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

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Monograph – ‘Regulatory Framework for Long-term Demand Forecasting and Power Procurement Planning’
ACoS and Power Purchase Cost (2019-20)

Power purchase cost and average cost of power procurement

So: CER's Regulatory Database

States - Per Capita Electricity Consumption with Per Capita SGDP

Elasticity - 0.81
Electricity Demand Forecasting in India

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”

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**Historical projections of annual peak electricity demand (All India)**

[Graph showing historical projections of annual peak electricity demand (All India)]

Historical projections of annual peak electricity demand (All India)

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)


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

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**

Gujarat - Share of Economic Activities in SGDP

Chhattisgarh - Share of Economic Activities in SGDP

Madhya Pradesh - Share of Economic Activities in SGDP

Maharashtra - Share of Economic Activities in SGDP
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)
Uttar Pradesh - Projected Energy Demand at bus bar (Econometric Model)

Energy Required at Bus Bar

- High Growth: 271375 GWh
- Medium Growth: 225787 GWh
- Low Growth: 194692 GWh
- Realistic Path: 255997 GWh

Uttar Pradesh - Projected Energy Demand at bus bar (Econometric Model)

Energy Requirement without Captive

- High Growth: 260323 GWh
- Medium Growth: 218734 GWh
- Low Growth: 183640 GWh
- Realistic: 244845 GWh
UP’s Projected Electricity Demand - Comparison

### Compassion Projected Energy (19th EPS vs Estimated Value) GWh

<table>
<thead>
<tr>
<th>FY</th>
<th>CEA 19 EPS</th>
<th>Econometric model results (IIT Kanpur)</th>
<th>FY</th>
<th>CEA 19 EPS</th>
<th>Econometric model results (IIT Kanpur)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Realistic</td>
<td>High</td>
<td></td>
<td>Medium</td>
<td>Low</td>
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<tr>
<td>2016-17</td>
<td>108070</td>
<td>114512</td>
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<td>114512</td>
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<tr>
<td>2021-22</td>
<td>150797</td>
<td>163562</td>
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<td>166115</td>
<td>153757</td>
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<tr>
<td>2026-27</td>
<td>195323</td>
<td>227838</td>
<td></td>
<td>244238</td>
<td>206808</td>
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</table>

Note: For utilities only
* Without Captive Generation

### Projected Total sales (in MU)

<table>
<thead>
<tr>
<th>FY</th>
<th>PFA</th>
<th>Econometric Model</th>
<th>∆ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-17</td>
<td>83,789</td>
<td>92882</td>
<td>11%</td>
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<tr>
<td>2017-18</td>
<td>95,131</td>
<td>101267</td>
<td>6%</td>
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<tr>
<td>2018-19</td>
<td>1,03,173</td>
<td>110511</td>
<td>7%</td>
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<tr>
<td>2019-20</td>
<td>1,16,385</td>
<td>120706</td>
<td>4%</td>
</tr>
<tr>
<td>2020-21</td>
<td>1,26,046</td>
<td>130958</td>
<td>4%</td>
</tr>
<tr>
<td>2021-22</td>
<td>1,36,700</td>
<td>141753</td>
<td>4%</td>
</tr>
</tbody>
</table>

Note: Energy sold
* Without Captive and losses

### Methodology

1. Projection of peak load & energy requirement
   - Study the past growth pattern
2. Load profile and load duration curve analysis
   - Study category-wise connected load, electricity consumption and growth pattern
   - Inference from historical load profile and load duration curve
   - Account for demand profile influenced by supply
   - Projecting energy/peak load for future using statistical techniques

3. Expected demand for electricity (load curve) considering Solar gen. profile

4. GAMS Based optimisation model
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

Demand Load Profile

- High, Medium, Low & Realistic Growth Scenario
- With or Without Short Term
- Solar & DSM

Realistic Targets

- Fixed Position
- Floating Position
- For candidate Plants only

Policy Targets

- Similar Scenarios as for Realistic Targets

Fixed All Plants

Fixed 3 Plants

Float Panki @ (2023,24,25)

Float All Plants

Float 3 Plants & cancel 1 (H, J, O, P)
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 Chhatisgarh

OBJECTIVE - SALE OF SURPLUS POWER

Per Capita Annual Electricity Consumption - CS

Due to High Consumption in Iron & steel Industries
Share of Self Generating Industries in Total Energy Requirement for State

- FY-05: 26.3%
- FY-06: 17.0%
- FY-07: 37.8%
- FY-08: 26.2%
- FY-09: 38.5%
- FY-10: 34.4%
- FY-11: 50.7%
- FY-12: 51.2%
- FY-13: 48.0%
- FY-14: 49.7%
- FY-15: 48.6%
- FY-16: 47.6%
- FY-17: 50.8%

Power Supply Position – Peak Demand at State Periphery

- FY-07: 27.52 MW
- FY-08: 2631 MW
- FY-09: 2887 MW
- FY-10: 2819 MW
- FY-11: 3148 MW
- FY-12: 3239 MW
- FY-13: 3271 MW
- FY-14: 3365 MW
- FY-15: 3817 MW
- FY-16: 3932 MW
- FY-17: 3875 MW
- FY-18: 4169 MW
- FY-19: 4444 MW
- FY-20: 4746 MW
Power Supply Position – Energy at State Periphery

Econometrics Model for Estimating Long-term Energy Requirement
Chhattisgarh Per Capita Electricity Consumption with Per Capita SGDP (Base year 2011-12)

Functional form of Econometric Model

\[ Q = f\left(\text{SGDP}, P, U, Ps, Ss, T, D\right) \]

- \( Q \) – Per capita Electricity Consumption
- \( \text{SGDP} \) – 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

\[ \log(Q) = f\left(\log(\text{SGDP}), \log(P), U, Ps, Ss, T, D\right) \]
Forecasted Per Capita Electricity Consumption for Utility at Bus-bar - without COVID-19 impact

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

Chhattisgarh Load Profile Pre and Post Lockdown
COVID-19 Impact on State Electricity Demand

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

Percentage Decline in Energy Supply in April 2020 w.r.t April 2019
COVID-19 Impact on State Electricity Demand

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

Demand Forecast – Post Covid-19
Forecasted Per Capita Electricity Consumption for Chhattisgarh State at Bus-bar - with COVID-19 impact

Model 7 - Per Capita Electricity Consumption - CS State

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

Model 7 - Per Capita Electricity Consumption
Forecasted Total Energy Requirement for Utility at Bus-bar (excluding interstate sales) - with COVID-19 impact

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
Long-term Power Portfolio Optimisation

Simulation Scenarios

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

Modelling Results for Power Supply and Surplus Projection (October)
Scenario 2
BASE CASE + 500 MW SOLAR PLANT

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

Demand, Schedule, Surplus and Load Shed
Scenario 3
BASE CASE WITH 50% DC OF VRE

Modelling Results for Power Supply and Surplus Projection (October) – With VRE at 50% of Original DC
Surplus Stack of Thermal Units in Descending order of Variable Cost (October)

Surplus Stack of Thermal Units in Descending order of Variable Cost (November)
## Regulatory Best Practices for LTDF and PPP

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

<table>
<thead>
<tr>
<th>Objective</th>
<th>Australia</th>
<th>Japan</th>
<th>Thailand</th>
<th>Singapore</th>
<th>European Commison</th>
<th>California</th>
<th>West Virginia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsible organisation</td>
<td>National Transmission Plans (NTP)</td>
<td>Ministry of Economy, Trade and Industry (METI)</td>
<td>Ministry of Energy, along with the Electricity Generating Authority of Thailand (EGAT)</td>
<td></td>
<td>European Network of Transmission System Operators for Electricity</td>
<td></td>
<td>Public Service Commission of West Virginia</td>
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<tr>
<td>Forecast range</td>
<td>20 years</td>
<td>15 years</td>
<td>20 years</td>
<td>10 years</td>
<td>Seasonal, mid-term, 10 years</td>
<td>12 years</td>
<td>10 years</td>
</tr>
<tr>
<td>Frequency of forecast</td>
<td>Annual</td>
<td>Updated at least once in every 3 years</td>
<td>Revised in every 3 years</td>
<td>Annual</td>
<td>Updated annually</td>
<td>Updated annually for the next 10 years</td>
<td>Updated annually</td>
</tr>
<tr>
<td>Factors considered for forecast</td>
<td>Economic growth, weather conditions, electricity prices</td>
<td>Economic growth, Energy efficiency and conservation measures, population growth</td>
<td>Social (Population) and economic (long-term GDP) growth, Energy efficiency target, RE development target</td>
<td>Economic and Consumer growth</td>
<td>Economic growth, temperature, policy, demographics</td>
<td>Economics, demographics, weather, electric vehicle, etc.</td>
<td>Consumer growth, Annual growth rate</td>
</tr>
<tr>
<td>Peak load or energy</td>
<td>Both</td>
<td>Energy</td>
<td>Both</td>
<td>Both</td>
<td>Peak load</td>
<td>Both</td>
<td>Peak load</td>
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<tr>
<td>Forecast scenario</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Single</td>
</tr>
<tr>
<td>Corrective action(s) for forecast</td>
<td>Not defined</td>
<td>reviewed at least once in every 3 years</td>
<td>reviewed once in every 3 years</td>
<td>Annual forecast</td>
<td>Annual update</td>
<td>Annual update</td>
<td>Not defined</td>
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</table>

Sor: Singh et al. (2019), [https://cetk.ac.in/publications](https://cetk.ac.in/publications)
### Prevailing practices of LT demand forecasting

<table>
<thead>
<tr>
<th>State</th>
<th>Agency</th>
<th>Objective</th>
<th>Forecasting Horizon</th>
<th>Deadline</th>
<th>Information/data Sharing Responsibility</th>
<th>Compliance</th>
<th>Forecasting Methodology</th>
<th>Internal Review</th>
<th>Relevant Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP</td>
<td>DISCOM and STU</td>
<td>Tariff and transmission planning</td>
<td>10 years; first 5 years detailed, next 5 years simple</td>
<td>One year before the start of control period</td>
<td>DISCOM to furnish data to STU and ERC</td>
<td>Not specified</td>
<td>Public consultation; the Commission might need to independently assess, verify and validate</td>
<td>Guidelines for load forecast, resource plans and power procurement, Dec 2006; Reg 4 of 2005; Reg 10 of 2015; Reg 5 of 2005; Transmission and bulk supply license regulations (17.12); Distribution and retail supply license regulations (19.2)</td>
<td>Grid Code, Regulations 5.7, 23.1 and 23.2 of MYT Regulations, 2017</td>
</tr>
<tr>
<td>DL</td>
<td>DISCOM</td>
<td>MT and transmission planning</td>
<td>5 years</td>
<td>31st July of the base year</td>
<td>DISCOM to furnish data to ERC</td>
<td>Must consider all consumer types, DSM measures, policies, net metering and economic data</td>
<td>Grid Code, 2013; Guidelines for power procurement by Distribution Licensee (2 of 2013); Regulations 19.2, 9.5 and 9.6.2 of MYT Regulations, 2016</td>
<td>Grid Code, Regulations 5.7, 23.1 and 23.2 of MYT Regulations, 2017</td>
<td></td>
</tr>
<tr>
<td>GJ</td>
<td>DISCOM</td>
<td>Transmission and power procurement planning</td>
<td>10 years; hourly peak and energy for first 5 years, annual peak and energy for next 5 years</td>
<td>31st January of every year</td>
<td>DISCOM to furnish data to ERC</td>
<td>Trend analysis and reasonable assumptions for future after considering consumer types, DSM measures, policies and economic data</td>
<td>Grid Code, 2013; Guidelines for power procurement by Distribution Licensee (2 of 2013); Regulations 19.2, 9.5 and 9.6.2 of MYT Regulations, 2016</td>
<td>Grid Code, Regulations 5.7, 23.1 and 23.2 of MYT Regulations, 2017</td>
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### Prevailing practices of LT demand forecasting (Contd.)

<table>
<thead>
<tr>
<th>State</th>
<th>Agency</th>
<th>Objective</th>
<th>Forecasting Horizon</th>
<th>Deadline</th>
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<th>Compliance</th>
<th>Forecasting Methodology</th>
<th>Internal Review</th>
<th>Relevant Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP</td>
<td>DISCOM</td>
<td>MT and transmission planning</td>
<td>5 years, on a rolling basis</td>
<td>31st March (DISCOM to STU)</td>
<td>STU to maintain database</td>
<td>DISCOM to adopt appropriate method (Part IV of Power Purchase &amp; Procurement Process Regulations, 2006)</td>
<td>Operation and Coordination Committee (OCC)</td>
<td>Grid Code, Power purchase &amp; Procurement Process Regulations, 2004</td>
<td>Grid Code, Power purchase &amp; Procurement Process Regulations, 2004</td>
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<tr>
<td>OR</td>
<td>STU and DISCOMs</td>
<td>Transmission planning</td>
<td>First 5 years by DISCOM, next 5 years by STU</td>
<td>31st Dec (DISCOM to STU), 31st March (STU to ERC)</td>
<td>DISCOM to furnish data to STU for submitting the completed data to ERC</td>
<td>STU shall approach OERC in case of non-compliance</td>
<td>Operation and Coordination Committee (OCC)</td>
<td>Guidelines 3.19 (1) and (2) and 3.8 of Orissa Grid Code, 2015; Regulations 3 and 7.1 of Terms and Conditions for determination of Wholesaling &amp; Retail Supply Tariffs, 2014</td>
<td>Guidelines 3.19 (1) and (2) and 3.8 of Orissa Grid Code, 2015; Regulations 3 and 7.1 of Terms and Conditions for determination of Wholesaling &amp; Retail Supply Tariffs, 2014</td>
</tr>
<tr>
<td>PB</td>
<td>STU</td>
<td>Transmission and power procurement planning</td>
<td>10 years, month-wise</td>
<td>30th April (DISCOM to STU), 30th Nov (STU to ERC)</td>
<td>DISCOM to furnish data to STU for submitting the completed data to ERC</td>
<td>Month-wise peak load considering paddy/non-paddy seasons</td>
<td>Guidelines 3.19 (1) and (2) and 3.8 of Orissa Grid Code, 2015; Regulations 3 and 7.1 of Terms and Conditions for determination of Wholesaling &amp; Retail Supply Tariffs, 2014</td>
<td>Guidelines 3.19 (1) and (2) and 3.8 of Orissa Grid Code, 2015; Regulations 3 and 7.1 of Terms and Conditions for determination of Wholesaling &amp; Retail Supply Tariffs, 2014</td>
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<tr>
<td>UP</td>
<td>DISCOM</td>
<td>MTY</td>
<td>5 years</td>
<td>1st June (along with base year plan)</td>
<td>DISCOM to furnish the forecasts to ERC</td>
<td>Must consider economic indicators of the state</td>
<td>MYT Regulations, Grid Code</td>
<td>MYT Regulations, Grid Code</td>
<td>MYT Regulations, Grid Code</td>
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Prevailing practices of power procurement planning

<table>
<thead>
<tr>
<th>Who</th>
<th>By When</th>
<th>Horizon</th>
<th>Regulations</th>
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<tr>
<td>AP</td>
<td>DISCOMs</td>
<td>One year before the start of the control period</td>
<td>MYT</td>
</tr>
<tr>
<td>DL</td>
<td>DISCOMs</td>
<td>31st July</td>
<td>B Plan</td>
</tr>
<tr>
<td>GJ</td>
<td>HoldCo/ DISCOM</td>
<td>31st Jan</td>
<td>Rolling 5 year</td>
</tr>
<tr>
<td>MP</td>
<td>HoldCo/ DISCOM</td>
<td>31st Oct</td>
<td>Rolling 5 year</td>
</tr>
<tr>
<td>OR</td>
<td>HoldCo</td>
<td>30th Nov</td>
<td>10 year, revised yearly</td>
</tr>
<tr>
<td>PB</td>
<td>DISCOM</td>
<td>30th Nov</td>
<td>Rolling 10 year</td>
</tr>
<tr>
<td>UP</td>
<td>Holdco/ DISCOM</td>
<td>1st June</td>
<td>B Plan</td>
</tr>
</tbody>
</table>

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

A healthy ‘CEREAL’ for the Power Sector

[Contact information provided]