series method is used to derive growth indicators.
- End user electrical demand is aggregated to a certain level for definite trends.
- Based on the trends forecasts have been done for various categories of electricity consumers such as domestic, commercial, public lighting, public water works, irrigation, industrial, railway traction, bulk supply etc.

Policy Initiative & Emerging Aspects

- Transmission and Distribution losses
- Energy Efficiency Improvements
- Electric Vehicle
- Solar Roof Top/Solar Agricultural Pumps
- Green Hydrogen

DEMAND PROJECTIONS- 20th ELECTRIC POWER SURVEY



Year	PEAK DEMAND(GW)	ENERGY REQUIREMENT(BU)
2026-27	277.2	1907.8
2029-30	334.8	2279.7
2031-32	366.4	2473.8
2036-37	465.5	3095.5
2041-42	574.7	3776.3

Year	PEAK DEMAND (% growth)	ENERGY REQUIREMENT (% growth)
2021-22 to 2026-27	6.42	6.67
2026-27 to 2031-32	5.74	5.33
2031-32 to 2036-37	4.91	4.59
2036-37 to 2041-42	4.30	4.06

Econometric method

- Dependent Variable:
 - Monthly State Electrical Energy Requirement / Peak demand
- Independent Variable :
 - Electricity Demand lagged by one and 12 months
 - GDP lagged by 12 months
 - Cooling Degree Days
 - Heating degree days
 - Rainfall
 - To account the impact of multiple schemes and policies in electricity sector over time structural dummy is included

The Projections through econometric method varies in the range of $\pm 5\%$ from the PUEM Method

AI methods for Long Term Load Forecasting

- ANN, Fuzzy and Neurofuzzy, SVM(Support Vector Machine)
- Challenges with the AI based LTLF
 - Huge data requirement and computing power.
 - India being Developing country factors such as policy interventions and technological innovations significantly impact demand

Long Term Generation Capacity Expansion

National Electricity Plan

BROAD INPUTS (1 / 3)

Load profile:

- Average hourly load profile of previous years(2018-19 & 2019-20) analyzed for future load profile

Solar & Wind profile:

- Actual hourly generation profile of solar & wind of various states of each region.

Seasonal Hydro Profile:

- Average of actual monthly hydro generation of the existing hydro power plants for previous years(2019-22) .

Variable cost for Existing coal capacity:

- Based on the ARR of various discoms and Merit India website.

Fuel Constraints:

- Domestic gas availability as per gas generation during 2021-22.
- Peaking support from gas considered : 4-8 GW.

BROAD INPUTS (2/3)

Future investment options

- Capacity (super critical / ultra-super critical) identified for development
- Location specific hydro and PSP projects concurred or are under S&I stage
- the plants which have been accorded administrative approval and financial sanctions

Year on year investment limits for different technologies:

- 25-32 GW per year for Solar
- 7-10 GW per year for Wind

Technical Constraints:

- 55% for All coal based Plants, heat rate deterioration at part load operation
- Must Run status for RE
- Limited flexibility in nuclear generation
- Seasonal availability of Biomass based on previous years generation.
- Actual Storage hours of hydro/PSP generators modelled.

BROAD INPUTS (3 / 3)

Investment & O&M Cost:

- Year Wise trend of reduction of CAPEX & OPEX considered for different technologies(esp. for Off Shore Wind, BSES, and Solar)
- CAPEX value of Hydro & PSS candidate considered as per most recent project cost details furnished by developers.

Fuel Cost:

- Plant wise coal cost based on the distance from the mines
- Increase in fuel cost: 1% per annum for coal, 2% for gas

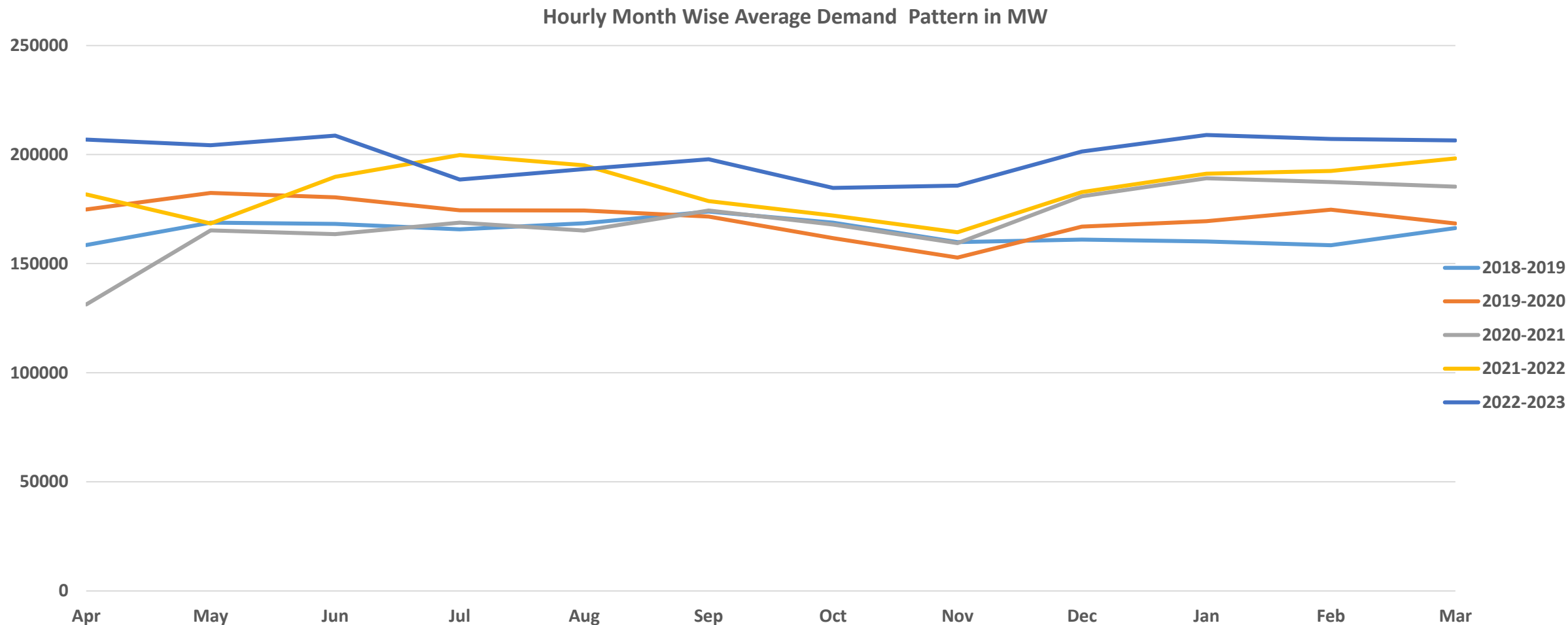
Transmission Capacity:

- Existing Inter regional transmission considered as on 2021-22.
- Additional candidate inter regional transmission link modelled

Emission Factors:

Fuel wise emission factors(Kg CO₂/MT) modelled for different fossil fuels.

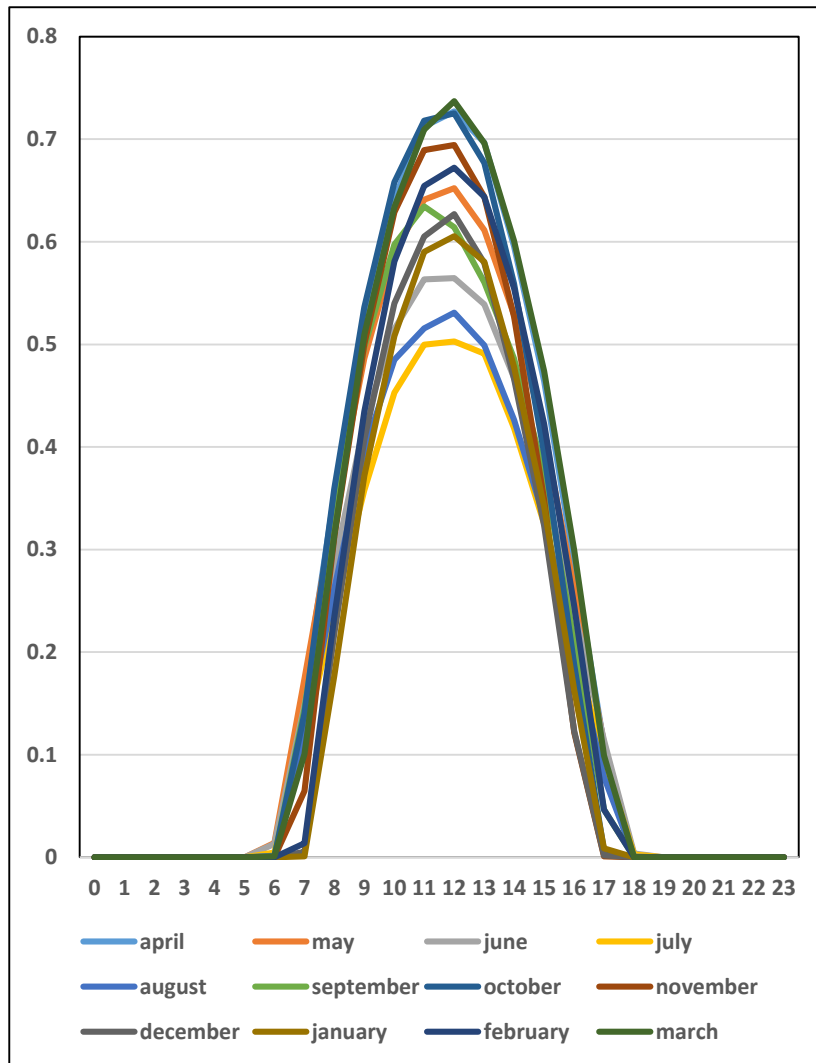
Study of Historical demand pattern



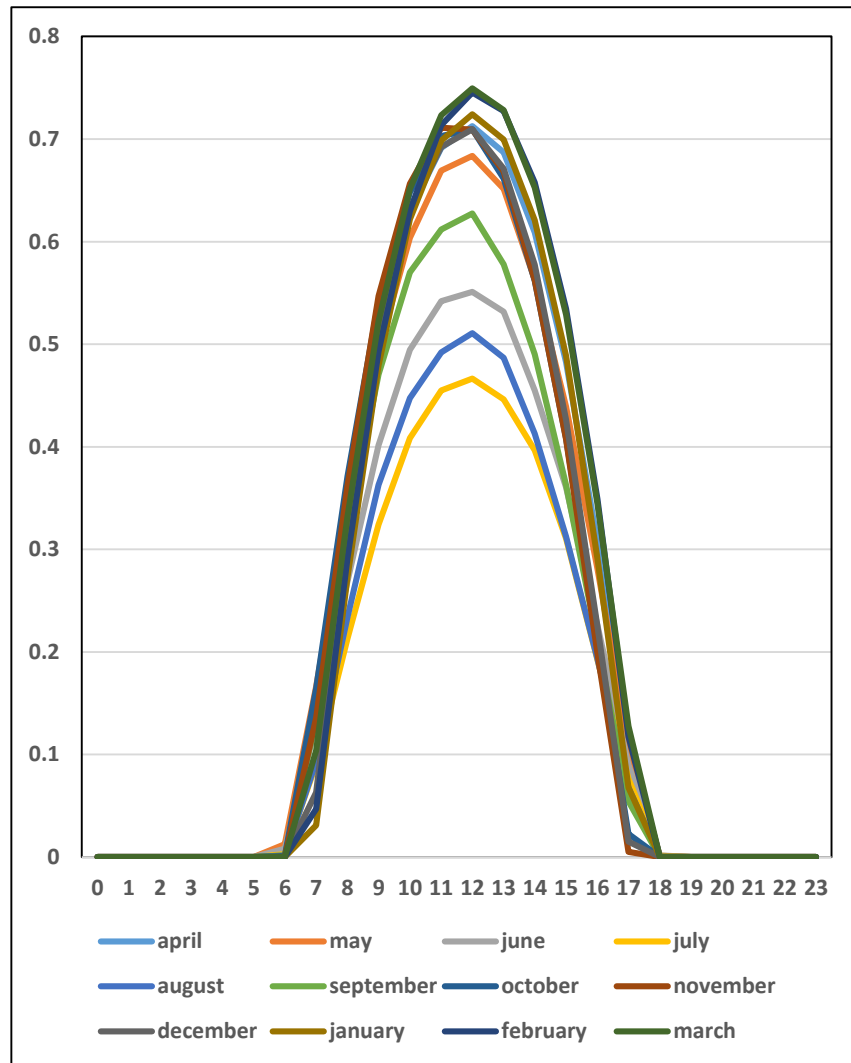
2018-19 and 2019-20 demand pattern is similar to 2022-23 while 2019-20 & 2020-21 demand pattern is different due to COVID.

Hourly Solar Generation profile Region wise

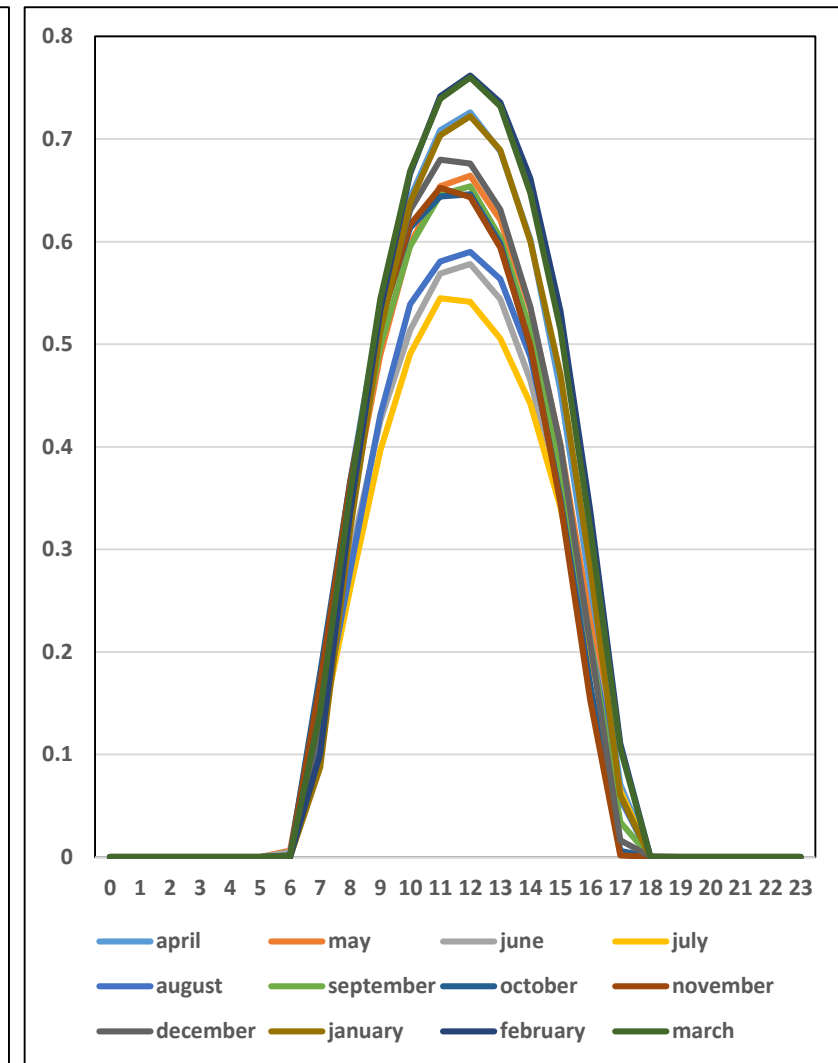
NR REGION



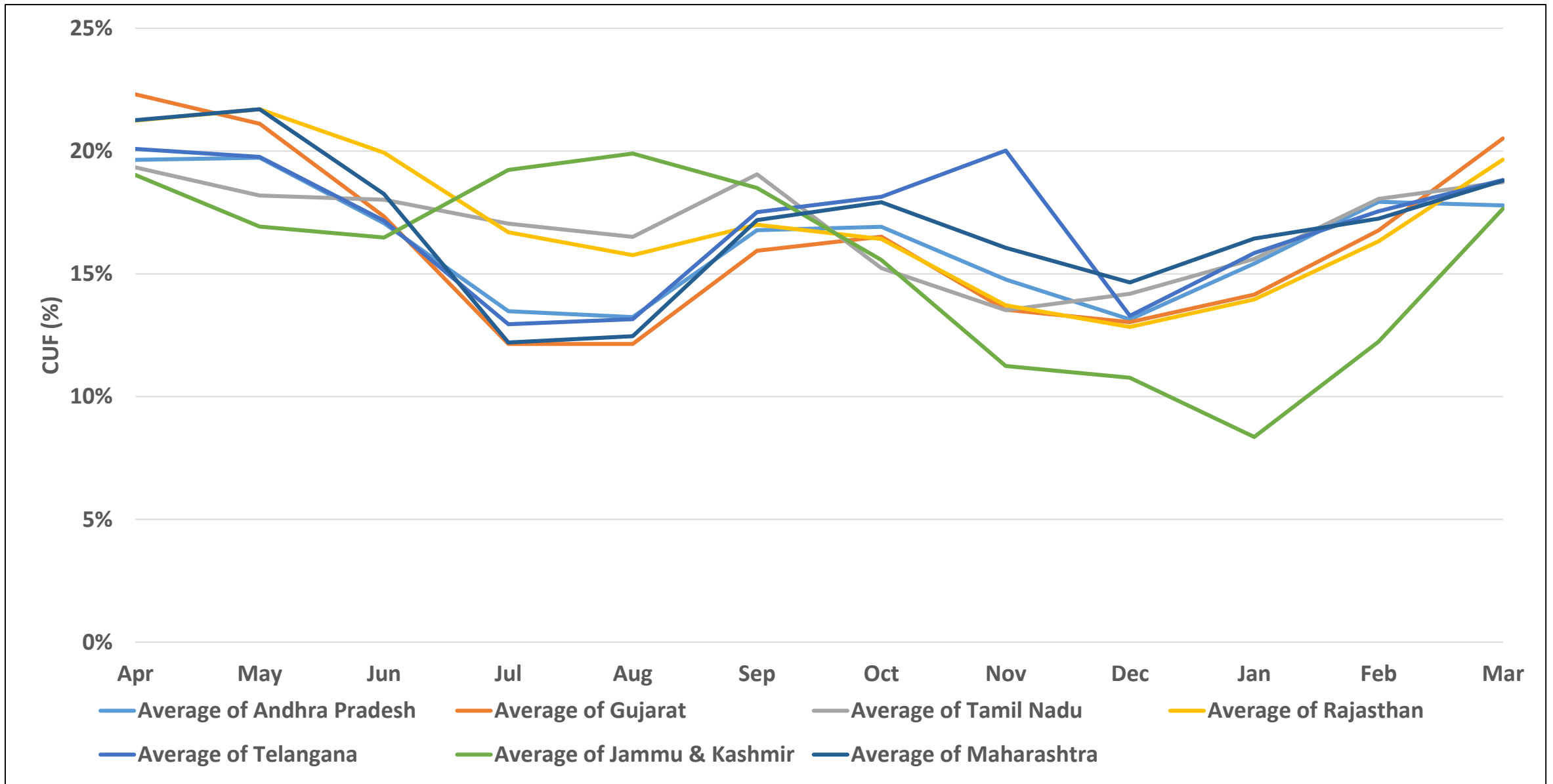
WR REGION



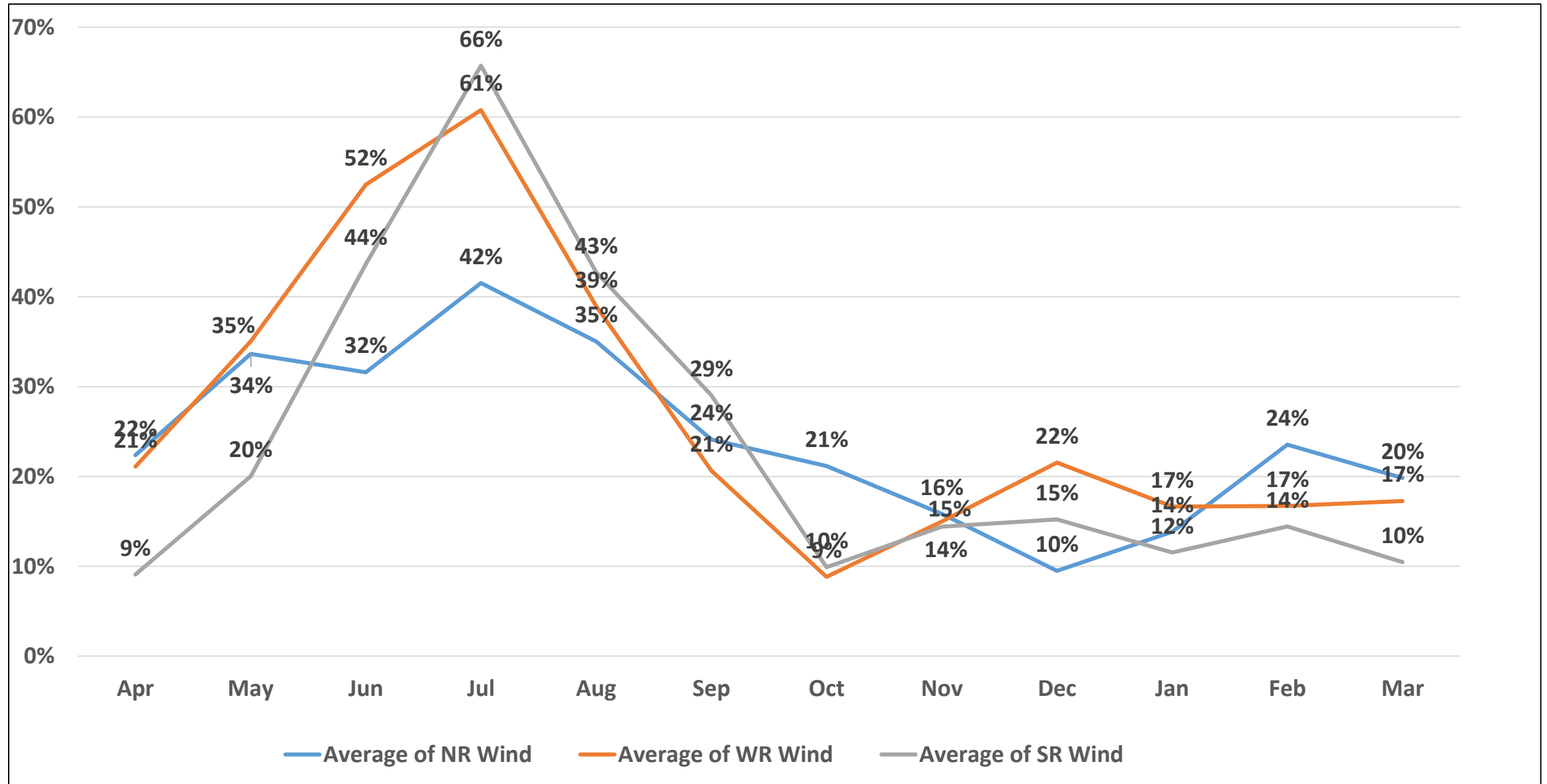
SR REGION



State Wise Solar CUF(%) variation



Wind CUF(%) variation Month Wise



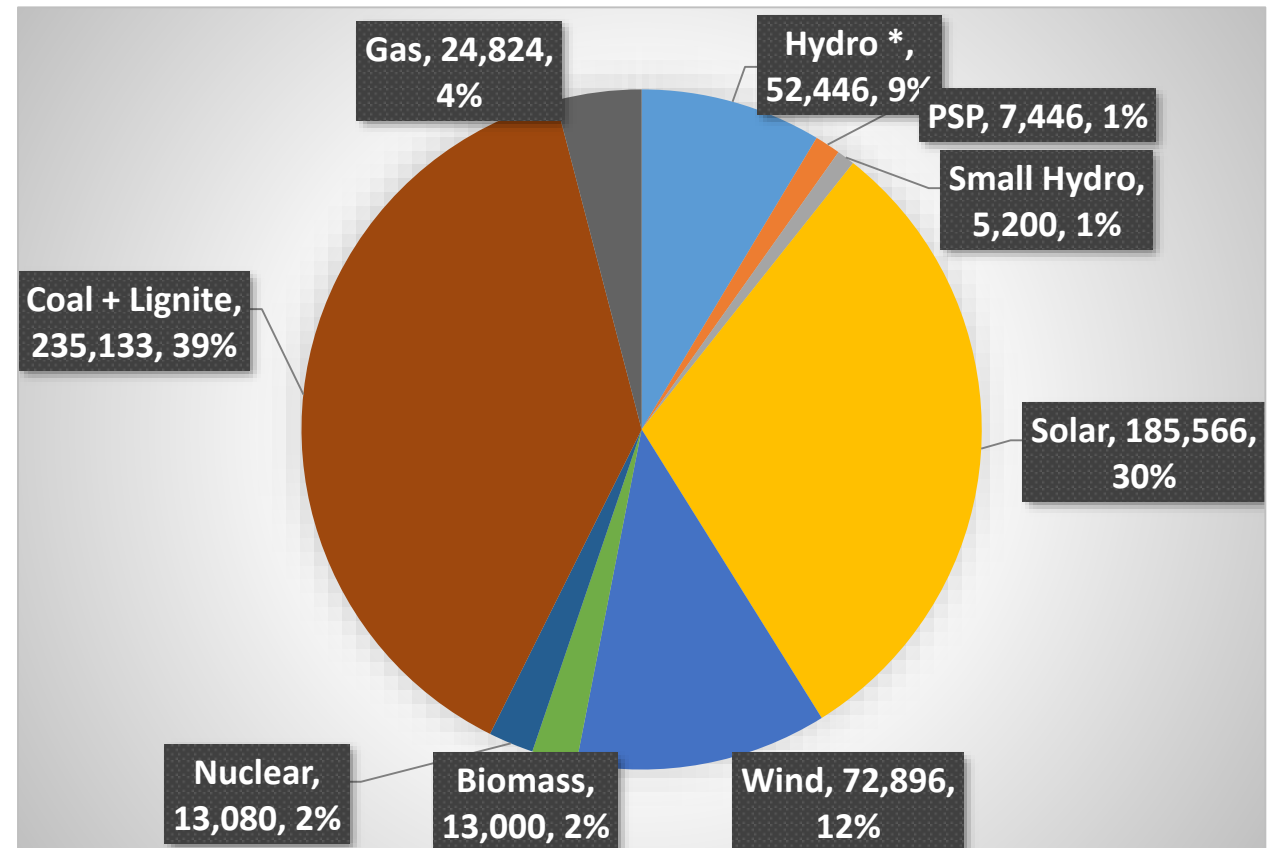
FINAL NEP RESULTS

2022-27



PROJECTED INSTALLED CAPACITY in 2026-27

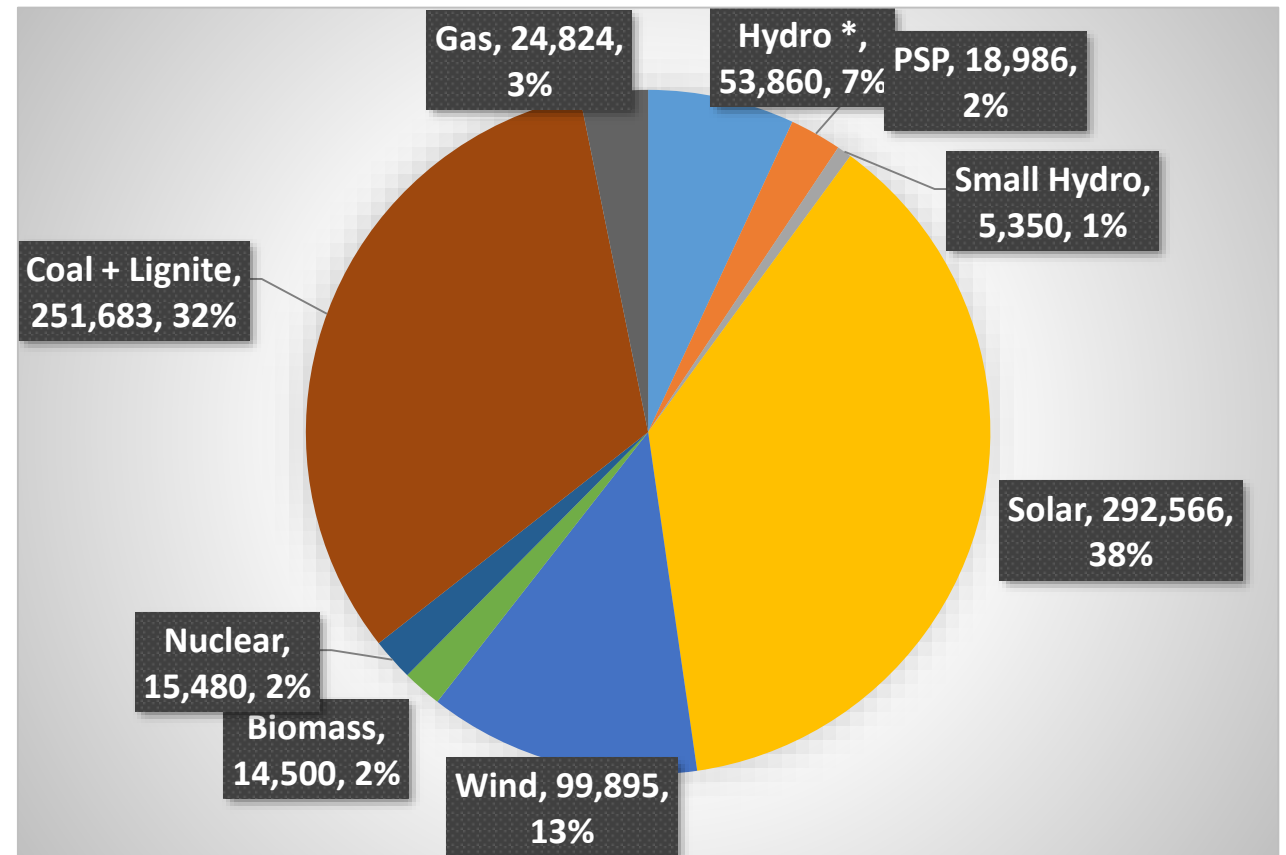
- Projected Total IC as on 31.3.2027 is **609.6** GW
- Battery Energy Storage system(GW/GWh):
8.7/34.8



* Excluding 5856 MW of Hydro Imports from Nepal and Bhutan.

PROJECTED INSTALLED CAPACITY by 2029-30

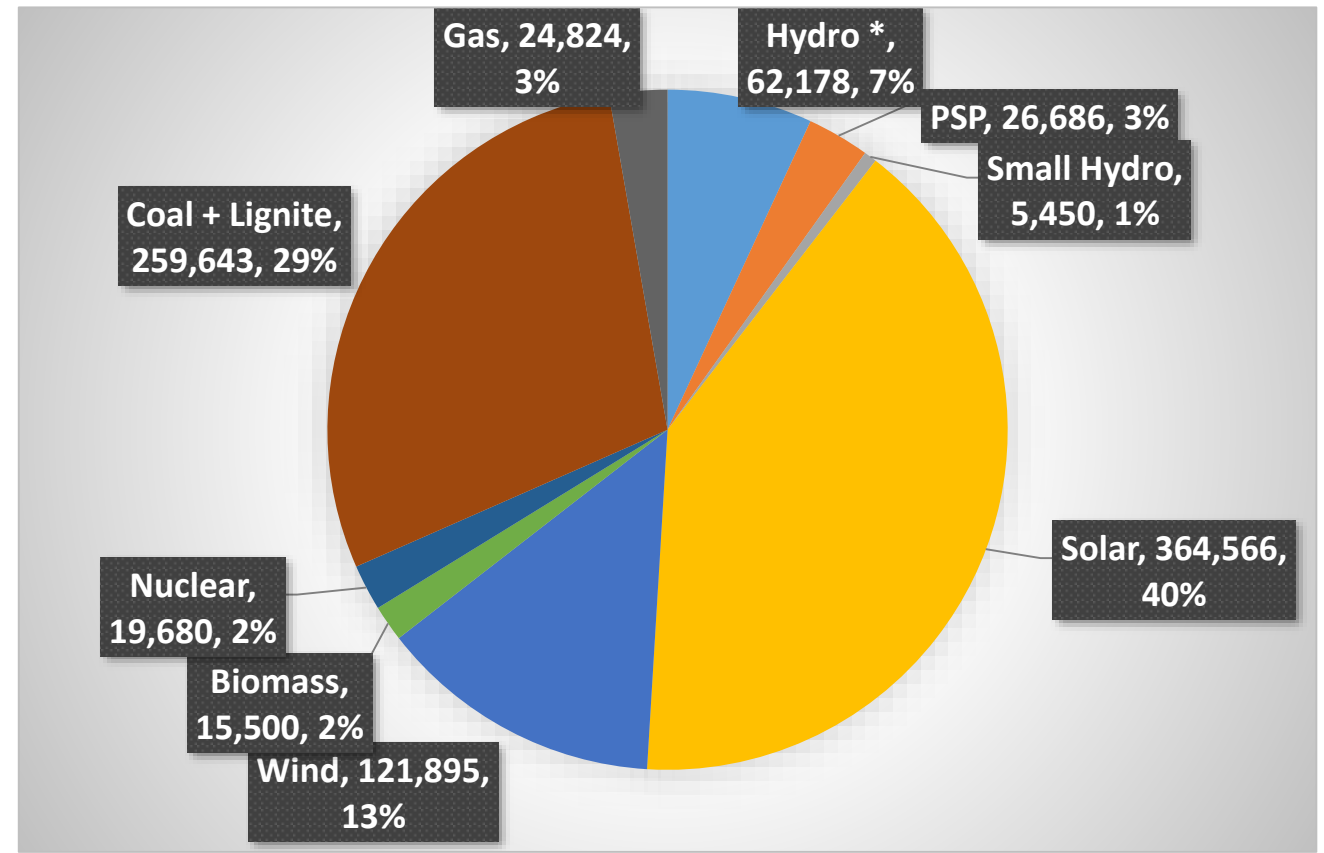
- Projected Total IC as on 31.3.2030 is **777GW**
- Battery Energy Storage system: **41.6GW/208.3 GWh**



* Excluding 5856 MW of Hydro Imports from Nepal and Bhutan.

PROJECTED INSTALLED CAPACITY by 2031-32

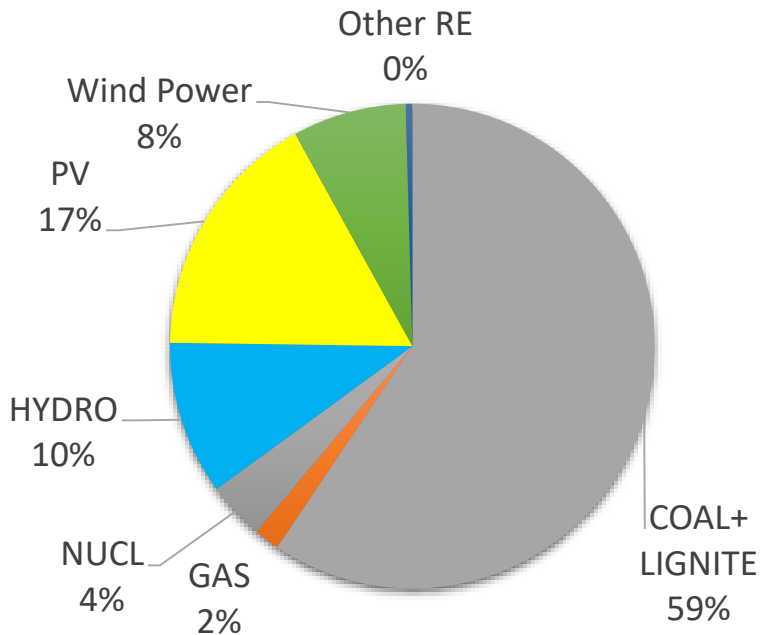
- Projected Total IC as on 31.3.2032 is **900.4 GW**
- Battery Energy Storage system: **47.3 GW/236.2 GWh**



* Excluding 5856 MW of Hydro Imports from Nepal and Bhutan.

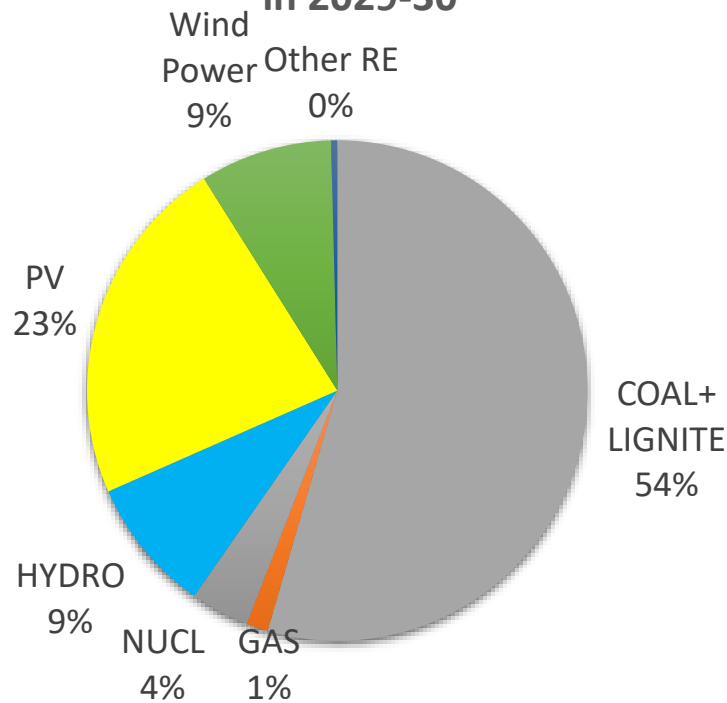
Projected Gross Generation 2026-27, 2029-30 and 2031-32

Source wise Projected Gross Generation
in 2026-27



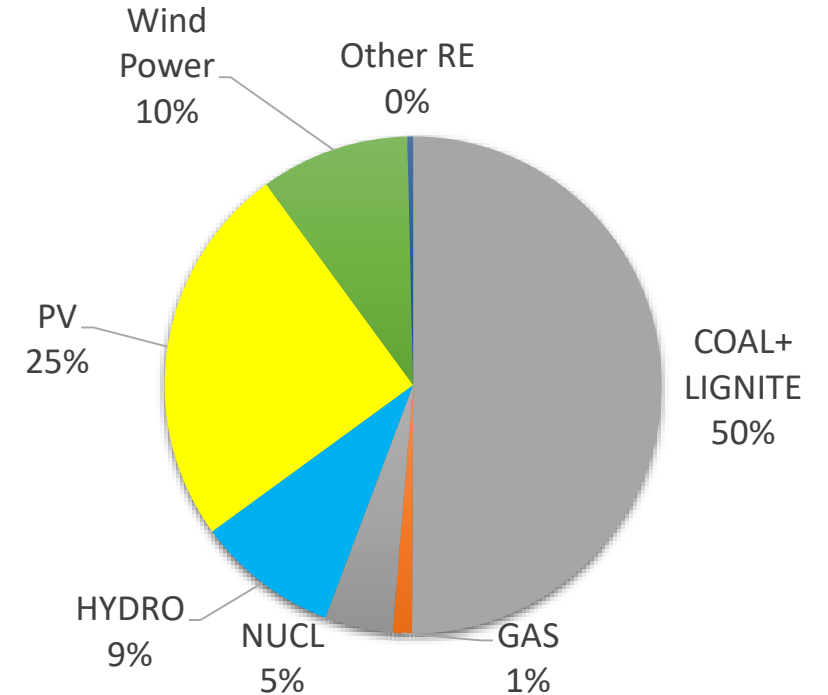
Total:2025 BU

Source wise Projected Gross Generation
in 2029-30



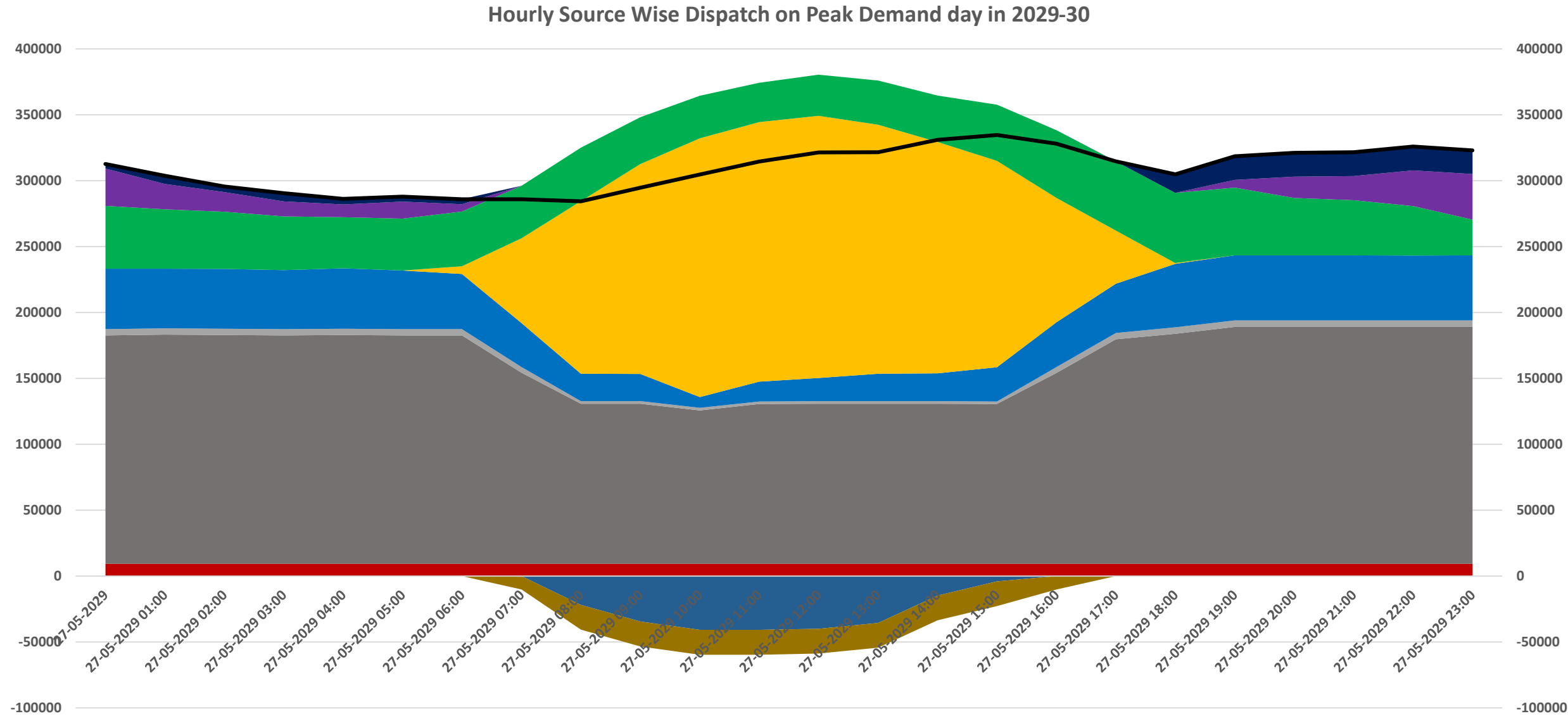
Total:2440.7 BU

Source wise Projected Gross
Generation in 2031-32

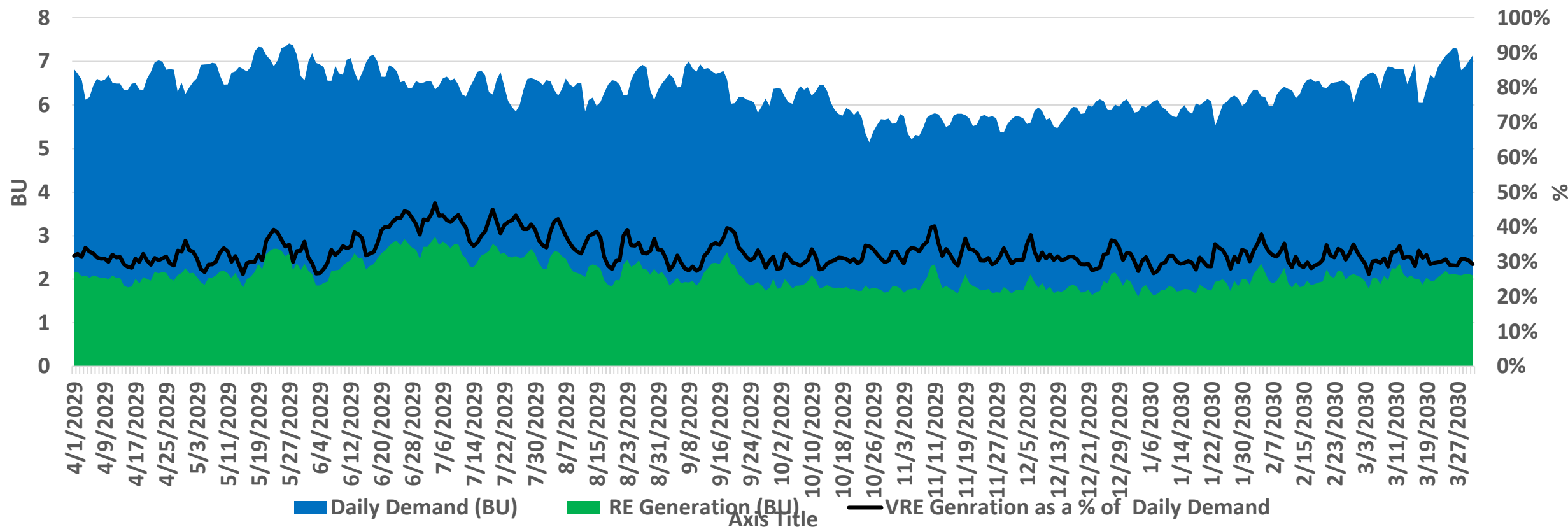


Total:2665.7 BU

Generation Dispatch on Peak Demand Day(2029-30)

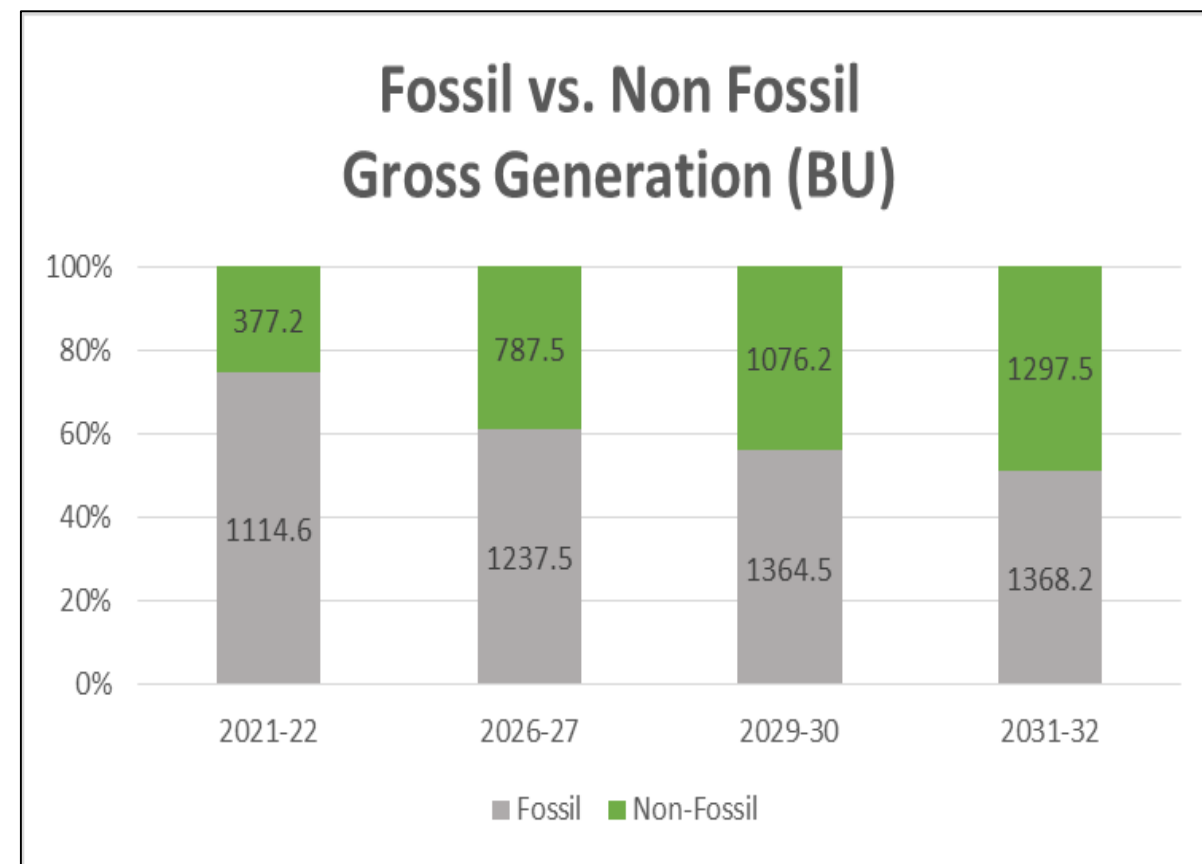
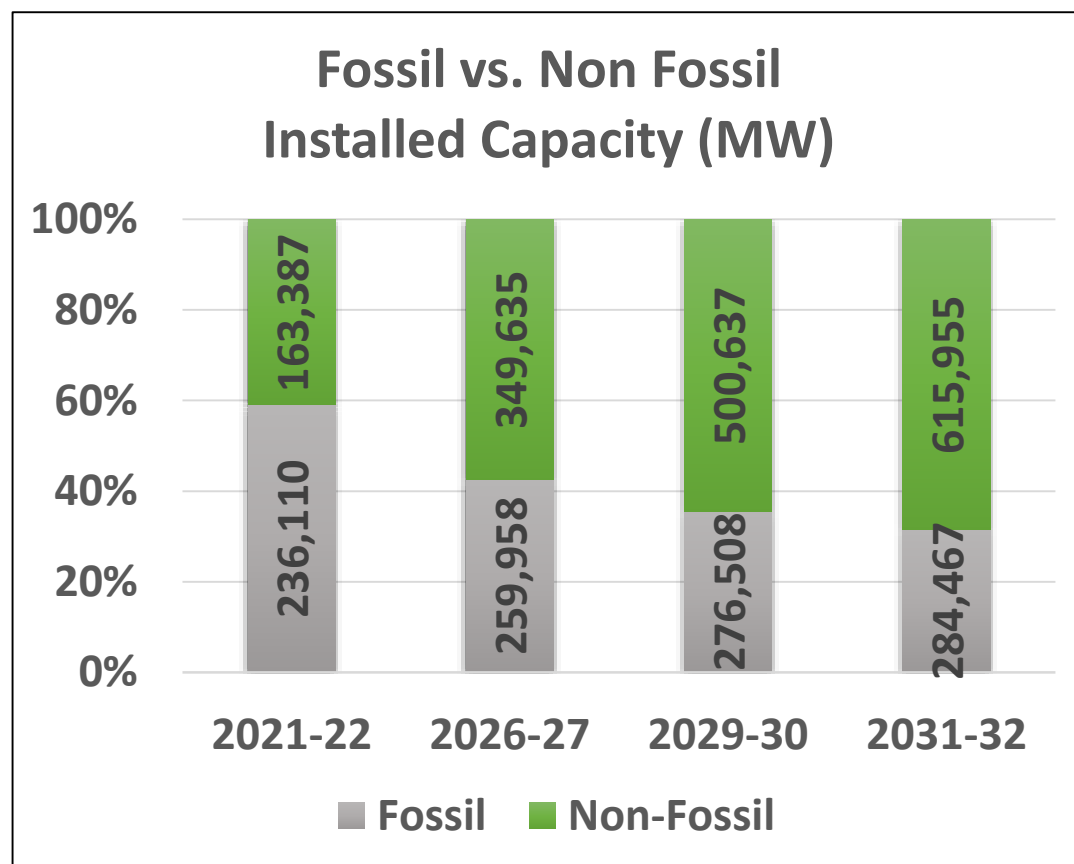


Daily Demand(BU) met from Daily VRE(Solar+Wind) Generation in 2029-30

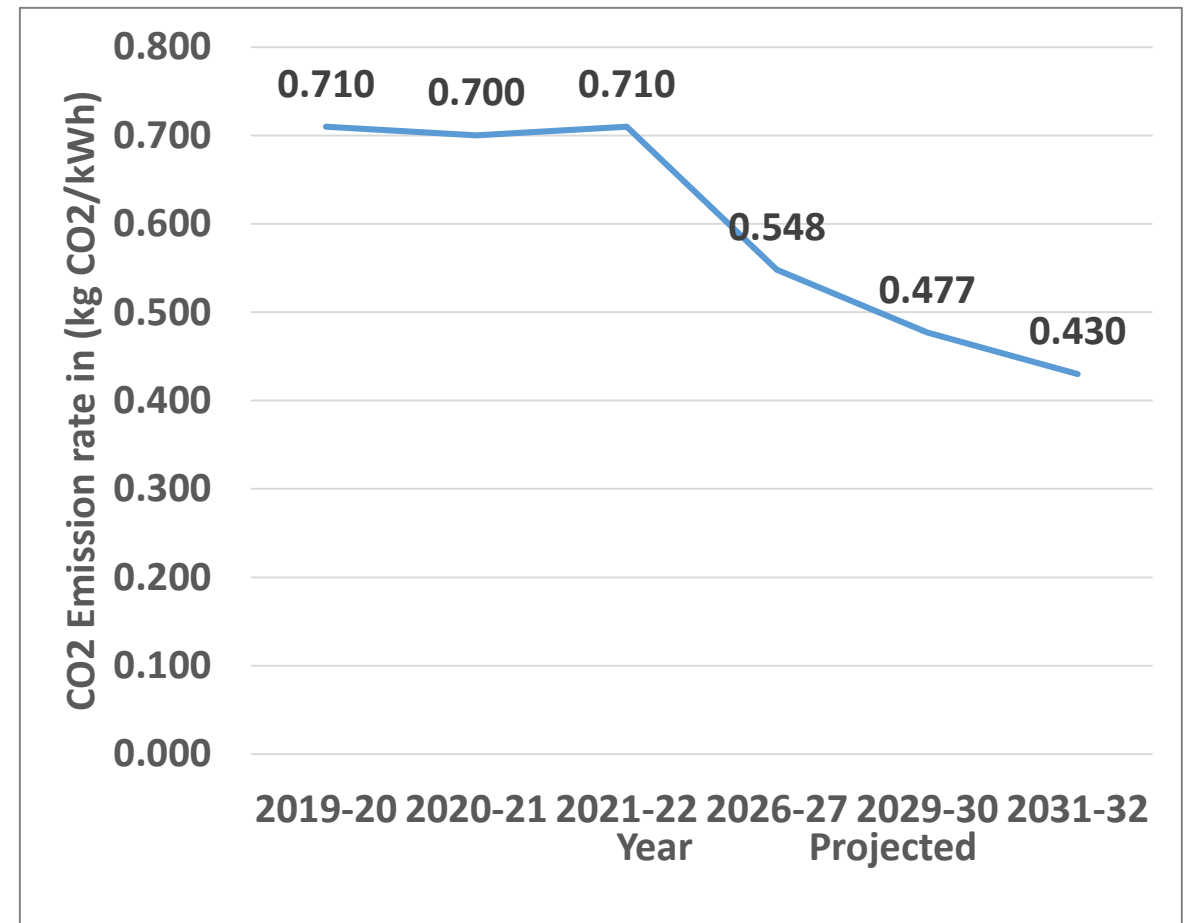
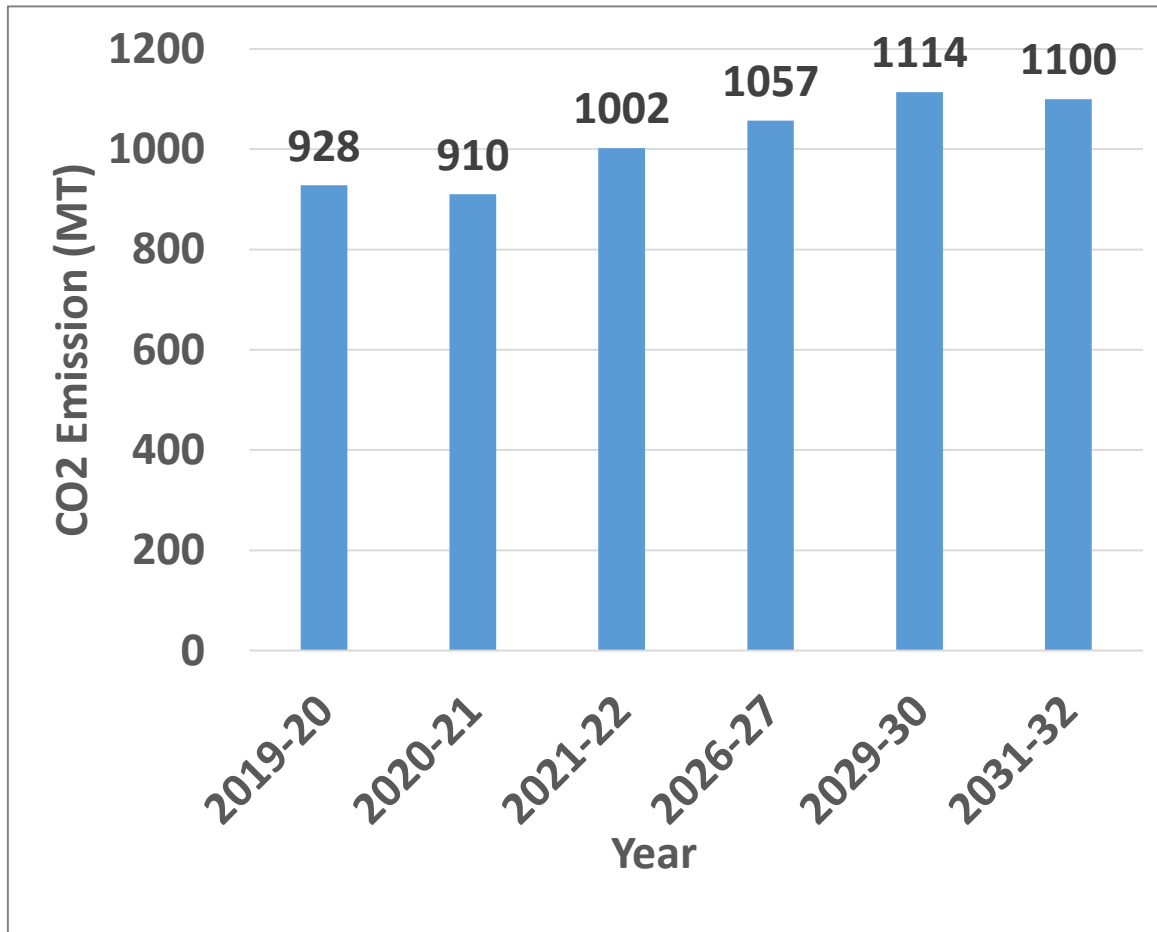


NDC Targets

Fossil vs Non-fossil Projected Installed Capacity(GW) & Gross Generation (BU)



Likely Reduction in CO2 Emissions by 2031-32



AI Potential Application for Generation Expansion

- Demand Pattern forecasting for study period.
- RE generation profile based on Weather Profile
- Forecasting gestation time and likely retirement

THANK YOU

Likely Coal based PLF and Coal Requirement

Year	Likely Gross PLF of Coal based capacity (%)	Likely Coal Requirement[@] (in MTonnes)
2026-27	58.4	895.3
2029-30	60.3	1019.6
2031-32	58.7	1054.2

Likely Projected CO₂ Emissions

Year	Likely CO₂ Emissions (MTonnes)	Emission Factor (kg CO₂ /kWh)
2026-27	1057	0.548
2029-30	1114	0.477
2031-32	1100	0.430

Energy Storage Requirement

Year	PSP (GW/GWh)	BESS (GW/GWh)	TOTAL (GW/GWh)
2026-27	7.45/47.6	8.68/34.72	16.13/82.32
2029-30	18.98/128.15	41.65/208.25	60.63/336.4
2031-32	26.69/175.18	47.24/236.22	73.93/411.4