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Review of Integrated Resource Planning and Load Forecasting Techniques in India

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Introduction

Changes in technology, load profiles, consumer energy end-use, and economic growth are leading to uncertainty in the demand of future electricity. Accurate forecasting of electricity demand is a crucial input in planning and investment decisions by the government, utilities and industries. This report will provide an overview of India's system of load research and integrated resource planning, describe related experiences in other developing countries, and end with recommendations to strengthen the process in India, and thereby enable the power sector to more reliably, efficiently and sustainably meet the country's demand for electricity.

Load Forecasting: An Overview

Load forecasting is a technique used by electricity utilities to predict the power or energy needed to balance future load demand and supply. Forecasting is for short term — day ahead to a week, medium-term week to a year, and more than a year long term. Demand in the short term can be forecast based on past trends. Change in weather patterns at a monthly level — such as temperature, rainfall and cloud cover — affect demand, particularly where the load is mainly for domestic and agricultural end-uses. At an annual level, GDP, technologies, population growth, urbanisation and other socio-economic factors impact electricity demand. Demand can be forecast using bottom up or top-down methods.

Some of the commonly used methods of load forecasting include non-parametric methods, panel data analysis, co-integration analysis, end-use approach, input-output models, econometric methods such as regression analysis, trend analysis, panel data, time series modelling, and artificial intelligence-based methods such as neural networks and fuzzy logic.

Load Forecasting in India

The Central Electricity Authority (CEA) is required to conduct studies pertaining to cost, efficiency, competitiveness and associated matters — an indirect reference to load forecasting.[1] The CEA also is directed to make short and long-term demand projections.[2] Under the Tariff Policy, 2016 State Electricity Regulatory Commissions (SERCs) are required to mandate discoms to undertake load forecasting and power procurement planning every year.[3] There is no regulatory requirement for utilities to use the CEA forecasts.

The primary national source of load forecasting is the CEA, which is responsible for forecasting electricity demand for all of India — all states, union territories, regions, and mega-cities. The forecasts are for electrical energy requirements (TWh) and peak demand (MW). The CEA's Power Survey and Load Forecasting Division constitutes an Energy Power Survey (EPS) committee, which publishes the Electric Power Survey Report every five years.[4] The survey used the Partial End Use Method (PEUM), a bottom-up approach, based on adding all electricity end-uses of various categories (such as residential, commercial, industrial, agriculture, and railways) and making corrections to account for changing scenarios in the future. The CEA uses regression analysis to periodically review and validate the forecasts.

The latest forecast is in Tables 1 and 2 below:[5]

[1] Government of India, Ministry of Law and Justice. (2003). *The Electricity Act, 2003*. Section 72 (i). https://cercind.gov.in/Act-with-amendment.pdf

[2] Government of India, Ministry of Power. (2005). *The National Electricity Policy, 2005*. https://powermin.gov.in/en/content/national-electricity-policy

[3] Government of India, Ministry of Power. (2016). *Tariff Policy, 2016*. https://www.wberc.gov.in/sites/default/files/tariff-policy-28.01.2016.pdf

[4] The most recent report can be found here: Central Electricity Authority. (n.d.). *Power Survey & Load Forecasting Division*. https://cea.nic.in/power-survey-load-forecasting-division/?lang=en

[5] Central Electricity Authority. (2019). *Long Term Electricity Demand Forecasting*. https://cea.nic.in/old/reports/others/planning/pslf/Long_Term_Electricity_Demand_Forecasting_Report.pdf

Table 1. Energy Power Survey Forecast for Electricity Demand, BU, 2017-2037

Year	7.3% GDP (BAU scenario	8% GDP (optimistic scenario)	6.5% GDP (pessimistic scenario)
2016-2017	1152.4	1152.4	1152.4
2021-2022	1471.5	1477.5	1443.5
2026-2027	1886.9	1905.4	1776.9
2031-2032	2378.7	2458.9	2186.7
2036-2037	2976.3	3175.4	2691.07

Source: Central Electricity Authority. (2019). *Long Term Electricity Demand Forecasting*.

Table 2. Energy Power Survey Forecast for Peak Demand, MW, 2017-2037

Year	7.3% GDP (BAU scenario	8% GDP (optimistic scenario)	6.5% GDP (pessimistic scenario)
2016-2017	158,994	158,994	158,994
2021-2022	201,481	202,330	195,133
2026-2027	255,911	259,628	239,299
2031-2032	319,794	333,152	293,462
2036-2037	398,172	427,497	359,882

Source: Central Electricity Authority. (2019). *Long Term Electricity Demand Forecasting*.

The EPS report contains load forecasts from 2019 to 2037, with discom-wise electricity demand forecasts to arrive at the state, region and Indian electricity demand projection. The projections are carried out in association with electricity transmission and distribution companies. The projections are also used by the government for long-term generation expansion planning, as well as a determining requirement for transmission and distribution facilities. Some discoms use the projections directly or compare them to their own forecasts for distribution facility planning as described in Table 3.[6]

In addition to CEA, other organizations such as NITI Aayog (the central government's policy research agency), the Brookings Institution and TERI[7] also create load forecasts, often using different methodologies. Table 3 contains a summary of recent load forecasts for 2030.

Table 3. India Load Forecasts, 2020

Study	Metric	Base year TWh	2030 TWh	CAGR
Transitions in Indian Electricity Sector (TERI 2017)	Demand/ Net generation	1115	3175	7.76%
Draft National Energy Policy (NITI 2017)	End-use demand including captive	804	2104	5.49%
		804	2244	5.87%
19th Electric Power Survey (CEA 2017)	End-use demand	921	2078	6.46%
India Energy Outlook (IEA 2015)	End-use demand	897	2241	5.53%
Quality of Life for All (CSTEP 2015)	End-use demand, including captive	745	2822	7.68%
		745	3343	8.70%

Source: Ali, S. (2018, October). *The Future of Indian Electricity Demand: How much, by whom, and under what conditions?*
Note: The base year values for the table vary as different years and different metrics were used to estimate base year load.

[6] Ali, S. (2018, October). *The Future of Indian Electricity Demand: How much, by whom, and under what conditions?* Brookings Institute. https://www.brookings.edu/research/the-future-of-indian-electricity-demand-how-much-by-whom-and-under-what-conditions/

[7] Spencer, T. & Awasthy, A. (2019, February). *Analysing and projecting Indian electricity demand to 2030*. The Energy and Resources Institute. https://www.energy-transitions.org/publications/analysing-and-projecting-indian-electricity-demand-to-2030/

At the state level, discoms are required to conduct load surveys under state tariff regulations passed in several states. For example, in Maharashtra under section 82.1 of the Multi Year Tariff Regulations, 2019, as a part of Aggregate Revenue Requirement (ARR) filing, discoms are required to submit a month-wise forecast of expected electricity sales for each consumer sub-category and tariff slab. The regulations do not state how the forecast is to be conducted, nor do they require forecasts beyond one year.

Based on a survey of utility ARRs, most utilities estimate the next year’s energy sales based on sales in the past year, as well as three-to- five years, and make adjustments to these figures. The SERC approves or modifies the forecast and, in some cases, examines the accuracy of past forecasts. A snapshot of the experience of utilities across India is in the following series of tables.

Table 4a. Maharashtra — Load Forecasting by Discoms, 2020

Regulations	Utility	Forecast methodology	Forecast period	Forecast	SERC ruling
Under the Multi-Year Tariff (MYT) Regulations, 2019,[8] discoms are required to forecast month-wise sales by consumer sub-category.	MSEDCL: Maharashtra State Electricity Distribution Company, Ltd.	• Historical trend, forecast based on past CAGR with adjustments for each category. • Inputs-sales, number of consumers. • Connected load/contract demand.	Forecast made in 2020 for control period FY 2021- 25.	CAGR for each slab estimated, ranging from 2% for HT commercial to 12% for LT residential > 200 kWh.	Recommends five-year CAGR projection, approves and modifies category-wise forecasts.[9]

[8] Maharashtra Electricity Regulatory Commission. (2019). *(Multi Year Tariff) Regulations, 2019*. https://www.mahadiscom.in/wp-content/uploads/2019/08/33.-01.08.2019-MYT-Regulation-2019_English.pdf

[9] Maharashtra Electricity Regulatory Commission. (2020, March). *Case No. 322 of 2019: Case of Maharashtra State Electricity Distribution Company Limited for Truing-up of Aggregate Revenue Requirement (ARR) of FY 2017-18 and FY 2018-19, Provisional Truing-up of ARR of FY 2019-20 and Projections of ARR and determination for the 4th Multi Year Tariff Control Period FY 2020-21 to FY 2024-25.* https://www.mahadiscom.in/consumer/wp-content/uploads/2020/03/Order-322-of-2019.pdf

Table 4b. Delhi — Load Forecasting by Discoms, 2020

Regulations	Utility	Forecast methodology	Forecast period	Forecast	SERC ruling
Under MYT regulation, 2007,[10] discoms required to forecast month-wise sales by consumer sub-category.	• BRPL • BSES Rajdhani Power, Ltd.	• Adjusted Trend Analysis Method used. • Due to Covid-19 lockdowns, forecast adjusted with inputs from: actual sales in April-May 2020. • Government orders that affected consumption, field inputs on consumer behaviour.	• Forecast made in 2020 for FY 2021. • All past forecasts revised downward due to Covid-19.	Downward revision ranging from -54% for Airport and Metro, to 25% for HT Industrial.	• Compares EPS projection, DERC projection and actual sales for 2017-2019. • Finds DERC forecasts more accurate and orders that CAGR to be used to project for half-year (H1, H2), to better forecast seasonal variations.[11]

[10] Delhi Electricity Regulatory Commission. (2007). *Multi Year Tariff for Generation, Transmission and Distribution Regulations*. http://www.derc.gov.in/regulations/multi-year-tariff-generation-transmission-and-distribution-regulations-posted-website

[11] Delhi Electricity Regulatory Commission. (2020). *Petition for determination of tariff for FY2020-21 and Truing up of Aggregate Revenue Requirement (ARR) for FY2018-19*. http://www.derc.gov.in/sites/default/files/BRPL%20-%20TARIFF%20ORDER%20FY%202020-21_0.pdf

Table 4c. Karnataka — Load Forecasting by Discoms, 2020

Regulations	Utility	Forecast methodology	Forecast period	Forecast	SERC ruling
Discoms required to make load forecast using EPS forecasts updated by annual revisions of their data, under KERC (Load Forecast) Regulations, 2009.[12]	MESCOM: Mangalore Electricity Supply Company	• Mixed CAGR method. • Specific consumption method and trend method. • Results of different methods compared. • MESCOM also compared own forecasts with EPS 2019, though results are not published.[13]	Forecast made for the period FY-20 to FY-24 in FY-21.	CAGR ranges from 0.76% for LT-Ia to 8.6% for LT II rural.	• Commission examined number of installations. • Compared forecasts to CAGR and accepted forecasts made for most categories.

12 Karnataka Electricity Regulatory Commission. (2009). *KERC [Load Forecast] Regulations, 2009*. https://kptcl.karnataka.gov.in/storage/pdf-files/RA/KERC%20(%20Load%20Forecast)%20Regulations%202009.pdf

13 Karnataka Electricity Regulatory Commission. (2022). *Tariff Orders 2022, MESCOM*. https://karunadu.karnataka.gov.in/kerc/TariffOrders2022/Order/MESCOM.pdf

Table 4d. West Bengal — Load Forecasting by Discoms, 2020

Regulations	Utility	Forecast methodology	Forecast period	Forecast	SERC ruling
Under State Grid Code 2006,[14] discoms are responsible for 10-year load forecasts, using their own data and EPS forecasts.	WBSEDCL: West Bengal State Electricity Distribution Company, Ltd.	• CAGR method. • No growth assumed in certain categories on account of Covid-19.	Forecast made for the period FY-21 to FY-23.[15]	• CAGR of period 2015-16 to 2019-20 considered for load forecasting projections. • No growth assumed in FY-21 for certain categories due to Covid-19.	WBERC accepted forecasts made for most categories.

[14] West Bengal Electricity Regulatory Commission. (2006). *(Draft State Grid Code)*. https://wberc.gov.in/sites/default/files/draft1.pdf

[15] West Bengal Electricity Regulatory Commission. (2022). *In Regard to the Tariff Application of the West Bengal State Electricity Distribution Company Limited for the Years 2020-2021, 2021-2022 and 2022-2023, under Section 64(3)(a), read with Section 62(1) and Section 62(3) of the Electricity Act, 2003*. https://wberc.gov.in/sites/default/files/TP-89_20-21.pdf

Table 4e. Assam — Load Forecasting by Discoms, 2020

Regulations	Utility	Forecast methodology	Forecast period	Forecast	SERC ruling
Under MYT Regulations, 2021,[16] discoms to forecast load in accordance with central authorities for capital investment plan.	APDCL: Assam Power Distribution Company, Ltd.	• CAGR method. • Reasonable estimates about growth rates assumed for certain consumer categories.	Forecast for MYT period 2022-23 to 2024-25.	Forecast growth rate ranging from 13% for Domestic B to 1% for LT small industries.	AERC approved total forecasted energy sales for FY22 but revised the forecasts within categories based on impact of Covid-19 and estimated growth rates.[17]

[16] Assam Electricity Regulatory Commission. (2021). *Assam Electricity Regulatory Commission (Terms and Conditions for Determination of Multi- Year Tariff) Regulation, 2021*. http://aerc.gov.in/SOR_MYT_2021.pdf

[17] Assam Electricity Regulatory Commission. (2022). *Tariff Order March 21, 2022, True Up for FY 2020-21, APR for FY 2021-22, ARR for FY 2022-23 to FY 2024-25, and Tariff for FY 2022-23*. http://www.aerc.nic.in/APDCL-MYT-Order-Final-Sd-version-2022.pdf

Load forecasts made by discoms are key to tariff setting and power purchase decisions. They are, however, primarily implemented based on historic demand. Important factors that can lead to load variation — such as regional and seasonal variations in demand, time-of-day use, expected differences in load demand based on income categories, change in future load profile due to energy conservation, investments in end-use efficiency, increasing electrification (EV charging), ,and reduced load on the grid (rooftop solar) — are typically not considered as inputs into the forecast model by utilities.

There has been limited analysis of the performance of load forecasting, including its accuracy and how the forecast is related to utilities' decisions to build or acquire generation plants, sign PPAs or implement demand side management programs. One such study of long-term load forecasts in 12 electricity utilities in the western U.S. has shown that most resulted in overestimates of energy consumption and peak demand.[18] The evidence shows that a U.S. utility frequently overestimates load demand and over-procures capacity, leading to higher consumer costs. In a cost-plus system, utilities have an incentive to err on the higher side, to build more infrastructure that goes into the rate base to earn a return. System operators also err on the higher side, to ensure supplies are adequate and the system is reliable.

This tendency to overestimate load demand, coupled with the ad hoc nature of load forecasting, can lead to inefficiencies, including stranded capacity and increases in consumer tariffs, that impact consumers and utility finances.

Integrated Resource Planning (IRP) for the power sector

Integrated resource planning (IRP) is a process used by utilities to determine the least-cost, long-term means (through combinations of both supply- and demand-side investments) of meeting demand for energy services, subject to public policy objectives (e.g., reliability, service quality, emissions reductions, equity, etc.). Forecasts of energy and peak demand are a critical component of the IRP process. While countries around the world include renewable energy resources in planning, there is a need to compare all supply- and demand-side options as a part of the evaluation process.[19]

Figure 1 shows the major components of IRP:[20]

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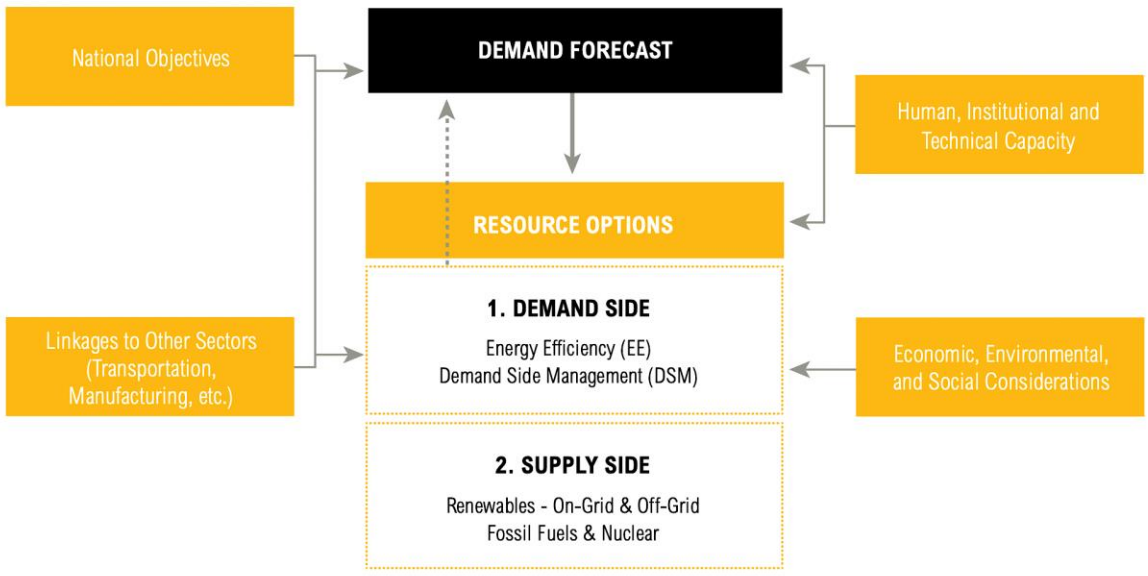
[18] Carvallo, J. P., Larsen, P. H., Sanstad, A. H. & Goldman, C. A. (2018). Long term load forecasting accuracy in electric utility integrated resource planning. *Energy Policy*, *119*, 410-422. https://doi.org/10.1016/j.enpol.2018.04.060

[19] D'Sa, A. (2005, July). Integrated resource planning (IRP) and power sector reform in developing countries. *Energy Policy, Elsevier, Vol. 33*(10). Pages 1271-1285. https://ideas.repec.org/a/eee/enepol/v33y2005i10p1271-1285.html

[20] Jairaj, B., Dixit, S., Chitnes, A., Martin, S., Wood, D. & Kundu, A. (2014, May). *10 Questions to Ask About Integrated Resources Planning*. World Resources Institute. https://www.wri.org/research/10-questions-ask-about-integrated-resources-planning

Figure 1. Components of IRP



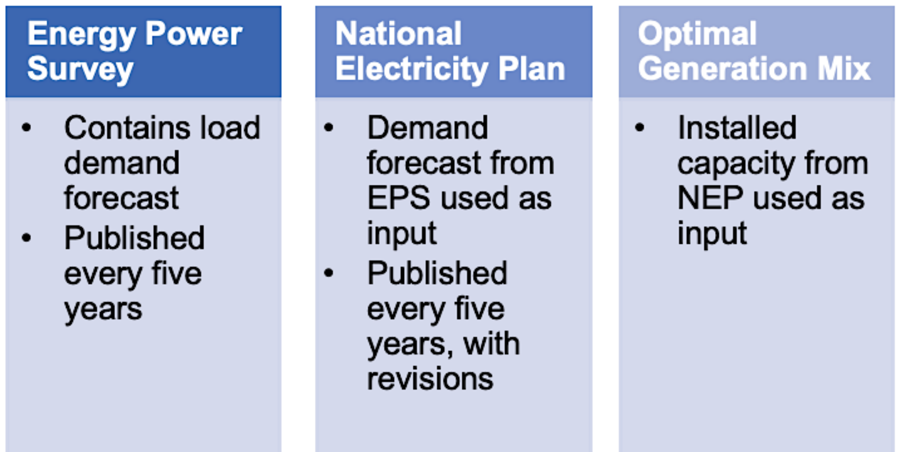
Source: Jairaj, B. et al. (2014, May). *10 Questions to Ask About Integrated Resources Planning*.

In India, under the Electricity Act, 2003,[21] the CEA is required to prepare the National Electricity Plan (Generation) every five years and work out a feasible mix for expansion planning of power generation. The installed capacity projected in the midterm review of the National Electricity Plan (NEP) is used as an input to determine the future generation capacity required for the coming decade in the Optimal Generation Mix (OGM) reports, published by the CEA's IRP division.[22] Figure 2 shows the process of planning for power in India, which has some components of IRP, but is missing the inclusion of demand side management as a resource.

[21] Government of India, Ministry of Law and Justice, 2003.

[22] Central Electricity Authority. (2020, January). *Report on optimal generation capacity mix for 2029-30*. Ministry of Power. https://cea.nic.in/old/reports/others/planning/irp/Optimal_mix_report_2029-30_FINAL.pdf

Figure 2. Power Supply Planning Process in India



Source: MP Ensystems Research, 2022

Under the National Electricity Plan 2018,[23] capacity additions in coal, hydro, nuclear and renewables are considered to determine required capacity addition. Avoided generation due to demand side management and energy efficiency programs — such as standards and labelling, Energy Conservation Building Codes (ECBC) for residential buildings, agriculture, demand-side management (DSM), and more — has been estimated for the period of 2006 through 2014. These numbers are used to project energy savings (in MWh) as well as peak avoided (in MW) until 2027, as seen in Table 5.

Table 5a. Projected Energy Savings from DSM, 2027

Details	2022-23	2023-24	2024-25	2025-26	2026-27
Savings Utility (BU)	217	230	244	257	273
Savings Non-Utility (BU)	47	51	55	60	64
Total (Billion Units)	264	281	299	317	337

Source: Central Electricity Authority. (2018, January). *National Electricity Plan*.

23 Central Electricity Authority. (2018, January). *National Electricity Plan*. Ministry of Power. https://cea.nic.in/wp-content/uploads/2020/04/nep_jan_2018.pdf

Table 5b. Projected Peak Avoided from DSM, 2027

Details	2022-23	2023-24	2024-25	2025-26	2026-27
Savings Utility (MW)	9900	10450	11037	11659	12324
Savings Non-Utility (MW)	668	720	774	835	900
Peak Avoided (MW)	10569	11169	11811	12494	13225

Source: Central Electricity Authority. (2018, January). *National Electricity Plan*.

Demand-side management and energy efficiency are not included, however, in the capacity addition mix. In order to develop a portfolio of resources to meet future demand, the levelized cost of energy of different sources needs to be compared.

Some of the results of inadequate forecasting in the Indian power sector are described below:

- Under the traditional approach to electricity sector planning, utility planners project future demand and expand their supply to meet that anticipated demand. As described earlier, there is a bias on the part of Indian utilities and system planners towards overestimating future demand, leading to excess capacity in thermal plants which may be under-utilised, leading to stressed assets and higher-than-necessary energy costs.
- In 2019, India announced it had a power surplus, with installed capacity of 350 GW and maximum load met of 180 GW. The headline figure, however, does not include transmission losses or infirm capacity from renewables and plants that have outages.[24] As the country's renewable energy penetration increases, the share of unforced capacity (UCAP) as compared to installed capacity (ICAP) is expected to fall, since the share of UCAP is close to 90% of ICAP for thermal power plants, but much lower for renewables.

  Despite the announcements of the power surplus and possible overestimation of demand, Table 6 shows that most regions in India were in a power deficit in the sample month of November from 2017 to 2021.[25]

[24] Parray, M.T & Tongia, R. (2019, August). *Understanding India's power capacity: Surplus or not, and for how long?* Brookings Institute. https://www.brookings.edu/research/understanding-indias-power-capacity-surplus-or-not-and-for-how-long/

[25] POSOCO. (2022). *2022 Monthly Reports*. https://posoco.in/reports/monthly-reports/

Table 6. Monthly Surplus/ Deficit in November 2017-21

Region	Surplus(+)/ Deficit (-) in MU					Peak Demand Surplus/ Deficit in MW				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
North	-389.4	-311	-319	-412	-161	-850	-513	-566	-569	-1025
West	-30.1	-18	-5	0	-8	-115	-156	0	0	-77
South	-84.4	-30	7	3	-4	-100	-102	0	0	0
East	-464.7	-516	-9	-16	-55	-597	-150	0	0	0
Northeast	-49.9	-56	-17	-19	-3	-57	-27	-25	-28	-27
All India	-1019	-931	-343	-444	-231	-1719	-948	-591	-597	-1129

Source: POSOCO. (2022). *2022 Monthly Reports*.

- The Ministry of Power has set up the National Merit Order dispatch to be managed by State and Regional Load Dispatch Centres (LDCs) to ensure lowest marginal cost resources are utilised first, instead of remaining idle while higher cost plants are run. And under the Indian Electricity Grid Code,[26] renewable energy has been granted must-run status. In case, however, discoms have PPAs with more expensive generators, they are forced to pay fixed costs to those generators that are non-operational.

The proposal to improve load forecasting in India, incorporate demand side options as a part of the energy mix, and conduct IRP can help alleviate the issues described above.

[26] Central Electricity Regulatory Commission. (2010, April). *Indian Electricity Grid Code*. https://cercind.gov.in/2010/ORDER/February2010/IEGC_Review_Proposal.pdf

Load Forecasting and IRP in emerging economies

Power sector load forecasting and planning for emerging economies, of which India is one, face unique challenges. The experience of other countries can be instructive. In this section, we take a look at how two other Pacific Rim nations, South Africa and Thailand, have engaged in these exercises.

In South Africa, the Department of Mineral Resources and Energy develops the national IRP as a "living plan."[27] The 2019 IRP contains a load forecast for 2017-2050. Regression models for each sector are aggregated to get the total energy demand forecast in three scenarios — upper, medium, and low. The IRP noted that the forecast for the 2010-2016 period significantly overstated the power demand due to GDP growth being lower than expected. The net electricity demand for the country declined by -0.6% compared to the forecast growth rate of 3% in the 2010-2018 period.

The IRP considered the following energy mix for the country: electricity generated from coal, nuclear, natural gas, renewable energy, hydro and energy storage options. While the IRP document considered the impact of energy efficiency, rooftop solar PV, building codes requiring solar water heaters, and more, they were not simulated as standalone scenarios, but higher energy efficiency and renewable energy use was considered to be part of the low load demand scenario.[28]

The state-owned Electricity Generating Authority of Thailand (EGAT) produces the Power Development Plan (PDP), [29] which acts as the country's roadmap for power generation, distribution and consumption. The load forecast was developed using an end-use model. Inputs in the forecast included population growth, urbanization and growth rate of electricity consumers by sector. The forecasting exercise was conducted in line with the targets of Alternate Energy Development Plan (AEDP), 20-year Energy Efficiency Development Plan (EEDP) and energy efficiency performance. The forecast was developed for a Business as Usual (BAU) and Base Case (BC) where energy efficiency targets were met.

The PDP lists future power supply from coal, natural gas, oil, nuclear power, renewables and imported hydro power from neighbouring countries, as well as expansion and renovation of the transmission system. Energy efficiency and DSM are not part of the country's proposed supply portfolio.

The features of load forecasting and IRP have been reviewed in Table 7.

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[27] Department of Mineral Resources and Energy, South Africa. (2019, October). *Integrated Resource Plan 2019*. https://www.energy.gov.za/IRP/2019/IRP-2019.pdf

[28] Wright, J.G., Calitz, J.R., Fourie, R. & Chiloane, L.D. (2019.) *Integrated Resource Plan 2019: Initial CSIR insights and risks/opportunities for South Africa*. Presented at CSIR, Smart Places, October 2019. https://researchspace.csir.co.za/dspace/handle/10204/11200; Hippel, D. V., Greacen, C., & Greacen, C. S. (2013, December). Integrated Resource Planning for Asia? Nautilus Institute. https://nautilus.org/napsnet/napsnet-policy-forum/integrated-resource-planning-for-asia/

[29] Ministry of Energy, Thailand. (2015). *Thailand Power Development Plan 2015–2036 (PDP 2015).* http://www.eppo.go.th/index.php/en/policy-and-plan/en-tieb/tieb-pdp

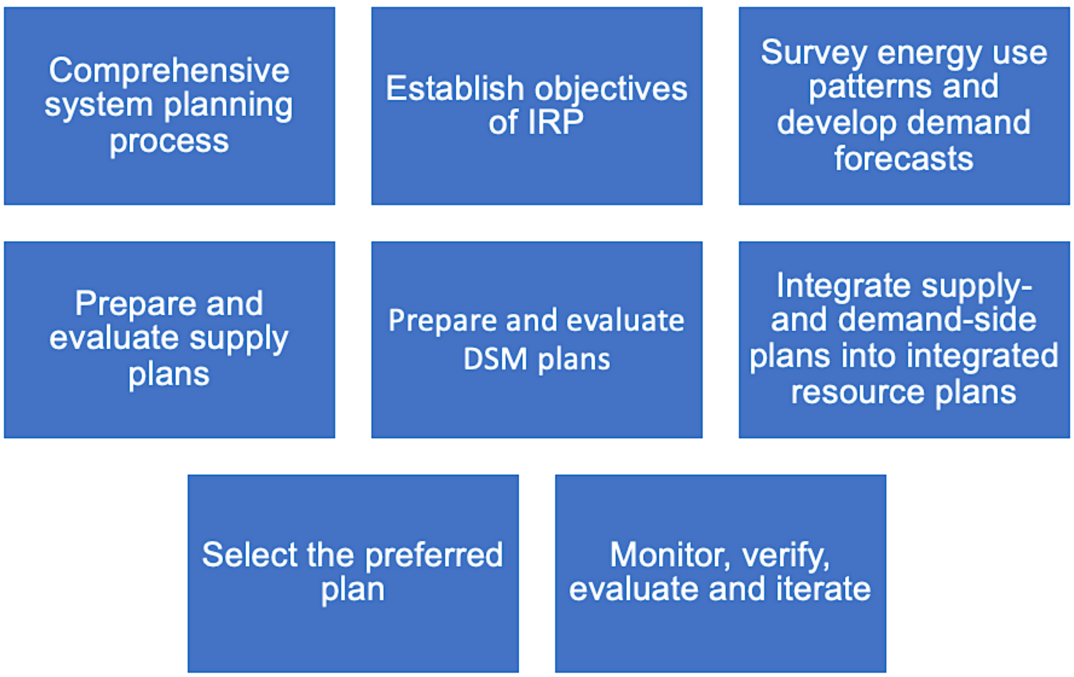
Table 7. Review of IRP in Three Emerging Economies

Feature	India	South Africa	Thailand
Transparency, Accountability, Participation, Capacity	• EPS published regularly. • Suggestions and objections invited on the NEP from licensees, generating companies and the public over 90 days. • NEP is published every five years. • No review of accuracy of load forecast on which projections are based. • High technical capacity of CEA to conduct load forecasting and projection. • Discoms conduct load forecasting based on past load.	• Draft IRP is published for public comment. • While IRP is to be revised every two years, the IRP was published in 2010 and 2019. • Accuracy of prior load forecast reviewed— the load forecast was found to significantly overestimate electricity demand.	• Comments solicited from stakeholders in developing PDP. • PDP published in 2018 and 2020. • Scenarios of energy efficiency, renewable energy considered while forecasting load. • Thailand to develop first NEP based on PDP.
Demand side as input in IRP	DSM included as energy saving measures. Not part of planned energy mix.	Energy efficiency viewed as a factor affecting demand forecasts. Not part of planned energy mix.	The proposed NEP includes a sectoral energy efficiency plan, not clear yet if it will be part of the supply portfolio.

Recommendations

Best practices for improving the load forecasting and IRP process are in Figure 3:[30]

Figure 3. IRP Best Practices



Source: Nichols, D., & von Hippel, D. (2000). *Best Practices Guide: Integrated Resource Planning for Electricity*.

Recommendations for implementing these practices in Indian load forecasting and IRP are in Table 8, along with roles and responsibilities of stakeholders.

[30] Nichols, D., & von Hippel, D. (2000). *Best Practices Guide: Integrated Resource Planning for Electricity*. U.S. Agency for International Development, the Institute for International Education and the Tellus Institute. https://pdf.usaid.gov/pdf_docs/PNACQ960.pdf

Table 8. Steps in a Successful IRP Process

Best Practices	Responsibility	Implementation
Comprehensive system planning process	CEA to create long-term planning framework with components, including reliability, economic, public policy, and inter-regional planning.	CEA to develop process, review it periodically.
Establish objectives of IRP	CEA to establish objectives in line with India's policies, commitments and as a part of system planning.	Already part of CEA's role.
Survey energy use patterns and develop demand forecasts	IRP was developed by vertically integrated utilities in the U.S. for companies that had the authority to build, operate and maintain facilities for generation, transmission and distribution of electricity.[31] In India, given the unbundling of state electricity boards, IRP needs to be modified with decentralised load forecasting. Discoms to conduct surveys of energy end use, develop demand forecast based on methodologies proposed by CEA; accuracy of past forecasts to be regularly reviewed; EPS to include inputs from discoms, and use different assumptions about the macroeconomic scenario to create an "if-then" framework, instead of a single forecast.[32]	Capacity building at discoms and SERCs; SERCs to monitor forecasts. Forecasts to also be used in preparation of MYT Annual Revenue Requirement (ARR) petitions. Future ARRs to compare forecasts and actual demand. SERCs to determine whether to penalise forecasts that diverge from actual demand beyond an acceptable band.
Prepare and evaluate supply plans	Generation, transmission, and distribution utilities to develop supply and investment plans.	Currently part of CEA's role under NEP. CEA can provide templates for utilities to prepare supply plans.
Prepare and evaluate DSM plans	DSM cell of discoms to conduct load survey, evaluate DSM program options proposed by CEA and BEE, use benefit cost analysis and tests to determine optimal program and incentive.	Part of discoms' mandate in states which have adopted DSM regulations.

[31] NYISO. (2022). *State of NYISO System & Resource Planning* [Draft]. https://www.nyiso.com/documents/20142/31614758/03%202021-2040_System_Resource_Outlook_Report_DRAFT_Chp1-4.pdf/2c3943bc-35b4-0b66-ad97-9b0a73eea348

[32] Spencer & Awasthy, 2019.

Integrate supply- and demand-side plans into IRPs	Discoms to develop IRP with training and inputs from CEA.	CEA should expand NEP to include DSM in its macro planning.
Select the preferred plan	CEA to create BAU, high and low scenarios, use TAP-C approach to include transparency, accountability, participation and capacity.[33] Utilities to apply this framework to their plan.	Part of CEA's role under NEP.
Monitor, verify, evaluate, and iterate	CEA to develop methodologies for a plan that is robust across most scenarios and allows for changes in investment, as circumstances change.	Utilities to submit modified demand forecasts during midterm review of ARR; CEA to conduct review of accuracy of all India forecast; IRP to be modified to include new methodologies, new energy supply options.

Sources: TERI, Prayas 2007, MP Ensystems 2022, NYISO 2022[34]

Conclusion

CEA conducts in-depth studies to forecast energy requirement and peak load demand in India under different scenarios — by estimating electricity end-use demands and modifying aggregate demands according to parameters such as GDP growth, weather, and historic electricity consumption patterns. Discoms in India produce their own estimates, typically by applying a CAGR to current electricity consumption, and some compare their estimates to those of the CEA. Based on the forecasts, the CEA proposes a least-cost generation mix to meet demand for the coming decade.

This paper proposes modifications to the process through enhancing forecasting efforts of discoms, CEA integrating renewable energy and DSM into plans, and modifying them to meet the changing requirements, including consumer demand patterns, adoption of technologies such as battery storage and phase-out of older thermal plants. These recommendations should contribute to improved cost-effectiveness, sustainability and reliability of the Indian electricity system.

[33] Dixit, S., Dubash, N. K., Maurer, C. & Nakhooda, S. (2007, June). *The Electricity Governance Toolkit*. The Electricity Governance Initiative, World Resources Institute. https://www.wri.org/electricity-governance-toolkit

[34] NY ISO 2022. *Draft System & Resource Planning Process*, PSC Technical Conference.

Annex – Key Acronyms

Key Acronyms	Definition
AERC	Assam Electricity Regulatory Commission
APDCL	Assam Power Distribution Company, Ltd.
ARR	Aggregate Revenue Requirement
BAU	Business as usual
BRPL	Bongaigaon Refinery & Petrochemicals Ltd.
BSES	Bombay Suburban Electric Supply
CAGR	Compound Annual Growth Rate
CEA	Central Electricity Authority
DERC	Delhi Electricity Regulatory Commission
DSM	Demand-side Management
ECBC	Energy Conservation Building Codes
EPS	Energy Power Survey
HT	High Transmission
ICAP	Installed Capacity
IRP	Integrated Resource Plan
KERC	Karnataka Electricity Regulatory Commission
LDC	Load Dispatch Centre
LT	Low Transmission
MESCOM	Mangalore Electricity Supply Company
MSEDCL	Maharashtra State Electricity Distribution Company, Ltd.
MYT	Multi-Year Tariff
NEP	National Electricity Plan
PEUM	Partial End Use Method
UCAP	Unforced Capacity
WBERC	West Bengal Electricity Regulatory Commission
WBSEDCL	West Bengal State Electricity Distribution Company, Ltd.

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