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RETHINKING DISCOM RESOURCE PLANNING – IN RENEWABLE ENERGY RICH ENVIRONMENT

WHITE PAPER

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RETHINKING DISCOM RESOURCE PLANNING – IN RENEWABLE ENERGY RICH ENVIRONMENT

White Paper

USAID - MNRE Partnership to Advance Clean Energy – Deployment (PACE-D) 2.0 RE Program

MESSAGE

Renewable energy (RE) technologies are set to play the role of a mainstream resource in the Indian power sector. The policies adopted in the last decade have led to significant capacity addition, cost reduction and maturity of market actors, however, India requires RE capacity addition at a much faster pace to achieve the national RE target. States and Discoms will play a very critical role in helping achieve India is RE goal of 175 GW and even expand it multiple folds in the next decade.

Over time, renewable energy policies such as feed-in tariffs, tax incentives, and renewable purchase obligation (RPO) have helped significant growth in RE capacities in RE resource-rich states. But some of these RE resource-rich states have shown indication of slowing down, due to various reasons. As the responsible party for meeting the majority of RPO targets, Discoms are reaching their absorptive capacity to add more renewables due to 1) surplus power situation, 2) financial losses, 3) limited capacity to plan and procure RE in a cost-effective manner and 4) grid management issues. The problems generated by a lack of a systematic and holistic planning approach and institutional capacities are also becoming exacerbated with more distributed generation, electric vehicles, storage, and other so-called “disruptive” technologies.

This requires efforts to mainstream RE into the power sector planning- requiring a rethink of planning approaches adopted so far for a fossil-fuel dominated scenario to RE-rich scenarios to plan and develop the best RE resources to meet the future energy demand. The second phase of Partnership to Advance Clean Energy Deployment (PACE-D 2.0 RE) program implemented by U.S. Agency for International Development (USAID) in partnership with the Ministry of New and Renewable Energy (MNRE) has initiated an assessment of the current mid and long term resource planning practices at the national and state level, to understand how this could be improved to include RE specific attributes in the demand forecasting, resource planning and portfolio optimization to ensure Discoms have the robust plans to accelerate the deployment of renewable energy.

I am glad this white paper addresses these issues and brings recommendations based on international best practices which will be helpful for making this shift in power sector planning in India. The planning will help distribution companies in accommodating higher RE in their power purchase portfolio and passing the benefit of the low cost of RE to their customers.

Amitesh K. Sinha
Joint Secretary
Ministry of New and Renewable Energy

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GLOSSARY (DEFINITIONS)

In this white paper, unless the context otherwise, requires, --

Additional resource	A resource needed to meet demand after considering current, retiring and future resources.
Ancillary services	The services necessary to support the grid's reliable operation, including frequency regulation and contingency reserves.
Availability-based tariff	Frequency based pricing mechanism
Behind the meter	The side of the meter where consumer appliances and equipment are connected.
Capacity expansion model	An optimization model used to develop least-cost investment plans for capacity expansion.
Demand	The amount of electricity consumers are willing to purchase at a given point in time (for this report, "demand" and "load" have the same meaning).
Demand forecasting	The prediction of the amount of consumer demand to optimize supply decisions.
Demand response (DR)	A method used to directly or indirectly manage consumer demand using incentive systems. Demand response can be price-based (e.g., time of use, critical peak pricing, real time pricing) or event-based (e.g., direct load control, curtailable load management).
Demand-side management (DSM)	Programs implemented to influence consumer consumption and/or demand patterns for peak clipping, valley filling, load shifting, energy conservation and other purposes. DSM includes all demand-reducing measures such as demand response and energy efficiency.
DISCOM	A power distribution company.
Dispatchable resource	A resource that can be controlled centrally by a system operator.
Distributed energy resources	Resources that are deployed at the distribution level, including distribution-level energy storage, distributed generation, and electric vehicles.
Econometric	A demand forecasting technique that includes behaviors of economic variables and regression modelling techniques.
End use	A demand forecasting technique based on estimates of the electricity used by each consumer category.
Energy not served	The expected amount of energy the system is not providing to consumers during a given period due to system capacity shortages, unavailable supply-side resources, or severe power outages.
Existing resource	A resource that is contractually obligated and available to serve consumer demand.
Generation adequacy	The power generation system's ability to match demand at all times.
Generation expansion planning model	A model that helps determine the type of technology, size and time at which new generation units must be integrated to the system, over a given planning horizon, to satisfy the forecast energy demand.

Least regret planning	Planning approach that prioritizes investments based on multiple plausible futures
Load research	The study of the way's consumers use electricity, either in total or by individual end uses. Load research is used to identify trends and general demand characteristics by consumer category.
Loss of load	The loss that occurs whenever system demand exceeds available generation capacity.
Loss of load probability	The probability that there will be shortage of power.
Network congestion	Congestion occurs when the power required to flow over transmission and distribution systems is constrained due to capacity limitations.
Non-pit head coal plants	Coal plants that are located away from the coal pit station.
Option analysis	The analysis of options to help determine the preferred resource plan.
Peak demand	The highest electrical power demand that has occurred over a specified time (e.g., day, month, season, year).
Partial end use method (PEUM)	A combination of the end use and time series methods normally used for demand forecasting and based on the quality of the available data.
Present value of revenue required (PVRR)	The present value of the revenue utilities needs to recover their costs and obtain the regulated return.
Procurement plan	The additional capacity identified in the resource plan that must be procured to meet future demand.
Reserve margin	The extra capacity available in the system after meeting all forecast demand.
Resource planning (RP)	The process distribution companies use to optimize supply resources to meet their long- and medium-term demand based on cost, environmental, energy security and other objectives.
Retiring resource	A resource that will no longer be available to serve consumer demand.
System	Refers to the network of transmission and distribution lines, substations, transformers and other associated equipment required for the flow of power in any electrical network, popularly known as the grid.
System-friendly procurement	The procurement of power that has a lower system integration cost.
System integration	Integration of renewable energy source-based generation in the grid
Unscheduled interchange charges	The incentive/penalty based on the under/over draw of power from the schedule based on the frequency of the system at the time of under/over draw.
Upcoming resource	A resource that will be available in future to meet consumer demand.

ACRONYMS

AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AMI	Advance metering infrastructure
AP	Approximation-based
APERC	Andhra Pradesh Electricity Regulatory Commission
APPC	Average power procurement cost
ARR	Aggregate revenue requirement
AT&C	Aggregate Technical and Commercial
BAU	Business as usual
BEE	Indian Bureau of Energy Efficiency
BMS	Battery management system
BSES	BSES Yamuna Power Limited
CAGR	Compound annual growth rate
CEA	Central Electricity Authority
CER	Centre for Energy Regulation
CERC	Central Electricity Regulatory Commission
CESC	Calcutta Electric Supply Corporation
CPRI	Central Power Research Institute
CSIRO	Commonwealth Scientific and Industrial Research Organization
CUF	Capacity utilization factor
DAPR	Distribution Annual Planning Report
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
DER	Distributed energy resources
DERC	Delhi Electricity Regulatory Commission
DG	Distributed generation
DISCOM	Distribution company
DNO	Distribution network operator
DR	Demand response
DSM	Demand-side management
EC	Energy Conservation
EE	Energy efficiency
EE&DSM	Energy efficiency and Demand-side management
EGEAS	Electric Generation Expansion Analysis Software
EMA	Exponential moving average
ENS	Energy-not-served
ENW	Electricity North West
EPS	Electric Power Survey
EV	Electric vehicles
FNA	Federal Network Agency
FOR	Forum of Regulators

GDP	Grid Development Plan
GERC	Gujarat Electricity Regulatory Commission
GUVNL	Gujarat Urja Vitran Nigam Limited
GW	Gigawatt
IIT	Indian Institute of Technology
INR	Indian rupee
IPDS	Integrated Power Development Scheme
IRENA	International Renewable Energy Agency
IRP	Integrated resource planning
ISP	Integrated system plan
kWh	Kilo-Watt Hour
LED	Light Emitting Diode
LOLP	Loss of load probability
LT	Long term
MILP	Mixed Integer Linear Programming
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MUs	Million Units
MW	Megawatt
MYT	Multi Year Tariff
MWh	Megawatt Hour
NEM	National Electricity Market
NEP	National Electricity Plan
NPTI	National Power Training Institute
PACE-D	Partnership to Advance Clean Energy-Deployment
PAT	Perform Achieve Trade
PEUM	Partial end use methodology
PFA	Power for All
PFC	Power Finance Corporation
PLF	Plant load factor
PPAs	Power purchase agreements
PSPCL	Punjab State Power Corporation Limited
PURPA	Public Utility Regulatory Policies Act
PV	Photovoltaic
PVRR	Present value of revenue return
RB	Reliability-based
RE	Electricity Generation from Renewable Energy Sources
REC	Renewable Energy Certificates
REZ	Renewable Energy Zones
RP	Resource planning
RUVNL	Rajasthan Urja Vikas Nigam Limited
SAE	Statistically adjusted end-use

SECI	The Solar Energy Corporation of India
SERC	State Electricity Regulatory Commission
SLDC	State load dispatch center
STU	State Transmission Utility
TERI	The Energy and Research Institute
TPDDL	Tata Power Delhi Distribution
TPP	Thermal Power Plant
TSOs	Transmission system operator
TWh	Terra Watt Hour
UDAY	Ujjwal DISCOM Assurance Yojana
UI	Unscheduled Interchange
UK	United Kingdom
UPERC	Uttar Pradesh Electricity Regulatory Commission
UPPCL	Uttar Pradesh Power Corporation Limited
USAID	United States Agency for International Development
US	United States

EXECUTIVE SUMMARY

The economics of renewable energy-based generation, coupled with innovative technologies, have been growing more favorable, largely due to changing market fundamentals. Realizing the opportunities offered by falling renewable energy (RE) prices, the distribution companies' (DISCOMs) best consumers have begun drifting away from their traditional suppliers. Today, DISCOMs have little choice but to rethink the way they have been running their business. The key step in this rethinking is resource planning, which allows DISCOMs to absorb more renewable energy into their systems at a lower cost and pass the benefits on to their consumers.

This paper seeks to encourage DISCOMs, policymakers and other stakeholders to rethink their current method of resource planning. It analyzes the current state of resource planning, draws lessons from renewable energy-rich countries (USA, Australia, Germany, UK and others), and makes recommendations to improve resource planning at DISCOMs so they can move from a fossil-fuel based power portfolio to an RE-based portfolio. (This paper focuses on long-term[1] resource planning; day-ahead planning is not within its purview.)

Spurred by ambitious national commitments (175 GW of RE by 2022 in the existing 362 GW grid with an ambition to achieve 450 GW by 2030) and rapid technological progress in the past five years, India has seen an unprecedented addition of renewable capacity (80.5 GW as of June 2019). In 2019, renewable energy (RE) accounted for 75% of the total capacity additions made to India's system and this trend is expected to continue with the maturity of RE market and falling costs.

However, success of this addition's hinges on DISCOM's who at the end are the primary off taker of RE. In the present scenario, the DISCOMs are not better equipped to deal with RE dominated portfolio. which is variable and do not corresponds to the peak demand period and creates excess power situation during the off-peak period. If India must achieve its RE ambition, DISCOMs hold the key, for which they need to be guided and supported for improving their resource planning strategies.

Resource planning is a process that helps DISCOMs to optimize their supply resources to meet long-term demand based on cost, environmental, energy security, and other objectives. It involves three sub-processes, which are implemented sequentially:

1. Forecast demand over the planning horizon.
2. Determine shortage of existing resources vis-à-vis the forecast demand.
3. Address shortage by developing or purchasing the best mix of additional resources that offers low cost at least regret.

DISCOM Resource Planning in India: Current Challenges

In India, resource planning is often done using the reference point of the peak demand to be met by fossil-based generation, rather than by using demand profiles, a process that could help use renewable

[1] Above five years.

energy when it is the least cost option. This is a matter of great importance, as renewable energy-dominated power portfolios can be cheaper than a fossil-based generation, and in turn can influence the cost of power procurement, which accounts for 60-70% of the average cost of supply.

One challenge DISCOMs face is that while conventional generation is firm, controllable and predictable, while renewable energy generation varies significantly over the day and across the seasons. Besides there is risk of sudden drop in RE generation due to natural vagaries (for example cloud burst in case of solar). However, the diurnal variation of RE can be matched with varying demand by better forecasting. This will minimize the system integration cost as well. More meticulous planning can also capitalize better the seasonal variability of RE and demand. This will help DISCOM to save extra money by not procuring the capacity for the full year. The natural vagaries can be covered in the risk analysis of resource planning and can be addressed through market mechanism. In the context of India, all this requires significant improvement in current planning tools and methodologies, and the capacities of power sector planners.

Poor resource planning in the past has impacted DISCOM's with either excess contracted demand (resulting in undue burden of fixed charges ultimately leading to higher consumer tariffs), or shortages impacting the economic growth and well-being of consumers (resulting from load shedding or costly power purchase). The current state of resource planning in India, at both the central and state levels, and a review of international best practices revealed the gaps shown as in Table 1.

Table 1: Current State of Resource Planning in India and Gaps Observed w.r.t to International Practices

Actors	
	• Central Electricity Authority (CEA) prepares long term demand forecasts based on a partial end use methodology (PEUM). Forecasts are published every five years through the Electric Power Survey. The forecast provides peak demand (MW) and energy (MUs) projections for 10-20 years are used as input to the Generation and Transmission Plans of the National Electricity Plan. • CEA uses generation expansion planning tools (EGEAS and Ordena) which identify the additional capacity requirement based on the priority matrix and are published in the National Electricity Plan every five years.
	• Demand forecasts are prepared using spreadsheet-based trend/time series methods; very few states have adopted econometric methods. Forecasts use the compound annual growth rate (CAGR) approach and are reviewed/revised every year. DISCOMs attach weight to CEA's numbers, but do not religiously follow them. • Resource planning is largely done using spreadsheets and is primarily tied to retail tariff setting for DISCOMs as part of aggregate revenue requirements and the approval of medium- and long-term power procurement agreements • States and DISCOMs use a simple arithmetic gap analysis to determine annual peak demand vs. supply availability. Few use a detailed time resolution. • There is little cognizance of developments behind the meter. Most of the resource planning is done by entity that does power procurement on behalf of DISCOM or

Actors	Resource Planning Approach
	by power purchase committee with multiple stakeholders. Focus of DISCOMs is more on addressing short term and day ahead planning.
International Best Practices	• Demand forecasts are generally based on end-use and econometric methods have a high degree of spatial and time resolution and employ complex software models. Load research is utilized to obtain and utilize quality data. • Risk and uncertainty are managed through undertaking scenario analysis, sensitivity analysis, probabilistic analysis and options development. • Regulatory frameworks for resource planning provide guidance and promotes public involvement to review the plans. • Use of demand response (DR), EE, DER, and behind-the-meter options. • Tariff-setting and resource planning is carried out in separate proceedings to provide enough time for each important activity.
Gaps	• There is a need to improve forecasts using load research techniques that yield high spatial and time resolution forecasts. Cognizance of new realities, RE, distributed energy resources (DER), electric vehicles (EV) and energy efficiency (EE)). Detailed analysis for risk and uncertainty management. • Low awareness to build capacity for resource planning at DISCOM level and limited inclusion and coordination between state and centre • Absence of judicious use of DR, EE, DER and behind-the-meter options. • Limited use of sophisticated tools to manage long term resource plan. • Absence of adaptive regulatory framework for resource planning. Limited engagement of all key stakeholders (public consultations, civic societies and state ministries); • Resource plan and ARR are examined by the regulator at the same time.

The existing practices of resource planning in India revealed significant gaps in comparison to international best practices. The planning process not only includes the new realities governed by RE dominated power portfolio, utilization for demand response measures or managing power system with pricing signal and better balancing utilizing ICT technologies but also have gaps in methodologies to have accurate resource plan. The DISCOMs approach to RE capacity addition is largely driven by pressure to support achievements of national targets or to reduce the power purchase cost. Well laid out plan to procure RE is almost nonexistent with limited support in form of frameworks for better coordination and engagement of stakeholders. In fact, due to limited understanding on how to plan procurements under the RE rich scenario, most of the DISCOMs in India are choosing to place requirement to procure RE on their behalf with Solar Energy Cooperation of India (SECI).

A resource plan that produces the best mix of resources at low cost with least regret is highly important to significantly reduce the power purchase cost of the DISCOM and increase the RE deployment. Two simulation study conducted for Karnataka and Rajasthan states have estimated annual saving of more than $140 million by better resource planning from the business as usual scenario. DISCOMs must be innovative in designing power procurement contracts so that RE is delivered at least cost instead of RE generated at least cost, ensuring they address future rollouts of renewable energy and the impacts of such disruptive technologies as energy storage and electric vehicles[2]. Based on the extensive analysis, consultations and review of practices this white paper has developed following recommendations to help DISCOMs develop accurate resource plans that would add more RE, reduce power purchase costs and ultimately, the consumer tariff.

Key Recommendations

1. **Institutional Level**: Sensitization is important on why resource planning is important in RE dominated environment and how useful resources plan will help in drawing the advantage of cheaper RE power. The sensitization may be different for each of the two important groups. For DISCOM it should be on methodology for accurate long term forecast while for regulators for examination of the methodology and assessment of its impact. Central Government (Ministry of New and Renewable Energy (MNRE)/Ministry of Power (MoP)/Central Electricity Authority (CEA)/State Governments) need to identify institutions that can develop and can run courses on resource planning such as CPRI, CER, IITs, NPTI etc.

2. **Regulatory Level**:

   There are two important aspects which are to be considered from regulatory guidance perspective.

   a. *Development of Regulatory Framework*

   Creation of regulatory framework for resource planning is most important. There exists no well laid-out regulatory guidelines for planning 60-70 percent expenditure of the distribution business. It will be useful if regulations are developed that provide comprehensive guideline of – methodology of resource planning, recommend utilizing robust software's, plan realistic horizon and encourage public participation. Mandate DISCOMs to undertake - load research, risk analysis and regular updates on resource plan. The Forum of Regulators (FoR) can develop model regulation for State Electricity Regulatory Commissions (SERCs) to adopt and DISCOM to implement.

   b. *Sufficient Time for Regulatory Review*

   It is important that resource planning review should be separated from ARR examination. Tariff-setting is given much more importance by the regulators, and resource planning gets limited attention. Resource planning should be carried out and reviewed in separate proceedings as it has a long-term horizon and needs to be expansive and comprehensive. Since resource plan is for 10 years, DISCOM should submit their resource plan to regulators early than filing ARR and it can be updated every two years.

3. **Capacity Building Level:** Renewable future cannot be built on old planning approaches of power sector. A significant attention to improve the capabilities of DISCOM staff is required. DISCOM planners need to be trained to undertake planning in era which is copious in RE and

[2] USAID's PACE-D 2.0 renewable energy team is developing a white paper on system-friendly renewable energy procurement.

undergoing transformation. It is important for them to gain practical insights and learnings on how to develop resource plans that incorporate the full palette of supply and demand options, how to utilize software's/model that properly account all variables and help plan the portfolio. Dedicated capacity building workshops on modelling, train the trainer programs, load research methodologies, trainings through international courses and country visits, webinars will support employees of distribution utility companies to learn and further apply the knowledge for development of resource plans.

4. **DISCOM Level:** Coordinated resource planning is key to make use of falling RE prices and associated economic gains of using higher RE in the system to remain cost effective. Each DISCOM thus must have a planning department that should be solely responsible for development of the resource plan.

Better resource planning offers the possibility of significant reductions in DISCOMs' power purchase costs which accounts for 60-70% of the total cost of electricity served to end consumers and is therefore, the most critical expenditure head of a DISCOM. It will also ensure that demand of electricity is met in the most economical and efficient manner. RE resource require less time in commissioning, they are cheaper and cleaner. Better planning strategies will lead to improvement in environment, prosperous utilities and satisfied consumers.

CHAPTER 1. INTRODUCTION

Power systems are operated by matching demand and supply at every instant of time. In India, a system with a frequency of 50 hertz denotes a perfect matching, while a lower frequency indicates excess demand and a higher frequency attributes to lower demand with respect to supply. Traditionally, demand has been considered uncontrollable. The only method available to control demand was to 'cut in' or 'cut out' supply feeder. Supply was considered firm and controllable. Supply-side control was exercised by stopping or starting peak (diesel, hydro and gas) generators, thermal backing (reducing coal-fired generation that does not require oil support) and/or stopping/starting the hydro machines.

Today, the "firm" status of electricity supply is becoming "variable" because of the increasing penetration of RE. The supply-side variations are based on the availability of solar radiation, wind and other renewable sources. With technology advancements and market-based mechanisms, it is now possible to control demand by demand response, tariff signals and distributed generation. The supply can be controlled by introducing flexibility, energy storage and other means. Since the deployment of demand control measures is still in its infancy, the costs of system flexibility to accommodate supply-side variations as a result of RE are loaded in the cost of RE generation. This system flexibility cost is referred to as "System integration costs."

Helping DISCOMs bring more RE into their portfolios and reducing their power purchase costs are key objectives of USAID's PACE-D 2.0 RE Program[3] (the "program"). Matching demand/supply variations will require meticulous resource planning (starting with accurate demand forecasts) and system-friendly RE procurement.[4]

This paper examines the process of resource planning, how better resource planning can ensure reduced grid integration cost, the existing status of resource planning in India, international best practices, and how better resource planning can support system-friendly procurement. It also provides recommendations for the policy, regulatory, institutional and methodological changes required to support improved resource planning in DISCOMs. The methodological changes proposed are being tested under the program in two states, Assam and Jharkhand, by developing a rigorous, modular and easy to adopt resource planning software tool.

This paper is based on intensive desk research and discussions with 1) state power sector planners and electricity regulatory commissions in Andhra Pradesh, Gujarat, Assam, Jharkhand, West Bengal, Rajasthan, 2) private DISCOMs Calcutta Electricity Supply Corporation (CESC), Tata Power Delhi Distribution (TPDDL), and BSES Yamuna Power Limited (BSES), and 3) central government agencies such as Central Electricity Authority (CEA), Central Electricity Regulatory Commission (CERC) and the Solar Energy

[3] USAID PACE-D 2.0 RE is a technical assistance program under the US-India bilateral energy program and is being implemented by USAID in partnership with the Ministry of New and Renewable Energy. The program has three components: A-Strategic Planning, B-Distributed Rooftop Solar, and C-Innovative RE Procurement.

[4] System-friendly RE procurement is the injection of RE into the system at a time, location in quantity that supports the system in matching demand and supply. While resource planning is covered under Component A of the program and system-friendly procurement is theme of Component C.

Corporation of India (SECI). Also, focused discussions and exchanges were held with consultants and firms working in power sector planning.

Structure of the White Paper

While the Chapter 1 introduced power system operation, Chapter 2 explains why a rethinking of resource planning is required in a renewable energy (RE) rich environment. Chapter 3 discusses what is resource planning. Chapter 4 analyze the current state of resource planning in India in detail both at the Centre and at States. Chapter 5 follows this with a review of international best practices in long-term planning in four countries with high amounts of RE in their generation mix: Australia, Germany, United Kingdom (UK) and United States of America (US) in detail and references a few other RE rich countries. Chapter 6 identifies gaps between current practices in India and international best practices and observations based on comparative analysis. Finally, Chapter 7 proposes actionable recommendations to improve the DISCOMs resource planning in India, readying it for a renewable rich environment. The recommendations provided have been categorized accordingly to relevance, how they will be implemented and who will implement them.

CHAPTER 2. WHY DISCOMS NEED TO RETHINK RESOURCE PLANNING IN A RENEWABLE ENERGY RICH SCENARIO

The importance of power sector resource planning has increased recently due to several developments. On the supply side RE has become a potential source due to much lower cost of generation in comparison to the cost from fossil fuel-based generation. RE is better resource from the environment and energy security considerations. On the demand side, with the advancement in technology, it is possible to control demand by demand response and other demand side measures. But RE generation has variations and requires support by way of storage or/and ancillary market services to eliminate the variations before it can be integrated into the grid. Fortunately, the cost of storage technology is also reducing substantially.

The higher use of RE will reduce power purchase cost of DISCOM besides addressing the issue of environment and energy security. But renewable energy generation varies significantly over the day and across the seasons. Besides there is risk of sudden drop in RE generation due to natural vagaries (for example cloud burst in case of solar). This requires resource allocation (planning) based on seasons and hours while the conventional resource planning was based on peak and average demand. DISCOM are suggested to do this rethinking in their existing practice of resource planning.

This chapter discuss these developments and concludes with the estimation of possible reduction of power purchase cost of the DISCOM. Subsequent chapters cover how DISCOM should do resource planning to achieve these gains.

2.1 DEVELOPMENT 1: FALLING PRICES OF RENEWABLE ENERGY

Spurred by ambitious national commitments (175 GW of RE by 2022 in the existing 385 GW grid) and rapid technological progress in the past five years, India has seen an unprecedented addition of renewable capacity (80.5 GW as of June 2019). As shown in Figure 1, in 2019, RE accounted for 75% of the total capacity additions made to India's system.

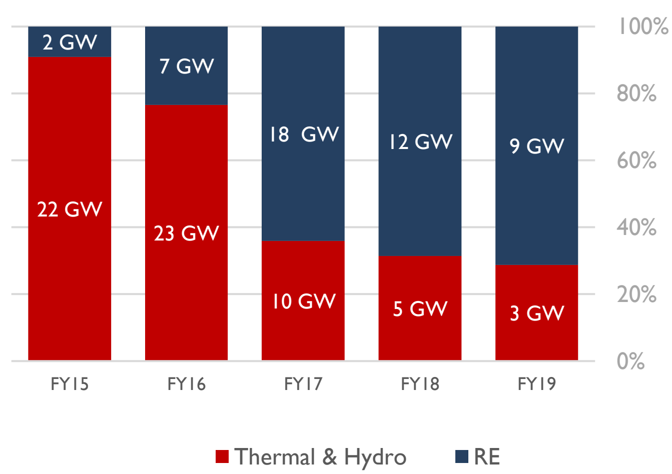

Figure 1: Recent Capacity Additions in India
Source: PACE-D 2.0 RE Research

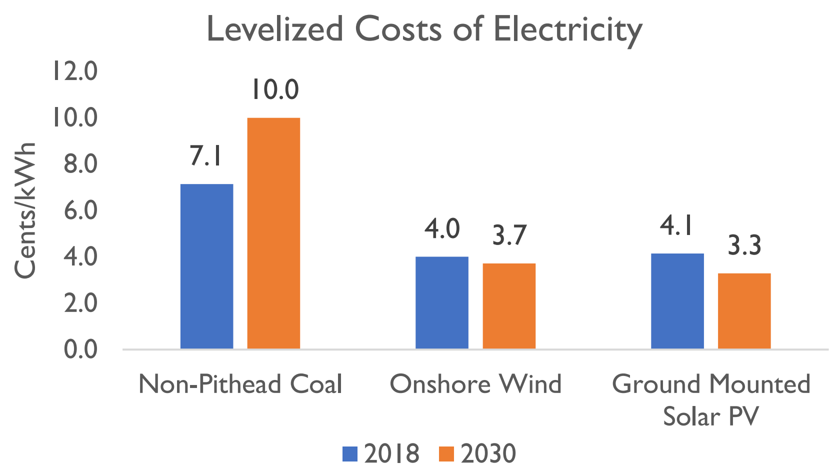

Figure 2: Future Power Generation Costs in India
Source: Accelerating India's Transition to Renewables

Two factors have driven these capacity additions. First, solar prices have fallen by 57% in the past five years (2013-2018), and second, the average power purchase cost of thermal generation at the national level has increased by a CAGR of 2%[5]. Future thermal generation costs from non-pit head coal plants is predicted to rise from 7 cents/kWh in 2018 to 10 cents/kWh in 2030, while onshore wind costs will fall from 4 cent/kWh to 3.7 cents/kWh and those for ground mounted solar PV will fall from 4.1 cents/kWh to 3.2 cents/kWh Figure 2.[6] The thermal generation cost is likely to get further increase for compliance of new emissions norms for SOx and NOx.

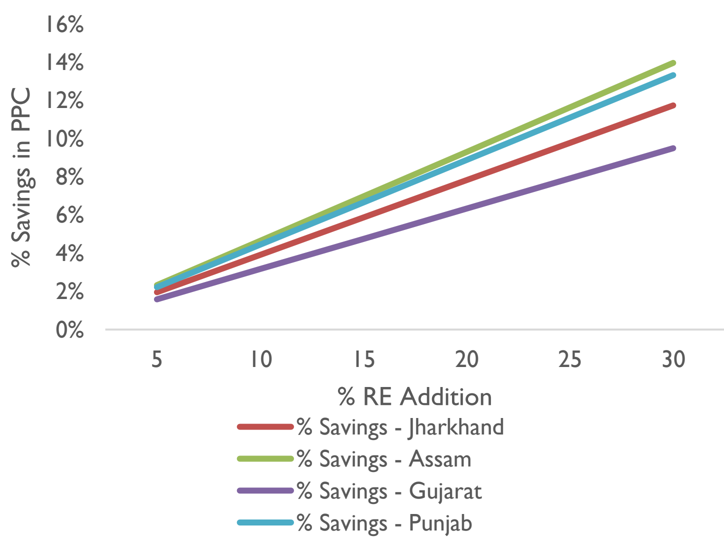

Figure 3: Savings in Power Purchase Cost with Increased RE Addition
Source: PACE D 2.0 RE research

With significant improvements in performance and cost competitiveness, RE technologies now have much lower costs than conventional sources and are candidates for a larger share of the power generation mix. They are also becoming important in DISCOM's strategies. This paper analyzes the four Indian states in Figure 3. This chart shows that in current scenario, if RE uptake is increased to 25% the power purchase cost of the DISCOM will reduce by 10%. For example, in Rajasthan, a 25% penetration of RE will translate to about USD 414 million of reduced power purchase costs annually.

[5] PACE-D 2.0 RE team research

[6] Climate Policy Initiative and TERI. (2019). Accelerating India's Transition to Renewables – A Report from US Climate Policy Initiative and TERI.

Therefore, DISCOMs are looking for ways to substitute RE for as much thermal generation as possible because it positively impacts their power purchase cost. Unfortunately, simple substitution is not possible due to variable nature of RE in comparison of stable power from fossil fuels and it requires system flexibility to accommodate RE variations.

2.2 DEVELOPMENT 2: BETTER CORRELATION BETWEEN DEMAND SUPPLY CURVE WILL REDUCE GRID INTEGRATION COST FOR RE

Amid this accelerating transition, renewable energy sources (especially wind and solar) present new challenges. Renewables are variable, uncertain, complex and unpredictable. Smart planning, which helps match variable demand and supply, can limit the challenge of balancing supply and demand. Integrating large amounts of RE with the grid requires better forecasting of RE, storage (as RE is not available 24x7), and larger balancing power to accommodate variations in the availability of RE.

Managing this variability in the system incur additional cost, which could undermine the cost benefits of RE if the integration cost is not brought to minimum. The CEA of India estimates grid integration costs at 2.2 cents/kWh in Tamil Nadu and 2 cents/kWh in Gujarat.[7] It also estimated an all-India figure of 1.5 cents /kWh for 2022 (Figure 4).

Details of calculation for All India scenario for 2022

S.no	Balancing Cost	Rs./ Unit	Cents/ Unit
1	Total balancing charge for Gas based station (fixed +fuel charge)-Spread over renewable generation	0.04	0.06
2	Impact of DSM per unit- Spread over renewable generation	0.30	0.43
3	Impact on tariff for All India discom for backing down Coal based generation assuming solar and wind at Rs. 2.50/kWh (3.6 cents/kWh) and tariff of coal based generation at Rs. 3.50/kWh (5.0 cents/kWh) - Spread over renewable generation	0.00	0.00
4	Stand by charge - Spread over renewable generation	0.50	0.71
5	Extra transmission charge - Spread over renewable generation	0.26	0.37
	Total Impact - Spread over renewable generation	1.11	1.59

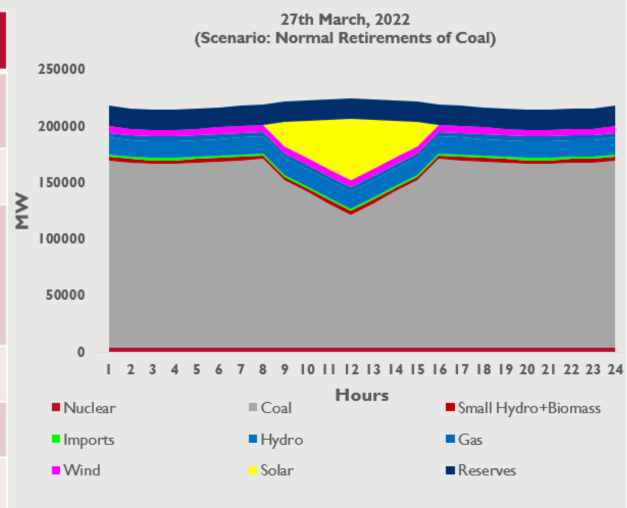

Figure 4: Balancing Cost for Accommodating Renewables
Source: CEA Report, 2018

This study is based on the ramp rate of the available thermal machines in the respective states and does not consider the possibility of matching the demand and supply curve with a higher correlation coefficient, thereby reducing the grid integration cost significantly. This will require better modeling efforts and looks

[7] CEA. (2017). Study of Optimal Location of Various Types of Balancing Energy Sources/Energy Storage Devices to Facilitate Grid Integration of Renewable Energy Sources and Associated Issues

high potential area of reducing grid integration cost for RE. USAID PACE-D 2.0 RE team is already working to develop such model for the state of Jharkhand and Assam.

2.3 DEVELOPMENT 3: DSM MEASURES PROVIDE ADDITIONAL RESOURCE

Historically, in resource planning, demand was considered uncontrollable parameter while resources were considered controllable and were planned to meet the demand. With advances in electronics, communication and storage technologies, it is now possible to control demand by demand response, energy efficiency, and distributed energy resources. Worldwide, several utilities have successfully used these measures to control demand. In US the quantity of demand which can be controlled by these measures is considered as a resource for balancing the demand and supply. In India this has been tested as pilots in the pockets but there is no DISCOM level scaling. In India DSM measures presently are considered in resource planning as a fix and constant reduction in demand. (Ref Chapter 3 and 4). However better utilization of DSM measure will be to fill the intermittent resource gap across time in comparison to new capacity addition with lower utilization factor. DSM measures can also be used to mitigate the variations in RE generation if accurate forecasting of RE is available in place of storage technologies. In view of the falling storage prices a comparative analysis between storage technologies and DSM measures is needed in resource planning to decide which is the better candidate and when.

2.4 CONCLUSION

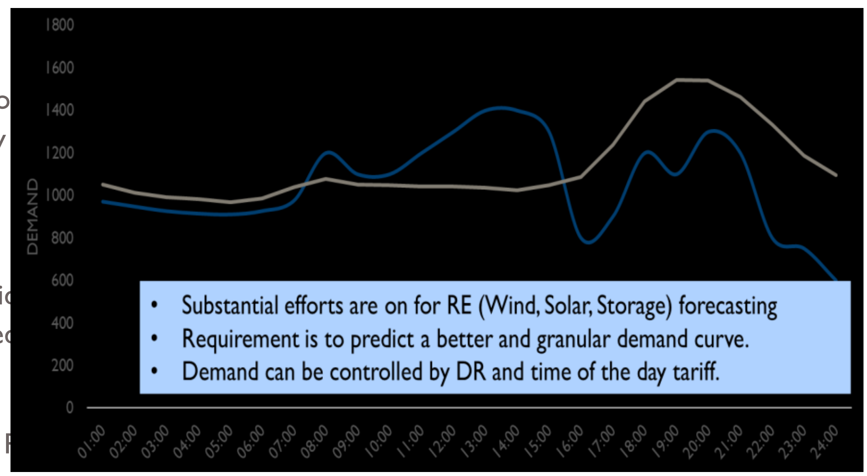

Figure 5: Matching Demand Supply Curves Lower System Integration Costs

In the future, supply-side resources will no longer supply firm power but will vary significantly as a result of their higher RE component. Better matching of the variations in supply with demand across space-time will reduce the cost for gric integration of the RE which is now estimatec to be 1.5 cents/kWh for 2022 in India.

This requires accurate forecasting for both F resources and demand. The greater precision in the demand forecast, will result in better allocation of RE rich resources (Figure 5). The better resource planning will increase the uptake of RE capacity with less investment for grid integration. The higher uptake of RE will reduce the power purchase cost of the DISCOM. To validate this hypothesis, two simulation exercises were conducted for the states of Karnataka and Rajasthan (see Annex 2). In case of Karnataka there will be annual saving of 142 million USD from 2030 onwards from business as usual scenario (new capacity requirements are met by coal-based generation as per current resource planning practices). In case of Rajasthan the power purchase cost will get reduced annually by 265 million USD for 2022 scenario.

Thus, the current practice of resource planning requires a rethinking to accommodate higher RE in the system with minimum grid integration cost, use of technology driven measures of DSM for optimizing the supply and demand balancing on time spatial.

CHAPTER 3. RESOURCE PLANNING: AN INTRODUCTION

Resource planning is the process used to optimize supply resources to meet medium- and long-term demand at a low cost with least regret. Because supply resources are capital intensive and have a long life, their planning has significant impacts on the finances of distribution companies.[8]

In India, the State Electricity Boards had strong planning departments before the power sector was unbundled. This plan was used by all stakeholders for example all investments in a state's power sector were based on the projections made in the plan One of the fallouts of unbundling was that the planning function got siloed and the plan is limited to the functions of the unbundled entity. For example, DISCOMs role got limited to demand forecasting and power purchase. There were attempts in some of the states[9] for coordination among unbundled entities by creating single power buyer entity for the state. This effort could not restore the meticulous planning of the pre-unbundled era. The importance of long-term and medium-term planning was diluted, and focus shifted to managing short term causalities. The introduction of unscheduled interchange penalty under availability-based tariff also shifted the focus to day ahead planning.

This section describes the process of developing a resource plan to meet consumers' medium- and long-term electricity demands.

3.1 THE RESOURCE PLANNING PROCESS

Resource plans are typically prepared for a planning period of 5-10 years for (medium-term plans) or 10-20 years (long-term plans). Figure 6 depicts the process of resource planning, which involves three sub-processes in sequence:

1. Demand forecast over the planning horizon
2. The shortage of existing resources and forecasted demand (identified in sub-process 1)
3. Plan to meet the "shortage" (identified in sub-process 2) by developing or buying the best mix of additional resources at low cost and least regret, monitor and feedback to sub-process 2.

Like planning in other sectors, power sector planning encounters demand and resource uncertainties, resulting in risks. To mitigate these risks, a good resource plan includes four analyses: 1) scenario, 2) sensitivity, 3) probabilistic, and 4) option. The following subsections describe the process of resource planning in detail.

[8] System-friendly RE procurement is the injection of RE into the system at a time, location in quantity that supports the system in matching demand and supply. While resource planning is covered under Component A of the program and system-friendly procurement is theme of Component C.

[9] For example, in Gujarat and Andhra Pradesh state have single power buyer as GUVNL and APTRANCSO.

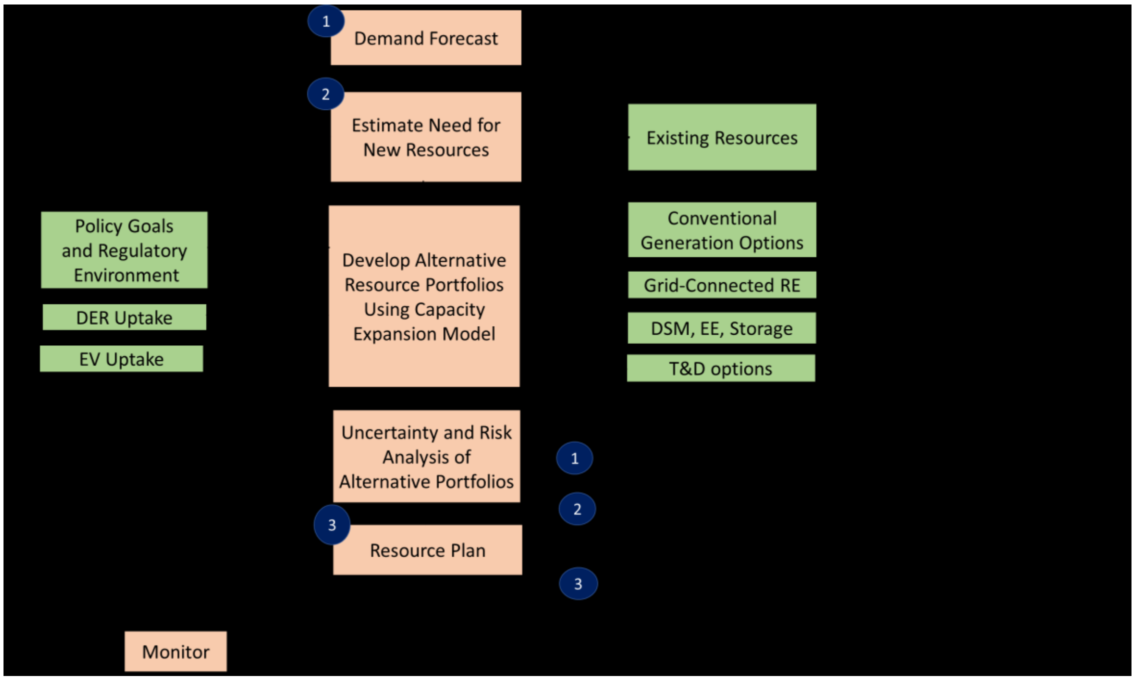

Figure 6: Resource Planning Process
Source: Adapted from Kahrl, et al. The Future of Electricity Resource Planning, 2016

3.2 DEMAND FORECASTING

Demand forecasting is a science and art of predicting the cause, magnitude and location of electric demand over different period of planning horizon. Demand forecasting assumes a greater importance because, underestimation of demand lead to under capacity, which results in poor quality of service including localized brownouts or even blackouts. An overestimation could lead to authorization and construction of a plant that may not be needed for several years.

In the process of making predictions, forecasters bear in mind the feedback effects of pricing and policy changes, and therefore, participates in the process of designing ways and means to meet consumer demands (such as developing demand profiles to manage peaks and troughs of electricity demand).

While there is array of methods that are available today for forecasting demand, we have focused on most commonly used approaches to demand forecasting. The first is a ***trend line***, where the historical growth rate is used to extrapolate future demand. While this approach is easy to use, it is not very accurate because it assumes that a historical trend will continue, but often it does not. This approach does not consider econometric, demographic, policy or technological parameters. Compounded average growth rate (CAGR) method practiced by state DISCOMs is one such example.

The second is to use ***econometric parameters*** such as growth in GDP, income per capita, penetration of appliances and growth in electricity-intensive industries to determine the demand forecast. Econometric models are top-down models.

The third approach is to use ***end-use models***, which use a bottom-up approach. They use consumption data for each end-use to estimate electricity use for each consumer category. End-use models facilitate an understanding of the factors that affect consumption, and consequently can account for a change in consumption due to improvements in appliance efficiency or an increase in the penetration of an appliance. End-use models help estimate future demand in considerable detail by type, category, and size likely be demanded in the future. They also assist in tracing and pinpointing any time where and why actual consumption has deviated from estimated demand. A major disadvantage of end-use models is the need for end-use data. Load research is conducted to obtain such data.

Methods of Demand Forecasting

Time-Series (Trend Line) – Quick and easy. Based on the historical CAGR growth rate. Projects future based on historical past and limits the inclusion of new economic developments and environmental factors.

Econometric – Includes the behavior of economic variables and regression modelling techniques. Limited by the availability of good information and useful when large and predictable changes are expected.

End-Use – Focuses on determining various categories of consumers' final energy needs and then their aggregation. Data on end-use not easily available and takes time and investment to collect.

Generally, econometric and end-use models are combined to capture the best features of each. In the United States, the Electric Power Research Institute developed such models, which include behavioral features to determine electricity price elasticity and produce more accurate demand forecasts due to econometric parameters on the baseline developed by the end-use method.

LOAD RESEARCH

Load research helps utilities to understand how various consumer categories (residential, commercial, industrial, etc.) use electricity in a day and how diversity in their usage helps flatten the demand curve. Knowing this diurnal variation of demand also helps in allocating supply resources.

Load research is centered around end-user level metering of a sample of consumer premises for an extended period. Metering must be preceded by planning and sample design and selection. Metering data are processed and analyzed. Figure 7 gives one example of the information load research provides.

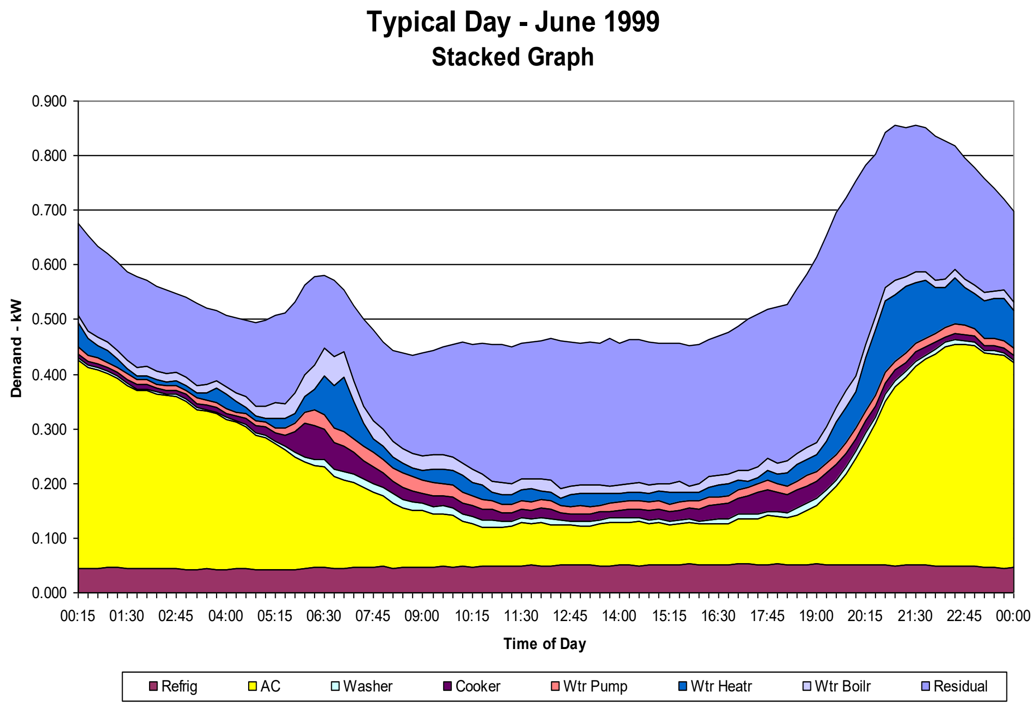

Figure 7: Example of the Load of a Household in Thailand on a Typical Summer Day Based on Load Research
Source: Electric Power Research Institute, Load Research Program for Demand Side Management Project, Contract No. EGAT 47/1-48-0407-40228, February 2000.

With the implementation of advanced metering infrastructure (AMI), DISCOMs will be able to obtain this information directly from meter data. This will make load research simpler and less time consuming, while increased sample size (it may be possible to consider the entire population if all consumers are connected to AMI) will significantly increase the accuracy of the load research.

3.3 ESTIMATING ADDITIONAL RESOURCES

Once the demand forecast has been established, existing supply resources and their availability are mapped over the planning horizon. The supply resources should include all DISCOM-owned resources and the power purchase agreements (PPAs) from which the DISCOM has contracted power. Comparing the demand forecast with the resources available each year produces an estimate of the additional resources needed to meet the demand of each year. Usually, this is developed on a peak, average, and hourly basis.

An hourly estimation has become important for the better utilization of RE resources, which have high diurnal variations. This will require hourly estimations of both demand and resources. The granular (hourly and in time blocks of 15 minutes) estimates of additional resource requirements can theoretically bring the cost of RE grid integration to zero by exactly matching RE diurnal variations with demand diurnal variations.

3.4 DEVELOPING ALTERNATIVE RESOURCE PORTFOLIOS

Historically a plan for additional resources is developed to meet average and peak demand based on running baseload and peaking power plants on a least-cost basis. Nowadays this exercise has become more complex as a resource plan is not expected to just minimize the cost but also to optimize other parameters such as emissions, land, water, indigenous energy resources, etc. Other dependent variables that add to this complexity include 1) the availability of many options (RE, power trades through energy exchanges, captive power, etc.) and 2) technology advances and their influence on the demand side (DR, EE, DG, tariff signals, etc.).

Therefore, the popular capacity expansion model no longer serves its purpose; a more sophisticated model that support electrification, redefine reliability needs, enable new technology inclusion and enhance competitive procurement is needed to generate several options based on the priorities of the central or state government. For example, a clean energy scenario would have a high penetration of EE, DSM and RE, while a high prosperity scenario would assume high GDP growth. In the renewable rich scenario, conventional generation can be equipped with enhanced technologies and run with improved operational practices that allow for more flexible use (less frequent dispatch and fewer generating hours) of conventional plants and be less expensive. Adding degrees of model sophistication has a direct relationship with the need for accuracy and extent of the resource plan's optimization.

3.4.1 CONSIDERING RENEWABLE ENERGY RESOURCES

While evaluating conventional supply options is relatively straightforward, evaluating RE resources is more complicated and requires attention to four characteristics of RE:[10]

- **Variability and Non-Dispatchability**. This affects RE's contribution to firm capacity, because it cannot be simply related to its nameplate capacity, as is done for conventional generating resources. Variability and non-dispatchability also affect the system's requirement for flexible generation.
- **Uncertainty.** The accurate forecasting of RE is a challenge as it requires massive amounts of historical data and accurate weather forecasts. Most countries have recently established weather and other data gathering centers, but it will take time to make good and reliable use of them. This impacts the requirement for flexible generation from other resources.
- **Locational Constraints**. Grid-connected RE generating units are usually located where the RE resources (insolation or wind) are abundant. These locations are often far from demand centers, and thus require additional transmission capacity.
- **Non-Synchronous.** Solar PV generators do not have a rotating machine connected directly to the grid and thus cannot easily provide frequency and voltage response for power system stability. Even wind generators' ability to do so is limited.

[10] IRENA. (2017). Planning for the Renewable Future: Long-Term Modelling and Tools to Expand Variable Renewable Power in Emerging Economies.

Measures to compensate for the impacts of the limited voltage and frequency response from RE generators are expected to add marginally[11] to the cost of generation and are not discussed further.

3.5 MANAGING RISK AND UNCERTAINTY

Several developments are changing the power sector's historical practices, including rapid technology advances, climate change and energy security concerns, changes in electricity consumption in response to economic and other parameters, and the development of new consumer loads (e.g., electric vehicles). DISCOMs often perceive these developments as a threat to their survival. In such a fast-changing environment, long- and even medium-term planning require much more detailed analysis of uncertainties and risks, and the development of risk mitigation plans. In the early days of resource planning, addressing uncertainty meant carrying out sensitivity cases only. Now the techniques for addressing uncertainty have become much more sophisticated, aided considerably by much greater computational power. A robust plan should consist of scenario planning, sensitivity analysis, probabilistic analysis, and options development.

In a broad sense, ***scenario planning*** means development of plausible and internally consistent futures. It lists the parameters to be considered in resource planning and helps in identifying uncertainties. Scenario planning is generally done through consultations and discussions, and thus tends to be an inclusive and participatory exercise.

Sensitivity analysis is carried out to understand how changes in a parameter are likely to affect the other parameters and its impact on the present value of revenue return (PVRR) for a resource portfolio. It answers "what if" questions about changes in demand growth, fuel prices, etc. A sensitivity analysis must be run all important parameters and sometimes a few parameters are clustered to mirror reality more closely where several related variables change.

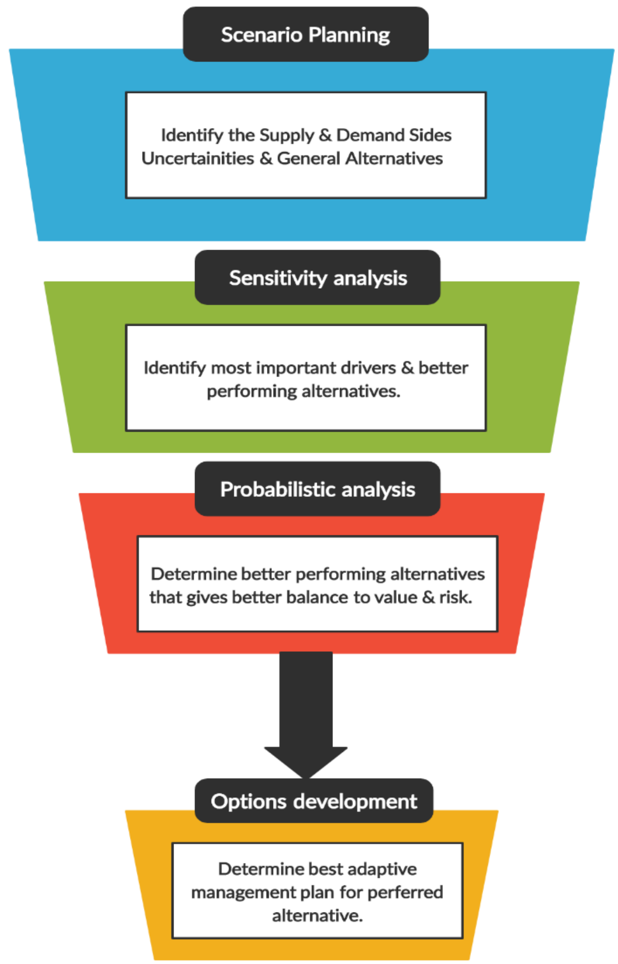

Figure 8: Risk Based Resource Plan Identification

Source: Borison, A., 2014, Electric Power Resource Planning under Uncertainty: Critical Review and Best Practices, White Paper, California: Berkley Research Group

[11] IRENA. (2017). op. cit.

Probabilistic analysis helps in establishing scenarios with quantified certainty. It overcomes the limitations of sensitivity analysis by varying several parameters simultaneously. A probability distribution is assigned to each key parameter and the model is run multiple times to get the PVRR for different combinations of the key parameters. The results are generally obtained using either decision trees or Monte-Carlo simulations. The result of the analysis is a probability distribution of the PVRR. Probabilistic analysis gives an idea of how the resource plan's PVRR will vary under changing conditions and allows a comparison of plans. Plan A may be lower cost than Plan B under one set of conditions. But it is possible that Plan A's costs may vary greatly if conditions change and become riskier hence Plan B should be preferred.

The advantages of probabilistic analysis do come at a price. Probabilistic analysis will be more data intensive because it requires estimates of how key variables are likely to change (i.e., the probability distribution of key variables). Such probability distributions are not always readily available.

Options development is done based on scenario, sensitivity and probabilistic analysis. Generally, three to four options are developed and compared to manage risk. Sometime one option is considered for one period and thereafter the next option is considered. Thus, option development provides dynamicity to the decision making at do not treat it as one-time event. For example, instead of thinking of the setting up of a power plant as a one-time decision, it can be seen in stages: purchase of land; design of the plant; obtaining clearances; and then the actual construction which is the most expensive. If at each stage, the decision is re-evaluated based on additional information about load growth, fuel prices, etc., overall costs to the utility can be reduced, reducing the risk for the utility.[12]

[12] Singh and Swain. (2018). Fixated on Megawatts.

CHAPTER 4. RESOURCE PLANNING IN INDIA: CURRENT STATE ASSESSMENT

The electricity sector is on the Indian Constitution's Concurrent List[13] and resource planning for the sector is administered by both the central and state governments. The central government undertakes resource planning considering its mandate to develop national-level policies for achieving societal expectations and country-wide objectives. States' resource planning is done with state-specific objectives in mind, which are sometimes additional and/or different from central government objectives. States government and its DISCOMs are responsible for planning infrastructure upgrades and purchasing power within their borders. DISCOMs must comply with regulatory tariff filings to ensure they provide reliable and affordable electricity to their consumers. This chapter discusses the Indian system for resource planning and the spectrum of practices followed at both the central and state levels.

Currently, the CEA, on behalf of the federal government, develops the National Electricity Plan once every five years. All power sector planning at the national level is based on this plan. It also publishes its estimates of demand every five years in the Electricity Power Survey. Although the CEA does take data from the states when developing this survey, its projections are not a simple aggregation of all state data.

Each year, state regulators approve the annual revenue requirements (ARR) in the DISCOMs' power procurement plans, the transmission companies' transmission plans, and the generation companies' generation plans. While developing their plans, utilities can use CEA data, their numbers, or a combination of the two.

On paper, it may seem that there is good coordination between the central and state levels, but in practice, there is neither uniformity nor consistency in use of the plans for infrastructure development, tariff setting, or for the development of policies and regulations. Sometimes plan variations reflect the differences between state and federal objectives and in others, decisions are made based on convenience (renewable purchase obligations (RPO) targets non-compliance is a classic example).

Sections 4.1 and 4.2 describe the practices employed to forecast demand and develop resource plans at the central level. Sections 4.3 and 4.4 describe these activities at the state level. Section 4.5 summarizes the findings and identifies areas where more accurate and useful resource planning is required to meet the RE rich environment in India.

4.1 CENTRAL DEMAND FORECASTING

4.1.1 ELECTRIC POWER SURVEY

[13] Both the central and state governments can make laws on the subject areas on the Concurrent List; when there is a conflict, the most recent law prevail.

Since 1982, CEA has published its Electric Power Survey (EPS) every five years. It provides electricity demand projections for DISCOMs, states/Union Territories, and regions; the all-India electricity demand for the next ten years is published annually. CEA also provides forecasts for the 15th and 20th years from the survey's date of issue. Figure 9 shows the evolution and methods used by CEA in developing the EPS.

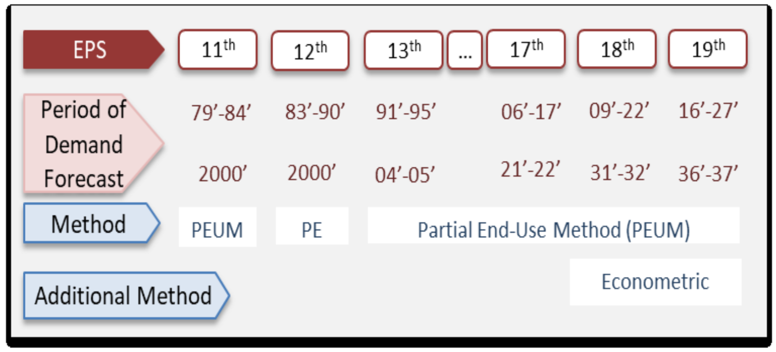

Figure 9: EPS Survey Evaluation Methods

PARTIAL END-USE METHOD

For the EPS, CEA uses a partial end-use method (PEUM), which is a combination of the end-use method and time-series analysis. The PEUM is a "bottom-up" approach focusing on end uses or the final energy needs of different categories of consumers (domestic, commercial, irrigation, industrial, railway, etc.). Where end-use data are not available or are limited, the time series exponential moving average (EMA) method[14] is used to forecast demand for specific classes/categories using historical consumption data. Annex 1 gives details on the data that are used for each consumer category.

Methodology

I. **Collection of Data**: Data by consumer category are taken from DISCOMs (billing, type and number of connected loads, number of consumers, hours of load operation, peak demand, annual load factor and T&D losses (planned and estimated).

II. **Assessment of Policy Initiative Impacts**: Trend/qualitative assessment is used to determine the impacts of central programs/policies against state targets (Power for All (PFA), demand-side management, energy conservation and efficiency improvement measures, Make in India, penetration of roof-top solar, electric vehicles, etc.).

III. **Calculation of Total Energy Requirement**: Data are aggregated to determine the total electricity consumption for each DISCOM.

IV. **Forecast of State Demand**: MUs (energy requirement) are converted to MW (demand) utilizing a load factor based on historical peak and energy consumption and DISCOM loss trajectories.

V. **Forecast of National Demand**: The peak demand for the country is obtained by aggregating the state-wise peak demands and applying an all-India diversity factor.

CEA is taking several commendable steps in the development of the EPS. The first is the use of a consultative approach and the solicitation of the views of most major stakeholders. Second, the method recognizes most of the policies, initiatives and trends in the electricity sector that could have a significant impact on the forecast of electrical energy requirements (demand). However, projections generally remain on higher side (Table 2 indicates percentage of overestimated consumption), leading to higher generation capacity planning.

[14] The exponential moving average method places greater weight on the most recent data points.

Table 2. Deviation in Demand (Actual and Forecast)

Year	Actual Consumption (MU)	18th EPS Projections (MU)	Overestimated Consumption in 18th EPS (%)
2010-11	861,591	870,831	1%
2011-12	937,199	936,589	0%
2012-13	995,557	1,007,694	1%
2013-14	1,002,257	1,084,610	8%
2014-15	1,068,943	1,167,731	9%
2015-16	1,114,408	1,257,589	13%
2016-17	1,142,928	1,354,874	19%
2017-18	1,212,134	1,450,982	20%

Source: Singh, A. et al. (2019), Center for Energy Regulation (CER), IIT Kanpur[15]

Some aspects of the demand forecasting approach could be improved. First, while it recognizes the factors or initiatives that could have a significant effect on electricity consumption, it uses a heuristic approach to estimate the impact of policies, initiatives and trends. No quantitative analyses are used to estimate the impacts, which could lead to significant errors. Second, there is no measurement of usage at the end-use level and not much load research is done at the state level.

Third, there is little granularity, either in time or space, in its demand forecast, which is critical for planning under a RE-rich environment (Chapter 3). Last, the CEA model is largely spreadsheet based and relies heavily won state DISCOMs and other state agencies for data, opinions, and even forecasts. There is a need to develop a more sophisticated software models to more accurately forecast demand. In addition, the granularity of forecasts across time and space could be improved to accommodate more RE in resource plans with minimum system integration cost.

4.2 CENTRAL RESOURCE PLANNING

4.2.1 NATIONAL ELECTRICITY PLAN

In accordance with the Electricity Act 2003, CEA develops a National Electricity Plan (NEP) every five years. It is essentially a resource plan for the whole country. The NEP assesses the additional generation capacity required in the next five and ten years, by considering existing installed capacity, probable/ planned retirements, and planned capacity additions under various government policies to meet the demand estimates made in the EPS.

In developing the NEP, a capacity expansion model (Electric Generation Expansion Analysis Software (EGEAS)) is used. This Electric Power Research Institute tool selects a minimum cost set of generation

[15] Anoop Singh, Manvendra Pratap, Abhishek Das, Piyush A. Sharma, and Kamal K. Gupta. (2019). Regulatory Framework for Long-term Demand Forecasting and Power Procurement Planning.

investments from a range of generation technologies (including RE) and sizes it to satisfy constraints on demand (forecasted), reserve, environmental concerns, and reliability levels. EGEAS utilizes two objective functions: total present worth costs minimization and therefore lowering levelized annual consumer rates. Its modules consider supply data, demand data and reliability indices such as loss-of-load-probability (LOLP), the expected value of energy-not-served (ENS), and the reserve margin, as shown in Figure 10. The output from the tool provides annual information on, for example, the amount, type and timing of additional capacity, total system cost, annual production cost, annual fixed charges of new units, annual emission tonnage, annual energy generated by fuel type, required annual system capacity and reliability.

While CEA has been using the EGEAS model for its generation adequacy studies, in 2017 it acquired a new model, ORDENA – a mixed integer linear programming (MILP)-based tool that can carry out a reliability analysis and estimate the flexible generation needed to integrate RE with its inherent intermittency and variability. For NEP 2018, CEA validated the results of EGEAS using ORDENA.

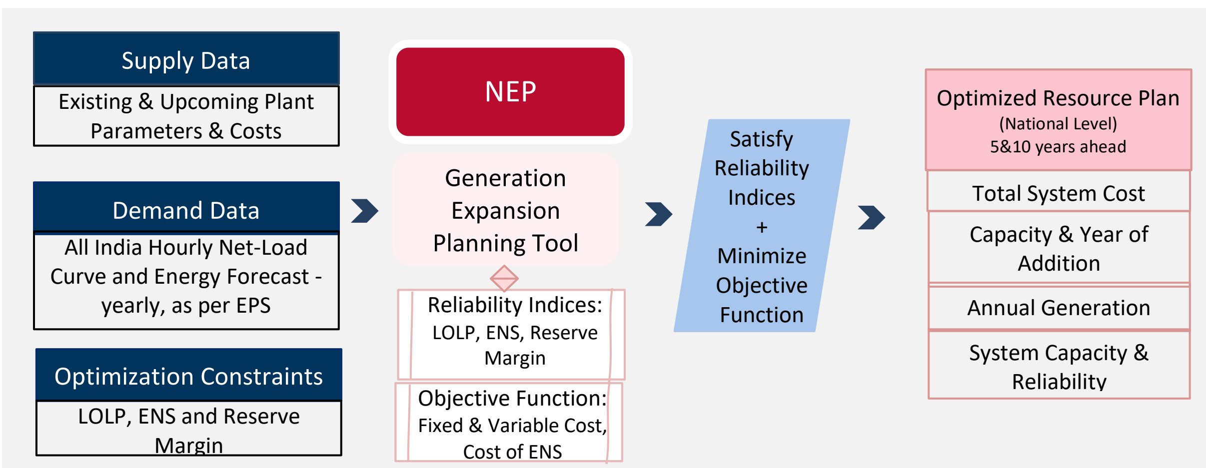

Figure 10: Generation Plan Methodology in NEP

In February 2019, CEA published a draft report on the optimal least-cost generation capacity mix required to meet India's electricity demand in 2029-2030. The study assessed RE absorption by reducing the presently stipulated technical minimum of the coal-based plants. Both battery energy storage and pumped storage systems were included. The cost of battery energy storage systems, assuming 4-hour storage and including balance of plant such as inverters, energy management systems and building management systems (BMS), was taken to be 1 Million USD/MW in 2021-22 and decreased linearly to 0.6 Million USD/MW in 2029-30. The CEA study reveals that the likely optimal installed capacity mix for 2030 will include 63% RE (solar, wind, hydro and biomass), with wind and solar contributing around 52% in total.

The development of the NEP and associated reports is a significant step in CEA's resource planning work. However, NEP's handling of uncertainty and risk management is inadequate. For example, no wide-ranging scenarios were considered. To counter the effect of uncertainties associated with demand forecasting, the NEP considers only few additional scenarios for generation planning studies which is basically a higher CAGR value to forecast the electricity demand and corresponding additional capacity addition.[16] However, this analysis for alternate scenario does not consider the case of higher penetration of renewable energy in the future. As a result, there is a scope to better handling of uncertainty and risk management by considering wide range of scenarios (such as higher RE, EVs etc.). Further, sensitivity analysis of these scenarios would help in better understanding the future needs for electricity. This is particularly true when we consider risk analysis with global best practices of US (Ref. Section 5.1).

4.3 STATE LEVEL DEMAND FORECASTING

Forecasting demand is the first step in developing a resource plan. Generation capacity additions depend on the DISCOMs' demand forecasts. The Electricity Act 2003 made electricity generation an unlicensed activity; after its passage, private investment in generation increased rapidly. The locus of planning and forecasting remain concentrated at the DISCOMs.

During the development of this white paper, consulted state and private DISCOMs and state load dispatch centers in Rajasthan, Gujarat, Delhi, and Uttar Pradesh were consulted to understand the process of demand forecasting at the state level. Table 3 shows the outcome of the discussions with utility professionals.

Table 3: Long-Term Demand Forecasting: Practices in States

LONG TERM (LT) DEMAND FORECASTING IN STATES						
	RAJAS-THAN	**GUJARAT**	**PUNJAB**	**ANDHRA PRADESH**	**DELHI**	**UTTAR PRADESH**
Regulatory Mandate for Long-Term Demand Forecasting	Power Procurement Regulations, 2004	GERC (Gujarat Energy Regulatory Commission) Guidelines for Procurement of Power by Distribution Licensees, 2013	Power purchase and procurement process of Licensee Regulations in 2012	APERC (Andhra Pradesh Electricity Regulatory Commission) Guidelines for Load Forecasts, Resource Plans and Power Procurement, 2006	-	Guidelines for Load Forecasting, Resource Planning and Power Procurement
Implementing Agency for Demand Forecasting	Energy Assessment Committee comprising DISCOMs, Trading Company, state load dispatch center	DISCOMs and STU (SLDC)	DISCOMs	DISCOMs and STU	DISCOMs	DISCOMs (UPPCL-Holding Company)

[16] CEA. (2018). Section 5.11, National Electricity Plan.

	(SLDC) and STU					
Demand Forecast Horizon	10 years ahead	10 years ahead	10 years ahead	10 years ahead	5 years ahead	5 – 10 years ahead
Demand Forecast Computation Frequency	Yearly or as-and-when-required	Yearly	Yearly	Yearly	Yearly	Yearly
Demand Forecast Resolution	Annual	Annual and seasonal. Historical demand curves projected	Annual and monthly	Annual and monthly (hourly load curves)	Annual and seasonal (hourly load curves)	Annual (Hourly Load Curves)
Long-Term Forecast Methodology	CAGR-based trend method	CAGR-based trend method	CAGR-based trend method	CAGR-based trend method	Econometric and CAGR-based methods	Econometric and CAGR-based methods
Use of Load Research	No	No	No	No	No	No
Tools for Demand Forecasting	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet and third-party software	Spreadsheet and third-party software
Impact of RE technologies (like rooftop solar) and energy efficiency and conservation considerations in forecasting	No	No	No	No	No	No

Source: PACE-D 2.0 RE research

As this table shows, most DISCOMs use simple trend analysis and their own experience in preparing long-term resource forecasts. EPS estimates are often used as a check. Some DISCOMs prefer to rely on EPS forecasts for their states. There is almost no-load research carried out to understand how various categories of consumers use electricity. Wherever the load research was conducted, it was survey-based and not based on end-use measurements.

DISCOMs still lack a focus on long-term planning and mostly juggle day-ahead demand projections, which helps them save on unscheduled interchange penalties.[17] They seem not to realize that medium- and long-term planning will help them in day-ahead planning. One reason for this is that there are no well-defined regulatory guidelines on planning, although procurement accounts for about 60 to 80 percent of distribution business costs. Resource planning is done in conjunction with ARR approval. During the

[17] Both the central and state governments can make laws on the subject areas on the Concurrent List; when there is a conflict, the most recent law will prevail.

examination and approval of the ARR, regulators do not have the capacity, resources or time for a detailed examination of the DISCOMs' projections of demand and additional power purchases.

Also, while the state provides the forecast data and the central government publishes state forecasts every five years, the states use different ARR forecasts. Thus, the feedback loop is very weak and there is only a moderate amount of coordination between the central and state governments.

4.4 STATE RESOURCE PLANNING

Capacity additions are planned mostly based on existing resource availability, which essentially means asking the question, "Do we have enough MW to supply demand?" In many states, other considerations influence these decisions significantly, such as a push to add more MW. This is often justified based on increases in demand due to state government's policy to electrify more villages/ households or to enable more manufacturing and other industrial activities. The horizon for resource plans is mostly 10 years as followed at central level and states use spreadsheets to come up with generation plans based on an algebraic supply demand gap methodology. Table 4 summarizes the resource planning practices of six states of India.

Table 4: Resource Planning in Six Indian States

RESOURCE PLANNING IN STATES						
	RAJASTHAN	GUJARAT	PUNJAB	ANDHRA PRADESH	DELHI	UTTAR PRADESH
Regulatory Mandate for Long-term Resource Planning	Power Procurement Regulations, 2004	GERC Guidelines for Procurement of Power by Distribution Licensees, 2013	Power Purchase and Procurement Process of Licensee Regulations in 2012	APERC Guidelines for Demand Forecasts, Resource Plans and Power Procurement, 2006	Delhi Energy Regulatory Commission Terms and Conditions for Determination of Tariff Regulations, 2017	Uttar Pradesh Energy Regulatory Commission (UPERC) Multi-year Distribution Tariff Regulations, 2014
Resource planning Horizon	10 years ahead	10 years ahead	10 years ahead	10 years ahead	5-10 years ahead	5-10 years ahead
Computation Frequency	Yearly or as-and-when-required	Yearly or as-and-when-required	Yearly or as-and-when-required	Yearly or as-and-when-required	Yearly or as-and-when-required	Yearly or as-and-when-required
Resolution	Annual	Annual and seasonal	Annual and monthly	Annual	Annual and seasonal	Annual and Seasonal

Consideration of CEA's EPS Forecast?	Yes. Moderated between EPS and internally computed forecast	Yes. Moderated between EPS and internally computed forecast	Yes	Yes	Yes	Yes. Moderated between EPS and internally computed forecast
Methodology	Algebraic supply-demand gap	Algebraic supply-demand gap	Algebraic supply-demand gap	Algebraic supply-demand gap	Algebraic supply-demand gap	LP-based optimization for cost minimization
Tools for Resource Planning	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet	Spreadsheet and third-party software	GAMS
Assessment of Flexibility Requirement Based on RE Share/ Alternative Portfolios	No	No	No	No	No	No
RE Capacity Considerations for Firm and Peak Contribution (Capacity Credit) in Planning	No. Peak contribution from RE assessed based on CUF	No. Peak contribution from RE assessed based on CUF	-	-	No. Peak (annual & seasonal) contribution from RE assessed based on CUF	No. Peak contribution from RE assessed based on CUF
Uncertainty and Risk Management	No	No	No	No	No	No
Development of Preferred Plan and Implementing Agency for Resource Planning	RUVNL (Trading Company)	GUVNL (Holding Company)	DISCOM (PSPCL)	DISCOMs (APPCC)	DISCOMs	DISCOMs (UPPCL-Holding Company)

Source: PACE-D 2.0 RE Research

In most states, the responsibility and ownership of the resource plan is diffused. For example, the Punjab State Power Corporation Limited (PSPCL) has three cells whose work could be related to long-term resource planning and power procurement: 1) Power Purchase & Regulation Cell, 2) Planning Cell, and 3) ARR & Tariff Regulation. Yet the decisions related to long-term resource planning and procurement are taken by a Long-Term Power Purchase Committee.[18]

Resource planning is linked to the annual revenue requirement (ARR) review as a measure of power procurement, and the associated costs have traditionally been essential components of the ARR.

[18] Singh and Swain. (2018). Fixated on Megawatts.

Currently, demand forecasting and resource planning are done in conjunction with the ARR's approval and tariff determination. Tariff-setting is a short-term (generally three month) exercise and the amount of time needed to examine all components in greater detail is limited. In contrast, good resource planning has a long-term horizon, is expansive and comprehensive. It would be useful if regulations specific to resource planning were formulated and a nodal entity be made responsible for submitting the plan to the regulatory commission in a process that is delinked from tariff filings and review proceedings. The approved resource plan would then be used as input to ARR. This would also give DISCOMs and regulators more time to concentrate on other components of the ARR and tariff setting.[19]

4.5 SUMMARY OF FINDINGS

The review of the practices followed for resource planning reveals significant variations between the state and central levels. These variations are summarized in Table 5.

Table 5: Summary of Prevailing Practices of Resource Planning in India

DEMAND FORECASTING	
DISCOMs (Private & Public): State Level	**CEA: National Level**
• Horizon of 10-20 years • Conducted annually for regulatory compliance as part of the ARR • CAGR-based trend method • Econometric models are adopted by some DISCOMs, but not standardized • Yearly resolution, with peak and energy forecasts • Spread sheet primarily used for modelling • Demand curves not estimated; if done, historical curves are used • No load research is conducted • No impact of RE capacity additions is incorporated for determining annual peak • Impacts of RE technologies and energy efficiency are not primarily modeled	• Horizon of 20 years • Conducted every five years as part of the EPS survey • Partial End Use Method and Econometric Method (for validation purposes) • Results from PEUM are used as input for NEP • Yearly resolution, with peak and energy forecasts • Demand shape is not forecasted • No load research on end-use consumption is conducted • Impacts of RE capacity additions are incorporated to determine impacts on annual peak • Impacts of electric vehicles (EVs) are not considered • Impacts of energy efficiency and conservation are considered based on Bureau of Energy Efficiency (BEE) estimates
RESOURCE PLANNING	
• Horizon of 10 years • Conducted annually for long-term planning • Yearly resolution	• Horizon of 10 years • Conducted every 5 years as part of NEP • Yearly resolution

[19] Singh and Swain. (2018). Fixated on Megawatts.

• Algebraic supply-demand difference computed on an annual basis using spreadsheets • No resource planning tools used • Impact of clean technologies on supply-side not modeled, except for grid-scale solar & wind generation • State transmission company, power trading company or holding company develops an actionable resource plan on behalf of all the state DISCOMS. Private DISCOMs do it independently. • CEA estimates, in addition to own estimates, are considered for decision making • RE, energy efficiency and conservation decisions are guided by central govt. policy/targets/schemes. RE additions aided by renewable purchase obligation targets of SERCs • Technology decisions are largely based on fuel availability	• Optimization tools used for generation expansion planning • Tools based on Generalized Benders Decomposition, Dynamic Programming and MILP algorithms • Largely, production cost modelling is done, as against annual resource planning • Demand curves considered based on past three-year average • Hourly demand curves for target peri • Impacts of clean technologies on the supply side are not modeled, except for grid-scale solar & wind generation

Source: PACE-D 2.0 RE research

CHAPTER 5. INTERNATIONAL EXPERIENCE IN RESOURCE PLANNING

Having outlined the major steps in resource planning in Chapter 3, and the practices followed in India as described in Chapter 4, this chapter looks at how resource planning is implemented in four countries that are on the leading edge in the transition to an RE-dominated electricity sector: the United States, Australia, Germany and the United Kingdom.

In many countries, distribution companies do long-term planning to ensure the network can support the requirements the company will face. For countries and regions where there is retail competition (carriage and content are separate), long-term planning is still required to ensure the adequacy and reliability of supply. The reason of choosing the four countries examined here are:

- The *United States* has long experience in this area: almost all of its states have some form of resource planning required since the 1980s. Furthermore, the experience of those states where retail competition has not been introduced and distribution companies have a responsibility to procure power for their consumers is of relevance to India.
- In *Australia* there have been concerns about the reliability of the grid because much of the country's conventional generation capacity is nearing the end of its useful life just when there has been a rapid influx of RE. Australia has developed an integrated system plan to respond to these concerns and to guide the sector through the energy transition. Its extensive effort in resource plan development holds many lessons for other countries making the transition from fossil fuel-based generation to RE.
- *Germany* has been leading the implementation of RE, which is expected by 2030 to contribute 65% of the electricity the country consumes. It is important to understand the challenges Germany faces at these high levels of RE penetration and how the it addresses those challenges.
- The *United Kingdom's (UK)* government and regulator Ofgem have been nudging the distribution companies to prepare for the future by implementing smart systems and introducing greater system flexibility.[20]

These four countries provide valuable lessons as India seeks ways to improve its planning and prepares the electricity sector for a future RE-rich environment.

5.1 UNITED STATES OF AMERICA

One of the reasons resource planning is effective in the US is its regulatory framework, which not only mandates that DISCOMs file resource plans but also specifies how the process should be carried out and what is to be included in the plans. In the US, there are three ways in which resource plan rules have been established:[21] 1) through an act passed by the legislature, 2) through inclusion in the State Administrative Code, and 3) through orders of the regulatory commission.

[20] U.K. Government and Ofgem. (2017). Upgrading Our Energy System: Smart Systems and Flexibility Plan.

[21] Wilson and Biewald. (2013). The Regulatory Assistance Project, Best Practices in Electric Utility IRP.

The resource plan rules in many US states provide a good model. These rules have the following specifications for resource planning:[22]

- The planning horizon in most states is between 10-20 years, with 20 years being the most common.
- The frequency of updates is two or three years in most states.
- Almost all the resource plan rules require that utilities evaluate all supply and demand resources. For a good resource plan, requirements are recommended in the following areas: demand forecast, reserves and reliability, EE&DSM, all supply options, fuel prices, environmental costs and constraints, the process for handling uncertainty, and valuing and selecting plans.
- Stakeholder consultation is common.

Figure 11 depicts the status of resource planning or similar process followed in different states.

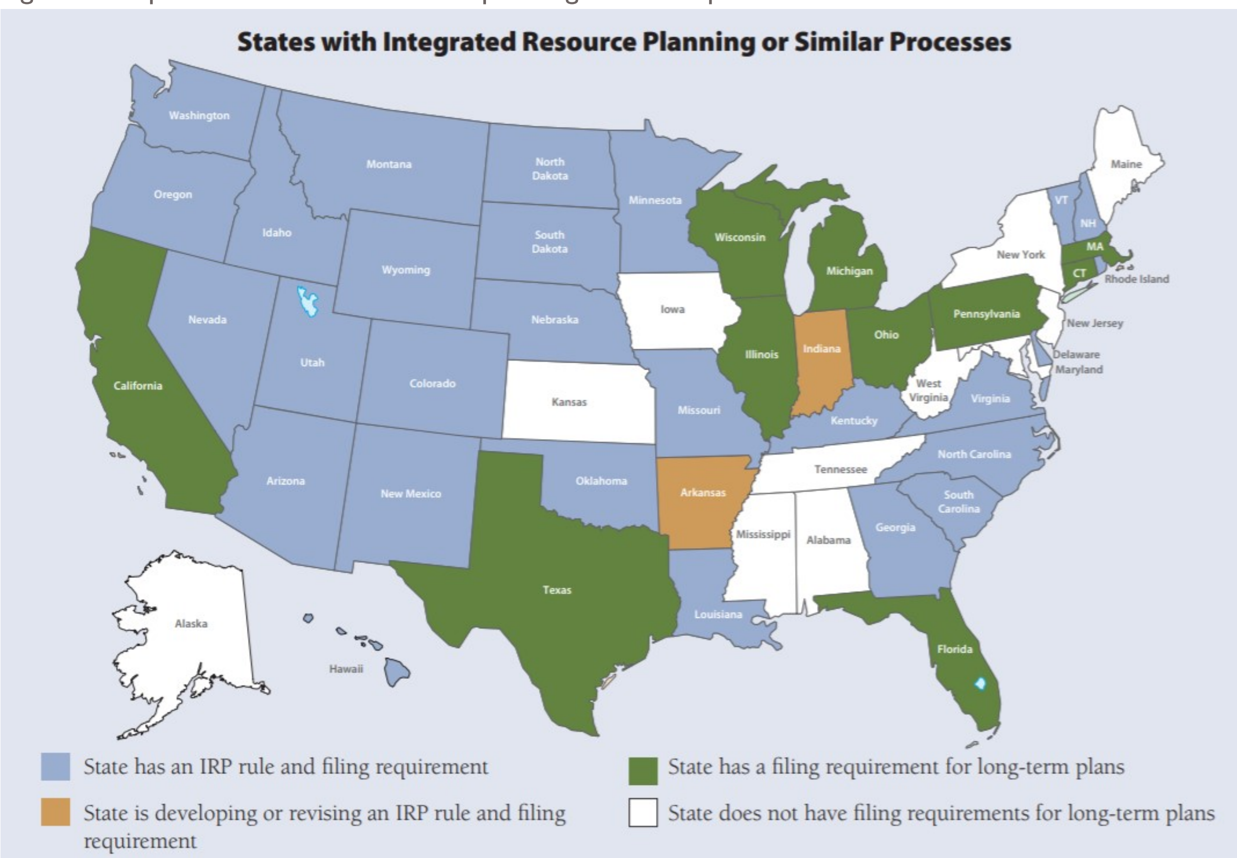

Figure 11: States with Integrated Resource Planning or Similar Processes,
Source: Best Practices in Electric Utility Integrated Resource Planning by Regulatory Assistance Project (RAP), 2013

5.1.1 DEMAND FORECASTING

[22] Wilson, Rachel and Paul Peterson. (2011). Survey of State Integrated IRP Rules and Requirements.

Of the twelve U.S utilities examined in a 2016 study,[23] it was found that four types of approaches are typically used for demand forecasting: time-series regression, cross-sectional regression, bottom-up, and statistically adjusted end-use (SAE). Three utilities used SAE models (hybrid models that combine end-use models and econometric variables) while others use econometric (regression) models.

Interestingly, the study found that from the mid-2000s to 2014, there was a persistent overestimation of demand growth. The utilities' most common explanation for this was the economic recession, which started around 2008-09. Even though the utilities did lower their forecasts, overestimation continued. The study concluded that more complex models provided only marginally greater benefits, and that it would be better to focus on ways to respond adaptively to changes in demand forecasts (techniques for addressing uncertainty are discussed in Section 4.1.3).

Load Research

Load research is carried out to determine the consumption patterns of various consumer categories. With the passage of the Public Utility Regulatory Policies Act in 1978, it became mandatory for utilities to carry out load research to support cost-allocation in their tariff filings.[24] The use of load research has now been extended to support the development of energy efficiency and demand response programs and time-of-use rates. More recently, it has been used in planning for distributed energy resources (DER) such as solar rooftop installations and energy storage. A recent example of load research is the directive from the California Public Utilities Commission to three investor-owned utilities to carry out research on electric vehicle charging behavior and to track service and distribution upgrade costs related to EV loads.

5.1.2 DEVELOPMENT OF ALTERNATIVE RESOURCE PORTFOLIOS

In the US, resource portfolios are almost always developed using capacity expansion models. These models minimize the overall cost, as quantified by the PVRR, over the entire planning period. For each resource portfolio, the model selects an optimal mix of various resources such as energy efficiency, grid-connected RE, and DER based-on demand requirements curves so that PVRR is minimized. Table 6 shows how these resources are included in portfolio development.

Table 6: Development of Alternative Resource Portfolios

RESOURCES FOR ALTERNATIVE RESOURCE PORTFOLIO DEVELOPMENT	
Energy Efficiency and Demand-Side Management	EE&DSM is included in the planning process in three ways: • A target either as a percentage reduction of load or an absolute level. • Based on cost-effectiveness tests. • Cost curves for EE&DSM measures are developed and the EE&DSM measures are treated like a supply resource by the capacity expansion model, resulting in the optimal amount of EE&DSM getting included in the resource plan. . In spite of its benefits, the use of this approach is still rare.

[23] Carvallo, P.J. et al., (2016). Load Forecasting in Electric Utility Integrated Resource Planning, Lawrence Berkeley National Laboratory.

[24] Association of Edison Illuminating Companies. (2017). Load Research Manual- 3 edition, Birmingham.

Grid-Connected RE	• Many utilities and RTOs/ISOs conduct RE integration studies to assess the operational impacts and associated costs of RE • Some vertically integrated utilities estimate separate cost adders for solar and wind on a $/MWh based on these studies and use them in evaluating alternative resources in their planning process. • In other cases where DISCOMs procure power from the wholesale market and purchase RECs to fulfill RPS requirements, responsibility for RE integration costs lies with generators. (e.g., New York, Pennsylvania)
Distributed Energy Resource	• Regarding impact of DER on bulk system, some simply scaled down the load with no change in load shape. Others developed a modified hourly load profile based on hourly DER profile. • Some distribution companies also consider targeted DER that is time- and location-specific based on network congestion and peak demand management to defer infrastructure investments.
Impact of Electric Vehicles	• In some progressive states like California, EV-specific load research to understand the impact on the utility demand curve and associated requirement for additional infrastructure.

Source: Kahrl et al., Future of Electricity Resource Planning, 2016

5.1.3 RISK AND UNCERTAINTY MANAGEMENT

There is wide variation in the sophistication of uncertainty analysis and risk management techniques used by US utilities. A recent study of resource planning in the US found that all seven of the vertically integrated utilities in the study carried out some form of uncertainty analysis while developing their resource plans.[25] But only four of the seven carried out a systematic analysis and reported on the measures of uncertainty in their plans. Of these four, two carried out sensitivity analysis only, while the other two used probabilistic analysis also. Table 7 provides how utilities in United States identify sources of uncertainty in the plans.

Each of the four techniques for uncertainty analysis and risk management discussed in Chapter 3 have advantages and disadvantages. Recent discussion of managing uncertainty and risk in the US suggests that rather than selecting one or another technique, these techniques can be woven into a logical progression to capture all the benefits which includes scenario analysis, sensitivity analysis, probabilistic analysis and options development.[26]

Table 7: Key Identified Sources of Uncertainty in Utility Resource Plans

UTILITY	SOURCES OF UNCERTAINITY ANALYZED IN PLANS
Duke Energy Carolinas (DEC)	Load forecast, fuel costs, capital costs, CO2 prices

[25] Kahrl, F., A. Mills, L. Lavin, N. Ryan & A. Olsen. (2016). The Future of Electricity Resource Planning, Berkley: Lawrence Berkeley National Laboratory.
[26] Borison, A. (2014). Electric Power Resource Planning Under Uncertainty: Critical Review and Best Practices, White Paper, California: Berkeley Research Group.

Florida Power and Light (FPL)	Not explicitly enumerated; may include load forecast, fuel costs, capital costs and environmental regulation
Georgia Power Company (GPC)	Load forecast, in-service dates for generation and demand-side resources, unit availability, fuel costs, capital costs, availability and cost of purchased power, environmental and other regulation
Hawaiian Electric Company	Load forecast, fuel costs, capital costs, energy efficiency, renewable energy regulations, environmental regulations, CO2 prices, operating costs, community sentiment (not modeled)
Pacific Corp	Load forecast, distributed generation resource forecast, hydropower generation, unit availability, fuel costs, capital costs, separate versus joint resource portfolio for balancing areas, availability of demand-side resources, availability of transmission, availability and price of wholesale electricity, availability of energy storage, CO2 prices, environmental regulation, RPS and environmental compliance strategies.
Tennessee Valley Authority	Load forecast, distributed generation resource forecast, fuel costs, capital costs, financing rates, O&M costs, availability of new hydropower, nuclear, and fossil generation, wholesale electricity prices, CO2 prices, environmental regulation
Northern States Power Company (Xcel Energy)	Load forecast, fuel costs, capital costs, coal unit retirements, CO2 prices

Source: Karhl et al, 2016

One such example is Tennessee Valley Authority (TVA) which conducted uncertainty analysis along two dimensions scenarios and sensitivities and then used stochastic analysis to develop risk metrics for evaluating different resource portfolios. Based on the evaluation of these metrics' TVA identified recommended ranges for new capacity additions and retirements of various demand side and supply side resources during IRP planning horizon. Refer Figure 12.

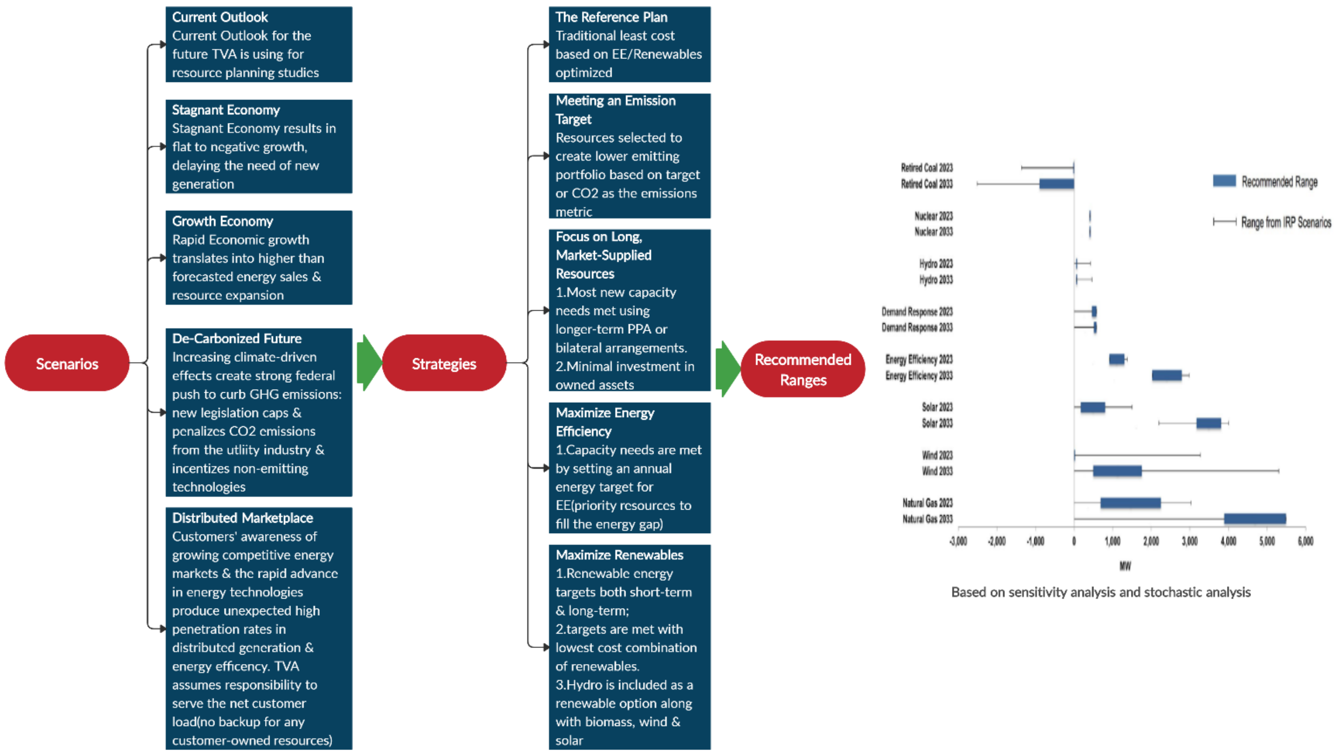

Figure 12: Tennessee Valley Authority Resource Planning: Risk and Uncertainty Management

5.2 AUSTRALIA

In Australia, generation, transmission, distribution and supply have been unbundled and all retail consumers can choose their supplier. The National Electricity Market (NEM) covers five southern and eastern states – New South Wales, Victoria, Queensland, South Australia and Tasmania – and the Australian Capital Territory.

The Australian Energy Regulator (AER) regulates electricity networks and NEM, and the Australian Energy Market Operator (AEMO) operates NEM. AER also regulates the revenues of the operators of the transmission and distribution networks. Each year, AEMO is required to prepare a National Transmission Network Development Plan. Similarly, each distribution network service provider conducts an annual planning review to ensure the adequacy of its network and identify any requirements for refurbishment, replacement or augmentation (National Electricity Rules, 2019). The minimum planning period for the annual review is five years and the results of the review must be published in a Distribution Annual Planning Report (DAPR).

There have been concerns about the adequacy of the NEM, and these concerns were heightened by the state-wide blackout in South Australia in 2016.[27] As a result, an independent review was undertaken (the Finkel Review), which recommended better system planning with AEMO playing a greater role in

[27] Finkel et al., (2017). Independent Review of the Future Security of the National Electricity Market: Blueprint for the Future.

planning the future transmission network, including the development of a NEM-wide integrated plan to inform future investment decisions.[28]

This section reviews the first Integrated System Plan (ISP) put out by AEMO in 2018. AEMO publishes its Electricity Demand Forecasting Methodology, which is used to provide a 20-year forecast to support the ISP. Ausgrid's DAPR was also reviewed; Ausgrid is the largest distribution company on Australia's east coast.

5.2.1 DEMAND FORECASTING

5.2.1.1 AUSTRALIAN ENERGY MARKET OPERATOR

AEMO uses different forecasting approaches for the various categories within its business consumer category, which includes both commercial and industrial consumers (Table 8).

Table 8: Demand Forecasting Approach Used by AEMO

	Manufacturing		**Other Business**			
Nature of Business	Aluminum Smelting	Other Manufacturing	Coal Seam Gas	Coal Mining	Other Business	EVs
Forecasting Approach	Survey-Based Modelling	Econometric	Consultant	Survey-Based Modelling	Econometric	Consultant

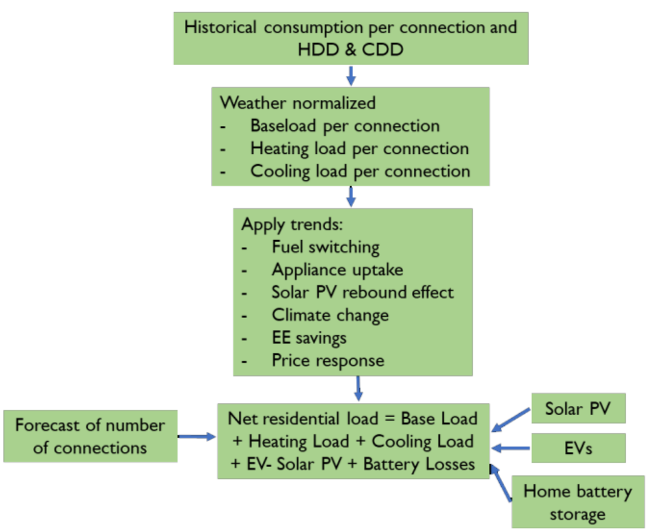

Figure 13: Demand Forecasting for AEMO's Residential Consumers
Source: Adapted from AEMO, Electricity Demand Forecasting Methodology Information Paper, February 2019

To forecast residential demand, AEMO normalizes historical consumption for weather and calculates the base, heating, and cooling demand per connection. It adjusts these per-connection demands for fuel switching, appliance uptake, solar PV rebound effect, climate change, energy efficiency and response to price changes. The adjusted per-connection demands are combined with forecasts for connections to forecast future consumption by residential category.[29] Figure 13 shows the demand forecasting done for residential consumers.

AEMO forecasts demand on a half-hourly basis. This is done by using the existing demand profile modified by newer technologies in

[28] Ibid.
[29] AEMO. (2019). Electricity Demand Forecasting Methodology Information Paper.

the target year.[30] Even though AEMO uses econometric models for forecasting the demand of many of its consumer categories, it says that it "continues to derive more detailed 'bottom-up' models" that better capture the impacts of newer technologies such as roof-top solar, energy efficient appliances and technologies that allow greater control by consumers of their energy use.

5.2.1.2 AUSGRID

While AEMO's forecasts, analyses and plans seem to be carried out on an aggregate basis with limited spatial granularity, Ausgrid's forecasts have a high degree of granularity. They are developed for an "area" which Ausgrid defines as a "collection of substations of similar geographic region."[31] They have little temporal granularity, perhaps because Ausgrid, being a distribution network operator (DNO), is most interested in peak demand to assess the adequacy of its network. The long-term forecast is based on econometric factors. The forecast for residential consumers is based on changes in the real price of electricity and in real household disposable income. The forecast for non-residential consumers is based on changes in the real price of electricity and the changes in the gross state product.[32] These forecasts are modified by the impact of DER, EVs and further improvements in energy efficiency.

5.2.3 MODELLING AND SELECTION OF RESOURCES

For developing its ISP, AEMO used the PLEXOS Integrated Energy Model.[33] The objective was to find the optimal mix of investments in electricity and gas infrastructure so that consumers were served at the lowest cost. AEMO used a multi-stage modelling approach for this (Figure 14).

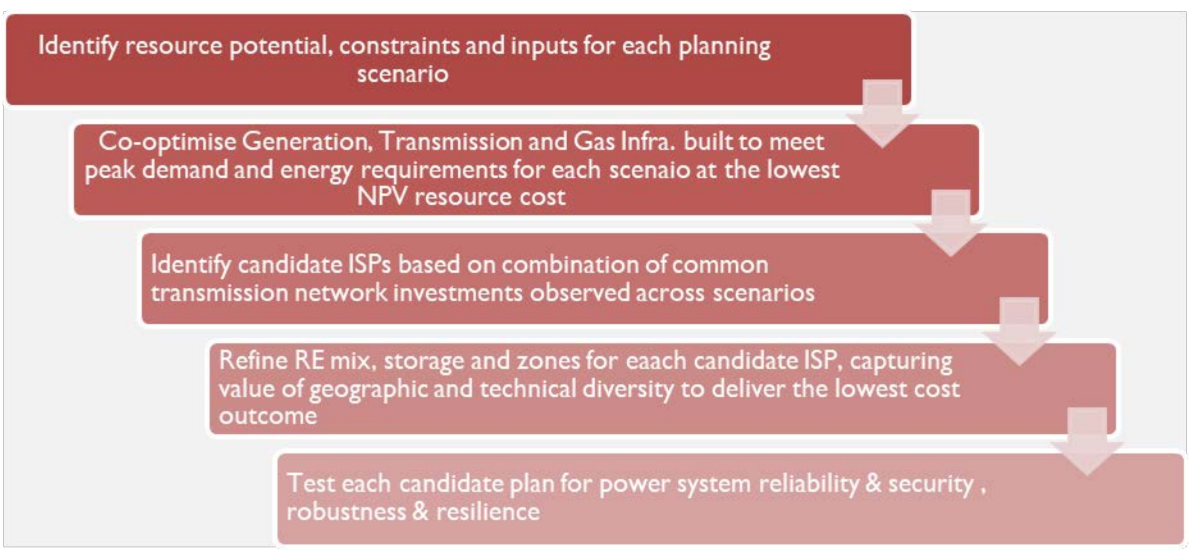

Figure 14: Multi-Staged Modelling Approach of AEMO
Reproduced from AEMO, 2018. Integrated System Plan for the National Electricity Market, July.

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30 Ibid.

31 Ausgrid. (2018). Distribution and Transmission Annual Planning Report.

32 Ibid.

33 Both the central and state governments can make laws on the subject areas on the Concurrent List; when there is a conflict, the most recent law will prevail.

To model the ISP, AEMO evaluated 34 potential renewable energy zones (REZ) by assessing each of them: the quality of the RE resource, the value of diversity, and the correlation to demand. It also considered minimum synchronous generation levels to ensure power system security and the value of DER to meet system needs. Rather than operate passively, DER was used to make the system more flexible and affordable.[34]

5.2.4 DEVELOPMENT OF SCENARIOS

AEMO uses two base case scenarios for its analysis: one with storage initiatives and one without. It creates three additional scenarios: slow change, fast change, and high DER. The slow and fast change scenarios refer to the speed of transformation; thus, the fast change scenario assumes a high uptake of EVs and high overall economic growth. The high DER scenario assumes: high rooftop solar, high PV, high unscheduled PV (from 100 kW to 30 MW), and high battery storage installed capacity. In addition to these five scenarios, AEMO explored two sensitivity cases, one with an increased role for gas and the other for the early exit of coal-fired generation.

For uptake of DER and EVs by modelling three scenarios: Slow, Moderate and Fast. The study provided projections for solar PV, battery storage and EVs, using consumer technology adoption theory for all three scenarios.[35]

5.2.6 RISK MANAGEMENT

Evaluating the results of the modelling studies for the five scenarios, AEMO "found strong signals for development of a combination of interconnector upgrades."[36] It thus concluded that its two base plans were optimal under all scenarios studied and expected to be robust in the face of a range of uncertainties.

5.3 GERMANY

In Germany's electricity sector, generation, transmission, distribution and supply have been unbundled and all retail consumers can choose their supplier. There are four transmission system operators (TSOs): TenneT, Amprion, 50Hertz Transmission and TransnetBW. There are about 890 distribution network operators (DNOs), many of them very small. The electricity sector is regulated by the Federal Network Agency (Bundesnetzagentur (BNetzA).

Most of the on- and off-shore wind generation in Germany is in the north of the country while the major demand centers are in the south and west.[37] Further exacerbating the problem, most of the

[34] AEMO. (2018). Integrated System Plan for the National Electricity Market.
[35] Graham et al, (2018).
[36] AEMO. (2018). Integrated System Plan for the National Electricity Market.
[37] Weimar et al., (2016).

retiring nuclear generating plants are located in the south. This has resulted in transmission bottlenecks and much of the attention in planning is directed at this challenge.

Long-term planning for the German electricity sector is done by the four TSOs, which are required to jointly develop and submit to BNetzA a ten-year Grid Development Plan (GDP) every two years.[38] The GDP should identify all grid reinforcement and augmentation that will be required to ensure secure and reliable network operation. The TSOs publish the draft GDP, hold public consultations and submit the draft to the BNetzA for review. After the GDP is final, it is integrated in the Federal Requirements Plan, which the German government puts up for consideration and enactment by the German Federal Legislature every four years.

5.3.1 DEMAND FORECASTING

The demand forecast is carried out by the district and consumer category. As a starting point, the TSOs deliver a normalized demand profile (no temperature sensitivity) for the coming years according to their best estimate of growth rates. As a second step, the sensitivity to temperature is added to the demand profiles according to common and correlated data, since weather conditions can significantly affect electricity demand.[39]

There are about 420 districts in Germany, and the population per district varies widely, between 40,000 people and 3,600,000. The demand shape from conventional end uses is assumed to remain the same as in previous years, and the impact of newer devices, such as heat pumps and EVs, is added on top of that. Residential electricity consumption is projected to increase proportionately to both the population and number of households, subject to scenario-specific reductions due to efficiency improvements in the household sector.[40] Commercial electricity consumption is projected to increase proportionately to the population, again subject to category and scenario-specific reductions due to energy efficiency. Industrial electricity consumption projections are subject to energy efficiency effects only. Projections for nationwide uptake of EVs are provided by a research institute.

For the GDP, the TSOs do not distinguish between DER and grid-connected RE. Furthermore, because these are long-term scenarios, the TSOs do not consider the actual location of DER to be as important as the aggregate effect and the knowledge that DER will play a significant role in meeting the RE target set by the government. The amount and location of DER vary between scenarios.

5.3.2 SCENARIO FRAMEWORK FOR PLANNING

The planning framework for GDP 2030 uses scenarios along two dimensions – transformation and innovation – as seen in Figure 15. Transformation refers to the speed of the electricity transition as measured by the share of RE in the generation mix. Innovation refers to cutting-edge developments such as the use of electricity in other sectors (EVs for transportation, electricity for heating, and

[38] (2019). Presentation Grid Development Plan 2030.

[39] (2018). Generation Adequacy Assessment 2.0, PLEF SG2.

[40] (2019). Entwurf def Ubertragungsnetzbetreiber, Szenariorahmen fur den Netzentwicklungsplan Strom 2030.

electricity for producing methane or hydrogen), and use of novel approaches for providing flexibility and storage.

GDP 2030 (2019) must meet the following minimum requirements:

- The contribution from RE by 2030 must be at least 65%.
- The plan must not exceed the CO_2 limits set by the government per the Federal Climate Protection Plan 2050.
- A maximum peak capping[41] of RE of 3%
- Assumes minimal transfer capacities for existing interconnectors with the rest of Europe, consistent with European planning protocols.
- Would include cost-benefit analyses for additional interconnectors.

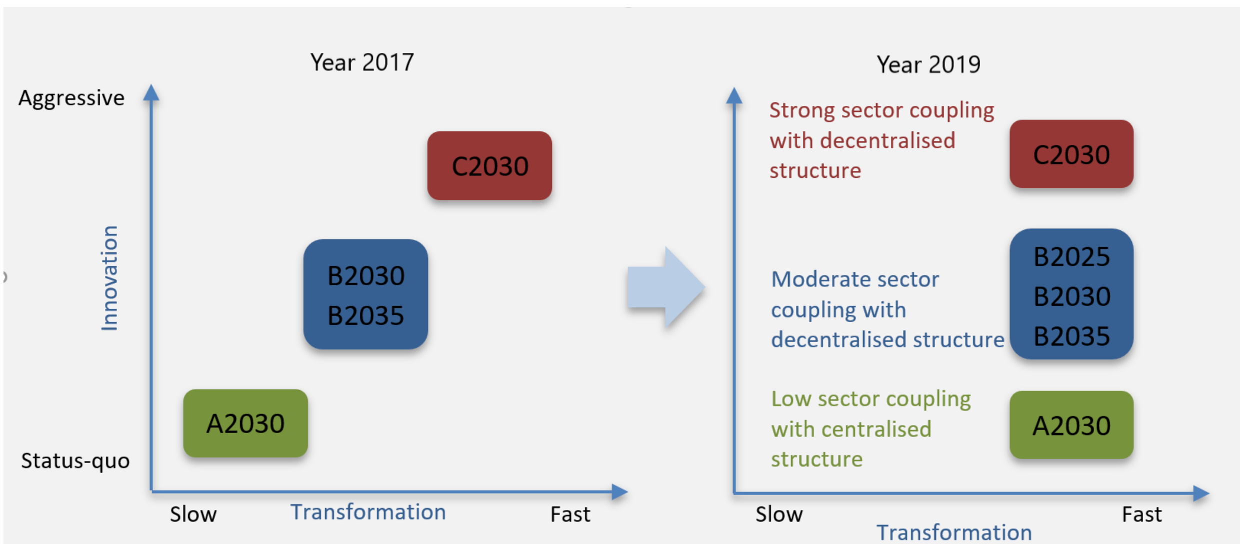


Figure 15: Scenarios for GDP 2030
Source: Reproduced from "Presentation, Grid Development Plan 2030 (2019)," second draft, 12 August 2019.

As Figure 15 shows, the scenarios in the 2017 version of the GDP differed in the level of transformation, implying different levels of RE as a percentage of total generation. In the 2019 version, all the scenarios have the same level of transformation to satisfy the requirements of the Coalition Agreement signed by the new federal government. That agreement requires that RE's contribution will be 65% by 2030.

5.3.3 DEVELOPMENT OF SCENARIOS FOR RESOURCE PORTFOLIOS

The mix of resources in the portfolios for each scenario is not based on the use of a capacity expansion model. Instead the portfolios are developed based on known investment projects and inputs from

[41] Recognizing that it would be too expensive to carry out a grid expansion that would be needed for just a few peak hours, the TSOs decided that the maximum capping of RE would be 3% of RE annual generation.

experts and other stakeholders.

5.3.3.1 DEMAND-SIDE OPTIONS

Assumptions about energy efficiency do not vary between the scenarios and are projected to lead to a reduction in conventional energy consumption of 30 TWh by 2030. DSM and DR vary between the scenarios – from 2 GW to 6 GW.

GDP 2030 also incorporates some flexibility options. For example, when there is not enough RE generation to meet the demand, electric power to produce hydrogen or methane etc. are used. The second group of flexible options is DSM and DR, where demand is shifted or reduced during times when demand is higher than RE supply.

5.3.4 RISK MANAGEMENT

The risk management plan consists of developing at least three scenarios, which are widely discussed in formal and informal processes. The final plan selected is thus robust, and the grid should be able to meet future demand for electricity without many variations.

5.4 UNITED KINGDOM (UK)

In the UK, generation, transmission and distribution have been unbundled. There is retail competition and all consumers can choose their supplier. There are six DNOs serving 14 distribution areas, excluding small independent DNOs that serve new housing developments and commercial establishments. The retail supply market is dominated by the six largest suppliers.

Electricity North West (ENW) is the operator of one of the country's 14 distribution networks. It recently issued the Distributed Future Electricity Scenarios, which describe its plans to support economic development and the transition to a low-carbon economy.

In order to reflect the various uncertainties, ENW created five scenarios along two dimensions: Green Future and Prosperity. Four of the scenarios reflect high and low values along these two dimensions as shown in Figure 16. The Central Outlook scenario represents the middle of the road on both dimensions. ENW says the forecasts are not meant to be predictions, but instead to understand how the various uncertainties will affect electricity demand and how the distribution network will be affected by changing economic conditions and political decisions. By recognizing uncertainties, ENW aims to use the forecasts in these scenarios to develop a strategy for a resilient distribution network for the future.

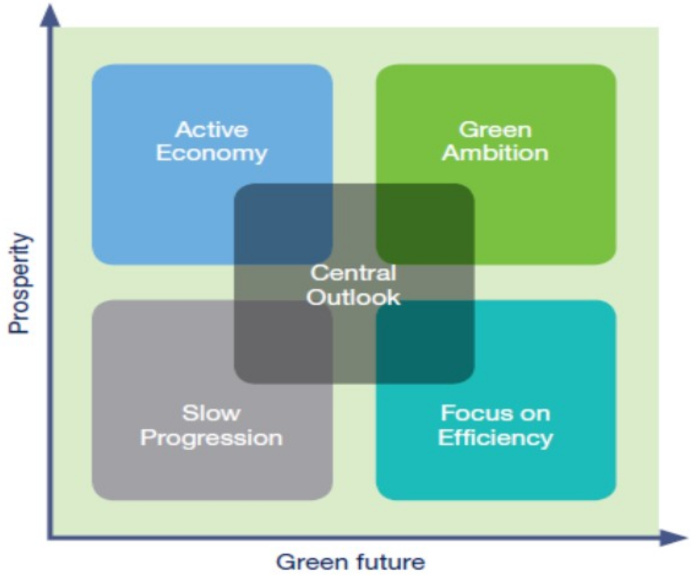


Figure 16: Scenario Used by Electricity North West for Planning,
Reproduced from Electricity North West Distribution Future Electricity Scenarios and Regional Insights, November 2018

ENW uses a bottom-up approach for forecasting that also has a high degree of spatial resolution. It states that its models forecast demand down to the level of postcodes. This approach highlights regional differences. For example, the uptake of EVs is expected to be higher in Manchester because of its shorter commutes. Similarly, the uptake of heat pumps varies across regions because of climatic differences.

ENW engaged with local authorities, local communities and investors to learn about their plans for future development. Recognizing that with the possibility of significant DER by consumers and with new technologies, consumers' patterns of electricity use could vary significantly, ENW has developed forecasts for each half-hour of the entire year. The Central Outlook forecast relied on many government documents and other research reports:

- The growth in the number of households was based on estimates from the Department of Communities and Local Government.
- Projections for improvements in residential energy efficiency were based on policies for Market Transformation of the Department for Environment, Food and Rural Affairs.
- The projected growth in national GDP was based on numbers from the Office for Budget.
- Non-residential energy efficiency improvements were based on EU energy efficiency targets.
- The numbers of EVs were based on results of an uptake model developed by Element Energy for the Department of Transport. The model is a consumer choice model that examines the decision by a consumer to buy a vehicle. ENW converted the data on number of EVs to electricity demand based on evidence on charging behavior it gathered during EV trials.

- The projections for residential heat pumps were based on work done for ENW by Delta EE and the University of Manchester.
- Heat pumps in the non-residential categories were based on numbers put out by the Department of Energy and Climate Change in 2014.

5.5 SUMMARY OF FINDINGS FROM INTERNATIONAL EXPERIENCE AND KEY LESSONS FOR INDIA

The major features of the resource planning practices in the four selected countries is summarized in Table 9.

Table 9: International Practices in Resource Planning

	USA	Australia	Germany	UK
Demand Forecasting	Mix of econometric, end-use, and statistically-adjusted end-use (SAE).	AEMO uses a mix of methods. Mostly econometric models and survey methods. Ausgrid uses econometric model	Residential consumption forecast on population and number of households. Commercial on population. Industrial essentially constant. All adjusted for efficiency gains.	Bottom-up models, fine spatial resolution down to postal code.
DER Uptake	Mix of target-based, technology-adoption models, and consumer-payback based models.	AEMO used technology adoption theory. Ausgrid used bill savings models specific to each consumer type	DER and grid-connected not separated. Overall uptake based on target of 65% RE by 2030.	Information not available
EV Uptake	California requires detailed studies by utilities	Both AEMO and Ausgrid used results from the model based on technology adoption theory from CSIRO.	Carried out by research institute.	From consulting firm using a consumer choice model.
Risk and Uncertainty Management	Many utilities carry out detailed modelling exercises using scenario analysis, sensitivity analysis and probabilistic modeling. Option analysis is being added by some pioneering utilities.	Five scenarios evaluated. Two additional sensitivity cases.	Three scenarios all required to meet RE goal. Differ by extent of use of electricity in other sectors: transport, heating, production of hydrogen and methane.	Four scenarios along two dimensions: green future and prosperity. Fifth scenario is middle of the road and called Central Outlook.

	USA	Australia	Germany	UK
Resource Planning (Resource Portfolios)	Mostly capacity expansion models. Some utilities have developed their own models.	Extensive modelling by AEMO using PLEXOS includes tests for reliability, security and robustness	No use of model. Based on known investment plans, expert and stakeholder inputs.	Information not available.
Regulatory Framework for Long-Term Planning	Very strong framework in almost every state.	AEMO, TSOs and DSOs are required to file annual plans.	Joint Grid Development Plan required every two years from TSOs.	Not known how often planning studies are required by the regulator.

Source: PACE-D 2.0 RE Research

There are some common lessons that emerge from the experience of the four countries:

- **Recognition of Uncertainty**. All four countries recognized and addressed the uncertainty in the electricity sector. Rather than rely on a single view of the future, all four planned for various scenarios that captured the range of uncertainty that distribution companies are expected to face.
- **Best Practice in Risk Management.** Recent work from the US shows that the four techniques generally used for addressing uncertainty (scenario analysis, sensitivity analysis, probabilistic analysis and options analysis) can be woven into a logical progression to capture the benefits of each.
- **Need for Regulatory Framework for Resource Planning.** The US experience shows the value of having a regulatory framework that requires distribution companies to carry out a resource planning exercise at regular intervals.
- **Improved Demand Forecasting**. With changes in consumer usage through DER, EV charging, and DR, DISCOMs should move to the greater use of end-use approaches and load research for demand forecasting with greater spatial and temporal resolution to be able to capture the benefits of some of these behind-the-meter technologies.
- **RE Integration Studies and Forecasts for Behind-the-Meter Technologies**. Either DISCOMs or TSOs should carry out RE integration studies to ensure that grid reliability is maintained as the contribution of RE to the generation mix increases. As DER, EV charging, and smart homes become more prevalent, distribution companies must carry out detailed studies, or have them done by other competent parties, to forecast their uptake.
- **Integration of Transmission Planning with Resource Planning**. As the experiences in Australia and Germany show, transmission can play an important big role in increasing the share of RE while maintaining grid stability and reliability.
- **Use of Software's:** Our analysis revealed that most global utilities rely on software tools for demand forecasting and resource planning. By using such advanced tools, the system simulation becomes closer to actual, thereby leading to a more accurate and reliable plan. The tools make use of scientific methods and modern techniques to provide a robust solution. These tools

come with sophisticated database for storing all relevant historical data. This historical data improves the forecasting capabilities of the tool, which in turn improves the overall resource planning. Some of these tools also come equipped with probabilistic techniques of analyzing the variations and uncertainties in the system parameters like RE generation and demand variations. Software tools used globally for energy forecasting, generation adequacy and power procurement are presented in Annexure 3.

CHAPTER 6. GAPS BETWEEN INTERNATIONAL BEST PRACTICES AND CURRENT INDIAN PRACTICES

Chapter 5 explored the resource planning practices in four RE-rich countries. While this is a small sample, their global leadership in the use of RE allows their practices to be viewed as international best practices. Table 10 provides a comparison of resource planning practices in India with the best international practices from the four countries.

Table 10: Gap Assessment - International Best Practices and Indian Practices in Resource Planning

ATTRIBUTES OF RESOURCE PLANNING	INTERNATIONAL BEST PRACTICES	CURRENT PRACTICES OF INDIAN DISCOMS	OBSERVATIONS
Regulatory Framework	Well defined regulatory requirements for resource planning	Limited and obsolete regulatory guidelines	A regulatory framework for resource planning is required
Responsibility for Long-term Resource Planning in DISCOMs	Utilities have specific division for developing and filing resource plans	Diffused and diluted responsibility	Each DISCOM should have a division with the sole responsibility for developing resource plans.
Consideration of Uncertainties-Risk Management	Consideration of multiple scenarios to account for uncertainty. Best practice consists of scenario, sensitivity, probability and option analyses woven together in logical progression.	Usually single view of the future. Little attention to minimizing risk except some cursory sensitivity analysis.	Rigorous risk management should be part of resource planning.
Demand Forecasting	End-use based. High degree of spatial and temporal resolution.	Simple trend analysis usually. Aggregated over large regions or consumer categories, and for the full year.	Better techniques of forecasting with greater spatial and temporal resolution should be followed.
Load Research	Extensive and regular load research with metering of consumer premises down to end-use level	Almost no metering-based studies. Some survey-based studies.	Need rigorous metering studies down to end-use level of representative sample of consumer premises.
Process for Selection of Resources for Developing Resource Portfolios	Head-to-head comparison of different supply and demand resources	No comparison of different types of resources	Better techniques of resource selection required using

			capacity expansion models.
Minimization of Total System Costs	Minimization of PVRR over the planning horizon.	Overall system costs not considered. Levelized cost of generation of resource evaluated, for a single resource at a time.	Focus of long term resource plans should be on minimization of PVRR while complying with all environmental limits.
Use of Models	Extensive use of models for capacity expansion, estimation of production costs, and risk management using sensitivity analysis and probabilistic analysis	Almost no use of models for planning by DISCOMs. Usually simple spreadsheet based. CEA uses models for some of its work.	Extensive use of models should be encouraged.
Consideration of EE, DER, DR, etc.	Targeted implementation of EE, DER and DR. Public campaigns to encourage use of DER, EE and DR by consumers.	For most DISCOMs, not much thought given to targeted use of demand-side resources. Awareness of EE & DSM but not much effort by DISCOMs.	Resource planning must give importance of EE & DSM, DER and DR as alternatives to satisfy consumer demand for electricity services.
Evaluation of EE&DSM Measures as Resources at par with Supply Resources	EE & DSM are considered as resource to meet the demand	EE is considered as demand reduction	
Estimation of the Need for Flexible Generation	As part of resource plan, some utilities carry out detailed study estimating need for, and cost of, flexible generation	Studies done by CEA. No studies by the states or the DISCOMs.	Need for flexible generation should be part of resource planning process. .
Forecast of Uptake of Behind-the-Meter Technologies: DER, EVs etc.	Detailed studies on such forecasts carried out, usually by external agency, and used by utility	Nascent Stage	Discoms should develop good forecasts of uptake of behind- the-meter technologies, either themselves or through research institutions or consultants.

CHAPTER 7. KEY CONSIDERTIONS FOR INDIA

To accommodate more renewable energy into the system with minimum system integration costs, India needs meticulous resource planning. But how should it go about this to make best use of RE resources? This chapter provides recommendations to help prepare DISCOMs to develop accurate resource plans that would add more RE, reduce power purchase costs and ultimately, the consumer tariff. The recommendations are largely drawn from the information and analysis provided in the previous chapters, state visits, stakeholder consultations, consultations with professionals working in this area, and internal and external reviews.

7.1 INCREASE AWARENESS OF THE IMPORTANCE OF RESOURCE PLANNING

Resource planning used to be done by a department of the State Electricity Board, but after unbundling, it became "no one's baby." On the other hand, its importance has been further enhanced in an RE-rich environment. Therefore, the first step in developing a resource plan is to increase awareness of its benefits among stakeholders.

Two key groups of stakeholders should be approached: state regulators and distribution companies. Workshops should be held with these groups to explain why resource planning is important and how a good resource plan will help realize the advantages of cheaper RE power. Sensitization may be different for each group. For DISCOMs it should be on the methodology that will produce the most accurate forecast while for regulators, it would be the examination of the methodology and assessment of its impacts (Table 11).

Table 11: Recommendation 1: Increase Awareness of the Importance of Resource Planning

Relevance of the Recommendation	The significant reduction in RE costs in comparison to fossil fuel costs has given rise to the possibility of reduced power purchase cost for DISCOMs. Demand can now be controlled through DR, DSM and DER. It is possible to match the variations in RE with demand and achieve substantial reductions in the cost of system integration. All these converge to indicate that accurate and robust resource planning will reduce the power purchase costs of the DISCOM through increased adoption of RE.
Recommendation Rationale	There is limited awareness among DISCOMs and regulatory agencies of how resource planning will help in adopting more RE with lower system integration costs.
How it will be implemented	Institution should be identified to give courses on resource planning (CPRI, CER, IITs, NPTI etc.)
Who will implement it	Central Government (MNRE/MoP/CEA/State Governments)

7.2 CREATE A REGULATORY FRAMEWORK FOR RESOURCE PLANNING

No important regulatory guidelines exist for planning power procurements, which account for 60-80 percent of a DISCOM's expenditures. Neither have regulators declared any mechanism to examine this cost in the annual revenue filings (ARR) of DISCOMs. It is difficult to find in ARR any detailed methodology DISCOMs have adopted for accurate demand forecasting or that sufficient effort has been made to find the least-cost resource for DISCOMs to meet demand.

When the regulatory commissions were formed in India in the 1990s, most of them issued regulations called "Guidelines for Load Forecasts, Resource Plans and Power Procurement." This was a time when demand was considered unregulated and generation resources were stable, dominated by coal. Now it is possible to control demand by DR, EE and DER and generation resources have/are likely to have significant variations due to RE. Therefore, these guidelines require a significant change.

7.2.1 FRAME REGULATIONS FOR RESOURCE PLANNING

Key clauses that need to be considered in such guidelines to meet the new requirements of RE-rich environments are:

- **Methodology.** Figure 1 summarizes the steps that should be followed in resource planning. The regulations should specify a process that DISCOMs should follow, including demand forecasting and estimating the additional resources on a least-cost basis. The methodology should provide for optimizing resource requirements by considering DR, EE, DER, EVs, energy storage systems, etc.
- **Load Research.** DISCOMs should be mandated to conduct good quality load research, based on measurements (not surveys) that provide enough spatial and time granularity to accurately predict the impact of changes in tariff on any consumer category and demand curves.
- **Use of Software.** The regulatory commissions, in consultations with CERC, FOR, CEA and DISCOMs, should try to develop a software tool DISCOMs can use for resource planning.[42] This will bring uniformity to the approach and ease the regulatory examination of the resource plan submitted by DISCOMs.
- **Risk Analysis.** DISCOM resource plans should take into account the analysis and mitigation of risk. This should include scenario analysis, sensitivity analysis, probability analysis and options analysis.
- **Planning Horizon.** A planning horizon of 10 years is recommended here; this period is long enough to incorporate long-term concerns but not so long that it becomes difficult to make reasonable assumptions about fast-changing future environments.
- **Frequency of Updates.** Resource plans should be updated every two years to account for changes in demand growth, technologies, availability of new resources, etc.
- **Public Participation.** Most SERCs already solicit inputs from the public on major proceedings through public hearings and invitations for comments on discussion papers. The outcome and inputs of the resource planning activity should also be included in that list.

Table 12: Recommendation 2: Frame Regulations/Guidelines for Resource Planning

Relevance of the Recommendation	The power procurement cost is around 60-80% of the ARR filed by DISCOMs. Thus, the regulatory framework must ensure prudence and transparency in this major expenditure.
Recommendation Rationale	Most of the SERCs lack regulations/guidelines for effective resource plans to be submitted by DISCOMs,
How it will be implemented	Draw global lessons and pass regulations that provide holistic guidance on the methodology for resource planning, recommend robust software, plan realistic horizons and encourage public participation. Mandate DISCOMs to undertake load research and risk analysis, and make regular updates to resource plan.

[42] Both the central and state governments can make laws on the subject areas on the Concurrent List; when there is a conflict, the most recent law will prevail.

Who will implement it	Forum of Regulators (FoR) to develop model regulation/State Electricity Regulatory Commissions (SERCs) to adopt and DISCOM to implement

7.2.2 SEPARATE PROCEEDING FOR RESOURCE PLANNING FROM ARR EXAMINATION

Today, the resource plan means the power purchase portfolio, which regulators examine as part of the ARR. By law, all DISCOMs are expected to submit their ARRs by December and regulators must issue revised tariffs orders by March of the following year; the tariffs can be implemented from the first day of the fiscal year. This does not provide enough time for regulators to give the resource plans the attention they deserve.

Since the duration of a resource plan is 10 years, it is proposed here that DISCOMs submit their resource plans to regulators six months early, every two years, and that regulator's approval process lasts three months. This will give the DISCOM and regulator enough time to focus on other important issues of rate making. This approved resource plan will be the major input to the ARR (Table 13).

Table 13: Recommendation 3: Separate Proceedings for Resource Planning

Relevance of the Recommendation	Regulators do not have enough time to examine the resource plans during the ARR examination.
Recommendation Rationale	It will give regulators sufficient time to consult other stakeholders and examine both the resource plan and ARR in greater detail.
How it will be implemented	Regulators to make this provision in the regulations/guidelines recommended in Section 7.2.1.
Who will implement it	SERC and DISCOMs

7.3 TRAININGS OF DISCOM STAFF ON RESOURCE PLANNING

The current state of long-term planning requires a huge leap in the capabilities of DISCOM staff. DISCOM planners should be trained to undertake planning in era which in which RE is undergoing a full throttle transformation. It is important for them to gain practical insights on how to develop resource plans that incorporate the full palette of supply and demand options, and how to utilize software/models that properly account all variables.

As India moves toward a high share of renewables, the continued mapping of new tools and data will be highly beneficial. It is essential for utility practitioners to exchange planning experiences with the international community. Dedicated capacity building workshops on software, train-the-trainer programs, load research methodologies, trainings through international courses and country visits, and webinars will support DISCOM employees of in learning and further applying knowledge for the development of resource plans (Table 14).

Table 14: Recommendation 4 – Build the Capacity of DISCOM Staff

Relevance of the Recommendation	Increased capability of DISCOM staff will help them understand how to use specialized software, resource planning methodologies, load research techniques, analyses used for resource planning and subsequently the development of resource plans for their DISCOM.
Recommendation Rationale	The current state of long-term planning is inadequate and should be restructured based on new realities and cost drivers

How it will be implemented	Through centrally organized capacity building courses (CEA/Ministry of Power/ Ministry of New and Renewable Energy), train-the-trainer workshops at the state level, webinars, and enrollment in international courses
Who will implement it	DISCOMs and SLDC at the state level, MOP and MNRE at the central level

7.4 DEVELOP A RESOURCE PLAN AT DISCOM LEVEL

Before state electricity boards were unbundled, utilities had a planning department that was responsible for making its state's generation, transmission and distribution plan. After unbundling each entity is expected to make its own plan. In some of the states holding companies are trying to play the role of planning department of the unbundled SEBs. This has significantly reduced the quality of long term and medium-term plan and unbundled entities could not focus on this important activity.

Coordinated resource planning for the DISCOM is key to make use of falling RE prices and associated economic gains of using higher RE in the system. Each DISCOM thus must have a defined department/cell whose sole function should be to develop resource plan. This plan should be complete, detailed and exhaustive and should obtain regulatory approval as mentioned in section 6.2 of this chapter. All departments of the DISCOM such as commercial/Finance for filling ARR, power purchase department for procuring power, project department for constructing new infrastructure etc. should take input from this department.

Table 15: Recommendation 5 - Develop a Resource Plan at DISCOM Level

Relevance of the Recommendation	Coordinated and accountable resource planning of the DISCOM is key to making use of falling RE prices and associated economic gains of using more RE in the system
Recommendation Rationale	Multiple divisions with diffused accountability are responsible for different, but interrelated aspects of resource planning, leading to poor quality long-term planning
How it will be implemented	DISCOMs to entrust one division with the responsibility for resource planning
Who will implement it	DISCOM

7.5 DEEPER COORDINATION BETWEEN CENTER AND STATE DISCOMS

In the current practice, Central Electricity Authority (CEA) on behalf of Federal Government develops the National Electricity Plan once in every five years and predicts the demand every five year in the Electricity Power Survey. CEA does take data from the States, but CEA projections are not simple aggregation of all the state data. All the power sector planning at national level are based on these data's.

At the state level, each year state regulators approve the DISCOM resource plans, which are contained in the DISCOMs' ARRs. While developing their resource plans, some DISCOMs use the EPS data (CEA data), some their own numbers, and other take from both. Numbers from EPS and DISCOMs' own numbers are not strongly correlated. Table *16* shows the percentage difference observed between the EPS and DISCOMs' (for example – Jharkhand, Assam, Gujarat and Uttar Pradesh) own projections.

Table 16: EPS Projections and DISCOMs MYT Petitions of Energy Requirements (in MUs)

DVC - Jharkhand				APDCL - Assam		
YEAR	19th EPS	MYT Petition	% Difference	19th EPS	MYT Petition	% Difference
2016-17	6,115	11,031.8	80%	6,689	7,486	12%
2017-18	6,399	11,698.6	83%	7,416	9,117	23%
2018-19	6,696	12,424.9	86%	8,223	10,864	32%
2019-20	7,007	13,200.5	88%	9,124	8,273	-9%
2020-21	7,333	14,008.3	91%	10,042	8,841	-12%
PGVCL - Gujarat				**MVVNL - Uttar Pradesh**		
YEAR	19th EPS	MYT Petition	% Difference	19th EPS	MYT Petition	% Difference
2016-17	33,124	30,391	-8%	-	-	
2017-18	35,265	31,862	-10%	15,695	18,684	19%
2018-19	37,393	33,432	-11%	17,396	25,224	45%
2019-20	39,568	35,037	-11%	19,189	33,223	73%
2020-21	41,788	36,754	-12%	-	-	

A bottom-up approach, where the capacity of the state should be built to improve planning based on a methodology developed and accepted by CEA, CERC and FOR is proposed. The plan as approved by state regulators should be communicated to central every four years and CEA should integrate and improve due to the diversity of resources and infrastructure in the country in consultation with the involved states and communicate back changes to the states. This should become a plan which CEA can declare every six years for every state to follow. The state with the approval of state regulators can fine tune this plan every two years. Similarly CEA can fine tune the plan every two years based on the revised numbers if any from state and any directions from CERC.

Table 17: Recommendation 6 – Improve Coordination between Central and State Institutions

Relevance of the Recommendation	Uniformity/ consistency in demand forecasting and resource planning data between the central government and DISCOMs will lead to improved resource utilization.
Recommendation Rationale	Demand projections reported by central and state vary significantly. Resource plans developed by the central government do not provide clear optics to the states.
How it will be implemented	State to provide information to CEA, and CEA to develop plans that every state should follow.
Who will implement it	CEA, CERC, SERC and state DISCOMs

ANNEXES

Annex 1: Calculation of Electricity Consumption by End Use

End-use category		Description
DISCOM ANNUAL ENERGY CONSUMPTION (RESTRICTED & UNRESTRICTED) FOR PAST 12 YEARS		
Domestic & Commercial *(Data Source: Energy Billing data of DISCOMs)*		• Number of consumers (past and projected) • Specific electric energy consumption • Electricity consumption (past and projected) • Consideration of improved living standards, reduced supply restrictions and impact of central programs on projections.
Irrigation	Pump sets/ tube wells	• Number of energized pump sets/tube wells (past and as per present energization program) • Connected demand • Capacity of pump set • Average hours of operation
	Lift irrigation Schemes	• Connected demand (past and as present per program) • Energy consumption (past and as per present program)
Industries, Public Water Works, and Public Lighting. *(Data Source: Energy Billing data of DISCOMs)*		• Connected demand (past and projected) • Hours of operation in a year • Electricity consumption (past and projected) • Central schemes like Make-in-India, etc., and energy efficiency schemes like LED street lighting and energy efficient pump set programs were considered
Bulk (Non-Industrial) *(Data Source: Energy Billing data of DISCOMs)*		• Location of bulk consumer • Connected demand (past and projected) • Energy consumption (past and projected)
Railway Traction *(Data Source: Ministry of Railways/ Railway Board)*		• Railway zone, section & sub-station contracted demand • Railway zone, section & sub-station energy consumption • Estimated demand based on track electrification programs
Peak Demand *(Data Source: STU & DISCOM)*		• Date of occurrence of annual peak • Time of occurrence of annual peak • Peak demand in MW • Demand shedding at the time of peak occurrence
T&D Losses *(Data Source: STU & DISCOM)*		• T&D losses in % terms
POLICY INITIATIVES/ GOVT. PROGRAMS		
AT&C Loss Reduction Programs (UDAY, IPDS, DDUGJY) *(Data Sources: Inputs from Ministry of Power, PFC, renewable energy certificates, REC and DISCOMs)*		• IPDS: program for providing 24x7 supply to urban areas • DDUGJY: Agriculture supply feeder segregation program, and rural electrification • UDAY: Reduction in AT&C losses program
DSM, EC&EE Programs (LED, S&L, PAT, EELS, SEEP etc.) *(Data Source: BEE)*		• Various DSM, EC and EE schemes implemented and planned. Impact assessment by BEE based on demand research

24x7 PFA Targets *(Data Source: MoP's PFA Documents for the respective states)*	State-specific PFA documents provide assessments of the energy required to provide 24x7 power for all connected and unconnected consumers,
Dedicated Freight Corridor *(Data Source: Ministry of Railways/ Railway Board)*	Considered as per the impact assessed and provided by the Railway Board
Make in India *(Data Source: State DISCOMs and Niti Ayog)*	Considered as per NitiAyog and state DISCOM assessments
Rooftop Solar Target *(Data Source: MNRE)*	Considered as per MNRE's 2020 target, as per impacts provided by MNRE
EV Target (NEMM 2012) *(Data Source: Dep. of Heavy Industries)*	Considering EV charging in off-peak hours, no impact was considered from EVs on demand

Annex 2: Case Studies

Simulation Study on Resource Optimization for Karnataka (2030)

Better resource planning could produce a significant increase in RE capacity, a reduction in power procurement costs, and less investments for grid-integration. A case study was carried out for a sample day in the peak month of FY 2019 (25 March 2019) in the state of Karnataka, using existing data.

The state's peak demand is about 11,245 MW, which is largely met by thermal and hydro as base demand. Figure 17 shows the actual generation dispatch on 25 March 2019, where solar generation contributes to the high demand period during the daytime and overlaps with the peak demand. Wind generation, on the other hand, remains the same throughout the day.

To meet its projected peak demand of 19,000 MW in 2030, Karnataka must develop a resources plan. Figure 18 shows the proposed generation dispatch for a typical peak demand day in 2030. To meet this demand, two capacity scenarios are considered: the business as usual (BAU) and renewable (RE) rich scenarios.

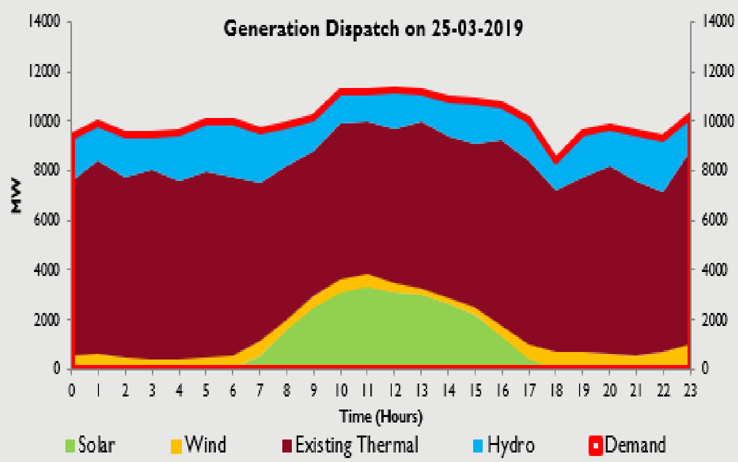


Figure 17. Generation Dispatch on 25-03-2019

Under the BAU scenario, 4,500 MW of thermal capacity are added to meet peak demand, but no RE capacity additions were considered. As a result, this scenario leads to large surpluses in the non-summer seasons and add to the fixed cost of utilities. The total cost for the utility comes out to be Rs. 18,461 Cr (USD 2637 million).

In the RE rich scenario, thermal capacity was reduced to 50% (2,400 MW) along with additional RE and storage capacity of 6,400 MW and 2,000 MW, respectively. The revised capacity is achieved through high RE uptake that includes solar, wind, storage, and hydro. Figure 17 shows that solar generation coincides with the peak demand, whereas hydro and storage are considered as balancing resources and are utilized when RE is not present. The total cost under this scenario comes out to Rs. 17,028 Cr (USD 2,432 million). Under this scenario, the utility saves Rs. 1,433 Cr. per annum (USD 204 million/annum).

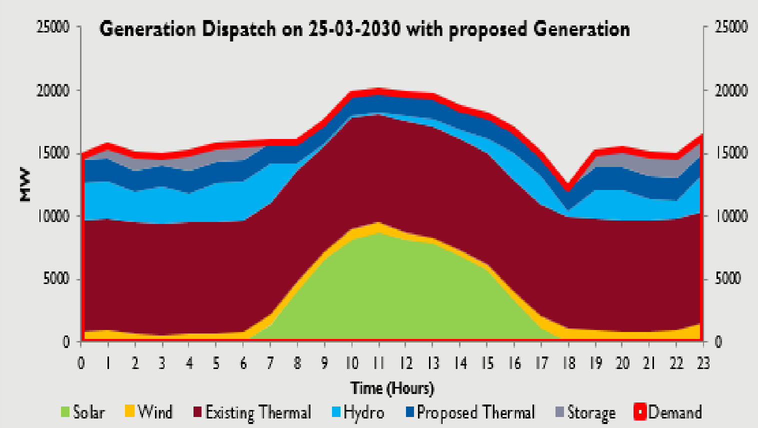


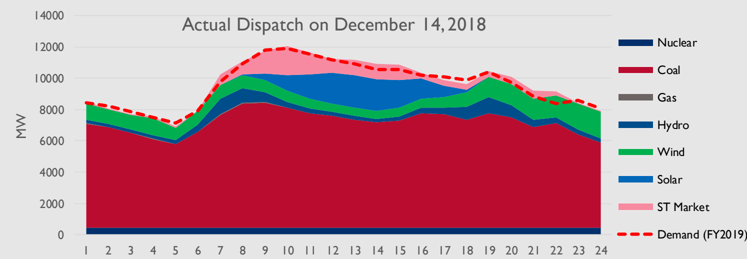
Figure 18: Generation Dispatch on 25-03-2030 with Proposed Generation

Simulation Study on Impact of RE Addition on Rajasthan (2022)

To demonstrate the benefits of dispatch simulation and demand-supply compatibility assessment for optimal long-term planning and RE uptake, dispatch and supply costs were simulated for a sample day in the peak month of FY 2018-19 (14 Dec 2018) using publicly available data.

Dispatch was simulated in Rajasthan to understand the utilization of available resources, especially RE, the ramp support provided by conventional power plants, and RE's compatibility with demand. The graph below shows that wind generation occurs mostly during low demand periods and provides some support in the evening peak. On the other hand, solar generation coincides with high demand periods during the day, but doesn't overlap with peak demand. Thermal plants (TPPs) have minimal ramp-down during the day, when the state's demand peaks occur. Due to low demand at night and aided by high wind generation, TPP plant load factors are lower, around 71% (indicating high stranded costs), with RE's share of generation at 15%. The average cost of supply for the day is around Rs 4.84/kWh (6.9 cents/kWh).

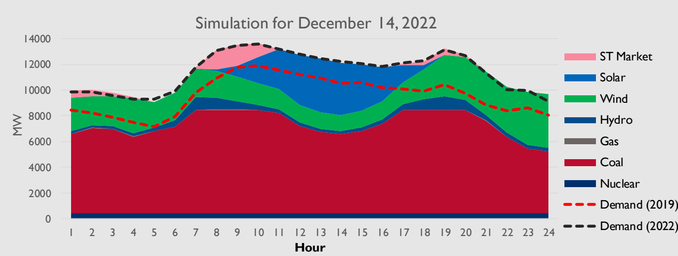
To assess Rajasthan's ability to absorb more RE in a cost-effective manner, a simple simulation was run to determine the suitability of supply resources with additional RE penetration, and the likely impacts on TPPs' use of coal and the state's average power procurement cost.



(Note: The hourly demand for 2022 was projected considering the growth rate of the past two years in the respective time blocks (a simple procedure was used assess demand for 2022). No new capacity addition of conventional power plants would be taken-up until 2022, in line with government policy.

To meet the projected demand on the sample day, wind generation capacity was increased by 150% and solar generation by 100% to 2018 levels. Generation from coal TPPs was changed to meet the unmet demand, in addition to procurement from short-term markets wherever there was capacity scarcity.

In this test simulation, there is a 4% reduction in the average power procurement cost to Rs 4.63/kWh (6.6 cents/kWh), and a 1% increase in utilization of coal TPPs (PLF of 72%), while meeting demand on all hours. This simulation demonstrates the benefit of Rajasthan adding more RE capacity, both in terms of supply adequacy and cost benefits.



(Note: For this case, capacity additions of 150% for wind and 100% for solar are considered intuitively, but resource planning tools would efficiently simulate various scenarios and help in choosing the optimal resource mix, including RE capacity, which could meet the given demand at least cost. Also, effective demand forecasting methodologies could help establish the demand-curve changes, so as to plan suitable supply proactively.)

Annex 3 (a): Summary of Global Practices

A summary of the findings of the global practices are summarized in the following table. From the table, it can be summarized that globally resource planning is done considering probabilistic and deterministic outlook using sophisticated commercial tools like Plexos, Antaares, Powersym, etc.

Table Summary of Global practices

	RESOURCE PLANNING	PERIODICITY	TOOL
Europe	• Econometric and End Use are most prevalent • Typically, Sequential Probabilistic Monte Carlo Method including deterministic constraints	Annually evaluated for a period of about 10 years by most Utilities.	Mostly ANTARES. Other tools include BID3, GRARE, PLEXOS and PowrSym.
America	• Econometric, End Use and Statistically Adjusted End Use (SAE) are most prevalent models • Approaches combining Deterministic and probabilistic outlook	Annually evaluated for a period of upto 20 years by most Utilities.	Strategist, PROVIEW, Metrix, LoadMAP-R and PLEXOS
Australia & New Zealand	• Econometric Method • Two Year Probability of Supply Adequacy Shortfall (2YRPSAS)	Annually evaluated for a period of upto 20 years	PLEXOS
Malaysia	• Time Series, Regression Analysis • Not Available	Evaluated for upto 20 years	Not Available

Source: PACE-D 2.0 RE Research

Annex 3 (b): Softwares Used Globally

Our Analysis revealed that most global utilities rely on software tools for demand forecasting and resource planning. By using such advanced tools, the system simulation becomes closer to actual, thereby leading to a more accurate and reliable plan. The tools make use of scientific methods and modern techniques to provide a robust solution. These tools come with sophisticated database for storing all relevant historical data. This historical data improves the forecasting capabilities of the tool, which in turn improves the overall resource planning. Some of these tools also come equipped with probabilistic techniques of analyzing the variations and uncertainties in the system parameters like RE generation and demand variations. Software tools used globally for energy forecasting, generation adequacy and power procurement are presented in Table below.

Table: Various software tools used globally for demand forecasting and resource planning

SOFTWARE	PARAMETERS	COUNTRIES
AleaDemand (Mid & Long)	**Input Parameters:** Explanatory variables include calendar days, weather, temperature thresholds, socioeconomic indicators, climatology and seasons.	Belgium, France, Italy, Germany, Netherlands, Poland, Spain and UK
Alyuda	**Input Parameters:** GDP, Population entity, Prices of fossil energy carriers, consumer sector sales expectations **Output Parameters:** Energy demand forecast and other key factors that condition profits, increase in efficiency of combination of cogeneration & district heating and ensure availability of power.	Australia, Chile, France, Germany and USA
ANTARES	**Input Parameters:** Technical and meteorological parameters **Output Parameters:** LOLP, LOLE, LOEE / EENS	Germany, Luxembourg, The Netherlands, Belgium and France
AURORA	**Input Parameters:** LP and MIP	North America
BID3	**Input Parameters:** Fuel prices and operational constraints, Detailed and consistent historical wind speed and solar radiation. **Output Parameters:** Simulation of all the major power market metrics on an hourly basis - electricity prices, dispatch of power plants and flows across interconnectors.	China, Europe and North America
EGEAS	**Input Parameters:** Planning Reserve Margin, emission constraint, Resource availability, Demand and energy forecast, Fuel forecasts, Retirements, CO2 costs, RPS requirements, Heat rate, Outage rate, Emissions rate, Fuel and O&M costs, For new resources - Capital cost, Construction cash flow, Fixed charge data, Years of availability **Output Parameters:** 20-year resource expansion forecast, Amount, type and timing of new resources, Total system Net Present Value (NPV) of costs, Annual production costs for system, Annual fixed charges for new units, Annual tonnage for each emissions type, Annual energy generated by fuel type, Annual system capacity reserves and generation system reliability	Australia and USA
GRARE	**Output Parameters:** RES forecast, and possible aggregation of area and fixed percentage of load, RE production, operational reserve level evaluation, Residual load distribution, Reservoir and pumping hydro optimization, ENS, LOLE, LOLP	Europe

PLEXOS	**Input Parameters:** Energy balance constraints, Operation reserve constraints, Generator and contract constraints: ramp, min capacity, energy limits, Transmission limits, Fuel limits and Emission limits **Output Parameters:** Optimal planning solution in the medium-term. Short-term unit commitment and economic dispatch Hourly electricity spot prices	Europe, Middle East and Australia
PowrSym	**Input Parameters:** Monte Carlo Scenarios and Climate Dependent Time series **Output Parameters:** Capacity factor, Emissions, Fuel burn, Electric energy generated, Costs (fuel; operation and maintenance, O&M; start up; emissions; total), Number of units starts, Operating hour	Japan, South Korea, Europe and North America
Synergi Forecaster	**Output Parameters:** Reduce imbalance penalties imposed by the regulator/transporter Optimize Capital Expenditures by pinpointing capacity constraints	Countries of Africa, America, Asia, Europe and Middle East

Source: PACE-D 2.0 RE Research

REFERENCES

Climate Policy Initiative and TERI. (2019). *Accelerating India's Transition to Renewables – A Report from US Climate Policy Initiative and TERI*.

CEA. (2017). *Study of Optimal Location of Various Types of Balancing Energy Sources/Energy Storage Devices to Facilitate Grid Integration of Renewable Energy Sources and Associated Issues*

IRENA. (2017). *Planning for the Renewable Future: Long-Term Modelling and Tools to Expand Variable Renewable Power in Emerging Economies*.

IRENA. (2017). op. cit.

Singh and Swain. (2018). *Fixated on Megawatts.*

Anoop Singh, Manvendra Pratap, Abhishek Das, Piyush A. Sharma, and Kamal K. Gupta. (2019).

Regulatory Framework for Long-term Demand Forecasting and Power Procurement Planning.

CEA. (2018). Section 5.11, *National Electricity Plan*.

U.K. Government and Ofgem. (2017). *Upgrading Our Energy System: Smart Systems and Flexibility Plan.*

Wilson and Biewald. (2013). *The Regulatory Assistance Project, Best Practices in Electric Utility IRP.*

Wilson, Rachel and Paul Peterson. (2011). *Survey of State Integrated IRP Rules and Requirements.*

Carvallo, P.J. et al., (2016). *Load Forecasting in Electric Utility Integrated Resource Planning, Lawrence Berkeley National Laboratory.*

Association of Edison Illuminating Companies. (2017). *Load Research Manual- 3 edition, Birmingham.*

Kahrl, F., A. Mills, L. Lavin, N. Ryan & A. Olsen. (2016). *The Future of Electricity Resource Planning, Berkley: Lawrence Berkeley National Laboratory.*

Borison, A. (2014). *Electric Power Resource Planning Under Uncertainty: Critical Review and Best Practices, White Paper, California: Berkeley Research Group.*

Finkel et al., (2017). *Independent Review of the Future Security of the National Electricity Market: Blueprint for the Future*.

AEMO. (2019). *Electricity Demand Forecasting Methodology Information Paper*.

Ausgrid. (2018). *Distribution and Transmission Annual Planning Report*.

AEMO. (2018). *Integrated System Plan for the National Electricity Market.*

Graham et al, (2018).

Weimar et al., (2016).

Netzentwicklungsplan Strom. (2019). Presentation *Grid Development Plan 2030.*

(2018). *Generation Adequacy Assessment 2.0, PLEF SG2.*

(2019). *Entwurf def Ubertragungsnetzbetreiber, Szenariorahmen fur den Netzentwicklungsplan Strom 2030.*

https://aleasoft.com/cases/ [Accessed September 2019]

https://www.alyuda.com/testimonials.htm [Accessed August 2019]

https://www.researchgate.net/publication/289478412_A_new_tool_for_adequacy_reporting_of_electric_systems_ANTARES [Accessed September 2019]

North American Electric Reliability Corporation (NERC), (2015). *Potential Reliability Impacts of EPA's Proposed Clean Power Plan*

https://www.poyry.com/BID3 [Accessed August 2019]

Electric Power Research Institute (EPRI). (2015). *Electric Power Resource Planning*

European Network of Transmission System Operators for Electricity (ENTSOE). (2018). Mid-term Adequacy Forecast

https://www.itron.com/se/customers [Accessed September 2019]

https://energyexemplar.com/resources/#case-studies [Accessed September 2019]

Operation Simulation Associates, Inc. (OSA). (2018). *Powrsym4TM*

https://www.powersim.com/main/services/partners/resellers/ [Accessed August 2019]

https://www.dnvgl.com/services/energy-forecast-software-synergi-forecaster-4454#Software [Accessed August 2019]

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