



Long-term Energy/Load Forecasting and Power Procurement Planning: Case Study of Uttar Pradesh and Chhattisgarh

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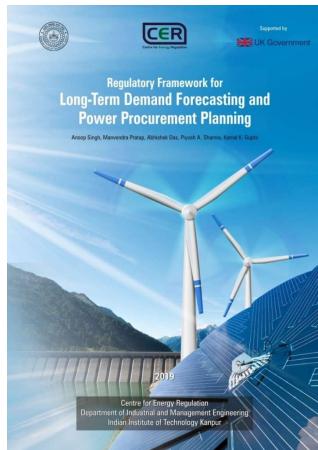
Indian Institute of Technology Kanpur

09-03-2021

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Monograph – ‘Regulatory Framework for Long-term Demand Forecasting and Power Procurement Planning’



conclude that some of the EPS had overestimated the demand for electricity. As shown in Figures 1 and 6 and Table 2 and 3, the 18th EPS had significantly overestimated the electricity demand, actual demand growth was much lower than expected. Therefore, demand projections in the 17th EPS were more accurate than the 18th EPS. The projected peak electricity demand in the 18th EPS was higher than the actual values of demand in the 18th EPS were closer to the actual values during the initial years, but there were significant deviations in the subsequent years. Compound Average Growth Rate (CAGR) of the projected peak electricity demand in the 18th EPS was 5.23 percent, whereas the CAGR of actual peak electricity demand in the 18th EPS was 5.28 percent. Moreover, the CAGR of peak demand for 2010–11 to 2014–15 was 5.23 percent, whereas the CAGR of actual peak electricity demand was 5.28 percent.

Table 2: Comparison of electricity demand projections in 18th and 19th EPS Reports

Year	Actual Peak Electricity Demand (MW)	18 th EPS		19 th EPS		Difference between 18 th and 19 th EPS Peak Electricity Demand (MW)		
		Overshooted	Projected	Overshooted	Projected	(4) + (2) - (1)	(6) + (2) - (5)	(7) + (3) - (5)
2010-11	1,13,562	1,13,562	1,13,562	1,13,562	1,13,562	0	0	0
2011-12	1,30,206	1,32,683	1,30,206	1,32,683	1,32,683	2,479	0	0
2012-13	1,34,413	1,43,967	1,34,413	1,43,967	1,43,967	9,554	0	0
2013-14	1,48,166	1,63,770	1,48,166	1,63,770	1,63,770	15,604	0	0
2014-15	1,48,166	1,83,493	1,48,166	21,223	21,223	-35,270	0	0
2015-16	1,53,562	1,83,962	1,53,562	1,61,434	1,61,434	2,292	17,700	17,700
2016-17	1,64,066	2,34,093	1,64,066	19,027	1,76,497	12,811	17,796	17,796
2017-18	1,64,066	2,34,093	1,64,066	20,927	1,82,024	11,997	17,979	17,979
2026-27	4,00,703	—	4,00,703	2,96,774	2,96,774	1,03,931	—	—

Source: 18th and 19th EPS (Electric Power Survey of India, ESI/U)

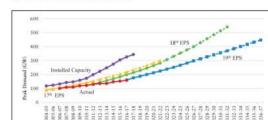


Figure 1: Historical projections of annual peak electricity demand (all India)
Source: Ministry of Power, Government of India (2019), State of Indian Electricity Sector (SIES) – 2019 (2019-20), and Conservation Balance Report (CBR), CSE (2019).

Recommendations
Based on the projected electricity demand, power procurement portfolio till 2026-27 was recommended for the realistic scenario, considering policy targets for RE and DSM, under two scenarios and to reduce short-term power procurement – as represented in Figures 26 and 27 respectively.



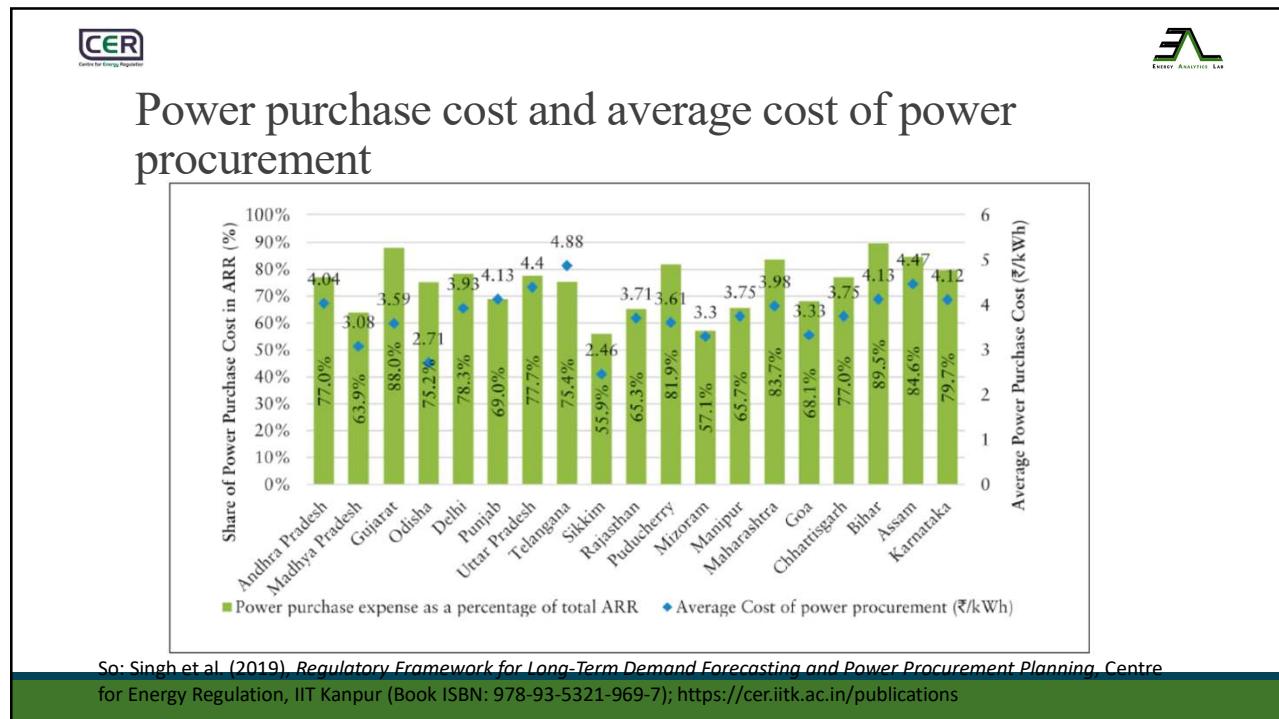
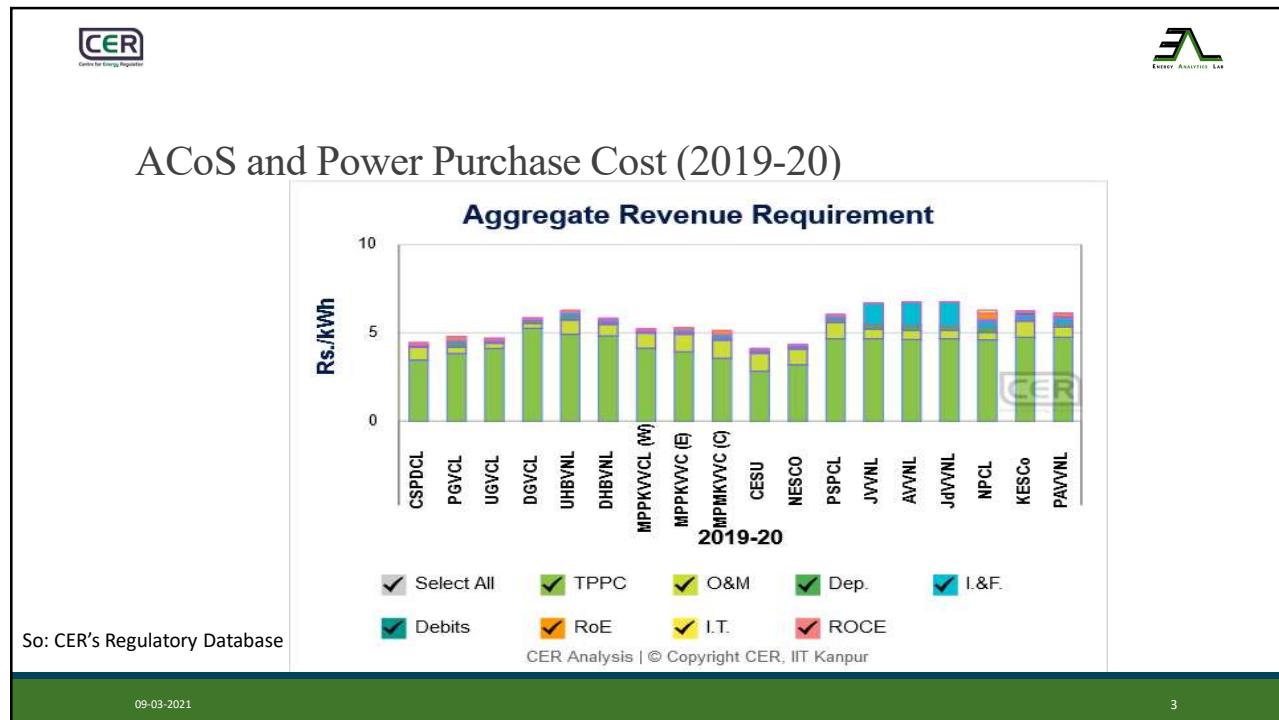
Figure 26: Realistic Growth – Policy target (with Short-term Power Procurement)



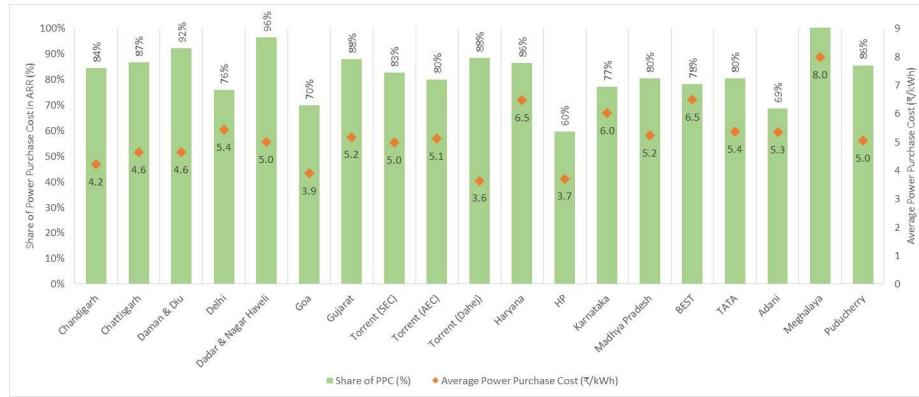
Figure 27: Realistic Growth – Policy target (without Short-term Power Procurement)

A number of alternative strategies included freezing the candidate plants to minimise the overall private and social costs. Based on the findings of the study, realising significantly higher economic benefits for the full-fuse option procurement strategy, it was suggested that the distribution utilities should undertake such as review more frequently.

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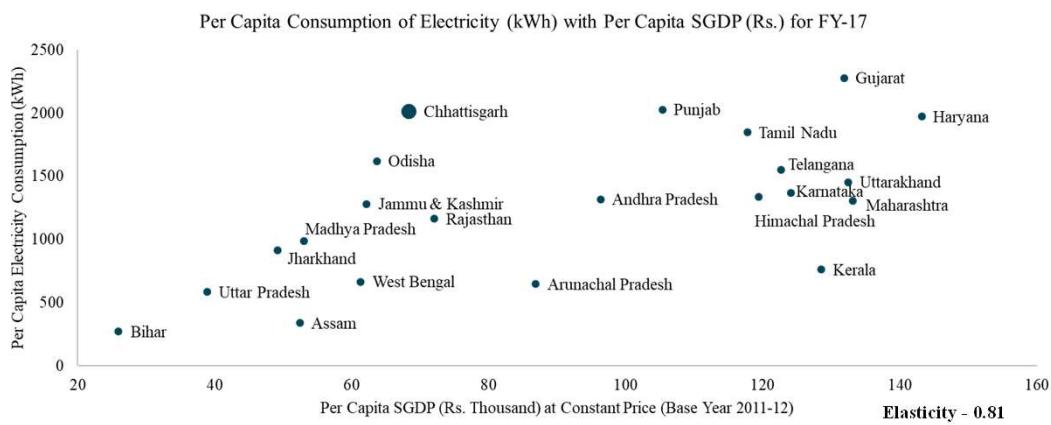


ACoS and Share of Power Purchase Cost (2020-21)



So: CER's Regulatory Database

States - Per Capita Electricity Consumption with Per Capita SGDP



Electricity Demand Forecasting in India

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Legislative and Policy Framework for LT DF and PPP Electricity Act, 2003

Section 61 (c) - ...State/Central/Joint Electricity Regulatory Commissions (SERCs/CERC/JERCs) to encourage competition, and consider efficiency, economical use of resources, better performance and optimum investments while determining tariff.

Section 62 (1) empowers ERCs to determine tariff for licensees and regulate the power purchase process.

Section 73(i) entrusts Central Electricity Authority (CEA) to carry out studies pertaining to cost, efficiency, competitiveness and associated matters which implicitly refers to load forecasting and power procurement planning.



Legislative and Policy Framework for LT DF and PPP (contd.)

National Electricity Policy, 2005: NEP also directs CEA to make short-term and long-term demand projections

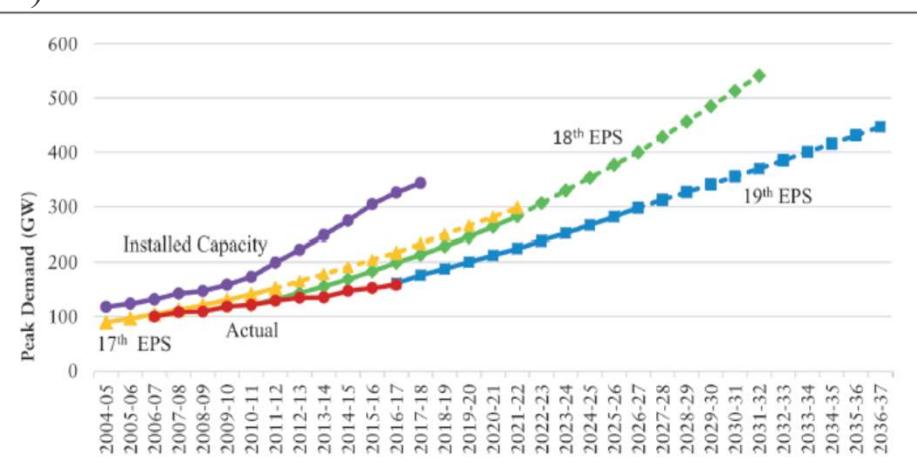
Tariff Policy, 2006: Silent on demand forecasting or power procurement planning.

Tariff Policy, 2016:

“The appropriate Commissions must mandate DISCOMs to undertake the exercise of load forecasting and power procurement planning every year”

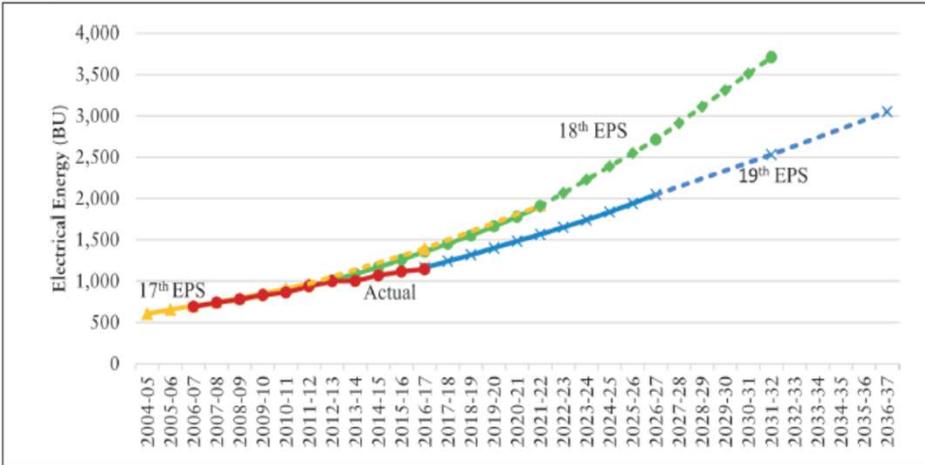


Historical projections of annual peak electricity demand (All India)



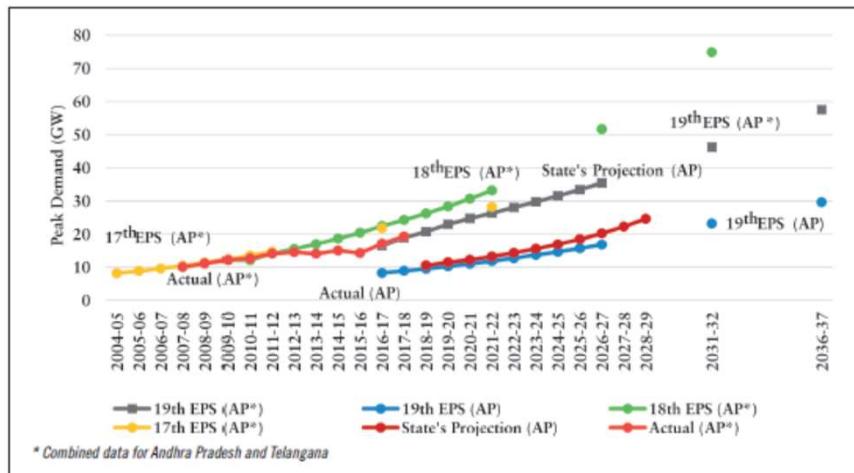
So: Singh et al. (2019), *Regulatory Framework for Long-Term Demand Forecasting and Power Procurement Planning*, Centre for Energy Regulation, IIT Kanpur (Book ISBN: 978-93-5321-969-7); <https://cer.iitk.ac.in/publications>

Historical projections of annual peak electricity demand (All India)

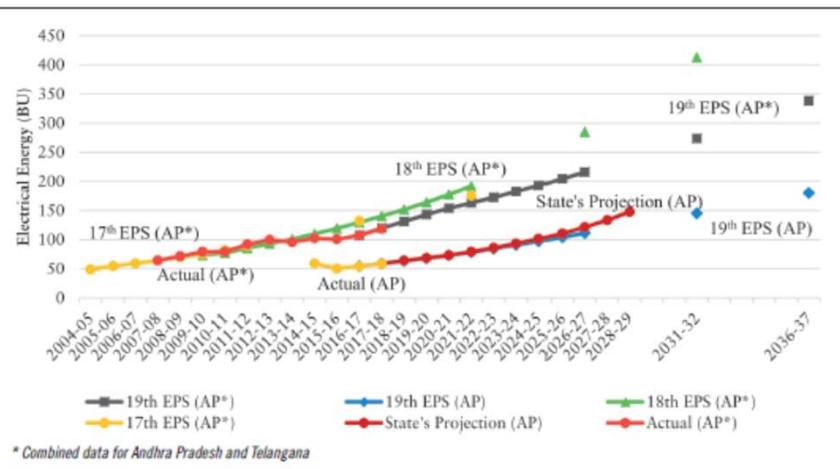


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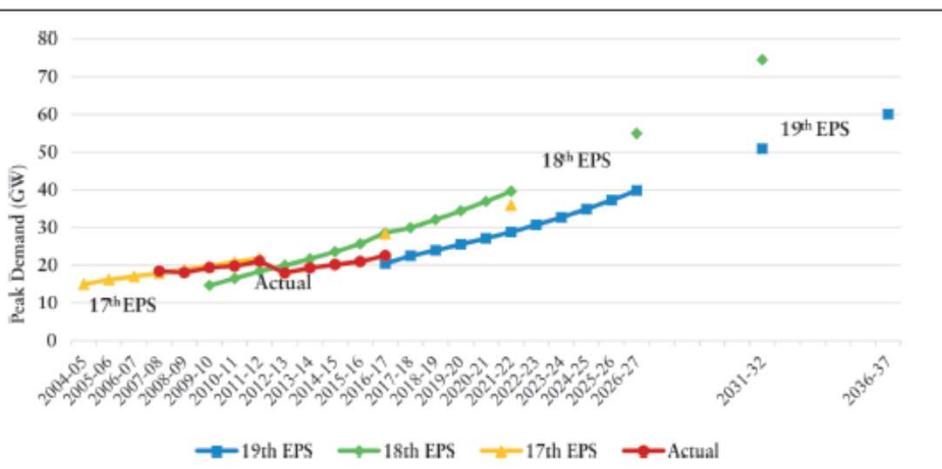
Actual peak demand vs. projections (Andhra Pradesh)



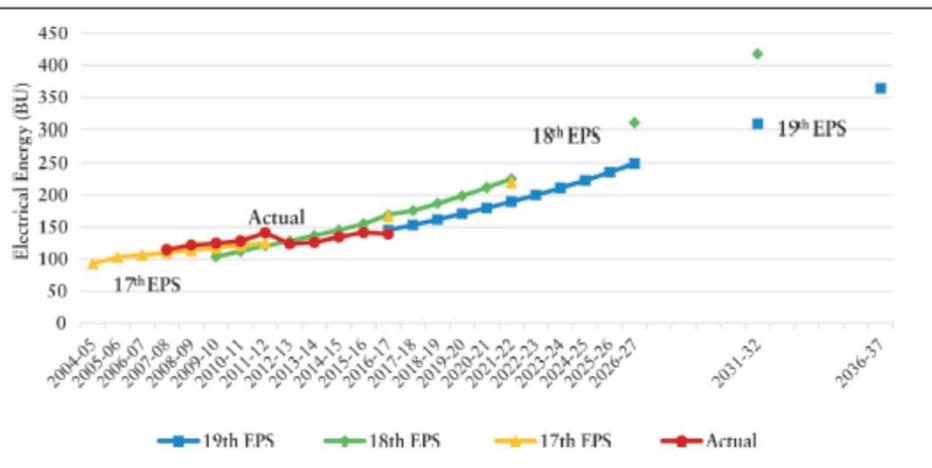
Actual electrical energy requirement vs. projections (Andhra Pradesh)



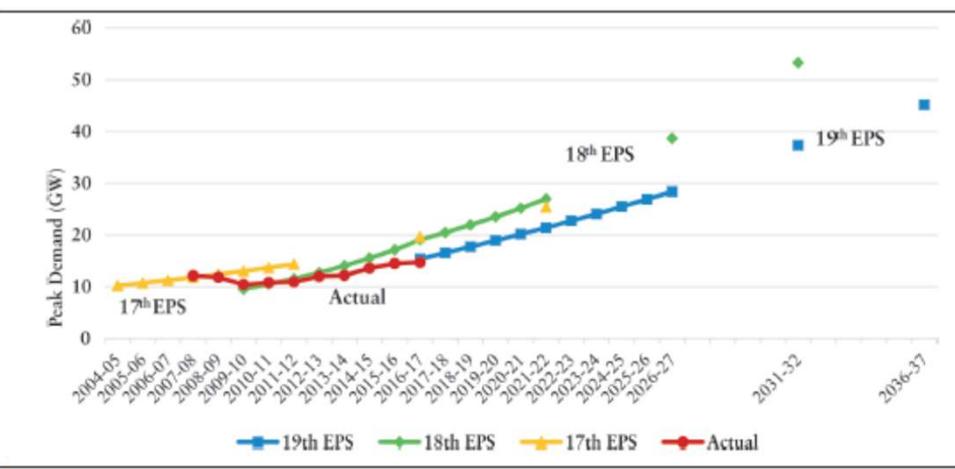
Actual peak demand vs. projections (Maharashtra)



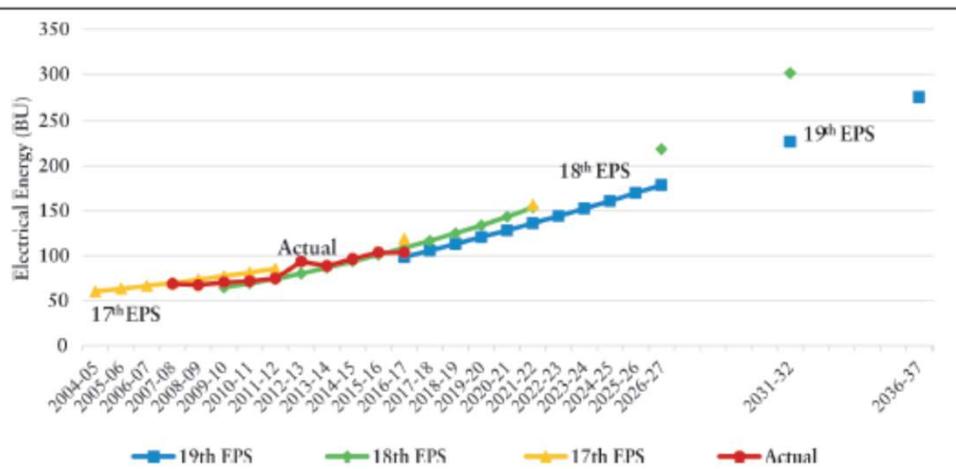
Actual electrical energy requirement vs. projections (Maharashtra)



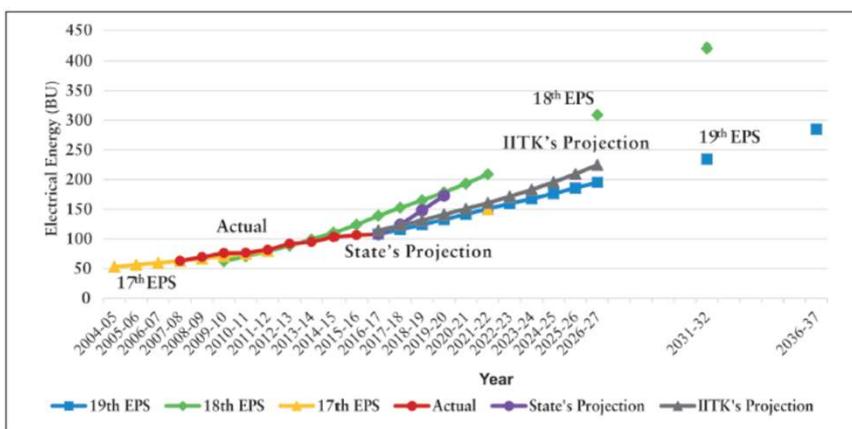
Actual peak demand vs. projections (Gujarat)



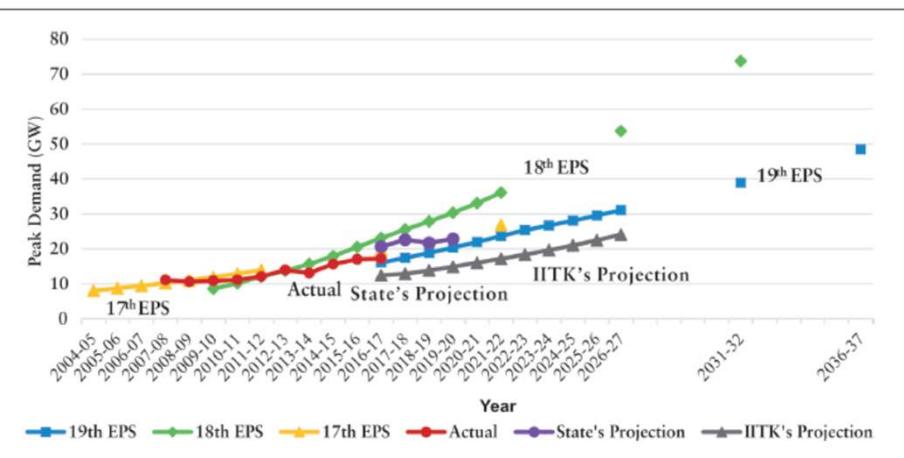
Actual electrical energy requirement vs. projections (Gujarat)



Actual electrical energy requirement vs. projections (UP)

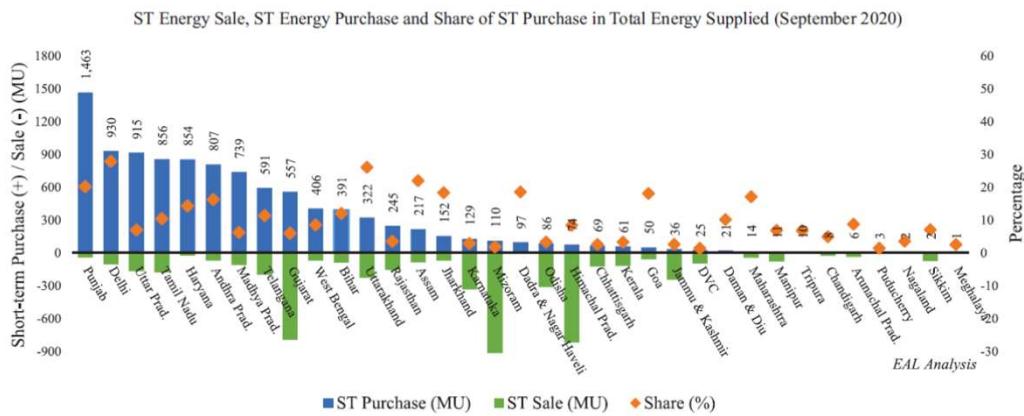


Actual peak demand vs. projections (UP)



Long-term Demand Forecasting and Power Procurement Planning – For State Utilities

ST Energy Sale/Purchase and Share of ST Purchase in Total Energy Supplied (Sept. 2020)

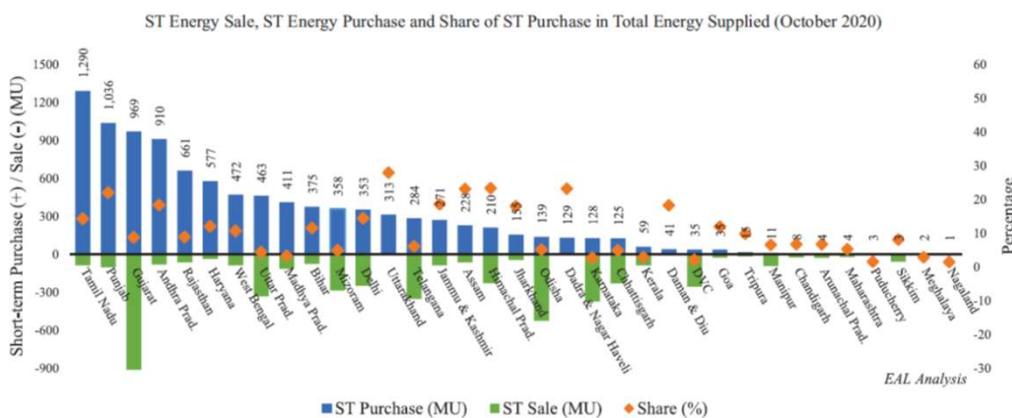


So: Power Chronicle Vol 3(3), EAL's Newsletter accessible at https://eal.iitk.ac.in/assets/docs/power_chronicle_vol_3_issue_3.pdf

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ST Energy Sale/Purchase and Share of ST Purchase in Total Energy Supplied (Oct. 2020)



So: Power Chronicle Vol 3(3), EAL's Newsletter accessible at https://eal.iitk.ac.in/assets/docs/power_chronicle_vol_3_issue_3.pdf

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LTDF and PPP - No One Size Fit All

UTTAR PRADESH

- Composition of SGDP – high agri and services
- Low share of industrial consumers in electricity consumption
- Higher proportion of domestic consumers
- Generally power shortage
- Significant number of new consumers added (domestic)
- ST power procurement and sale

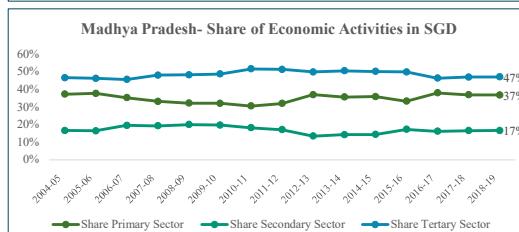
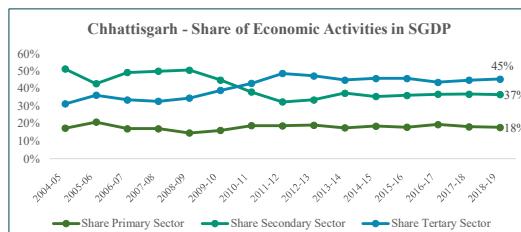
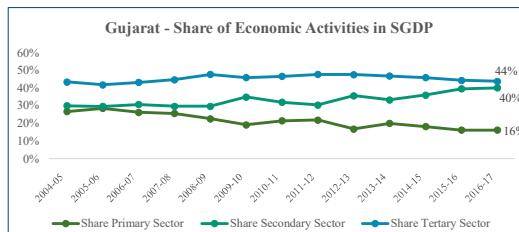
CHHATISGARH

- Composition of SGDP – very high Industrial
- High share of industrial consumers in electricity consumption
- Generally power surplus
- Significant number of new consumers added (domestic)
- Significant captive power generating capacity
- ST power sale and procurement

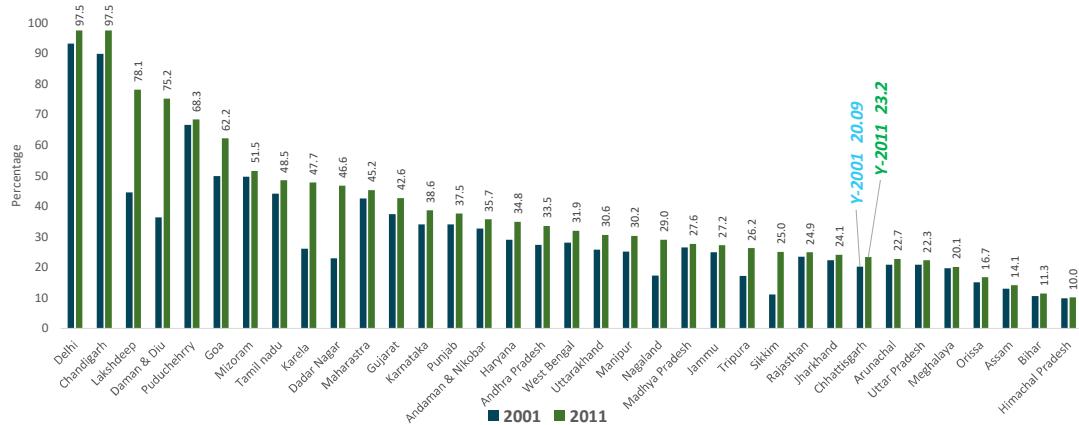
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Economic Activities Share in SGDP



Urbanisation

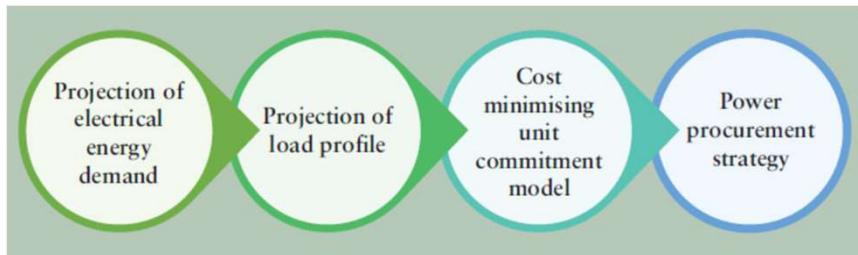


Source: Census 2001, Census 2011

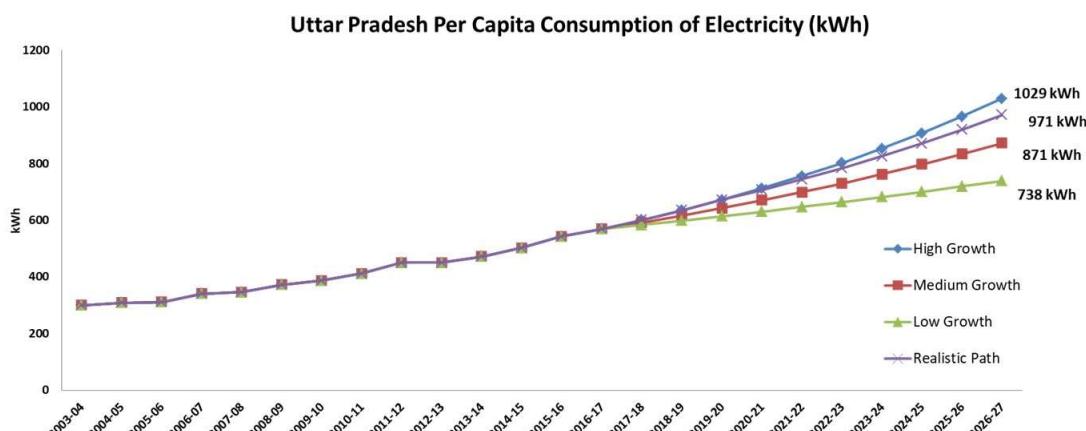
LTDF and PPP - Case Study of Uttar Pradesh

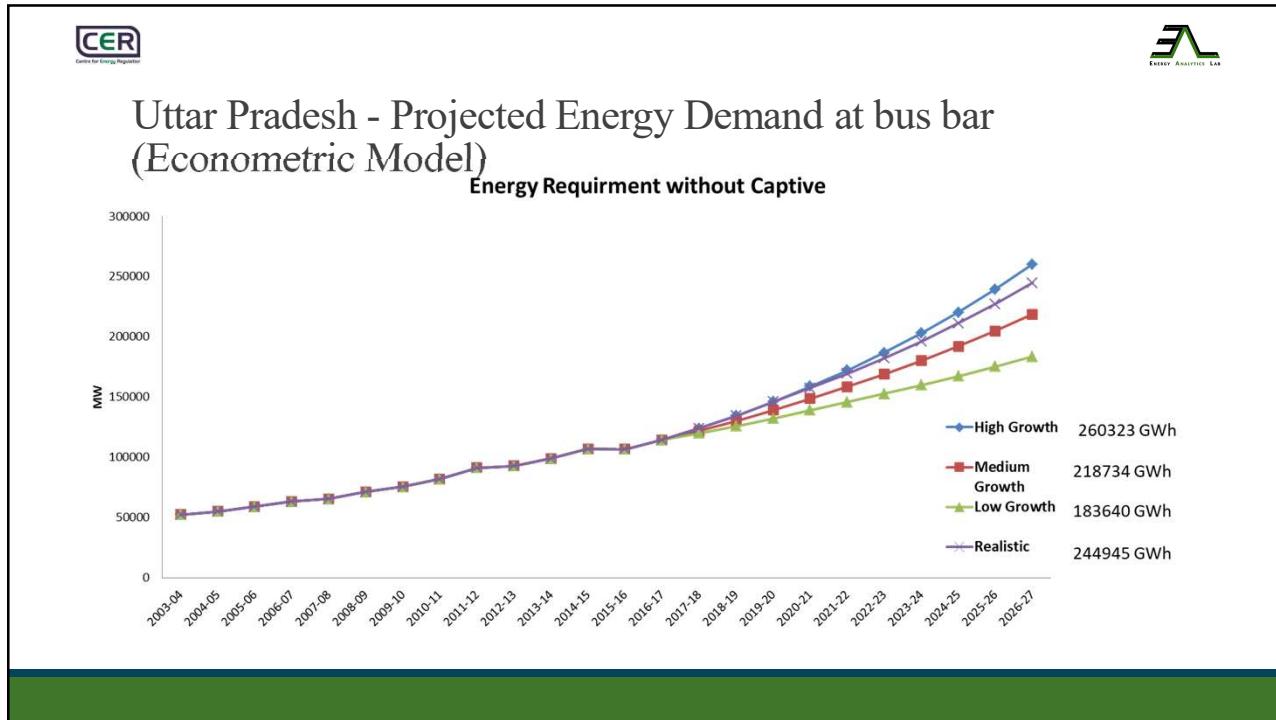
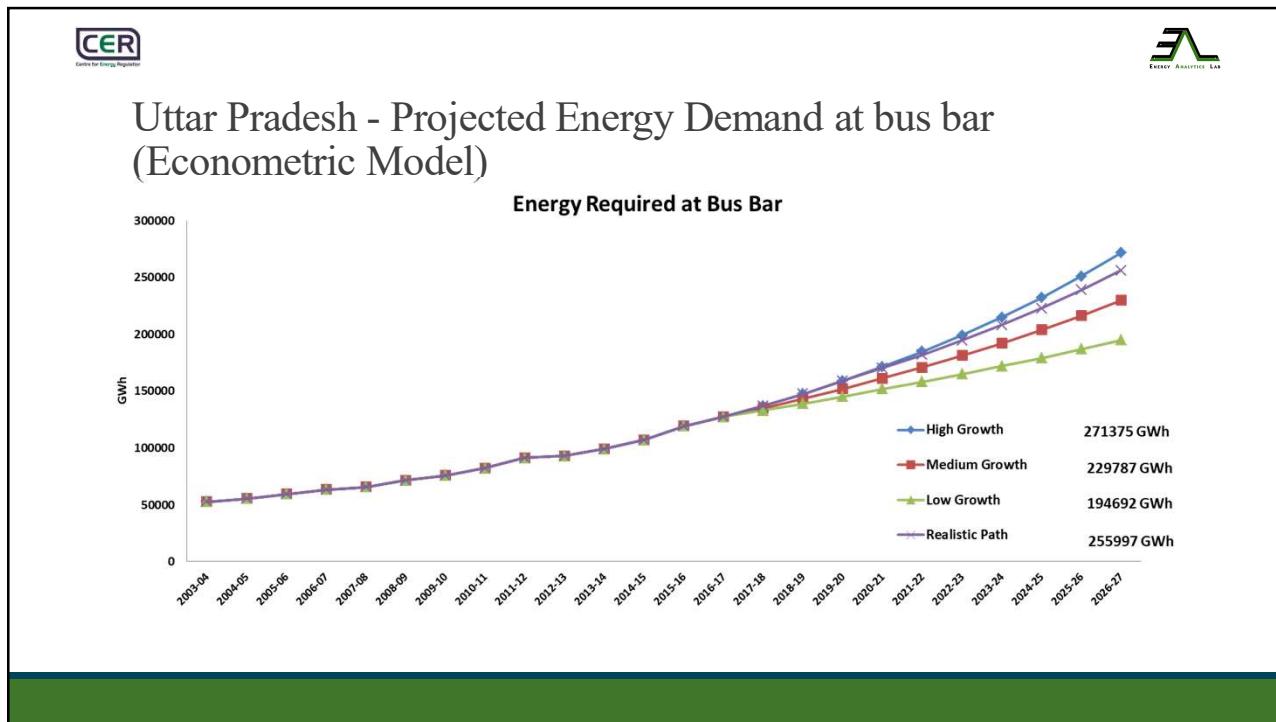
OBJECTIVE – NEW CAPACITY ADDITION

Approach for formulating power procurement strategy



Uttar Pradesh - Projected Values at bus bar (Econometric Model)







UP's Projected Electricity Demand - Comparison

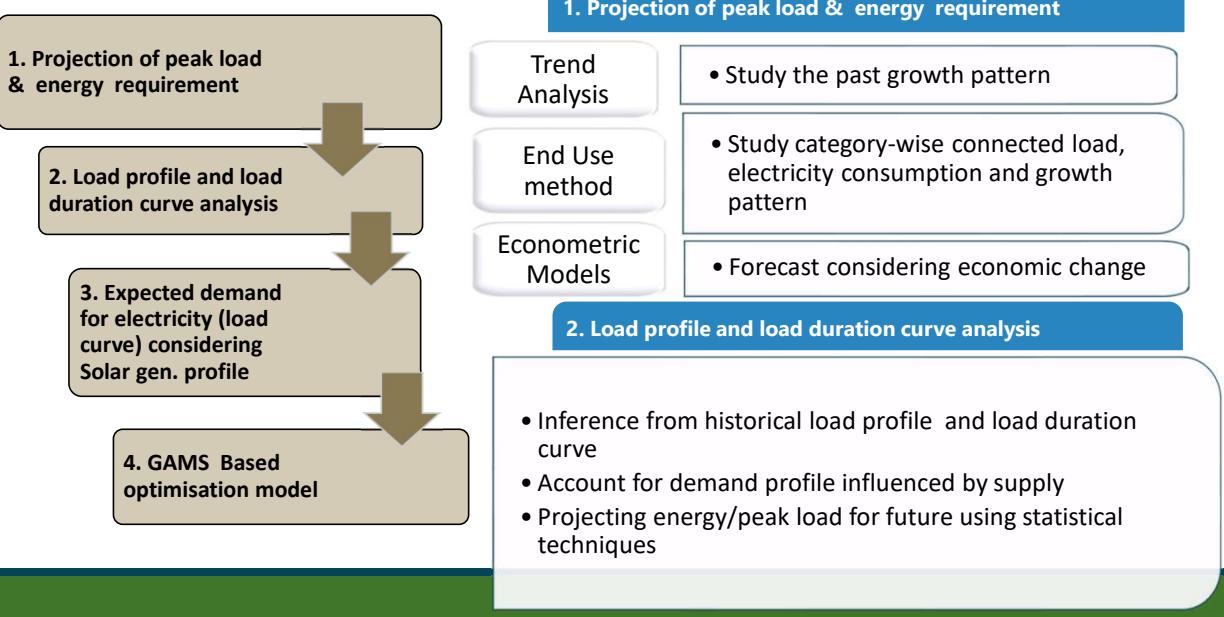
FY	Compassion Projected Energy (19 th EPS vs Estimated Value) GWh				
	CEA		Econometric model results (IIT Kanpur)		
	19 EPS	Realistic	High	Medium	Low
2016-17	108070	114512	114512	114512	114512
2021-22	150797	163562	166115	153757	142298
2026-27	195323	227838	244238	206808	175223

Note: For utilities only
 * Without Captive Generation

Projected Total sales (In MU)			
FY	PFA	Econometric Model	Δ %
2016-17	83,789	92882	11%
2017-18	95,131	101267	6%
2018-19	1,03,173	110511	7%
2019-20	1,16,385	120706	4%
2020-21	1,26,046	130958	4%
2021-22	1,36,700	141753	4%

Note: Energy sold
 * Without Captive and losses

Methodology



Methodology (continued)

3. Expected demand and load profile

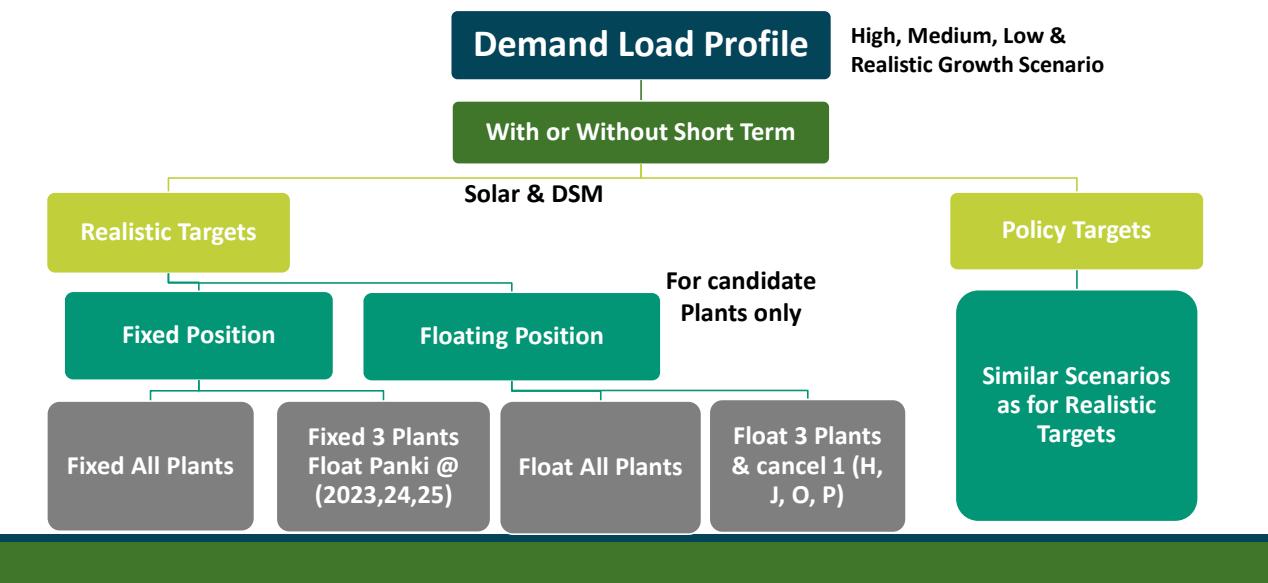
- Solar capacity and projected addition
- Solar generation curve and its effect on load profile
- Impact of ToD

4. GAMS Based optimisation model

- Projected Load profile
- Existing and candidate power procurement sources
- Cost of power procurement variables (base charge, Escalation factor, fixed & variable cost)
- Impact of RE and RTSPV Penetration

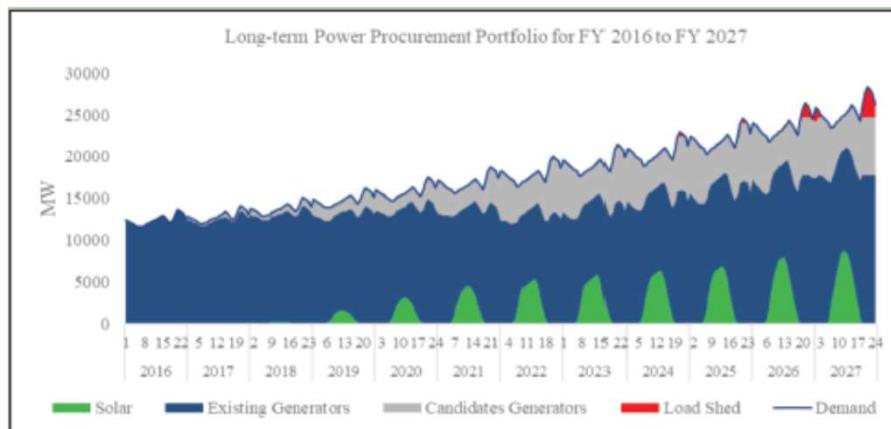


GAMS Simulation for Different Scenarios

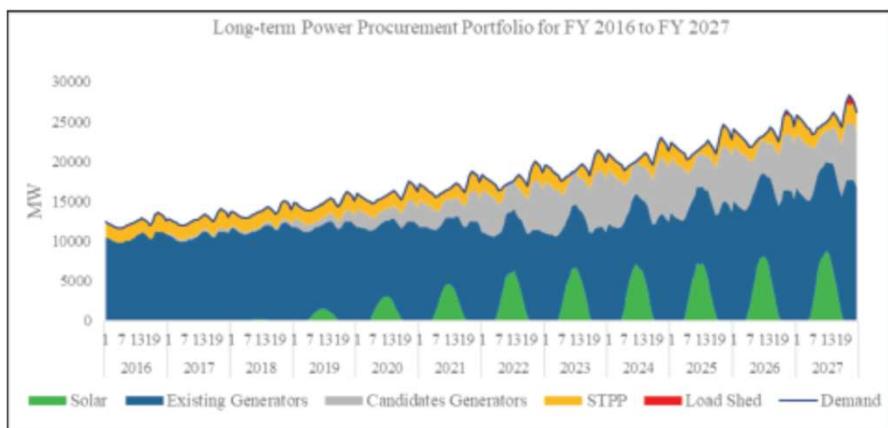




UP's LT Power Procurement Portfolio Realistic Growth – Policy Target (w/o Short-term Power Procurement)



UP's LT Power Procurement Portfolio Realistic Growth – Policy Target (with Short-term Power Procurement)



LTDF and PPP - Case Study of Chhattisgarh

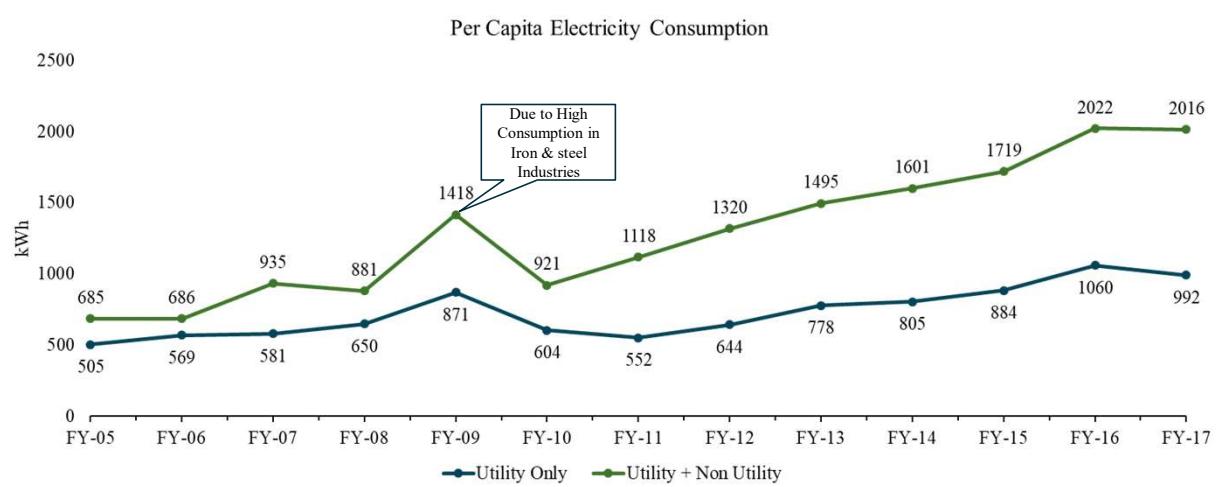
OBJECTIVE - SALE OF SURPLUS POWER

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Per Capita Annual Electricity Consumption - CS



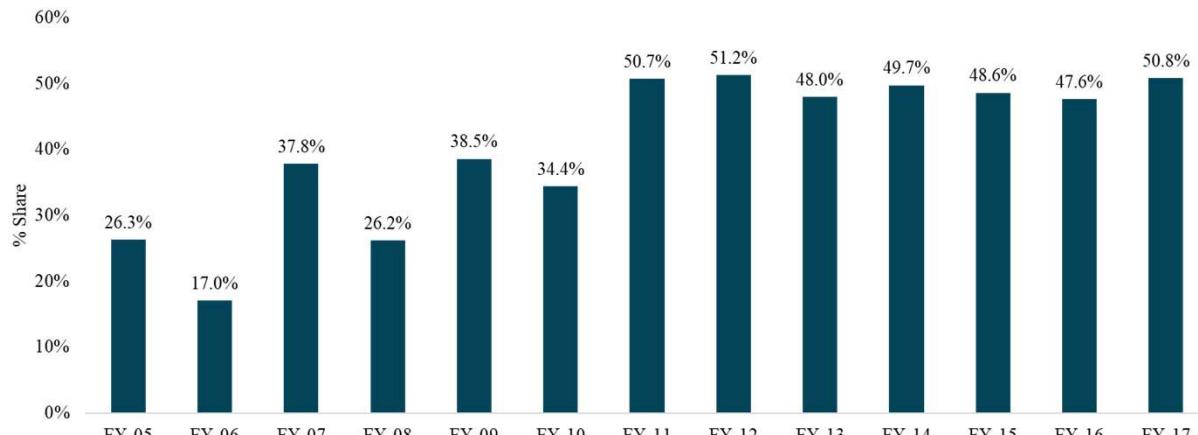
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Share of Self Generating Industries in Total Energy Requirement for State

Share of Self Generating Industries in Total Energy Requirement for State



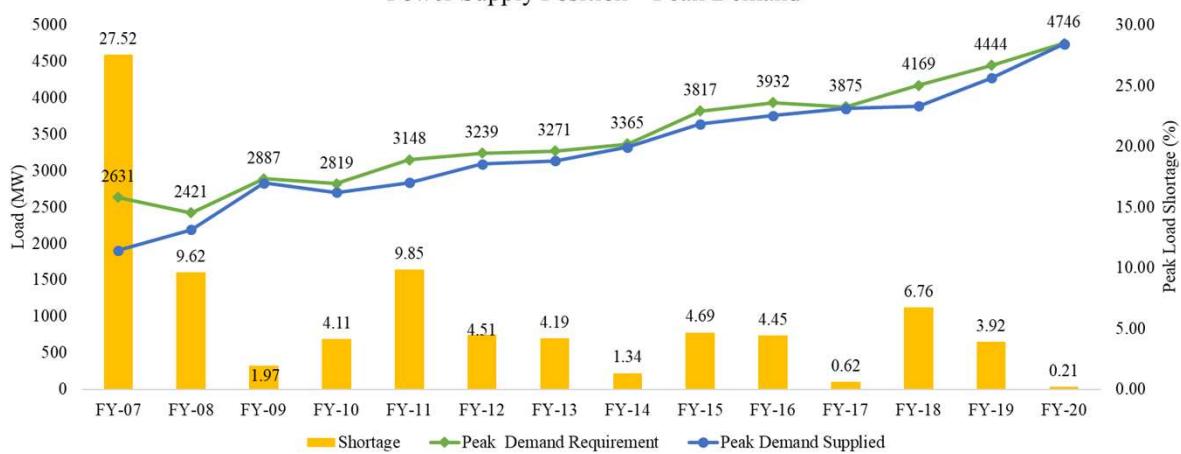
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Power Supply Position – Peak Demand at State Periphery

Power Supply Position – Peak Demand

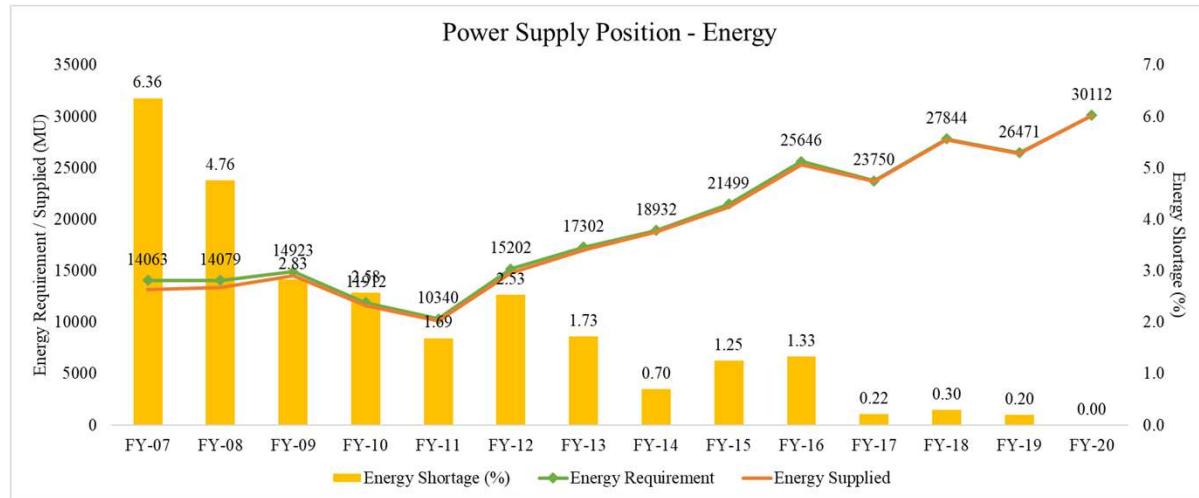


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Power Supply Position – Energy at State Periphery



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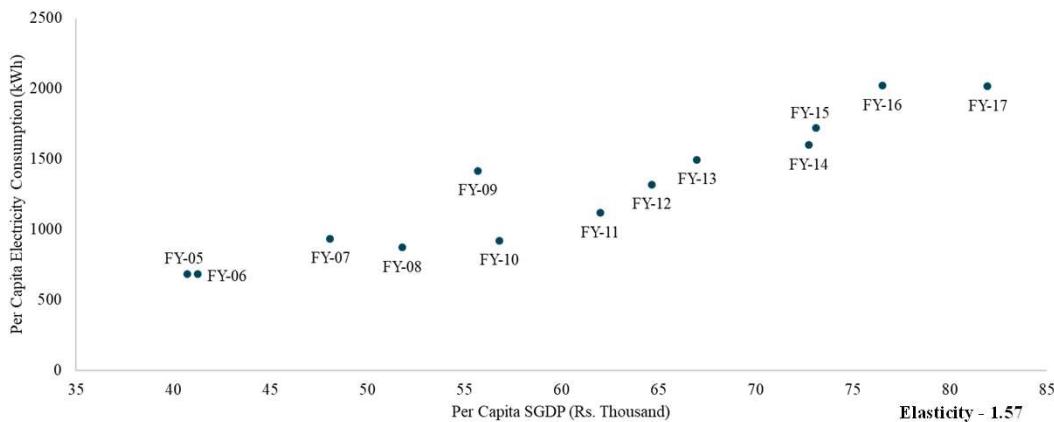
Econometrics Model for Estimating Long-term Energy Requirement

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Chhattisgarh Per Capita Electricity Consumption with Per Capita SGDP (Base year 2011-12)



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Functional form of Econometric Model

$$Q = f(SGDP, P, U, Ps, Ss, T, D)$$

Q – Per capita Electricity Consumption

SGDP – Per Capita SGDP (Rs.)

P – Electricity Price (Rs./kWh)

U – Urbanisation (%)

Ps – Share of Primary Sector in SGDP (%)

Ss – Share of Secondary Sector in SGDP (%)

D - Entity fixed dummy variables (Binary)

T - Time

Log-Log Model Used for Analysis

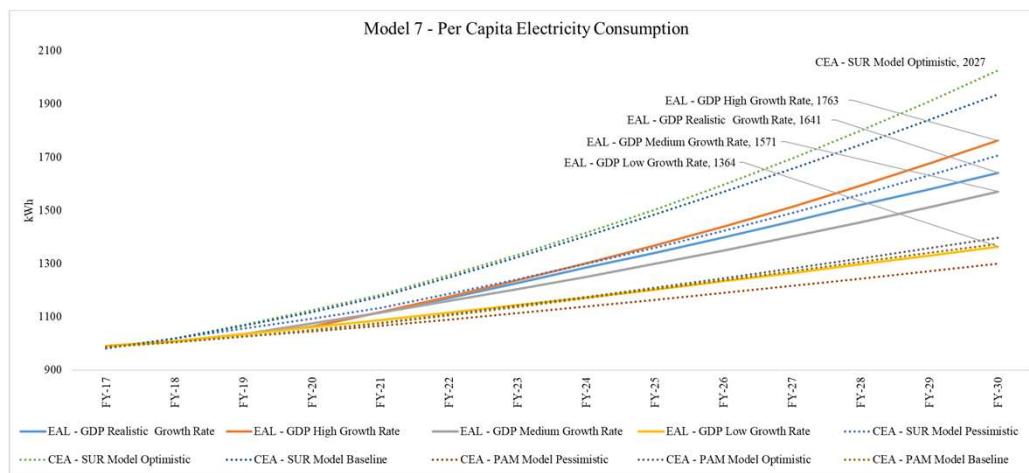
$$\log(Q) = f(\log(SGDP), \log(P), U, Ps, Ss, T, D)$$

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Forecasted Per Capita Electricity Consumption for Utility at Bus-bar - without COVID-19 impact

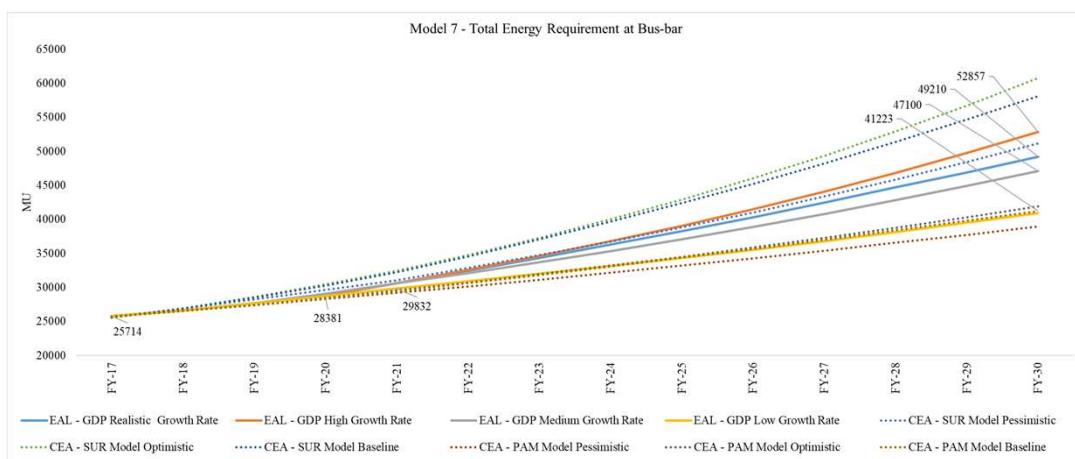


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Forecasted Total Energy Requirement for Utility at Bus-bar (excluding interstate sales) - without COVID-19 impact



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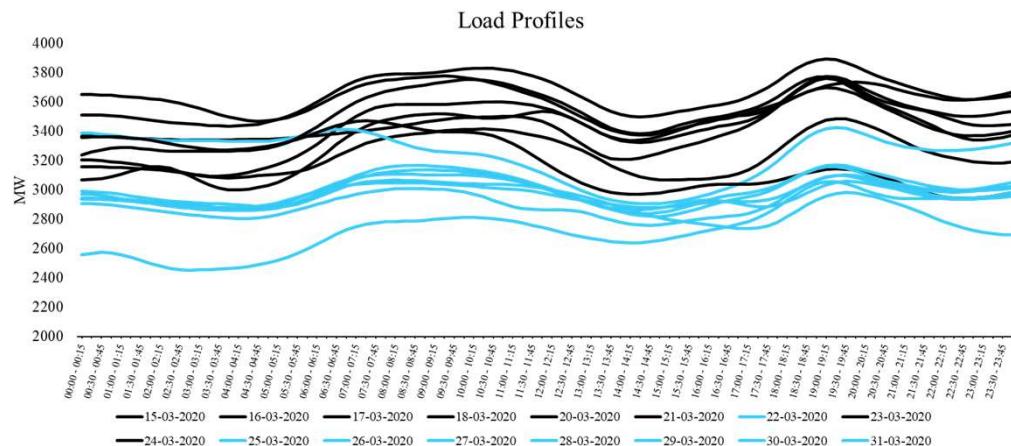
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COVID-19 Impact on Energy Requirement

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Chhattisgarh Load Profile Pre and Post Lockdown

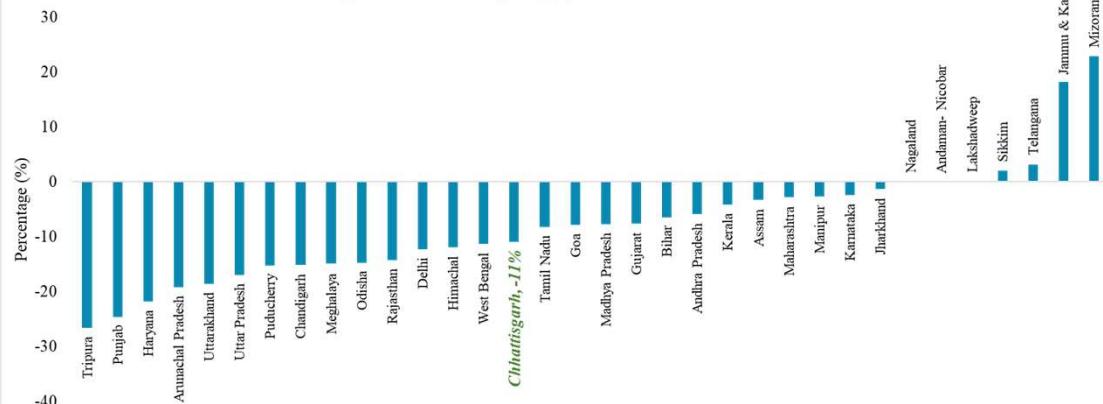


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COVID-19 Impact on State Electricity Demand

Percentage Decline in Energy Supply in March 2020 w.r.t March 2019

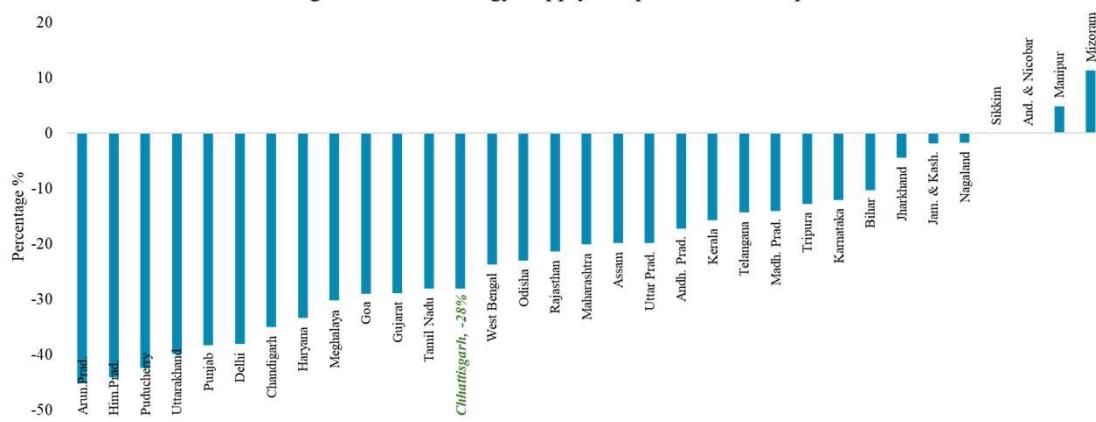


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COVID-19 Impact on State Electricity Demand

Percentage Decline in Energy Supply in April 2020 w.r.t April 2019



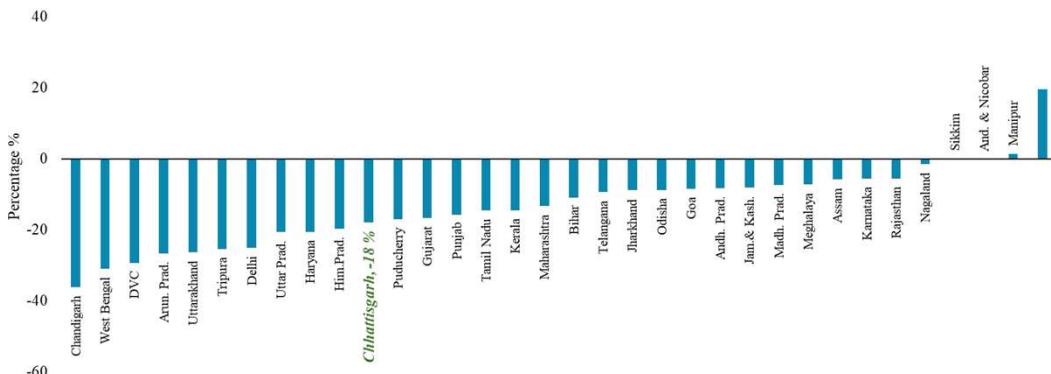
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COVID-19 Impact on State Electricity Demand

Percentage Decline in Energy Supply in May 2020 w.r.t. May 2019



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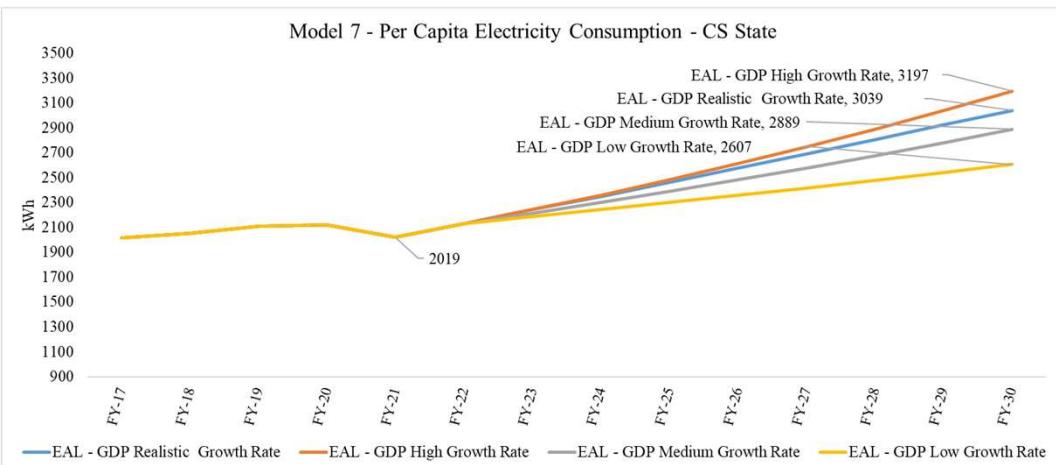
Demand Forecast – Post Covid-19

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Forecasted Per Capita Electricity Consumption for Chhattisgarh State at Bus-bar - with COVID-19 impact

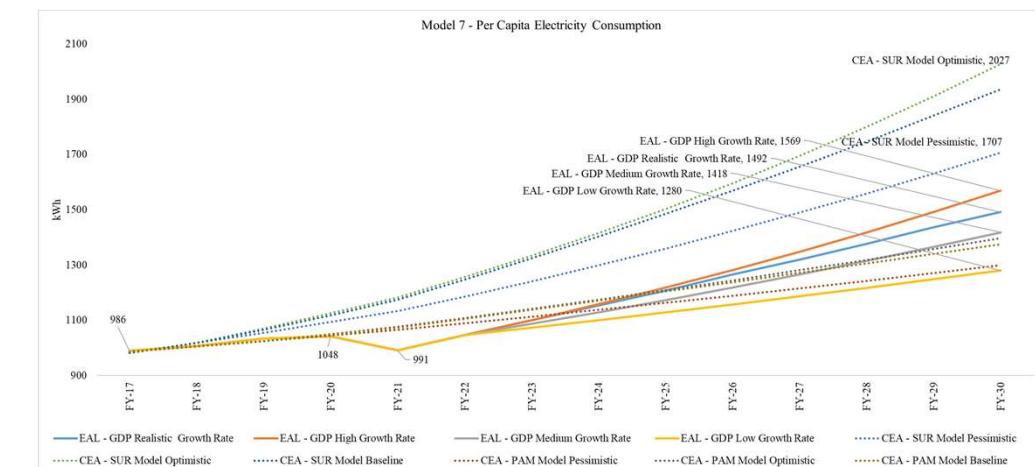


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Forecasted Per Capita Electricity Consumption for Utility at Bus-bar - with COVID-19 impact

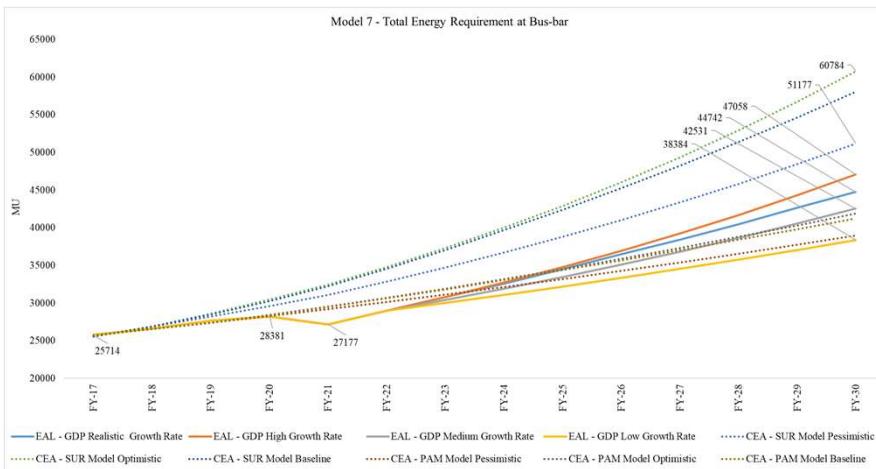


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Forecasted Total Energy Requirement for Utility at Bus-bar (excluding interstate sales) - with COVID-19 impact



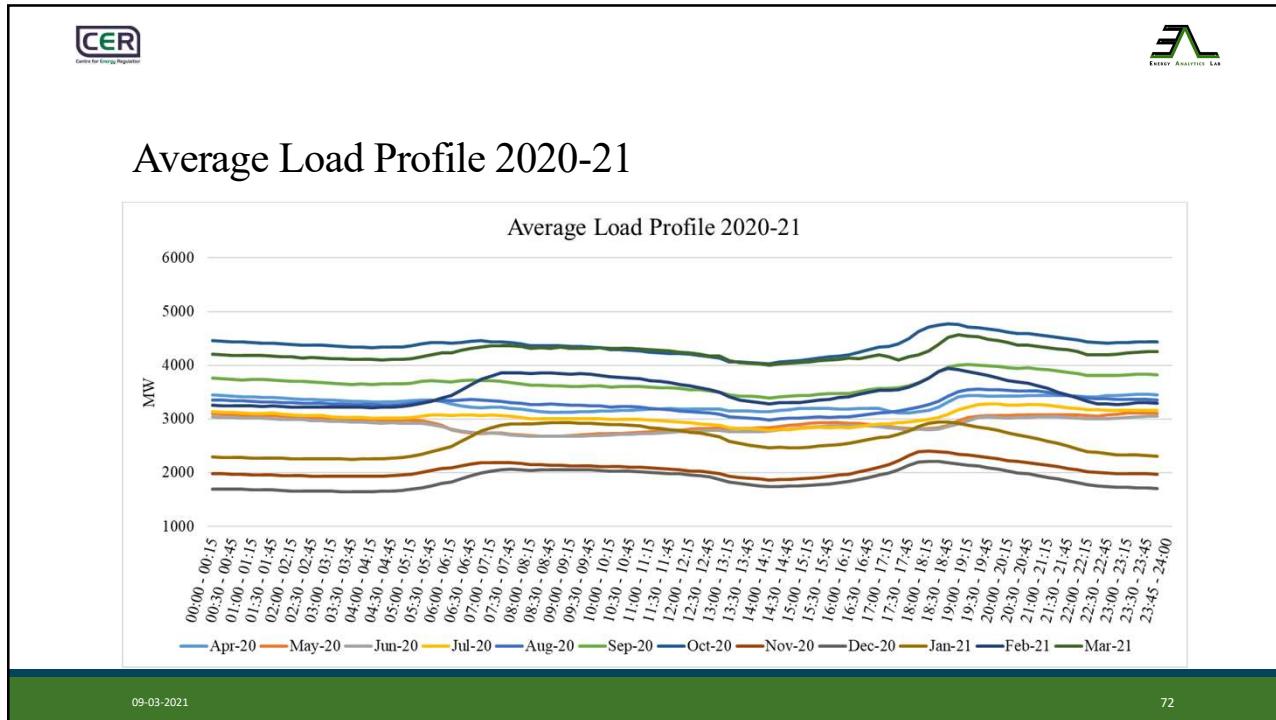
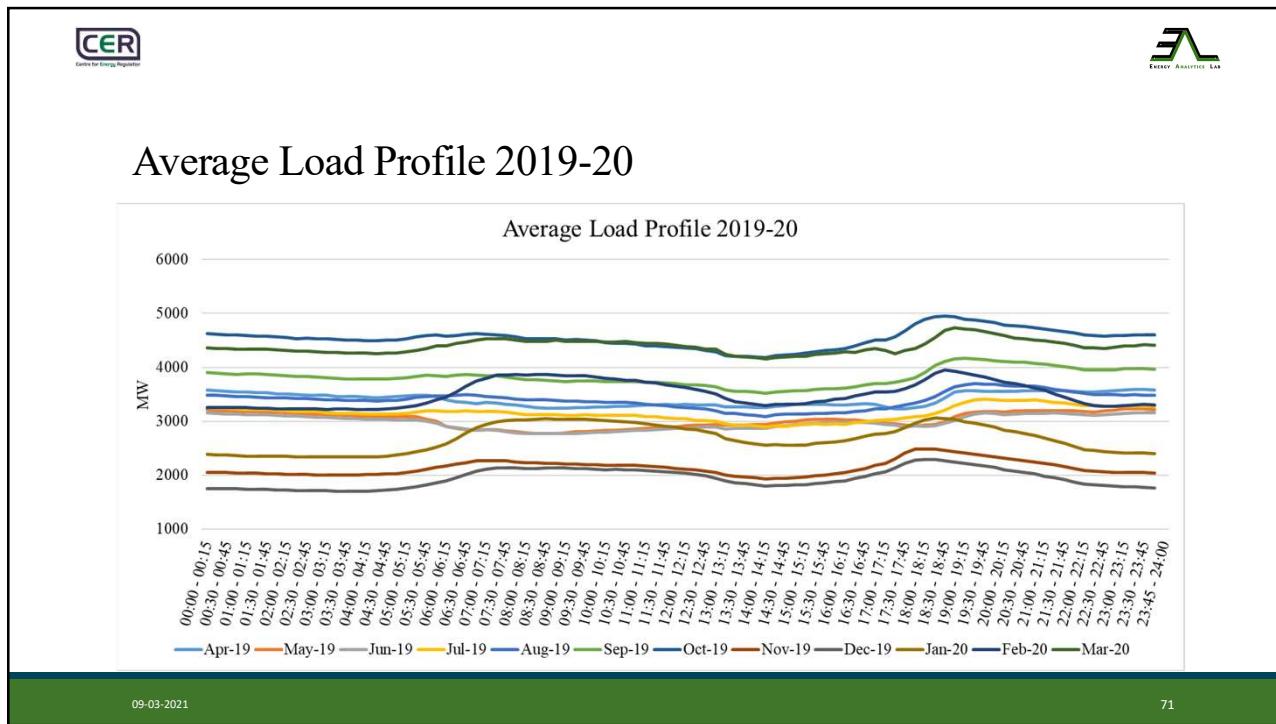
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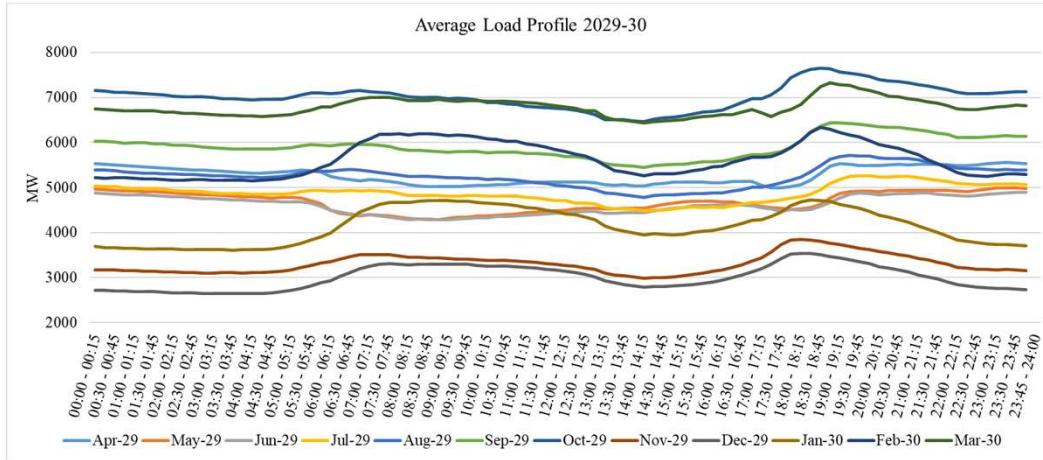


Monthly Load Profile

- Energy distribution is different across month of year based on seasonal demand pattern.
- Energy distribution over months in a year, is calculated from CEA power supply position and daily demand profile
- Future load profiles shape are considered similar to past load profile shape



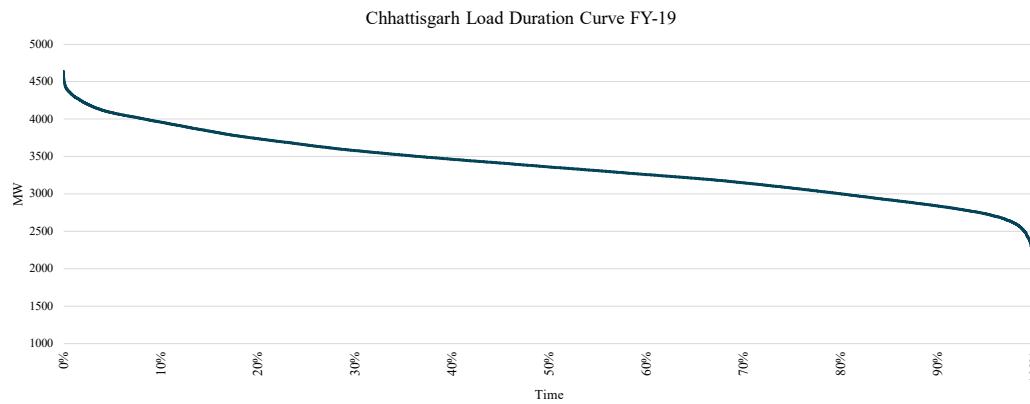
Average Load Profile 2029-30



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Load Duration Curve 2018-19



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Long-term Power Portfolio Optimisation

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Simulation Scenarios

- Scenario 1: Base case
- Scenario 2: Base case + 500 MW solar plant
- Scenario 3: Base case with 50% DC of VRE

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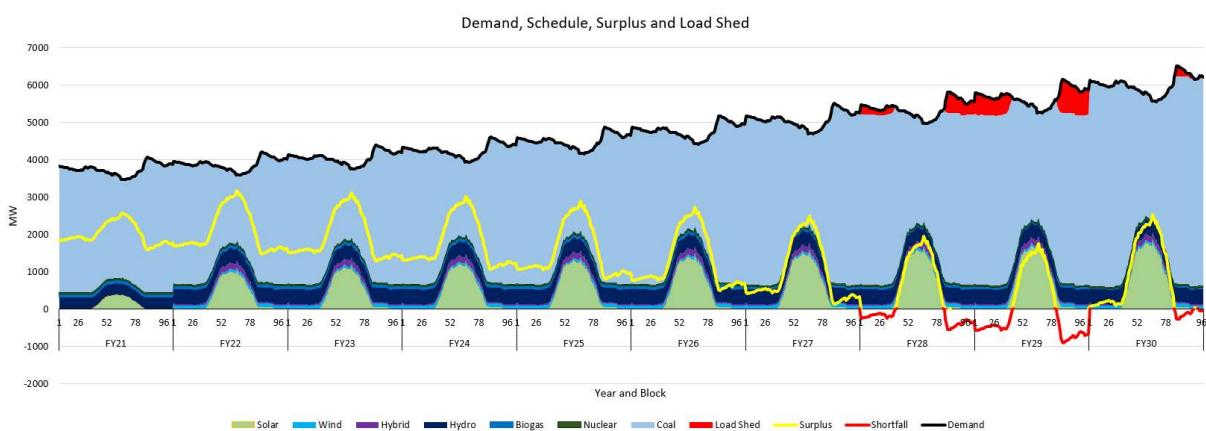
Scenario 1

BASE CASE STUDY

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Modelling Results for Power Supply and Surplus Projection (October)



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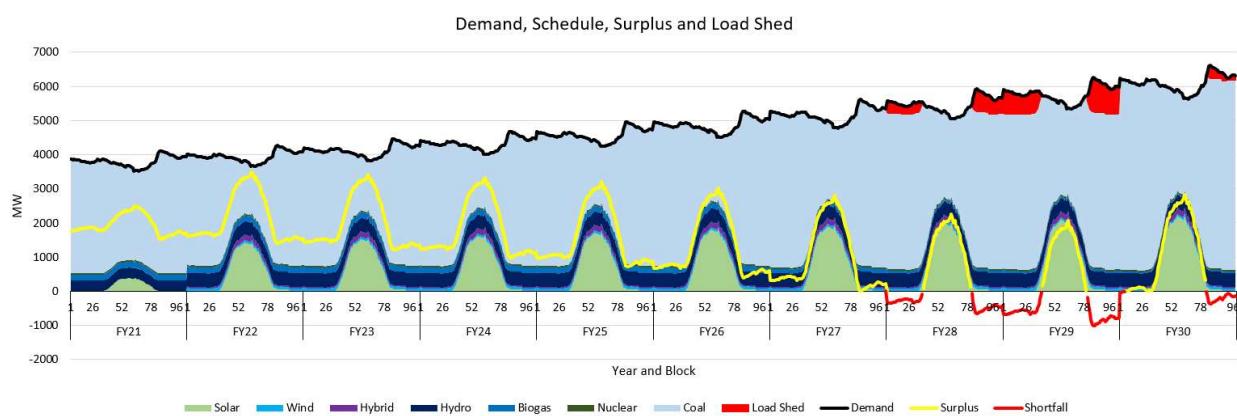
Scenario 2

BASE CASE + 500 MW SOLAR PLANT

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Modelling Results for Power Supply and Surplus Projection (October) – With Additional 500 MW Solar from 2021-22



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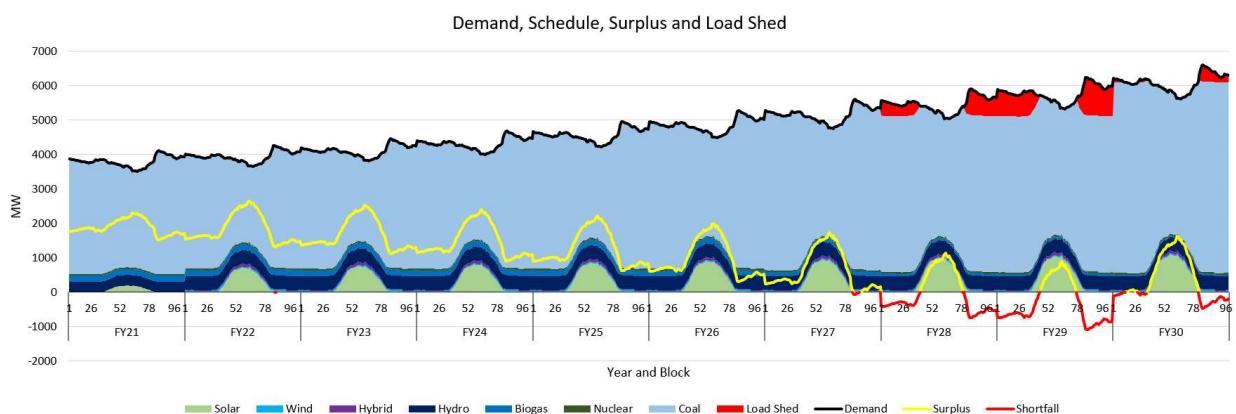
Scenario 3

BASE CASE WITH 50% DC OF VRE

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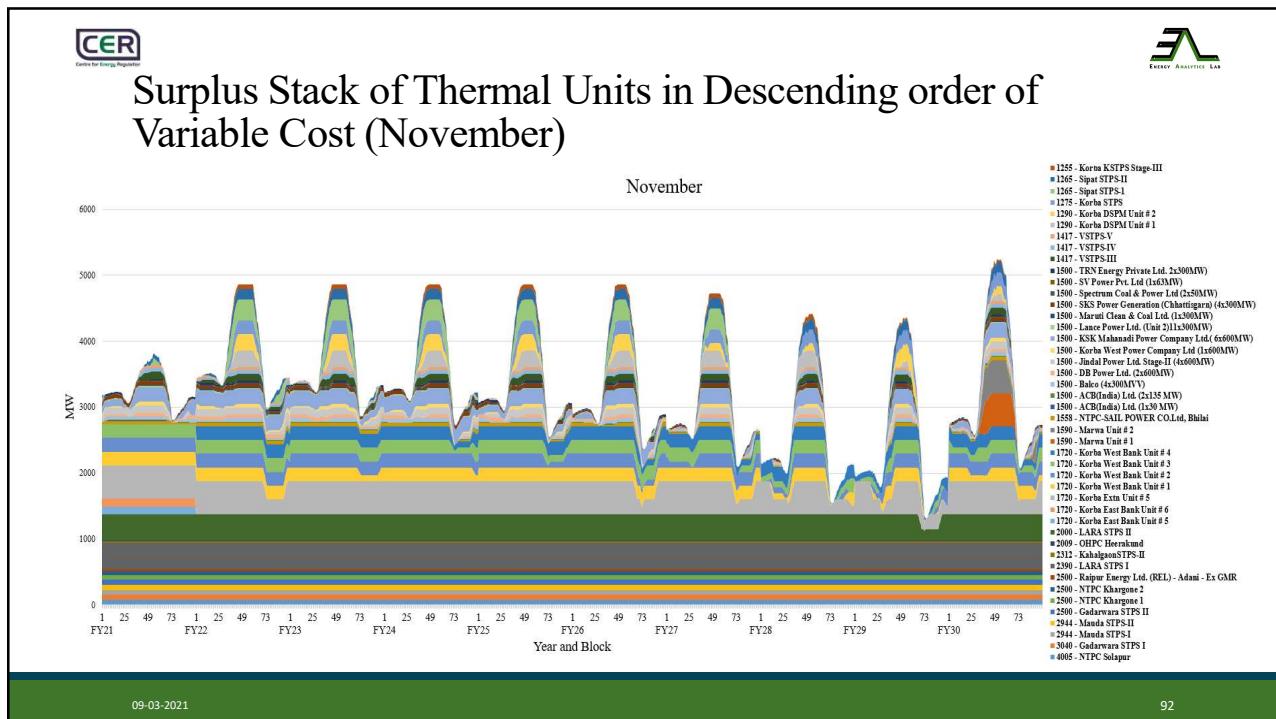
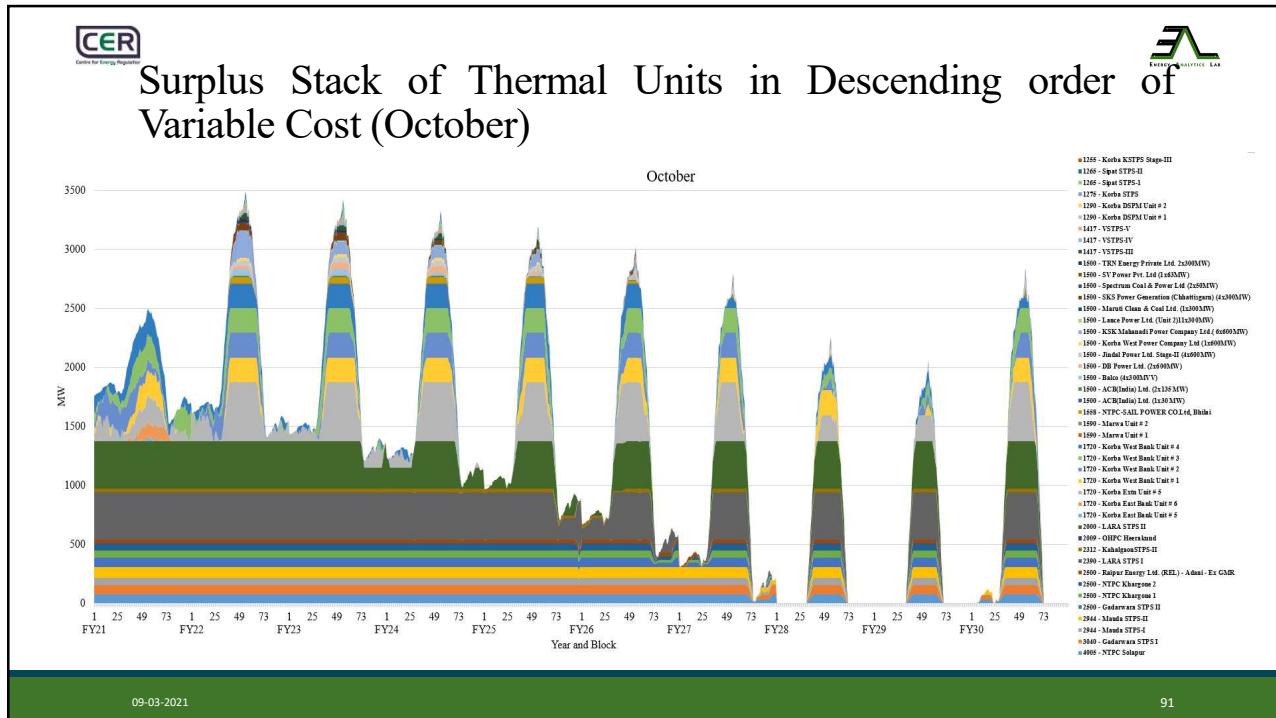
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Modelling Results for Power Supply and Surplus Projection (October) – With VRE at 50% of Original DC



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Regulatory Best Practices for LTDF and PPP

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International regulations on long-term demand forecasting and power procurement planning

	Australia	Japan	Thailand	Singapore	European Countries	California	West Virginia
Objective	Network planning	3E+S (Safety, Energy security, Economic efficiency and Environment)	Energy security, Economy and Ecology	Attracting investment in generation asset	Assessment of electricity generation adequacy	Preparing Integrated Energy Policy Report	Energy security
Responsible organisation	National Transmission Planer (NTP)	Ministry of Economy, Trade and Industry (METI)	Ministry of Energy, along with the Electricity Generating Authority of Thailand (EGAT)	Energy Market Authority (EMA)	European Network of Transmission System Operators for Electricity	California Energy Commission	Public Service Commission of West Virginia
Forecast range	20 years	15 years	20 years	10 years	Seasonal, mid-term, 10 years	12 years	10 years
Frequency of forecast	Annual	Updated at least once in every 3 years	Revised in every 3 years	Annual	Updated annually	Updated annually for the next 10 years	Updated annually
Factors considered for forecast	Economic growth, weather conditions, electricity prices	Economic growth, Energy efficiency and conservation measures, population growth	Social (Population) and economic (long-term GDP) growth, Energy efficiency target, RE development target	Economic and Consumer growth	Economic growth, temperature, policy, demographics	Economics, demographics, weather, electric vehicle, etc.	Consumer growth, Annual growth rate
Peak Load or Energy	Both	Energy	Both	Both	Peak load	Both	Peak load
Forecast scenario	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple	Single
Corrective action(s) for forecast	Not defined	Reviewed at least once in every 3 years	Reviewed once in every 3 years	Annual forecast	Annual update	Annual update	Not defined So: Singh et al. (2019), https://cer.iitk.ac.in/publications

Prevailing practices of LT demand forecasting

State	Agency	Objective	Forecasting Horizon	Deadline	Information/ data Sharing Responsibility	Compliance	Forecasting Methodology	Internal Review	Relevant Regulations
AP	DISCOM and STU	Tariff and transmission planning	10 years; first 5 years – detailed, next 5 years – simple	One year before the start of control period	DISCOM to furnish data to STU and ERC		Not specified	Public consultation; the Commission might need to independently assess, verify and validate	Guidelines for load forecast, resource plans and power procurement, Dec 2006; Reg 4 of 2005; Reg 10 of 2013; Reg 5 of 2005; Transmission and bulk supply licence regulations (17.12), Distribution and retail supply licence regulations (19.2)
DL	DISCOM	MYT and transmission planning	5 years	31st July of the base year	DISCOM to furnish data to ERC		Must consider all consumer types, DSM measures, policies, net metering and economic data		Grid Code; Regulations 5.7, 23.1 and 23.2 of MYT Regulation, 2017
GJ	DISCOMs	Transmission and power procurement planning	10 years; hourly peak and energy for first 5 years, annual peak and energy for next 5 years	31 st January of every year	DISCOM to furnish data to STU SLDC		Trend analysis and reasonable assumptions for future (after considering consumer types, DSM measures, policies and economic data)		Grid Code, 2013; Guideline for power procurement by Distribution Licensee (2 of 2013); Regulations 19.2, 96.1 and 96.2 of MYT Regulations, 2016

Prevailing practices of LT demand forecasting (Contd.)

State	Agency	Objective	Forecasting Horizon	Deadline	Information/ data Sharing Responsibility	Compliance	Forecasting Methodology	Internal Review	Relevant Regulations
MP	DISCOM	MYT and transmission planning	5 years, on a rolling basis	31 st March (DISCOM to STU)	STU to maintain database		DISCOM to adopt appropriate method (Part IV of Power Purchase & Procurement Process Regulations, 2004.)	Operation and Coordination Committee (OCC)	Grid Code; Power purchase & Procurement Process Regulations, 2004
OR	STU and DISCOMs	Transmission planning	First 5 years by DISCOM, next 5 years by STU	31 st Dec (DISCOM to STU), 31 st March (STU to ERC)	DISCOM to furnish data to STU for submitting the compiled data to ERC	STU shall approach OERC in case of non-compliance	Must consider past trends and economic data	Operation and Coordination Committee (OCC)	Clauses 3.10 (1) and (2) and 3.8 of Orissa Grid Code, 2015; Regulations 5 and 7.3 of Terms and Conditions for determination of Wheeling & Retail Supply Tariff, 2014
PB	STU	Transmission and power procurement planning	10 years, month-wise	30 th April (DISCOM to STU), 30 th Nov (STU to ERC)	DISCOM to furnish data to STU for submitting the compiled data to ERC		Month-wise peak/off-peak load considering paddy/non-paddy seasons		Clauses 3.4.3 and 3.5.1 of Grid Code, 2013
UP	DISCOM	MYT	5 years	1 st June (along with business plan)	DISCOM to furnish the forecasts to ERC		Must consider economic indicators of the state		MYT Regulations; Grid Code



Prevailing practices of power procurement planning

	Who	By When	Horizon	Regulations
AP	DISCOMs	One year before the start of the control period	MYT	Guidelines for Load Forecast, Resource Plans and Power Procurement, 2006; Regulations 4 of 2005; Regulations 10 of 2013; Distribution license;
DL	DISCOMs	31 st July	B Plan	Multi-Year Tariff Regulations 2017;
GJ	HoldCo/ DISCOM	31 st Jan	Rolling 5 year	Power Procurement Guidelines 2013; Multi-Year Tariff Regulations 2016;
MP	HoldCo/ DISCOM	31 st Oct	Rolling 5 year	Power Purchase and Procurement Regulations, 2004;
OR	HoldCo	30 th Nov	10 year, revised yearly	Terms and Conditions for determination of Wheeling & Retail Supply Tariff, 2014; Grid Code
PB	DISCOM	30 th Nov	Rolling 10 year	Power Purchase and Procurement regulations 2012;
UP	Holdco/ DISCOM	1 st June	B Plan	MYT Regulations



Recommendations on Regulatory Framework for LT Demand Forecasting

- Overall Scope
- Responsibility
- Forecast Horizon
- Scope of Forecast
- Nodal Entity
- Regulatory Process
- Base Year
- Resource Adequacy
- Methodology



Key factors influencing LT demand

- Existing and expected consumer mix
- Economic activities across key sectors like industrial, agricultural, commercial and transportation, etc.
- Growth in population across rural and urban areas
- Expected changes in lifestyle due to better availability of electricity and technological development
- Growth in open access, captive generation, solar rooftop, storage, retail competition, franchisee, etc.



Key factors influencing LT PPP

- Existing Contractual Agreements
- Network Constraints
- Renewable Energy
- Captive Generation and Open Access
- Disruptive Technologies
- Banking
- Franchisee, Distribution Sub-licensee (proposed), Carriage and Content Separation (future expectation)



Key Regulatory and Policy Takeaways

- Separate and dynamic regulation for LTDF and PPP
- Institutionalising a separate **Regulatory Process for LTDF and PPP**
– incl separate Petition, Public hearing and approval process for the same.
- Data Sharing and Warehousing
- Compliance Monitoring



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