Guidebook

Developing Resource Plan for DISCOM in RE Rich Environment using REPOSE Software

Contents

1. INTRODUCTION

Through the Partnership to Advance Clean Energy Deployment 2.0 Renewable Energy (PACE-D 2.0 RE) program, the U.S. Agency for International Development (USAID) supports India's transition to a green, renewable, energy-secure economy by making clean energy cheaper. In the new realities, the prices of renewable are reaching a level lower than the cost of generation from conventional sources. It warrants including higher RE in the procurement portfolio of distribution utilities (DISCOMs) to reduce the power purchase cost. Currently utility planners are not equipped with how to deal with renewable dominated portfolios and include them in resource plans.

In partnership with the Ministry of New and Renewable Energy (MNRE), USAID provides power distribution companies (DISCOMs) with a new approach to energy resource planning that helps predict consumers' energy needs more precisely, closely matches electricity demand with a power portfolio that integrates renewable energy technologies, and optimizes new renewable energy procurements to be more cost-effective. The new approach has the potential to reduce power purchase costs by 5 to 10 percent by utilising software "DISCOM Procurement Optimization and Smart Estimation Software, DISCOM-REPOSE" developed under the program.

The objective of is guidebook is to provide the DISCOM practitioners and other professionals with the following:

- Elementary knowledge about the resource planning
- Complexities of resource planning with variation in both demand and supply
- About DISCOM REPOSE software tool
- How to develop resource plan and optimization based on cost, RE uptake and carbon emission

The material presented here has been tested and verified by conducting a training on "Developing Resource Plan for DISCOM in RE Rich Environment using REPOSE Software". The target audience consists of the DISCOMs, electricity regulatory commissions, load dispatch centres, and researchers/consultants. The course had enrolment of 44 participants from 30 organizations in India, Nepal, Bhutan, Bangladesh, Sri Lanka, and Maldives.

To review the course content developed by the technical team, the program formed a review committee to review the course content. The review committee had members from Central Electricity Authority (CEA), Indian Institute of Technology (IIT), Kanpur, State and Private DISCOM and course faculty.

To deliver each module, the team chose faculty based on the experience required for the module. It chose the faculty from Indian Institute of Technology (IIT), Kanpur to cover the power economics and the international faculty from Brazil to cover current practices in resource planning and international best practices. The in-house PACE-D 2.0 RE team will cover all remaining modules.

2. TRAINING OUTLINE

The training effectively combines practice theory with application and flexibility with rigor to give participants a holistic professional education experience. The online delivery of the course is done by senior power sector professionals with decades of experience in utility resource planning. The presenters constitute a rich panel of esteemed speakers across the globe from USAID, PSR Consulting, Tetratech, India and PRDC India, and a group of esteemed professors from IIT, Kanpur.

The entire course is covered in five modules with discussion on theoretical concepts along with case studies and hands on experience on the integrated resource planning software tool developed under USAID PACE-D 2.0 RE Program.

The detailed list of sessions, topics covered under each of the session, and the speakers are listed in the following table.

Session	Faculty
Module I: Basics of Power Systems & Resource Planning *(About power systems; importance & attributes of resource planning; course pedagogy)*	Mr. Anurag Mishra + Dr. Rakesh Kumar Goyal + Mr. Sumedh Agarwal + Dr. Anoop Singh
Module II: Current Practices of Resource Planning and International Best Practices *(Global resource planning practices; case studies on resource plan development)*	Ms. Ammi Toppo + Mr. Raphael + Mr. Mario
Tutorial I Module I + Module II	Dr. Rakesh Kumar Goyal + Mr. Raphael
Module III: Demand Forecasting *(About demand forecasting; methodologies and demand forecasting in RE rich environment)*	Mr. Sumedh Agarwal + Mr. Manoranjan Kalita + Mr. Kashyap
Module IV: Resource Mapping and Power Procurement Optimization *(Outputs and benefits of resource mapping to states, Understanding MILP and tool display, Development of procurement plans for utilities; how to address uncertainty management/situations like COVID)*	Dr. Nagaraja + Mr. Rishi Nandan + Dr. Chandrasekhar Atla
Tutorial II Module III + Module IV	Dr. Nagaraja + Dr. Chandrasekhar Atla
Module V: Regulatory Framework for Resource Planning **Program Close Out** *(Importance of regulatory framework in RE rich environment, tutorial for module 5 and 6)*	Mr. Anurag Mishra + Dr. Rakesh Kumar Goyal + Mr. Amarjeet Singh

3. TRAINING MODULES

3.1 MODULE 1: BASICS OF POWER SYSTEM AND RESOURCE PLANNING

This module is designed to ensure that all participants have at least a basic understanding of power system, attributes of planning, importance of increasing renewable share in power portfolio, and market trends as a foundation for deeper dives in subsequent modules.

- **Objectives:**
  - Understanding of power systems
  - Understanding of resource planning
  - Why resource planning is more important in RE rich environment:
  - How resource planning can help in reducing power purchase cost
- **Content:**
  - Basics of power system operation
  - What is resource planning
  - Complexities in resource planning due to RE, DER, new technologies, new class of customers etc.
  - How to address uncertainties in resource planning with impact such as COVID.
  - Attributes of resource planning
- **Presentation:**

USAID-MNRE PACE-D 2.0 RE Program: Online Certificate Program for Utility Professionals on Designing Resource Plans for Future Utilities (September 25 to November 06, 2020)

Long Term Demand Forecasting and Power Procurement Planning in Practice

Anoop Singh

Professor, Dept. of Industrial and Management Engineering (IME), IIT Kanpur

Founder & Coordinator, Centre for Energy Regulation (CER) & Energy Analytics Lab (EAL)

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CER Centre for Energy Regulation

Energy Analytics Lab

Newsletter : *Regulatory Insights*

Issue 04 Volume 02 April, 2020

REGULATORY INSIGHTS

Regulatory Outlook

ERC Tracker

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Access online

cer.iitk.ac.in/news_letter

Editorial

COVID-19 pandemic has immediate as well as long-term concerns for the regulators and the policy makers. Its impact on power system is reflected in general decline of energy sales and, a change in composition of energy sales and demand profile. Given the higher proportion of fixed cost component in costs as compared to the proportion of revenue from fixed charges in total revenue, a decline in energy sale, particularly those of subsidizing categories, would widen the revenue gap. The need for tariff revision and/or additional subsidy for the current and subsequent financial years is a cause for regulatory concern. Further, the pandemic's impact would be felt across the supply chain due to low PLF of high variable cost generators and decline in the sale of coal.

Reduction in renewable energy cost, even below that of conventional sources, needs to be reflected in floor price of solar/non-solar RECs, which has been proposed to be brought down to zero. Further, the uniform forbearance price at ₹1000/MWh provides the right framework to do away with prevailing segregation by merging solar and non-solar REC markets.

Increasing share of RE generation in RE rich states such as Andhra Pradesh and Tamil Nadu is leading to regulatory proposals removing/diluting the available preferential benefits to RE based generation. Since such concerns are arising on account of variability and uncertainty associated with variable RE generation, changes in the regulatory framework are required to make them more accountable to grid through uniform applicability of deviation related charges, and by enabling creation of a market for storage services as it becomes more economical in future.

Real-time monitoring of solar rooftop installations is a key to ensure that distribution utilities do not lose the visibility of behind the meter solar generation. Large rooftop installations (say, above 50/100 kW) should have adequate capability to enable real-time monitoring at the cost of owners. A sample of smaller installations should also be monitored by the distribution utility by making adequate investment, which should be approved by the SERCs.

Regulatory lag in RE tariff determination inadequately reflects decline in RE cost. Dynamic linking of the regulated tariff to the one determined through competitive bidding can address this. Regulated tariff for small scale projects, which are not exposed to competitive bidding process, can also be linked with adequate margin to compensate for diseconomies of scale. As an alternative, a competitive market for small scale projects can be developed by bundling a large number of identified projects.

Anoop Singh
Founder & Coordinator, Centre for Energy Regulation

The Centre is hosted in the Department of Industrial and Management Engineering, IIT Kanpur and is seed funded by Government of United Kingdom through a project titled 'Supporting Structural Reforms in the Indian Power Sector' under Power Sector Reforms (PSR) programme.

UK Government

Centre for Energy Regulation (CER), Department of Industrial and Management Engineering, Indian Institute of Technology Kanpur, Kanpur – 208016 (India)
Stay Home Stay Safe.

Issue 03 Volume 02 January, 2020

REGULATORY INSIGHTS

Regulatory Outlook

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Editorial

Pre-paid smart meter rollout would bring clear gains for DISCOMs in areas with high technical and commercial losses. A cost-benefit analysis, considering technical and commercial aspects, should drive wider implementation.

The difference between saving on interest on working capital and rebate on pre-payment, if compensated through the truing-up, would moderate the benefits. In high collection efficiency areas, benefits of pre-paid smart metering may be exceeded by overall cost of implementation. A smart grid ecosystem, enabling implementation of a demand response program and ToD tariff can help in monetising further gains for the power sector.

Employee accountability for failure to meet SoPs can be implemented if DISCOMs demarcate each feeder and consumers connected to it as a business unit, allowing SoPs monitoring therein. A SoP index, formed on basis of SoPs and other performance parameters, can then be used to fix accountability and implement an incentive/penalty structure.

Net metering for rooftop solar provides incentive to the consumers by displacing energy from high tariff slabs but reduces revenue recovery for the DISCOMs. Pay-out for excess energy injected by consumers at lowest competitively discovered tariff for grid-connected solar PV, adjusted for the network losses, ameliorates this impact. The RE energy consumption, if accounted towards RPO of DISCOM, should also be adequately compensated with reference to the prevailing REC price.

PLF-based incentive, differentiated across peak and off-peak hours, should be avoided as this not only disturbs the relative economic value of a plant's availability across these time blocks, but also places difficulty in its implementation. Further, increase in scheduled generation due to SCED increment for supply elsewhere should not be included in the incentive. Truing-up of tax refund while grossing up the RoE, and need to match regulations with the timeline of SBI MCLR are also highlighted in the CER's opinion in this issue.

Biomass blending will help in addressing stubble burning, and the associated pollution, by providing greater economic benefit for agricultural residue, if primarily used for pelletization. This scheme should thus be promoted for thermal power plants located in areas with abundance of agricultural residue or biomass waste from industries.

The regulatory approach towards tariff determination for EV charging should include determination of a generic tariff or promote competitive bidding. In the absence of any specific guidelines, operationalizing the 'priority' for installation of public charging stations given to existing retail outlets of oil marketing companies would be difficult and may result in restrictive environment for the new entrants.

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CER's Regulatory Blog

Distribution ➤ Standard of Performance 2020-06-08 11:44:55

CS **CSERC Standard of Performance (SoP) in Distribution of Electricity Regulation, 2020**

Keywords: Standard of Performance, DISCOMs, ARR, Consumer Awareness, SoP Compensation.

Highlights -

The Standard of Performance (SoP) regulation issued by CSERC on 15th May 2020 allows variation across geographical areas of DISCOM, and across DISCOMs. A summary is below:
1. If the licensee fails to maintain SoP, it is liable to compensate consumer at rates specified in the regulation, which cannot be claimed in ARR.
2. To spread awareness regarding SoP among consumers and staff, the licensee to make manuals available at offices and on the website, display guaranteed standards of performance at local offices.
3. The licensee is to submit quarterly report on the level of performance achieved, and on the number of cases in which compensation was payable and the amount paid/payable in each case to the commission.

CER Opinion -

1. A SoP index can be developed based on key performance parameters for each feeder and consumers connected to it, which should be used for implementing a penalty/incentive framework for the associated employees.
2. Given that DISCOM would manage a system of complaint registration and follow thereof, such a system should have a mandatory audit trail with due communication (SMS/email) to the consumers.
3. The commission may periodically review the current level of performance and setup multi-year benchmarks for SoP.

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CER's Regulatory Blog

Fundamentals of Renewable Energy: Economics, Policy and Regulation ➤ RE Policy and Regulation 2020-07-06 15:17:36

WB **WBERC's Draft for Amendment to Cogeneration and Generation of Electricity from Renewable Sources of Energy Regulations**

Keywords: Renewable Energy, Cogeneration, Net-metering, Solar Rooftop, RPO Regulations, RPO Targets, West Bengal, Solar REC, Non-solar REC

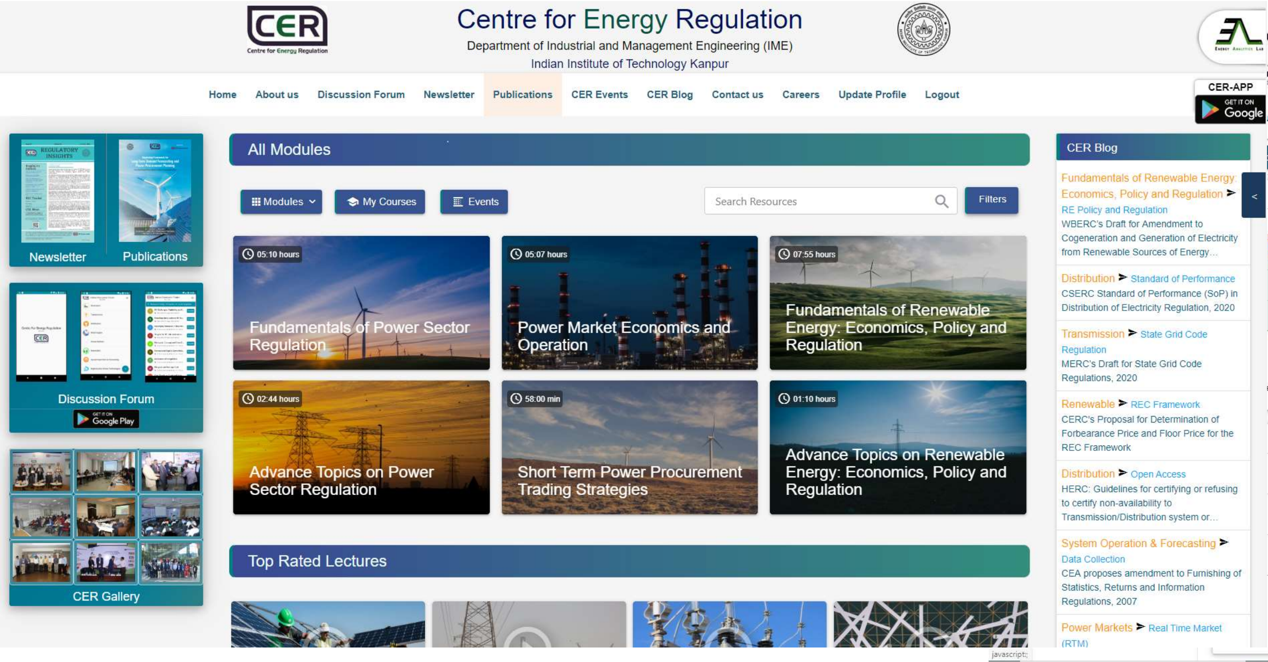
Highlights -

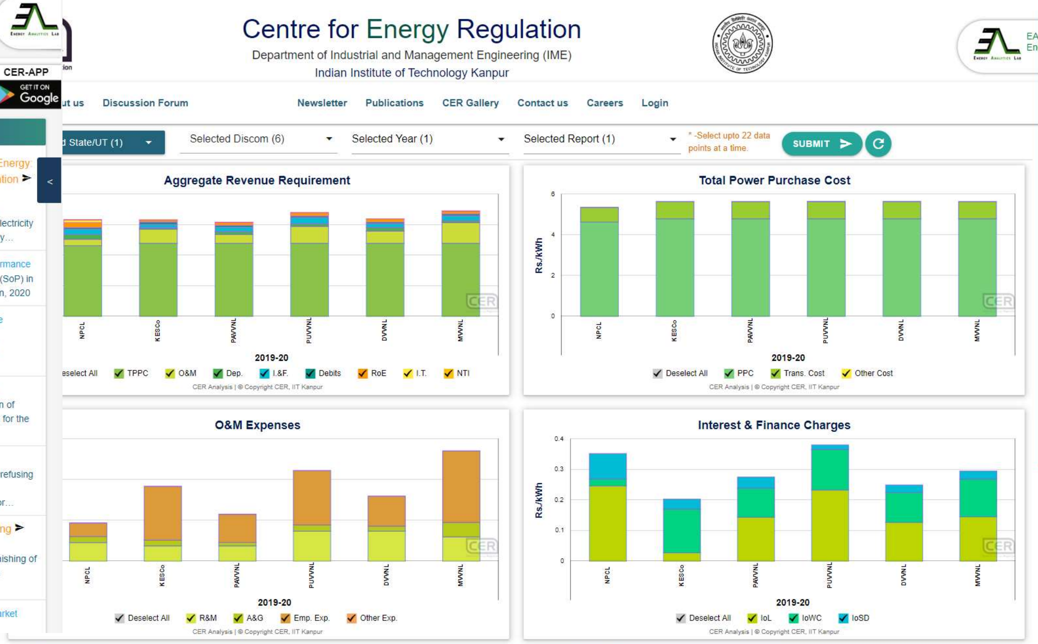
The WBERC notified draft for the amendment to Cogeneration and Generation of Electricity from Renewable Sources of Energy Regulations, 2013. Highlights are below:
1. Consumer can install rooftop system of 1 kW or above capacity (up to total sanctioned load or contract demand) can claim net-metering/net-billing benefits.
2. DISCOMs are proposed to procure 100% of energy from waste to energy plants in their respective areas.
3. Unmet solar RPO obligation above the 85% of total RPO can be met by non-solar energy, and vice-versa.

CER Opinion -

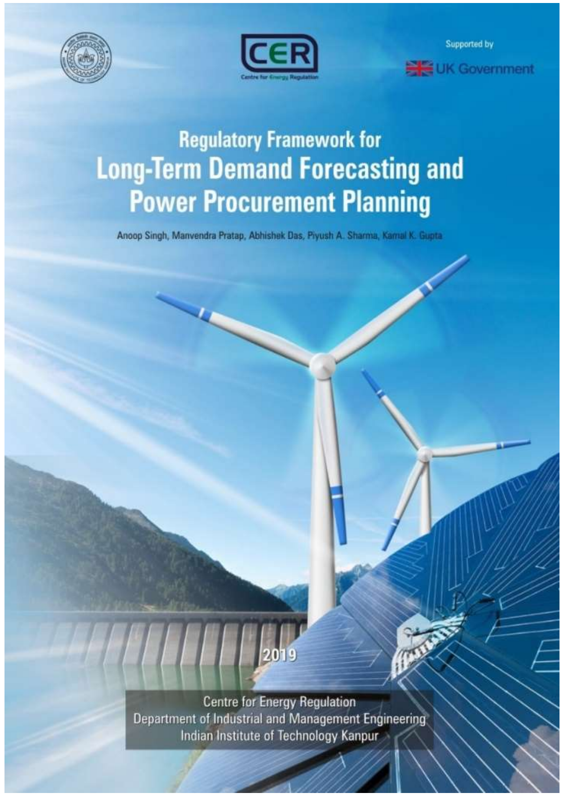
1. RPO trajectory for the state should be specified in advance so as to provide opportunity to obligated entities to make appropriate investments or plan to procure RE/REC.
2. In case the tariff for RE has been discovered under section 63 of EA, 2003 and has been adopted by the commission, the same should not be subjected to the price cap under regulation 6.0.
3. An RPO compliance framework, supported with penalty in proportion to the shortfall, would help ensure that obligated entities take adequate steps to meet their RPO

CER’s Regulatory Database Dashboard & Online Learning Platform (under development)





Monograph – *'Regulatory Framework for Long-term Demand Forecasting and Power Procurement Planning'*



conclude that some of the EPS had overestimated the demand for electricity. As shown in *Figures 5 and 6* and *Tables 2 and 3*, the 18th EPS had significantly overestimated the electricity demand; actual demand growth was much lower than expected. Therefore, demand projections in the 19th EPS were accordingly reduced by over 25 percent based on a lower estimated demand growth. The forecasted values of demand in the 18th EPS were closer to the actual values during the initial years, but there were significant deviations in the subsequent years. Compound Average Growth Rate (CAGR) of the projected electrical energy requirement during 2010-11 to 2015-16 was 7.62 percent, whereas the actual CAGR for the same period was 5.28 percent. Moreover, the CAGR of peak demand for 2010-11 to 2015-16 was actually 4.63 percent against the predicted value of 8.50 percent.

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

Year	Peak Electricity Demand					
	Actual Demand (MW)	18th EPS Projections (MW)	Overestimated Demand in 18th EPS (MW)	19th EPS Projections (MW)	Overestimated Demand in 19th EPS (MW)	Difference between 18th and 19th EPS (MW)
(1)	(2)	(3)	(4) = (2) − (3)	(5)	(6) = (2) − (5)	(7) = (3) − (5)
2010-11	1,22,287	1,22,287	0			
2011-12	1,30,006	1,32,685	2,679			
2012-13	1,35,453	1,43,967	8,514			
2013-14	1,35,918	1,56,208	20,290			
2014-15	1,48,166	1,69,491	21,325			
2015-16	1,53,366	1,83,902	30,536			
2016-17	1,59,542	1,99,540	39,998	1,61,834	2,292	37,706
2017-18	1,64,066	2,14,093	50,027	1,76,897	12,831	37,196
2021-22		2,83,470		2,25,751		57,719
2026-27		4,00,705		2,98,774		1,01,931

Source: 18th and 19th Electric Power Survey of India, CEA [4-5]

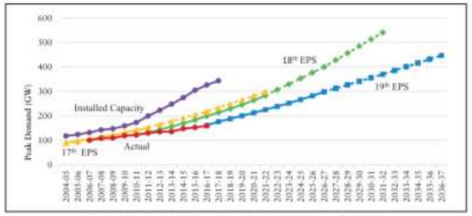


Figure 5: Historical projections of annual peak electricity demand (all India)
(Source: 17th, 18th and 19th Electric Power Survey of India, CEA [3-5], Load Generation Balance Reports (LGBR), CEA [6-15])

Recommendations

Based on the projected electricity demand, power procurement portfolio till 2026-27 was recommended for the realistic scenarios, considering policy targets for RE and DSM, under two scenarios – with and without short-term power procurement – as represented in *Figures 26 and 27* respectively.

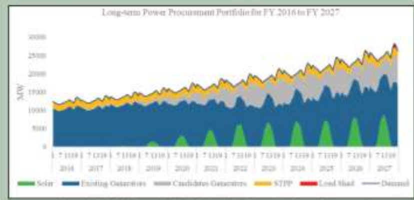


Figure 26: Realistic Growth – Policy Target (with Short-term Power Procurement)

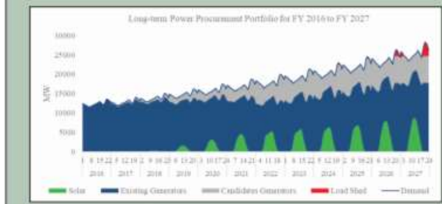


Figure 27: Realistic Growth – Policy Target (without Short-term Power Procurement)

A number of alternate strategies included floating the candidate plants to minimise the overall private and social costs. Based on the findings of the study, estimating significantly higher economic benefits for the full-float optimal procurement strategy, it was suggested that the distribution utilities should undertake such an exercise more frequently.

Energy Analytics Lab (EAL)

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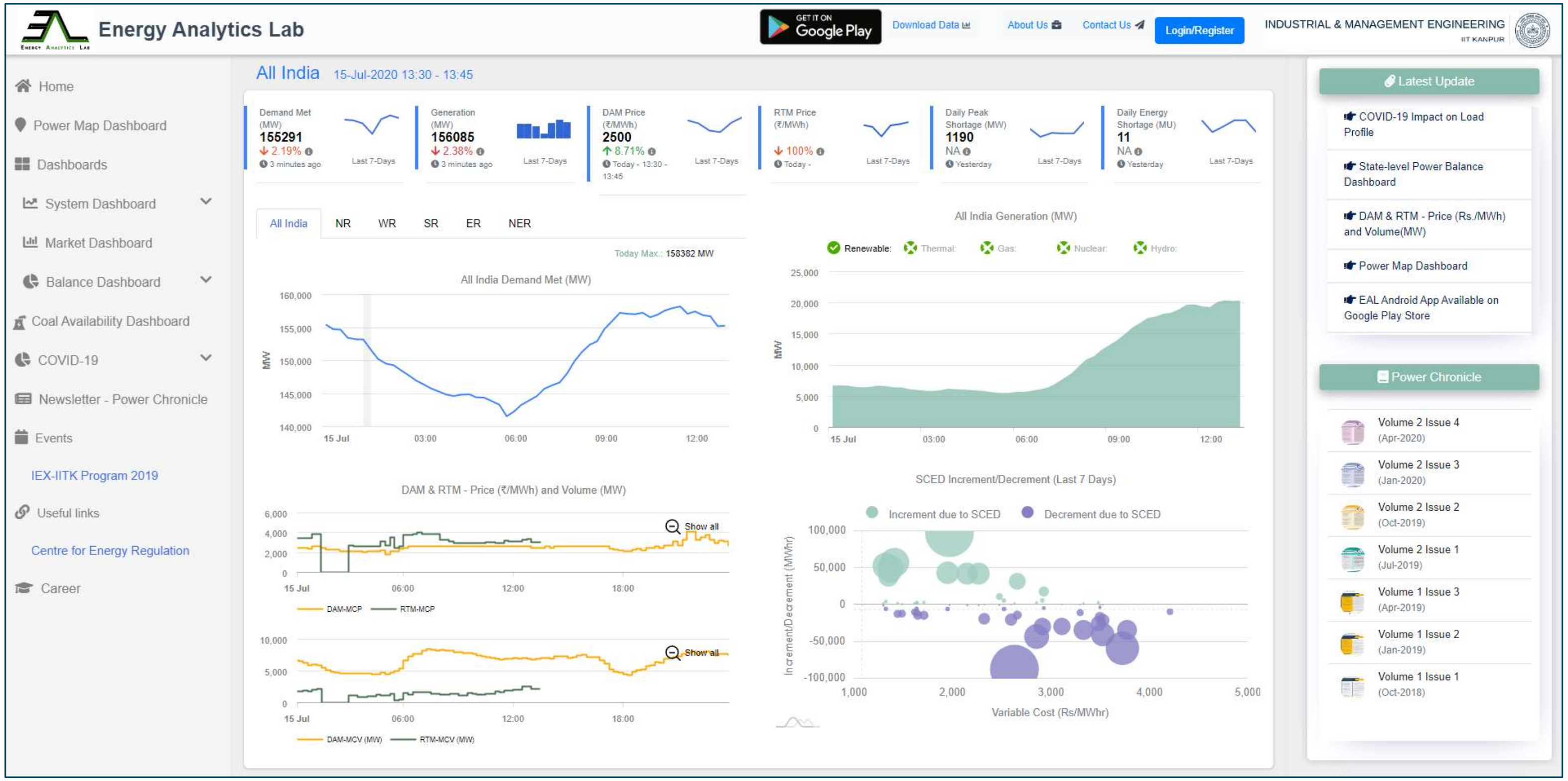
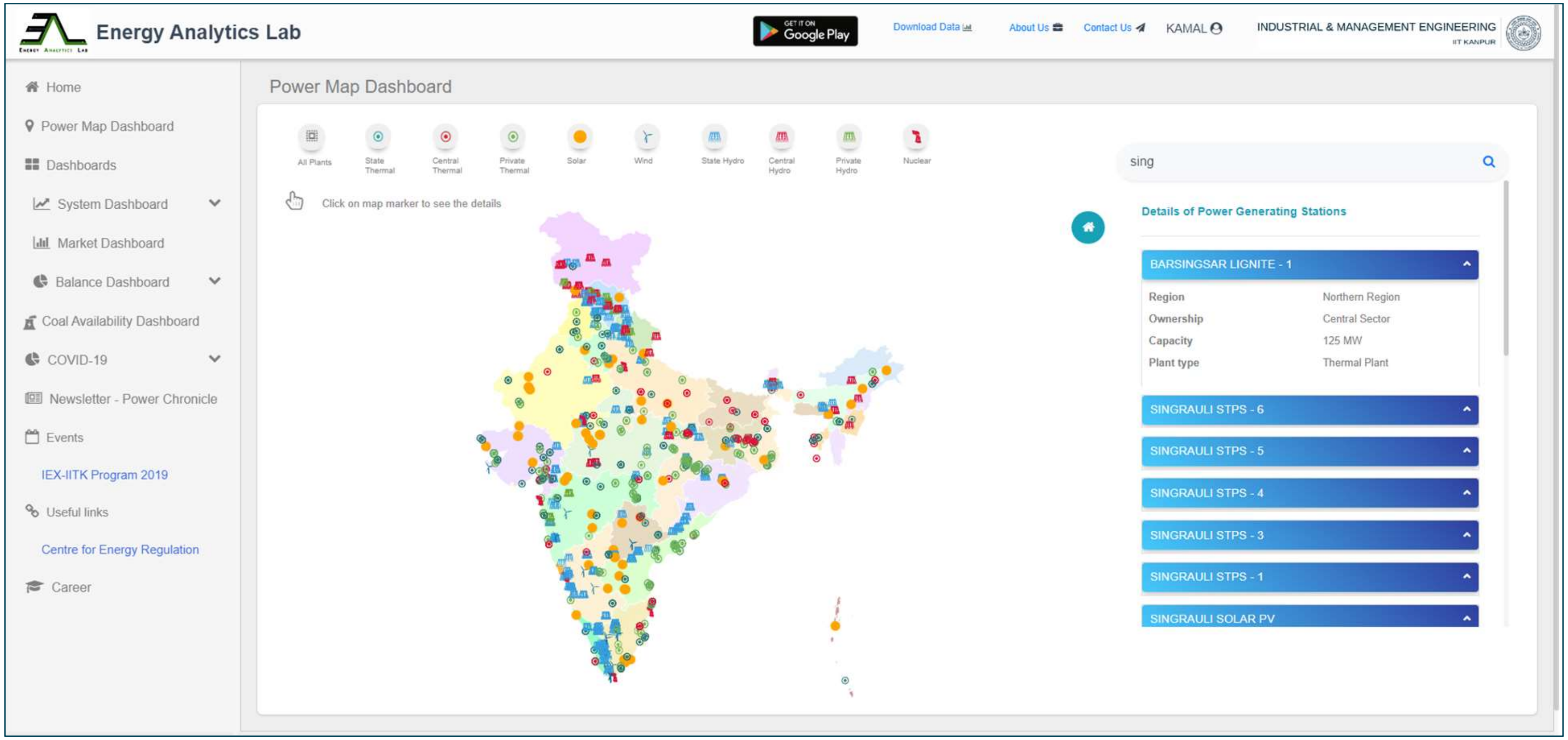
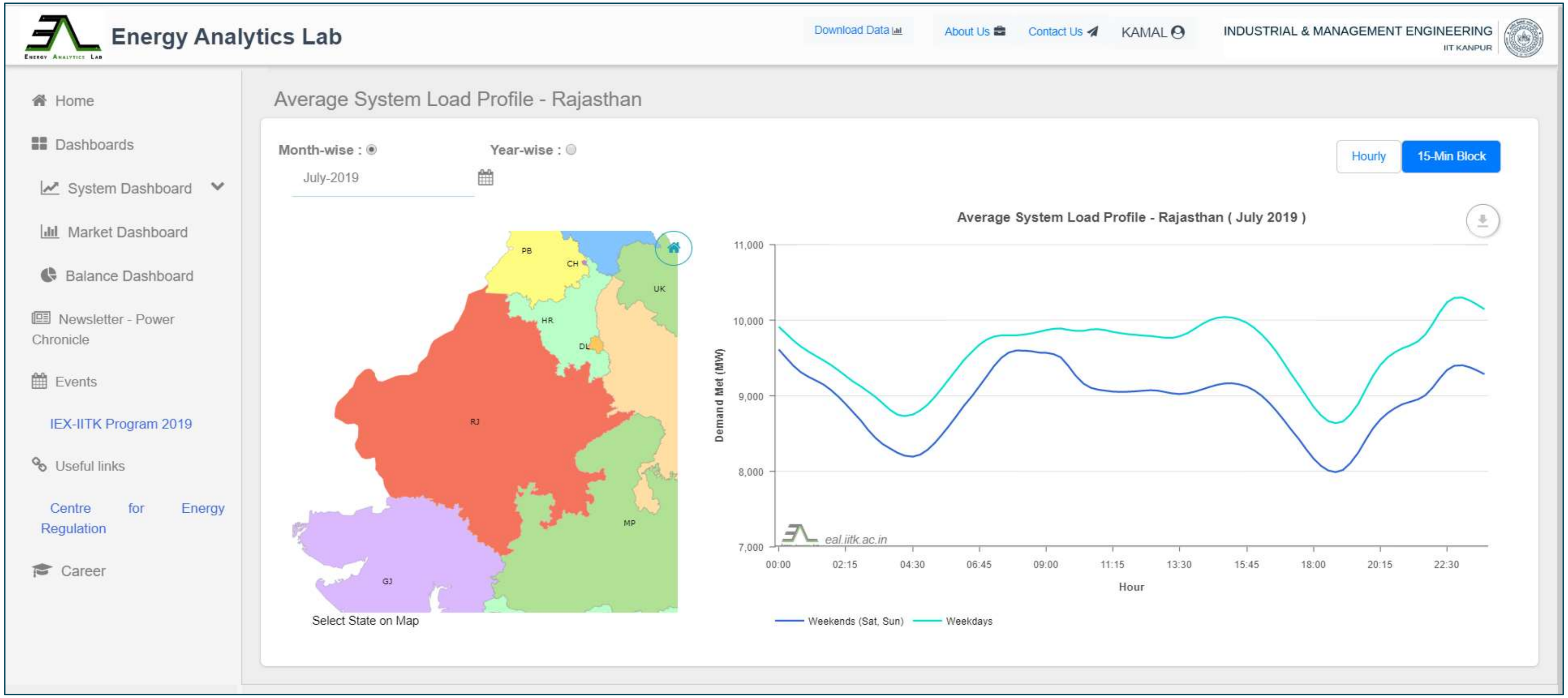
All India Demand-met & Generation - Snapshot



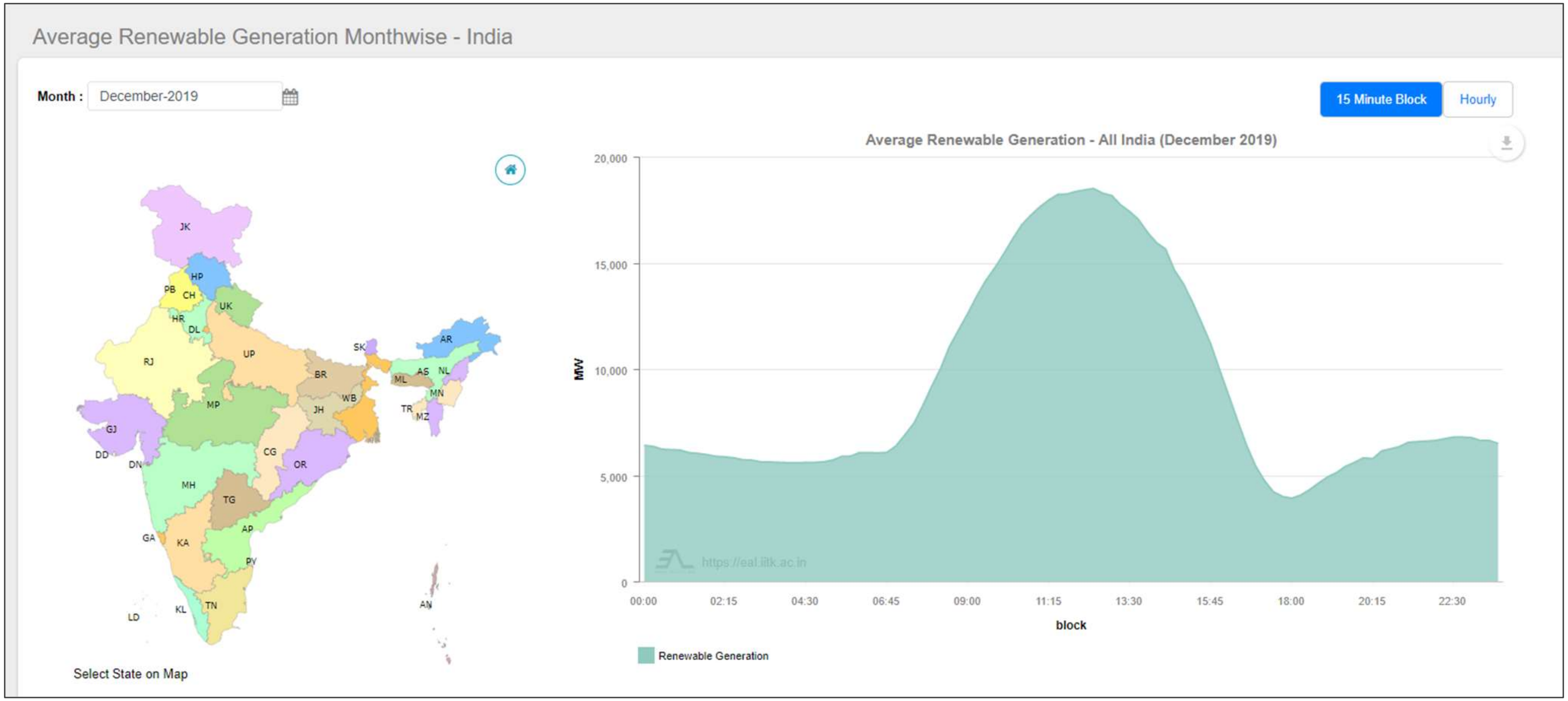
Power Map Dashboard (NEW)



States Annual (&Monthly) 15-min Block & Hourly Load Profile (NEW)

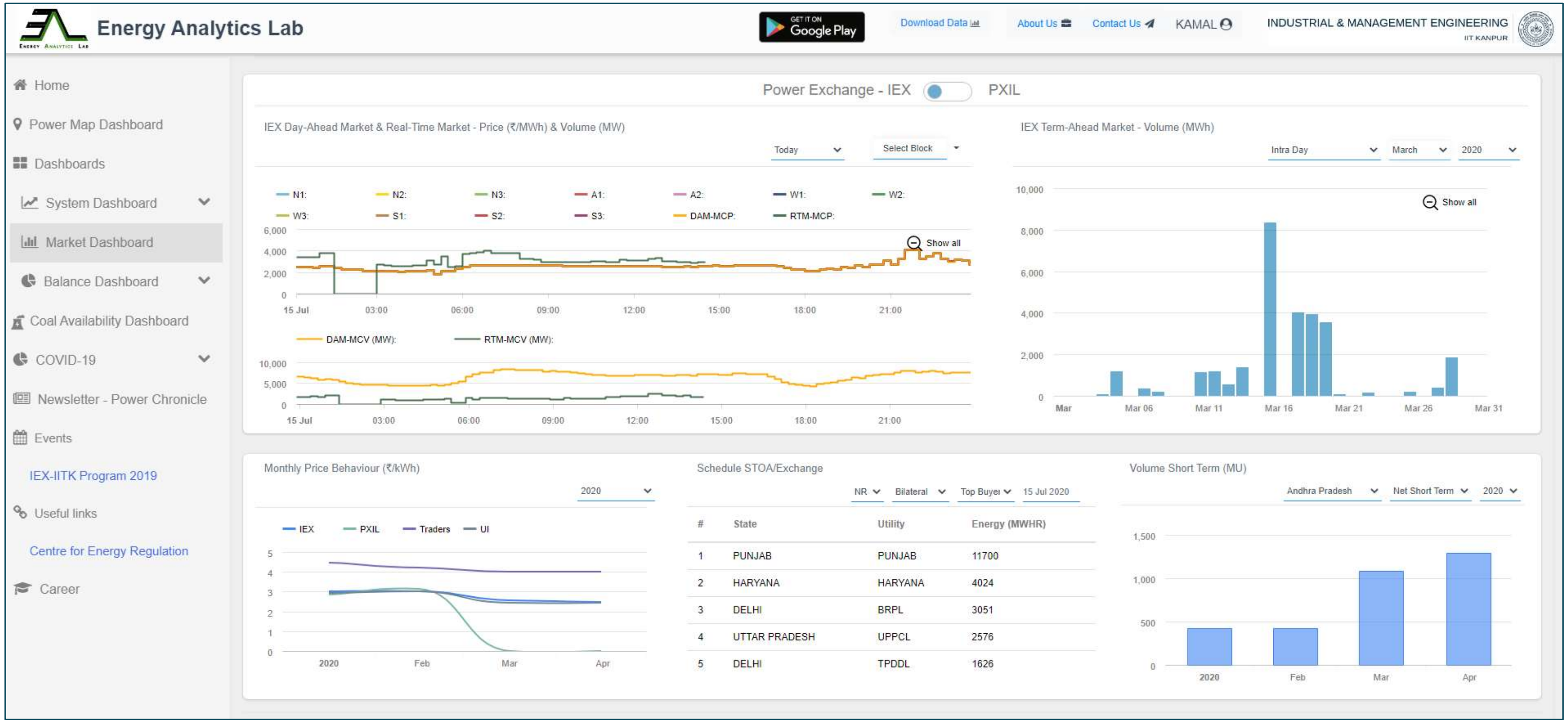


All India Annual & Monthly 15-min & Hourly RE Generation Profile (NEW)



Coal Stock Position at Power Plants (NEW)

Power Market Dashboard



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EAL Newsletter – *Power Chronicle*

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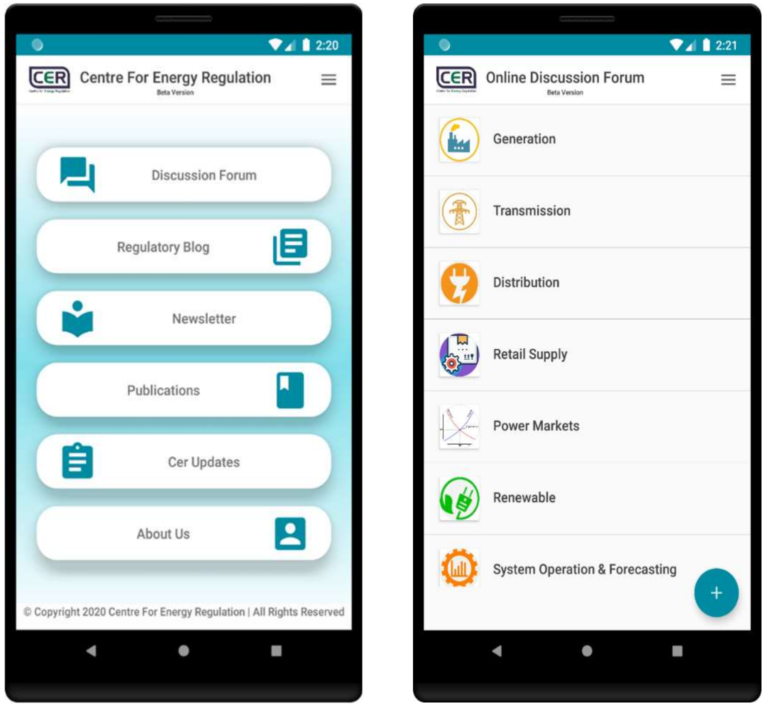
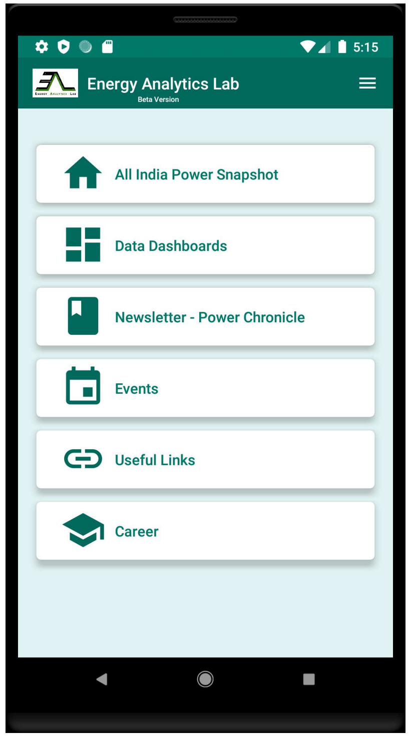


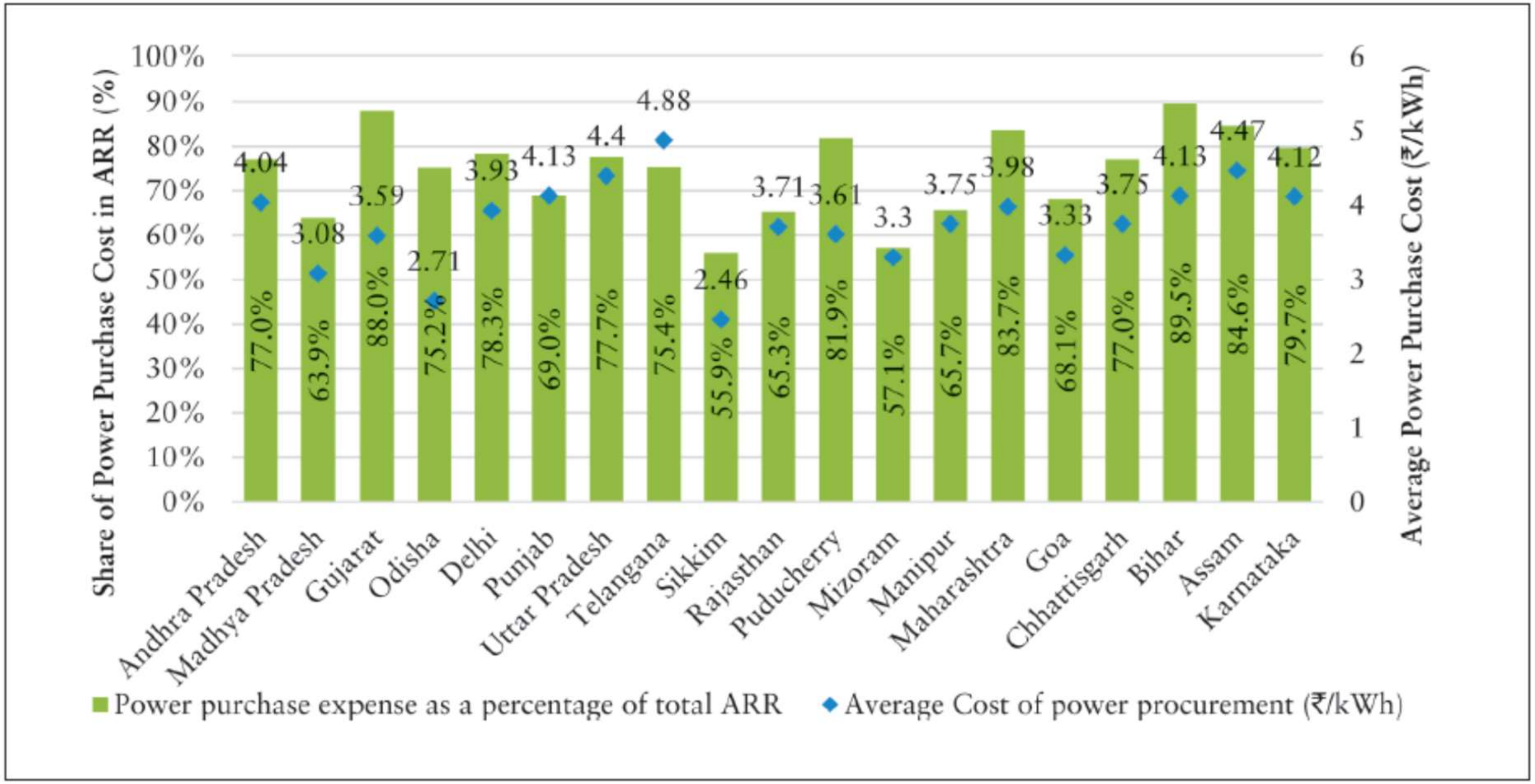
CER's Android App



EAL's Android App

Importance of LTDF and PPP

Power purchase cost and average cost of power procurement



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

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

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

So: Singh et al. (2019), https://cer.iitk.ac.in/publications

Legislative and Policy Framework for LT DF and PPP

Electricity Act, 2003

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

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

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

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

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

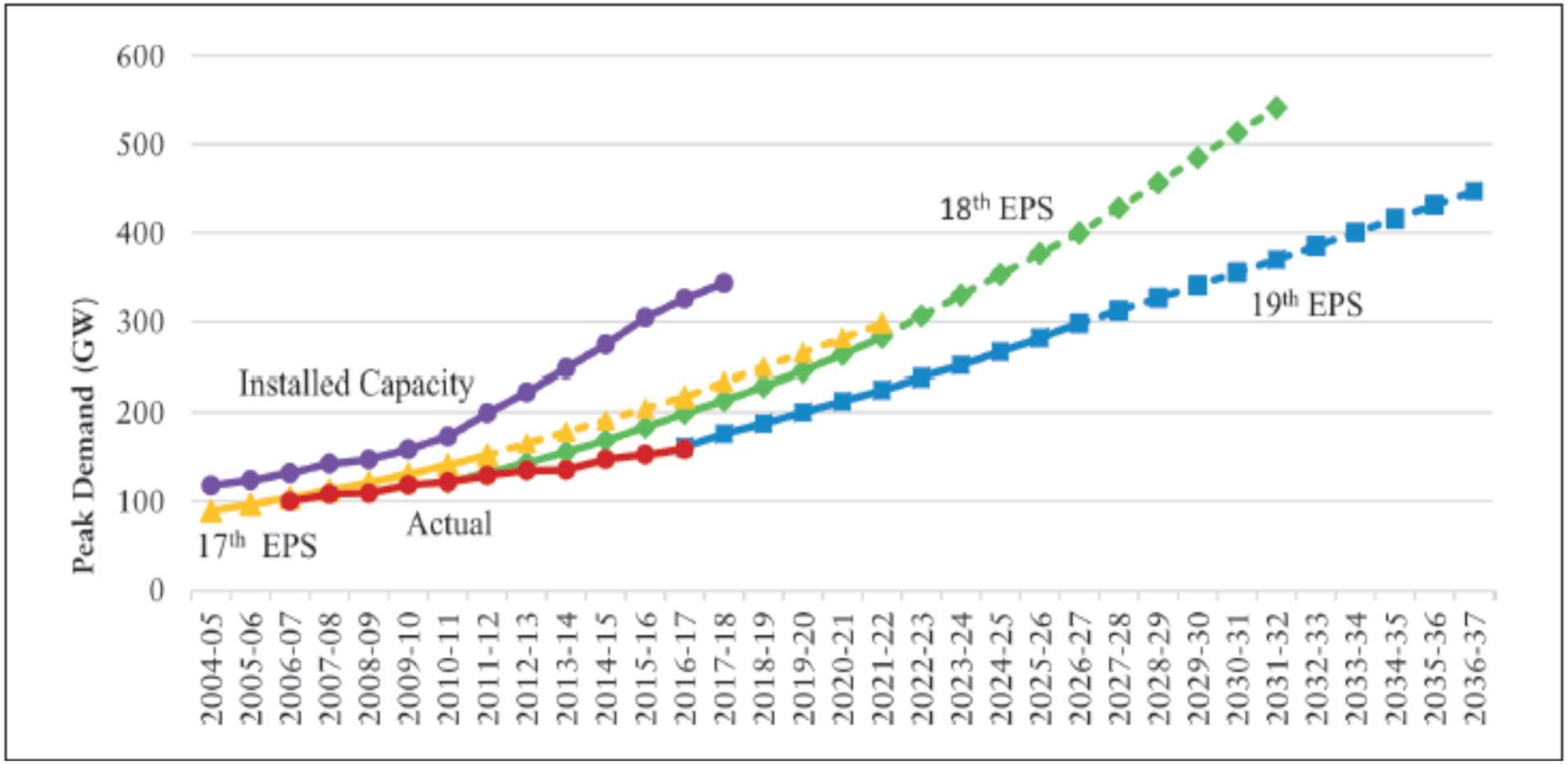
Tariff Policy, 2006: Silent on demand forecasting or power procurement planning.

Tariff Policy, 2016:

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

Electricity Demand Forecasting in India

Historical projections of annual peak electricity demand (All India)



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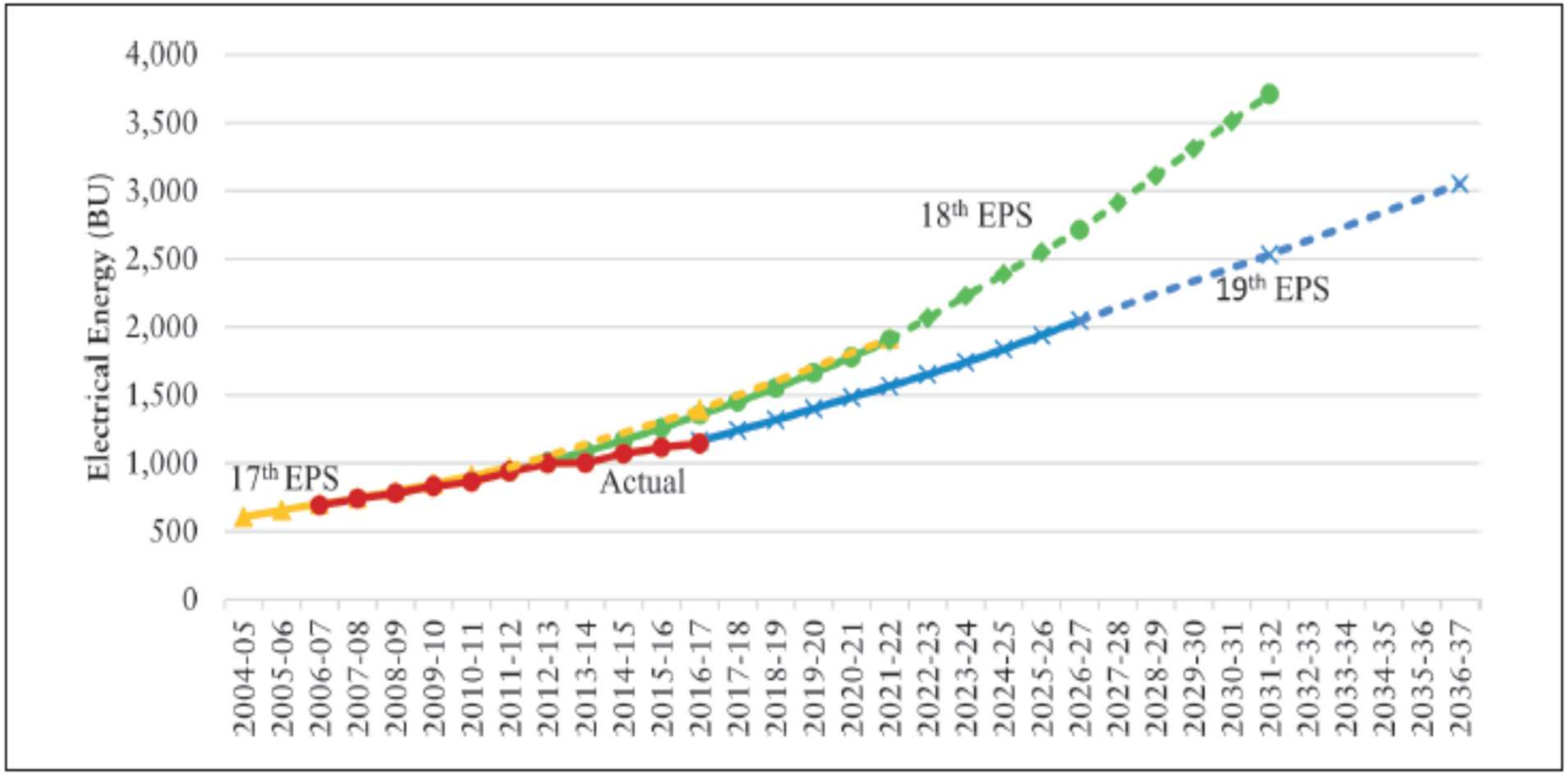

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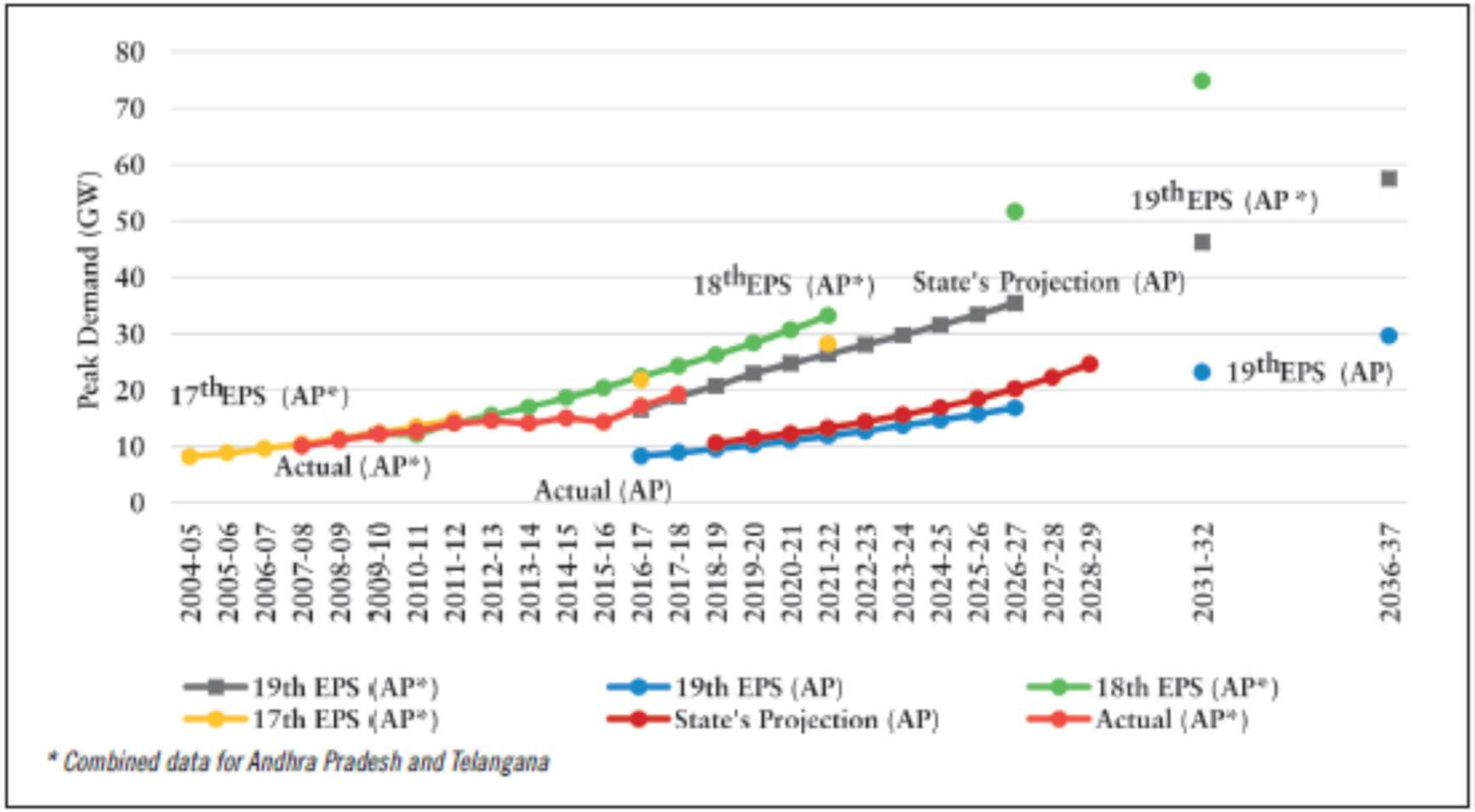
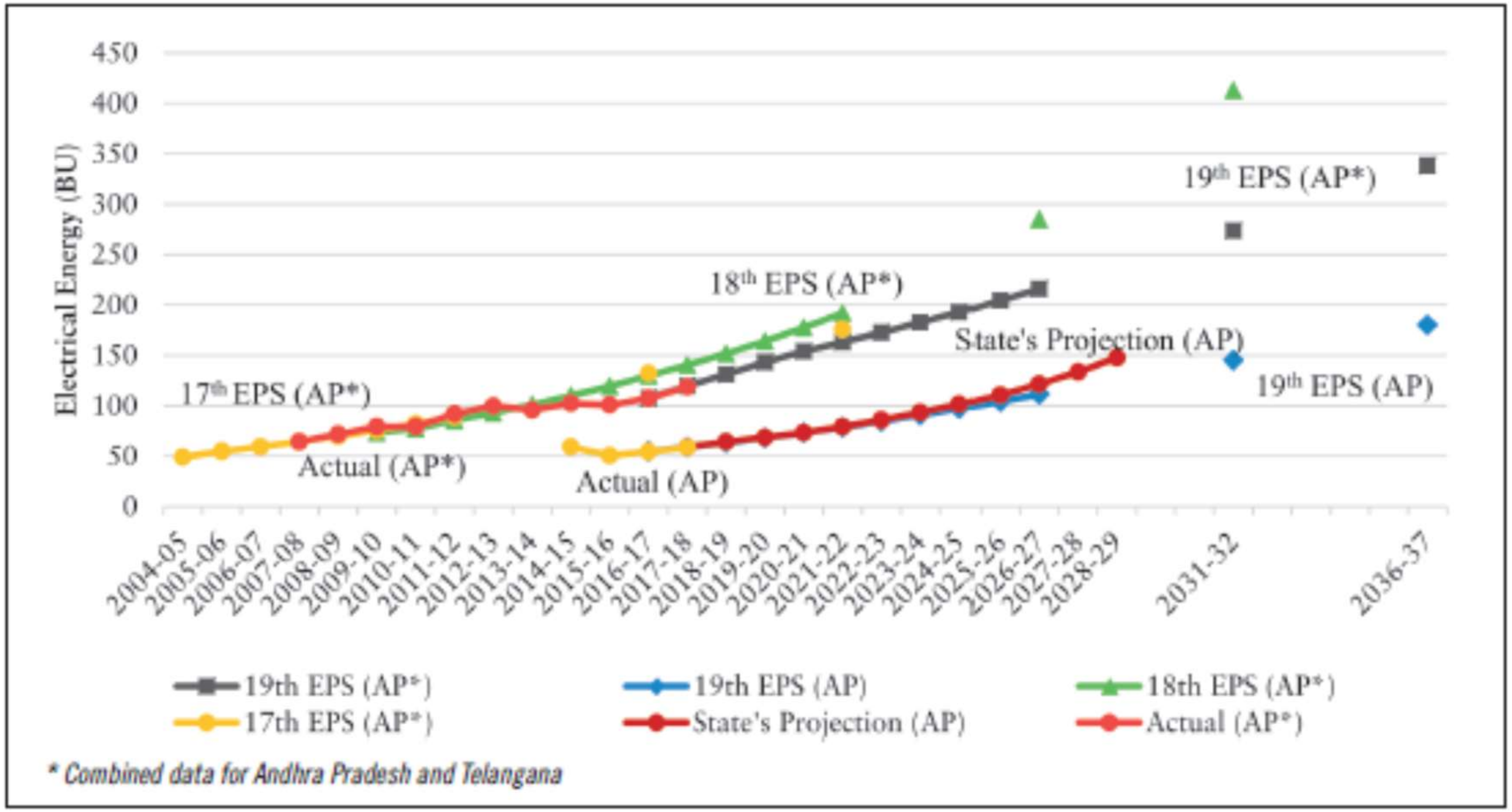
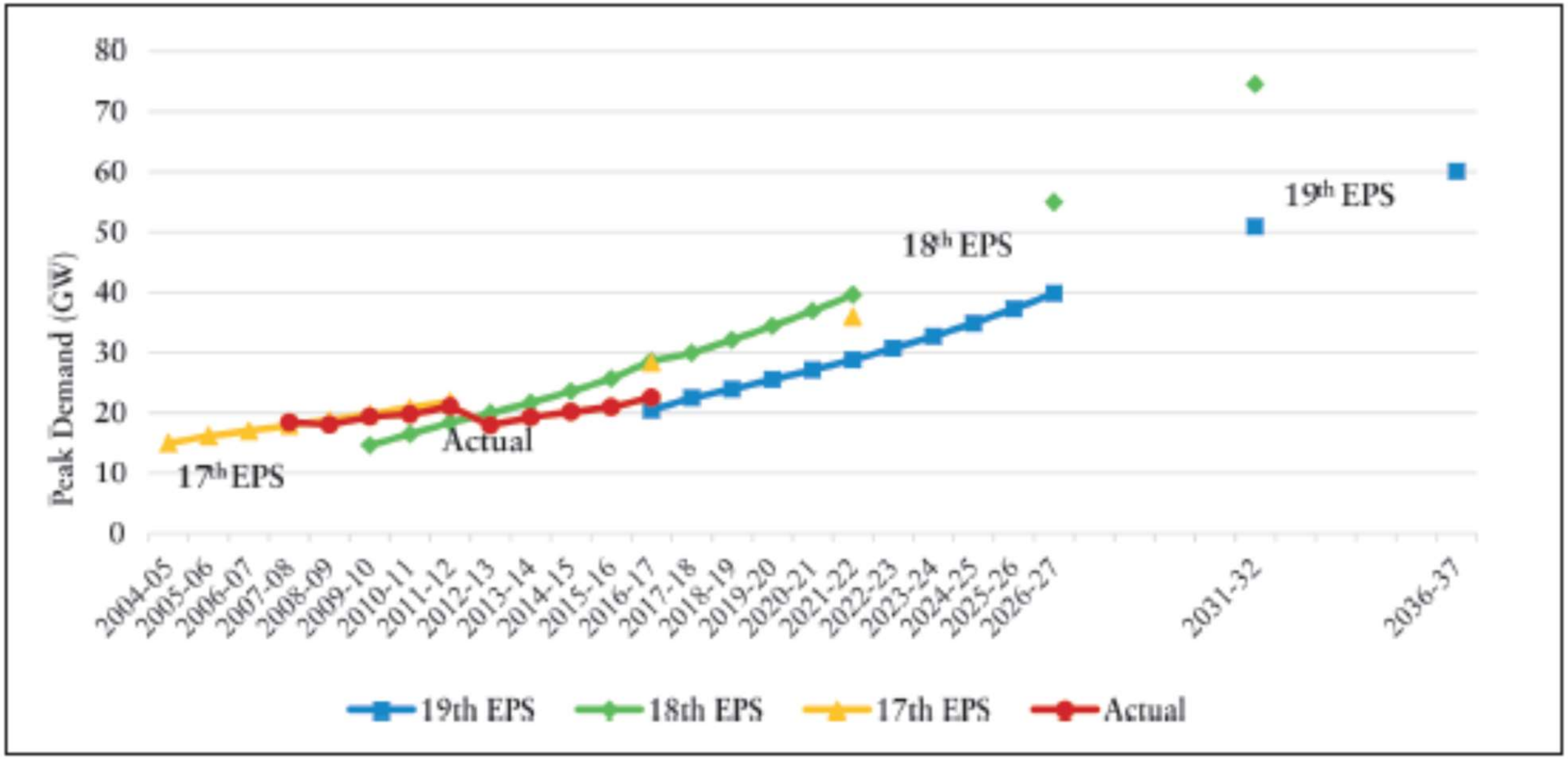
Actual peak demand vs. projections (Andhra Pradesh)



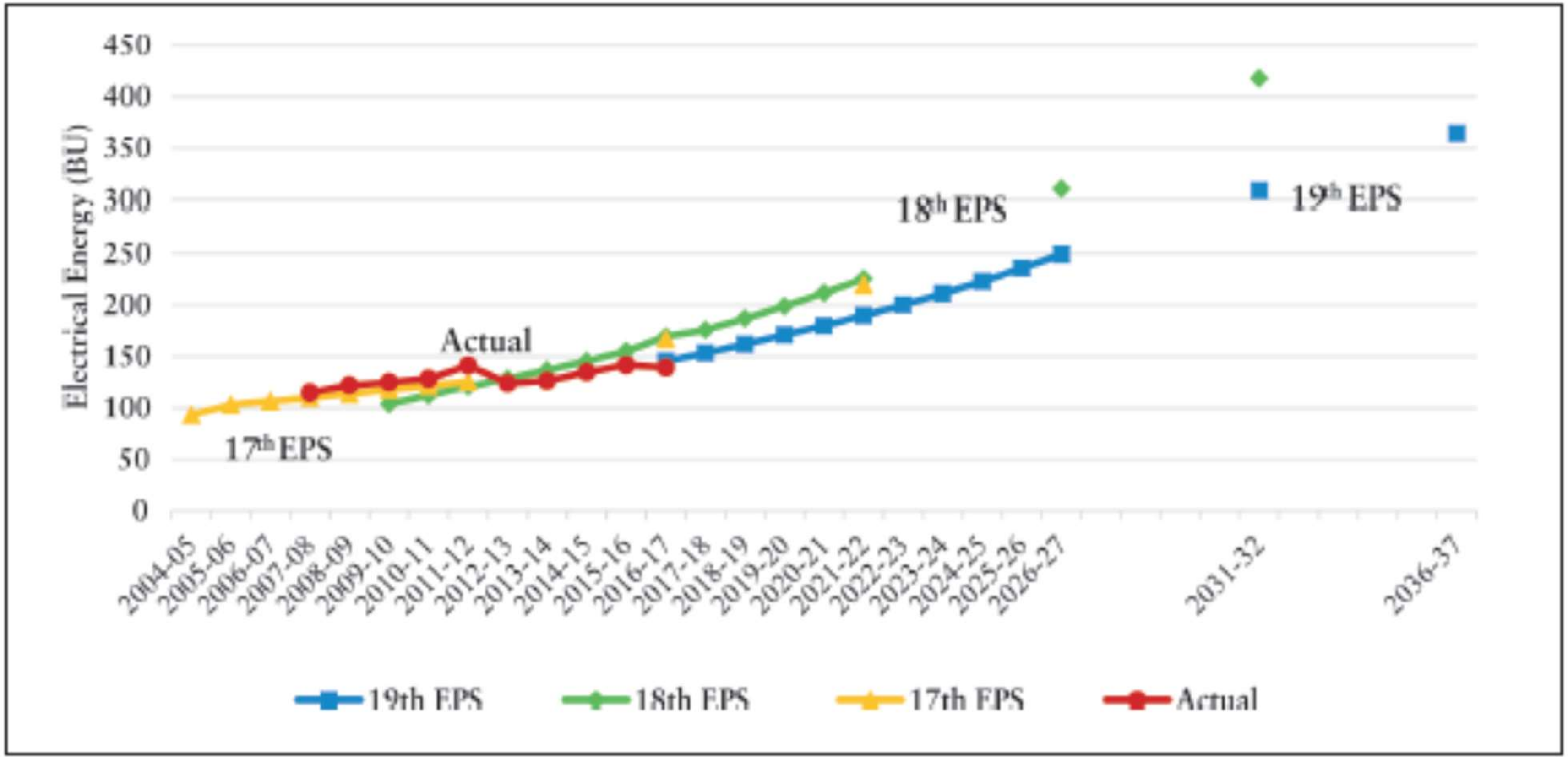
Actual electrical energy requirement vs. projections (Andhra Pradesh)



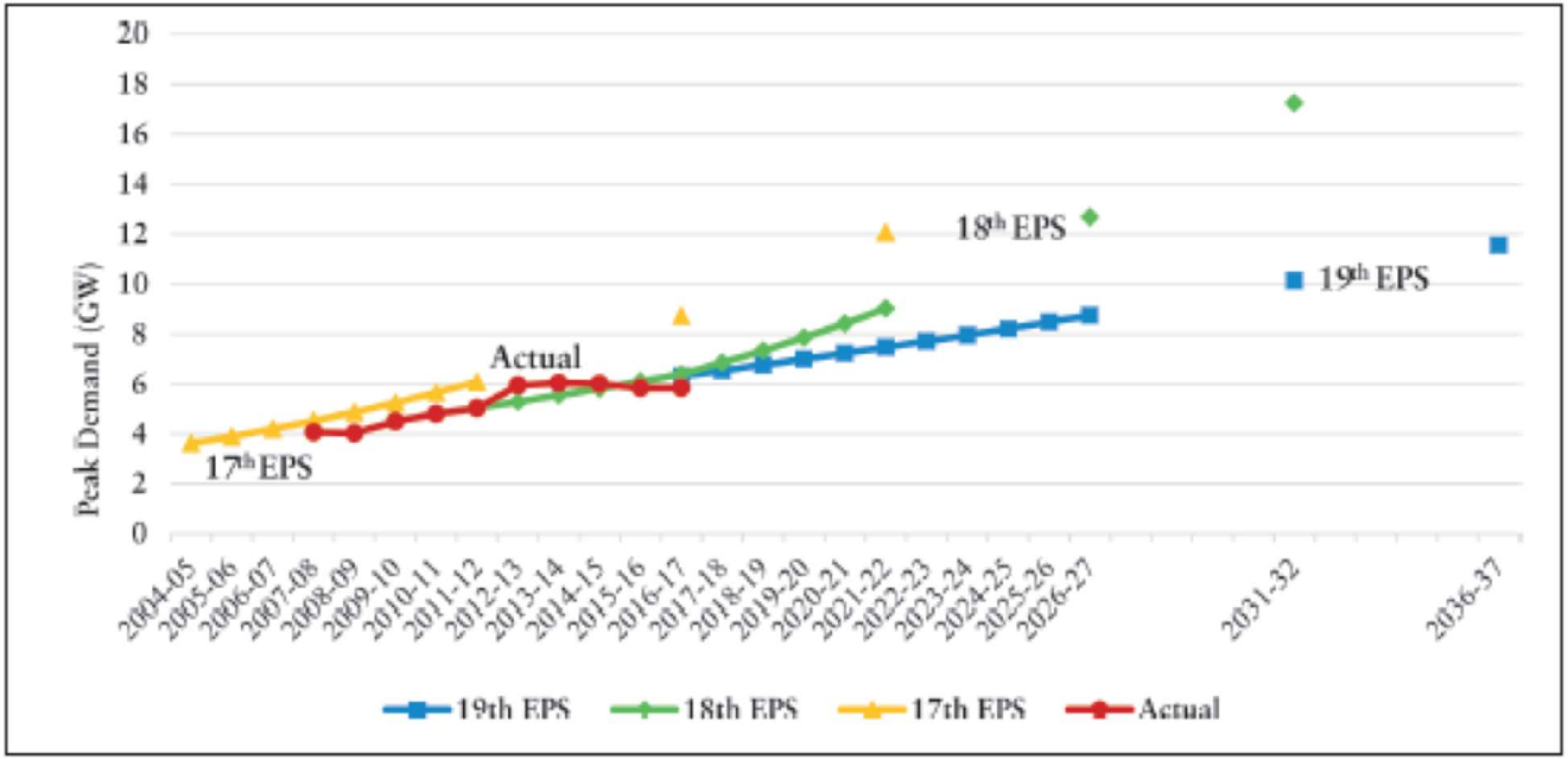
Actual peak demand vs. projections (Maharashtra)



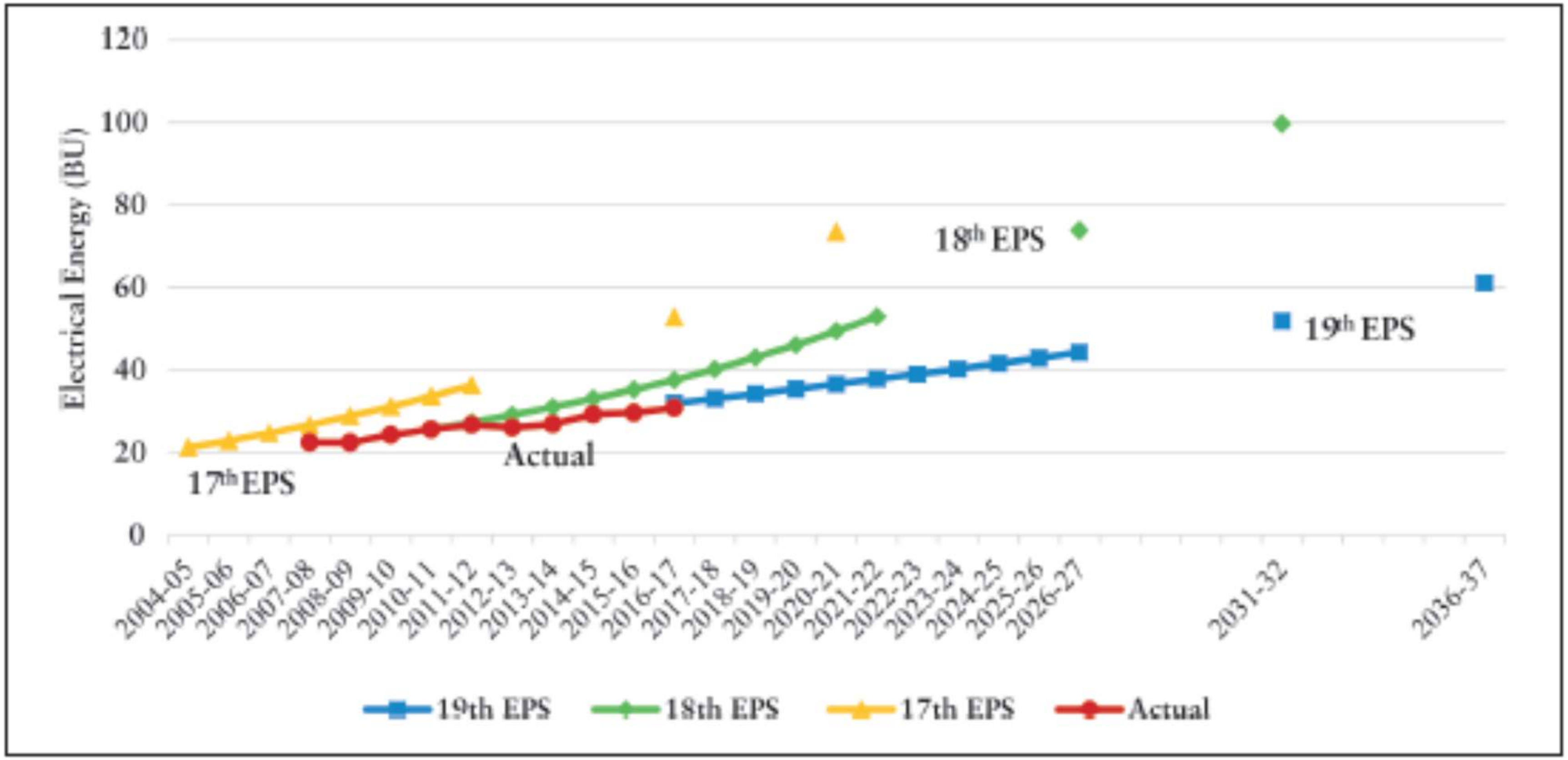
Actual electrical energy requirement vs. projections (Maharashtra)



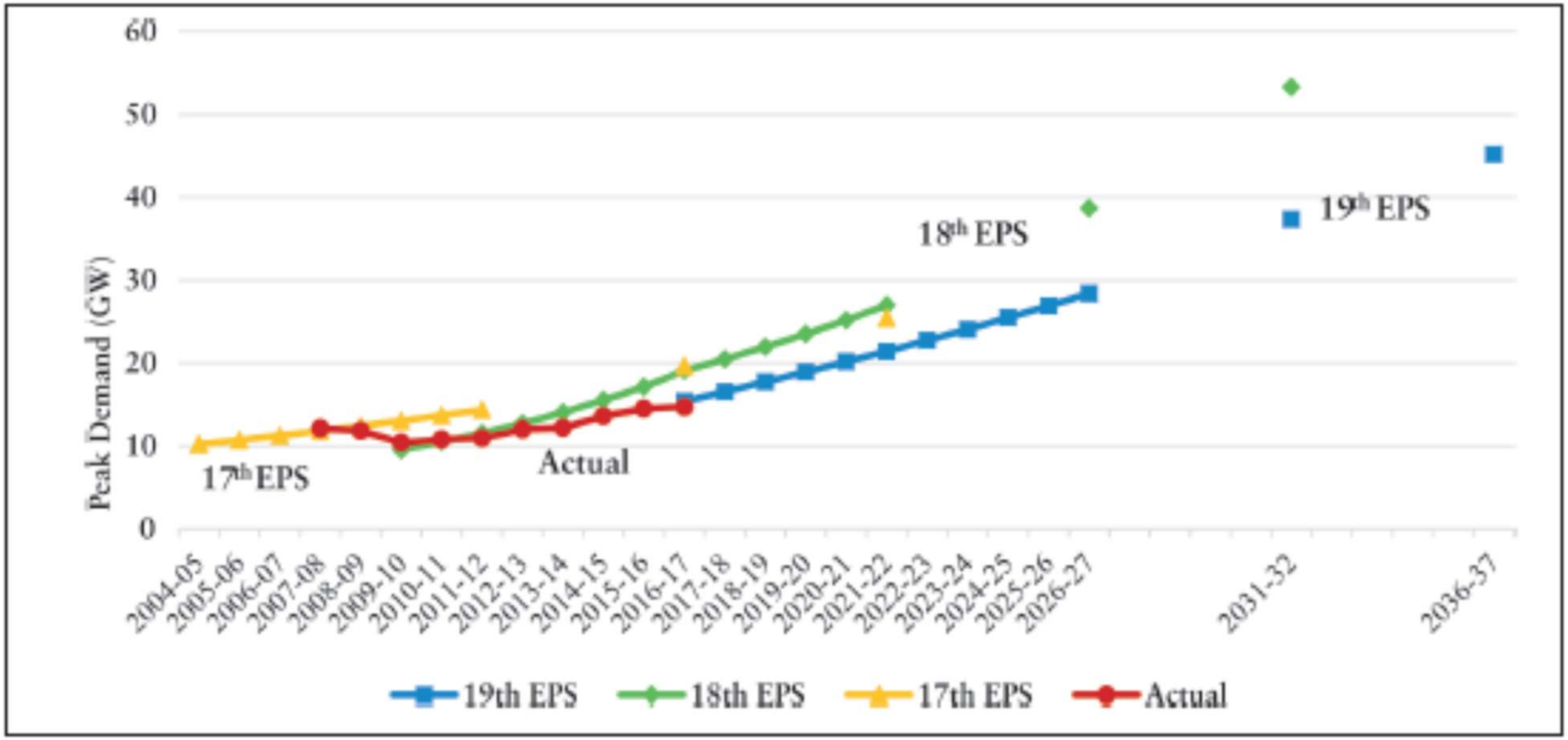
Actual peak demand vs. projections (NCT Delhi)



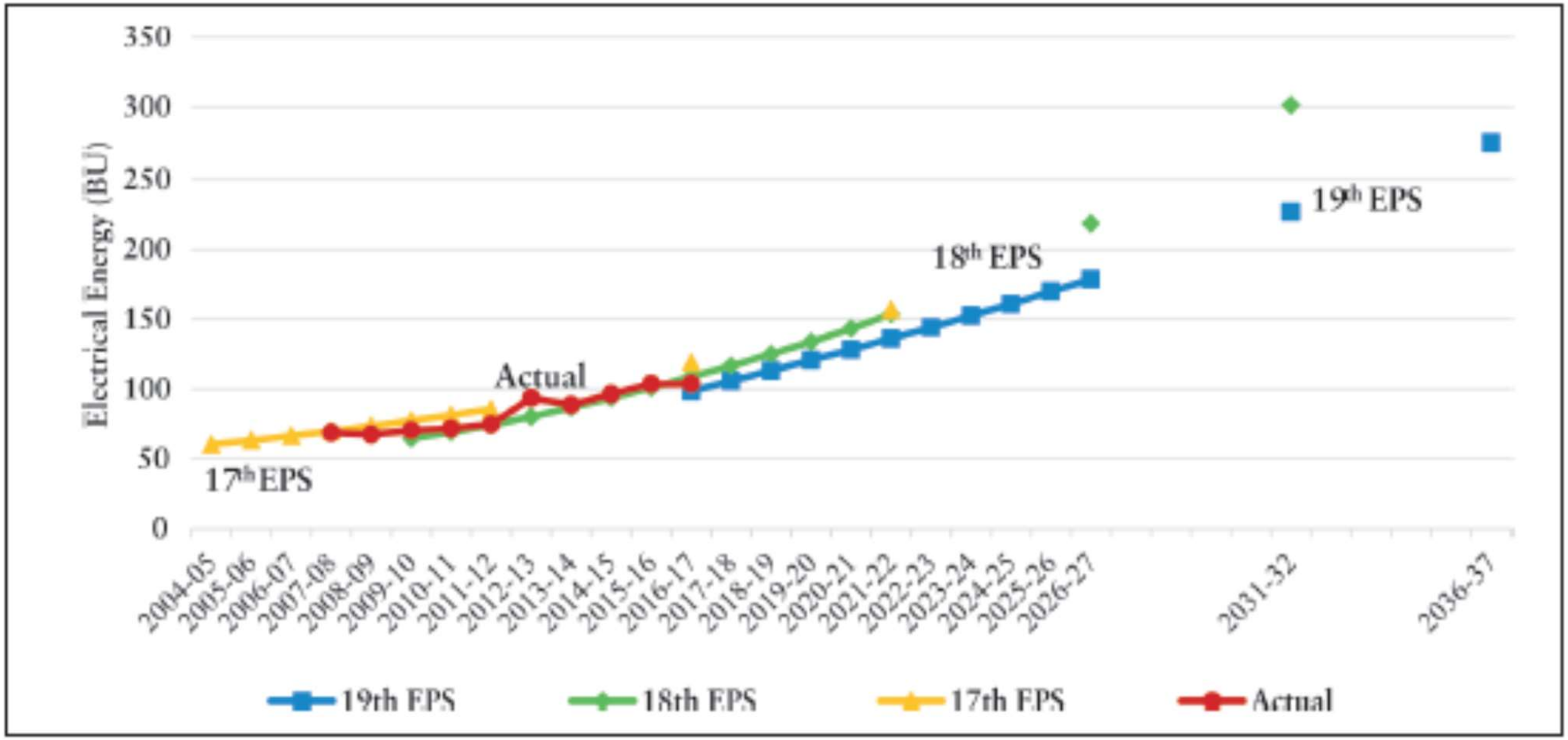
Actual electrical energy requirement vs. projections (NCT Delhi)



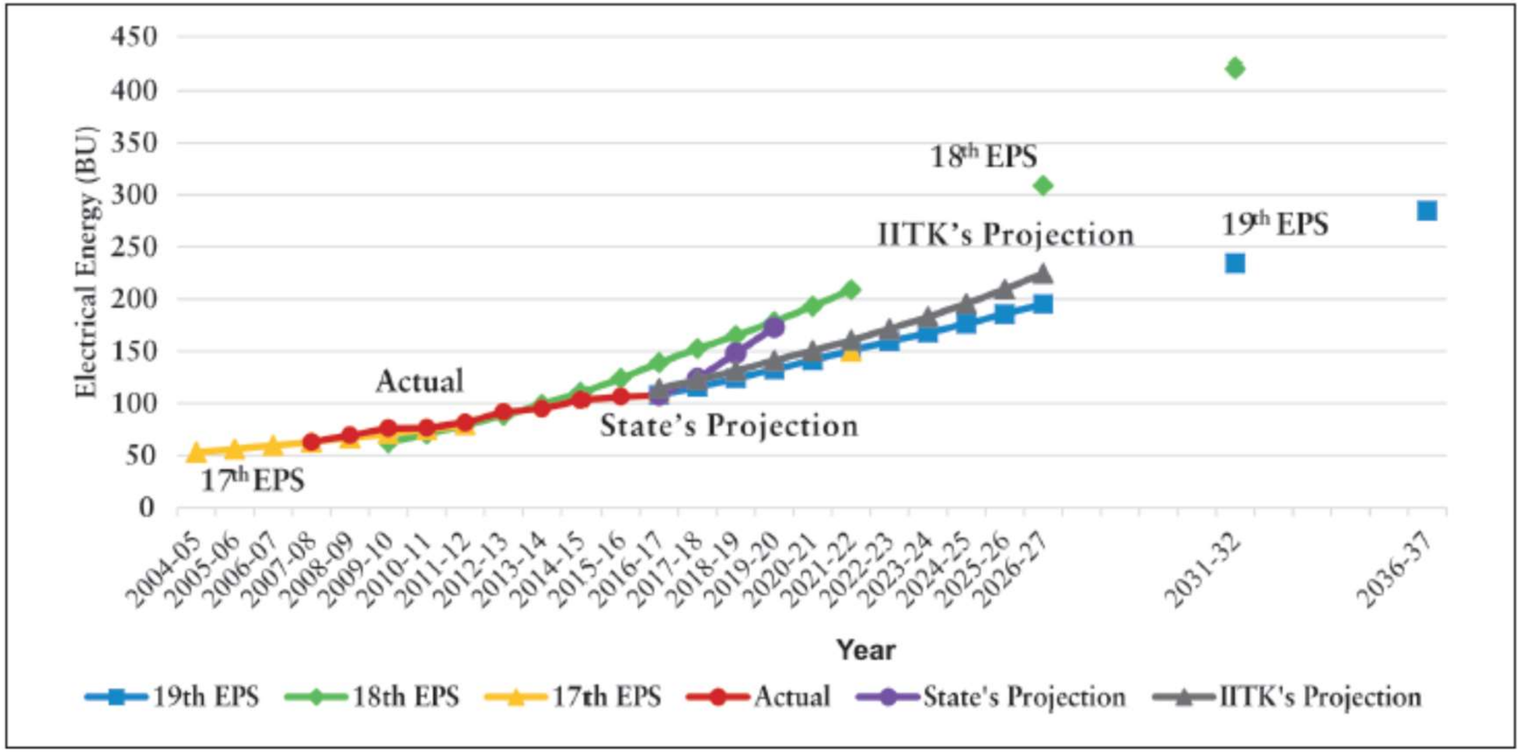
Actual peak demand vs. projections (Gujarat)



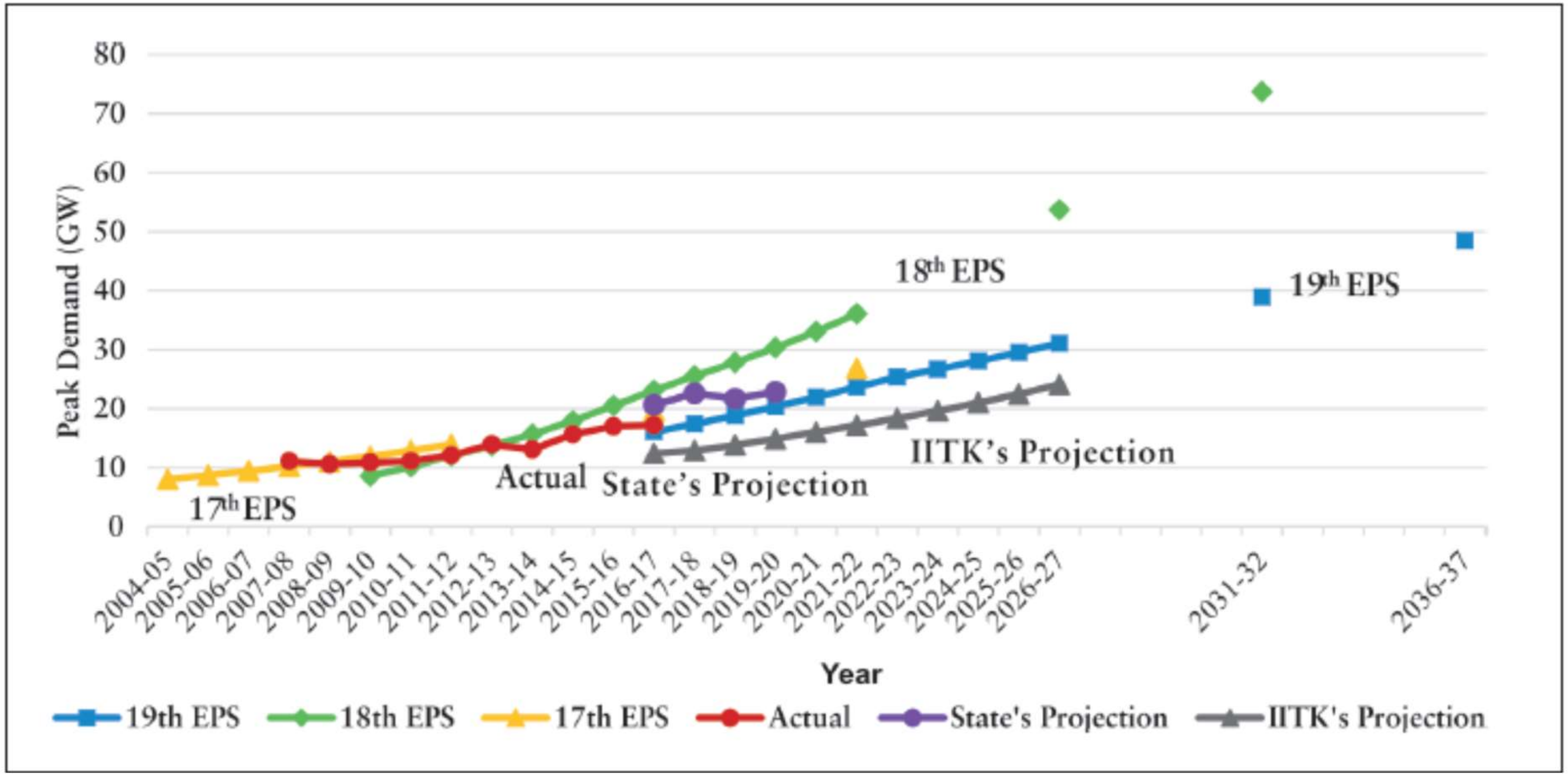
Actual electrical energy requirement vs. projections (Gujarat)



Actual electrical energy requirement vs. projections (UP)

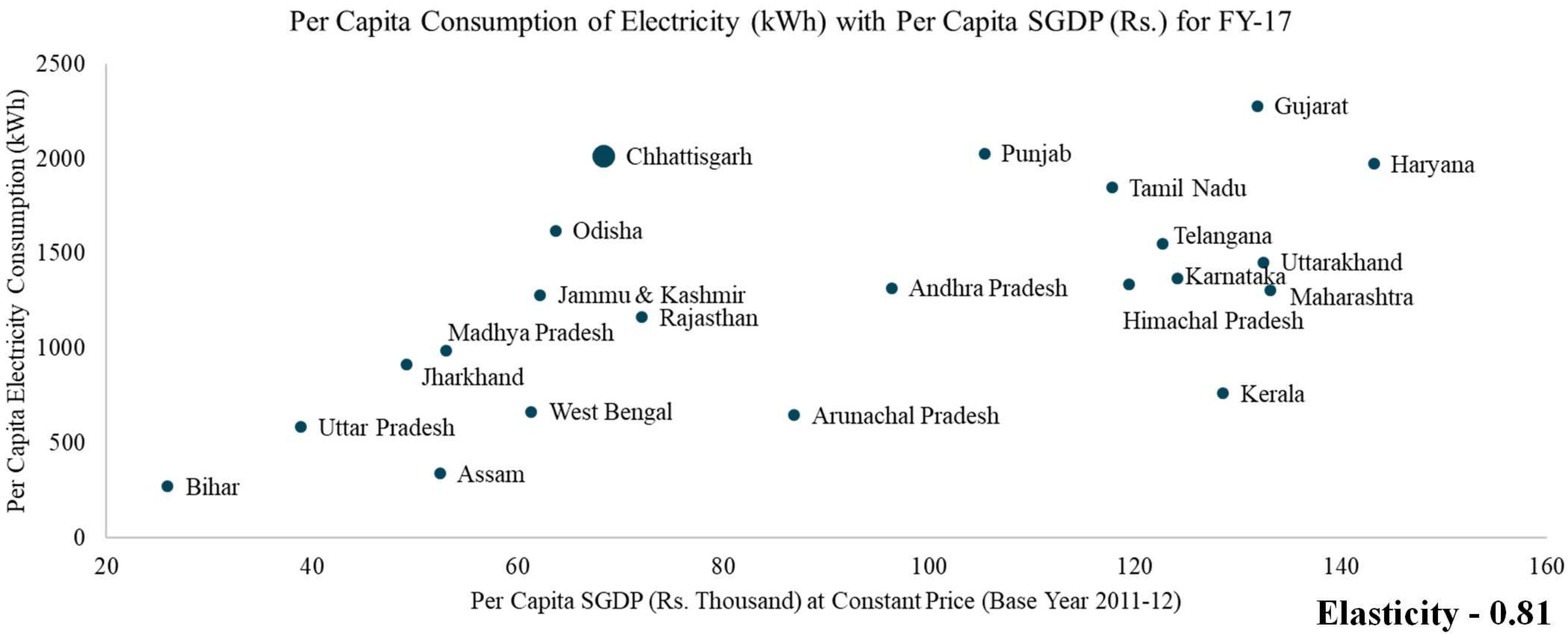


Actual peak demand vs. projections (UP)



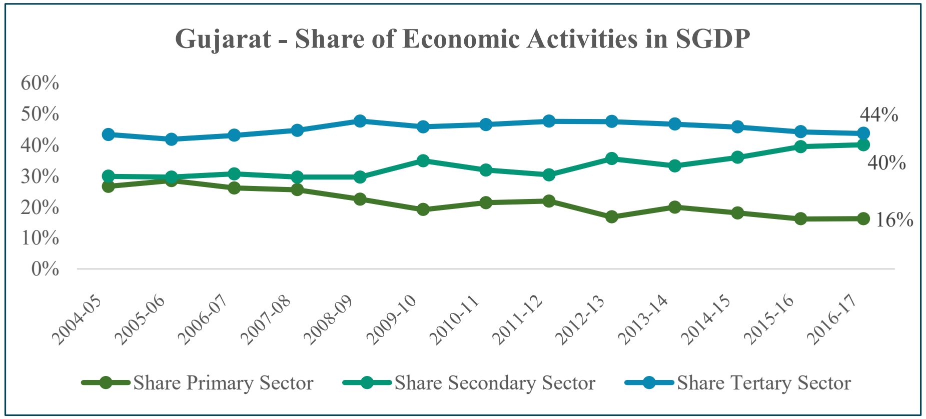
Long-term Demand Forecasting and Power Procurement Planning – For State Utilities

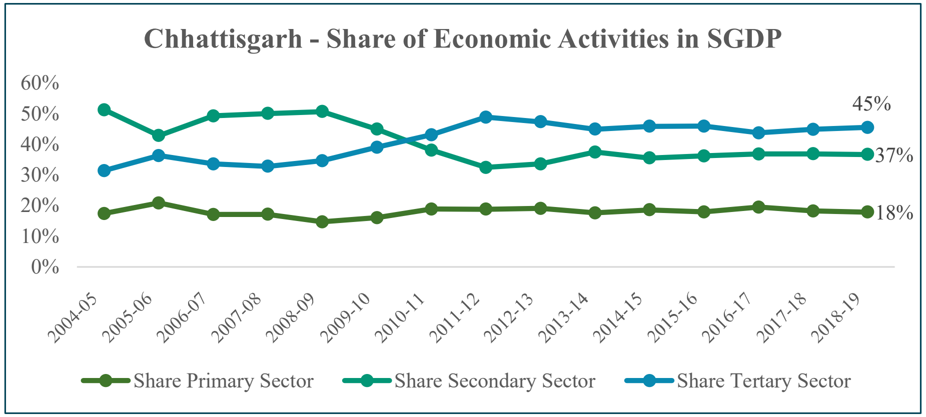
States - Per Capita Electricity Consumption with Per Capita SGDP

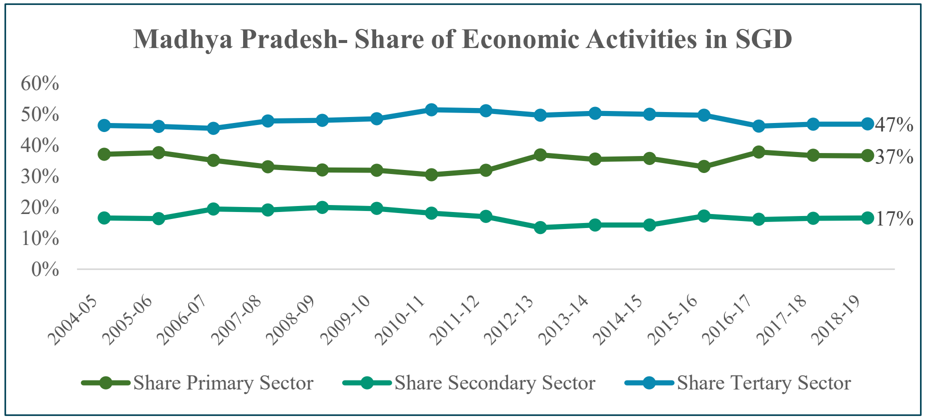


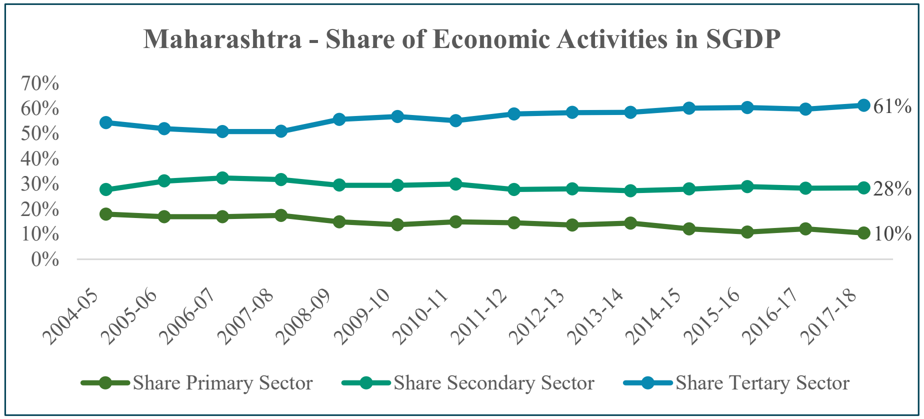
Elasticity - 0.81

Economic Activities Share in SGDP

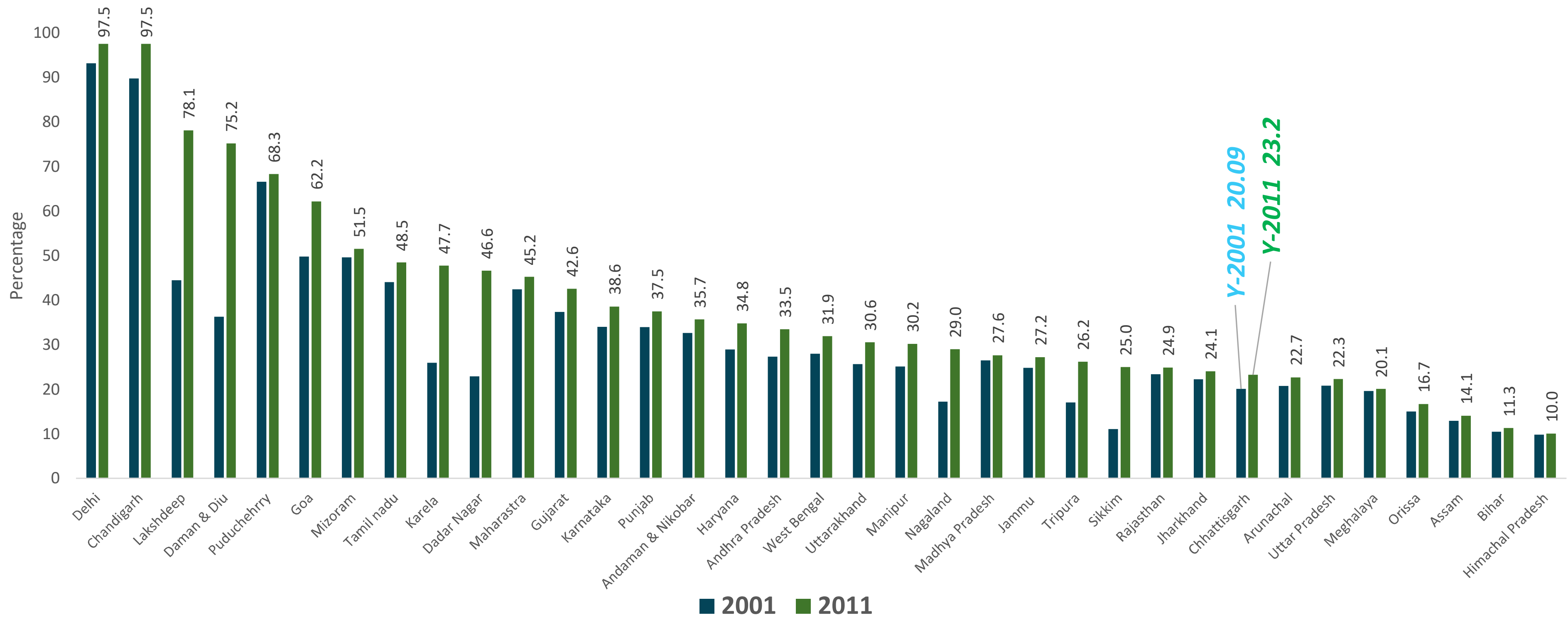






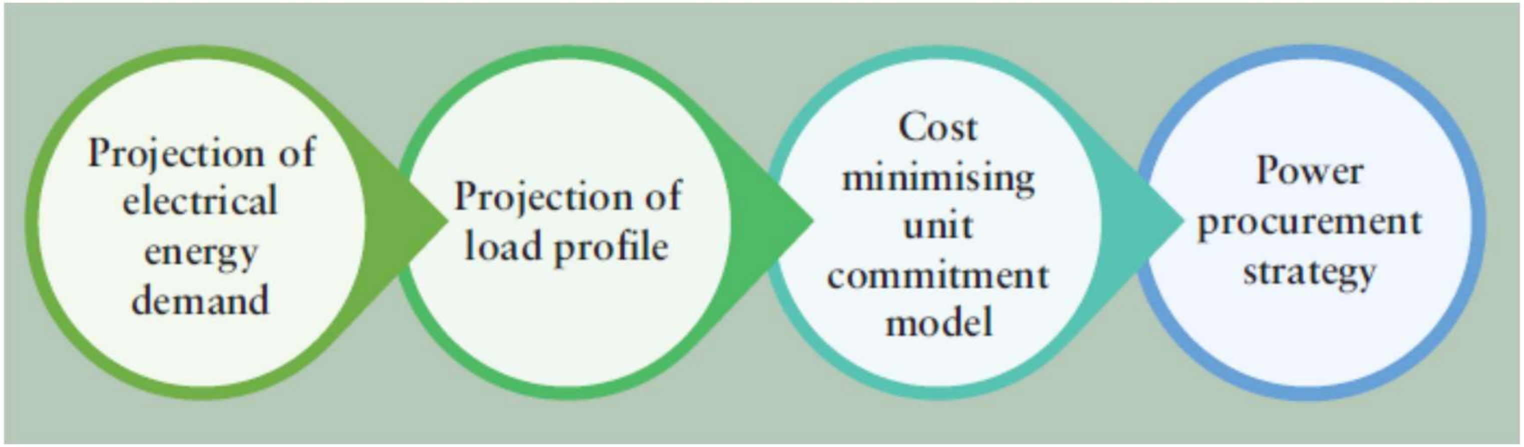


Urbanisation

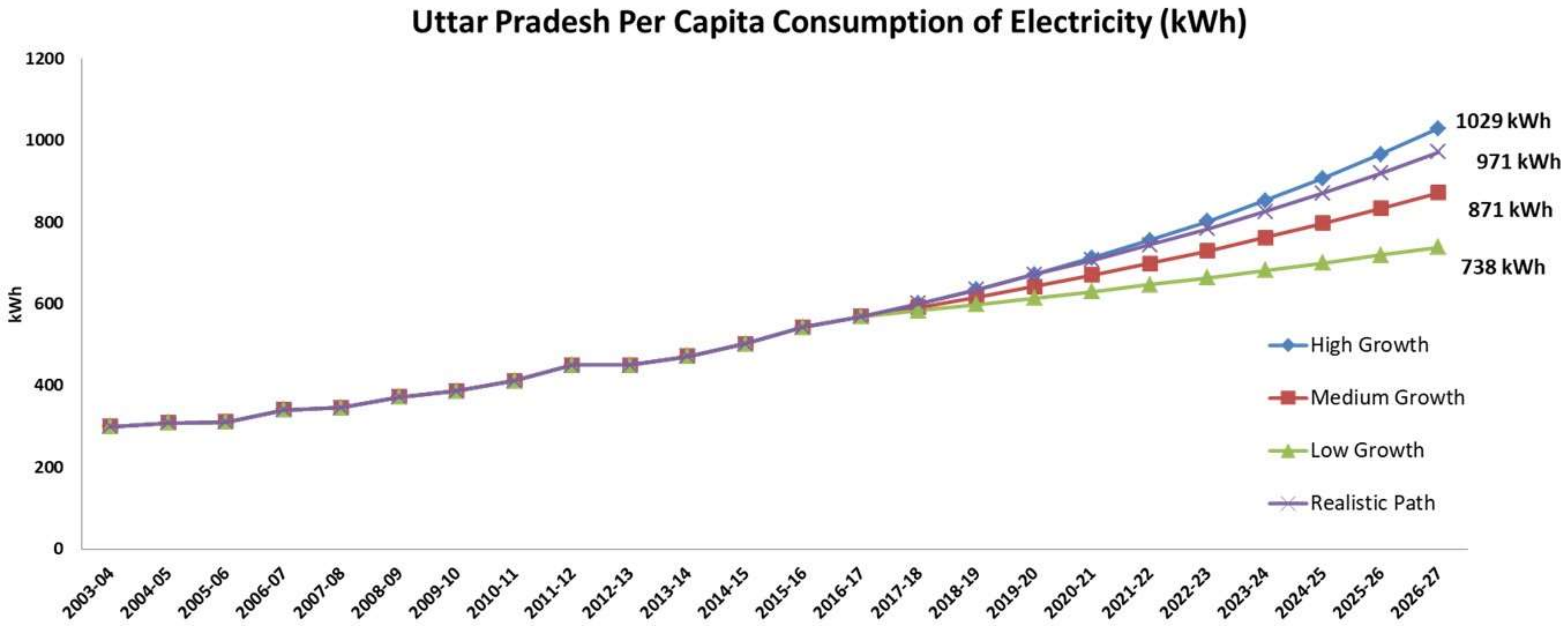


Source: Census 2001, Census 2011

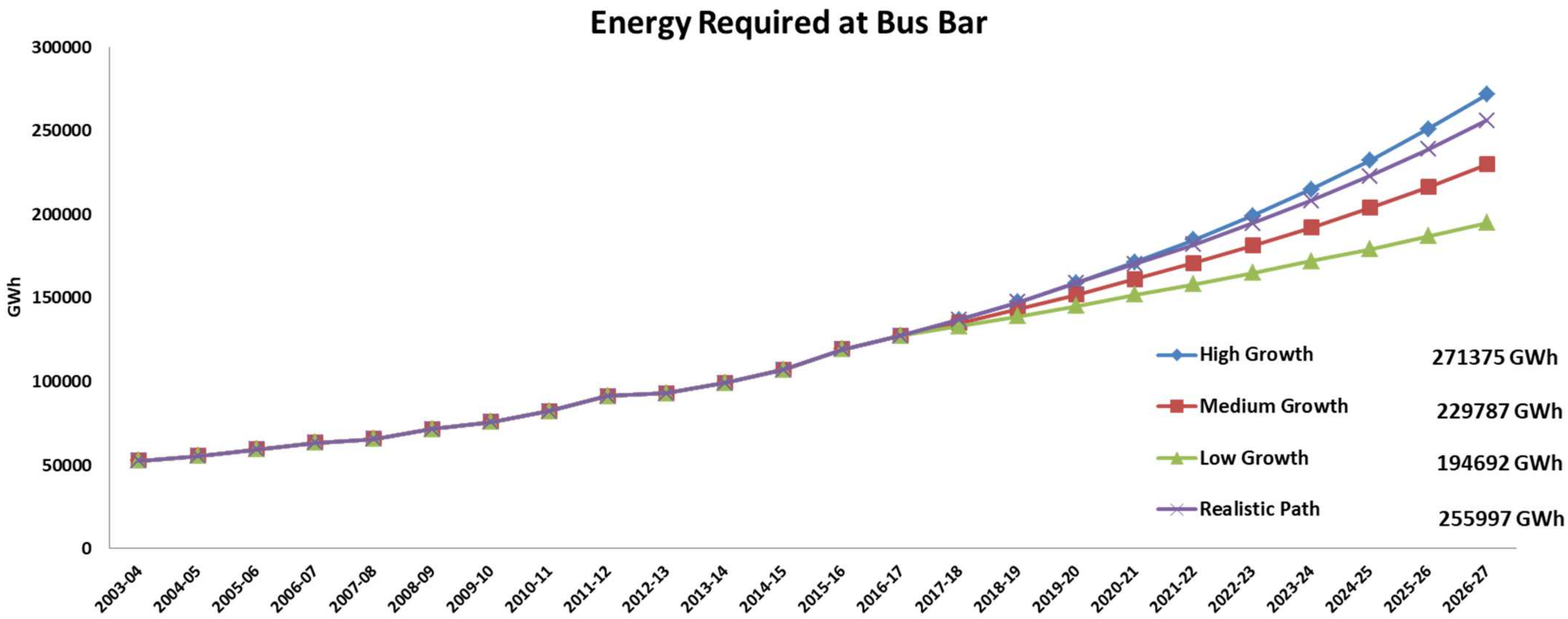
Approach for formulating power procurement strategy



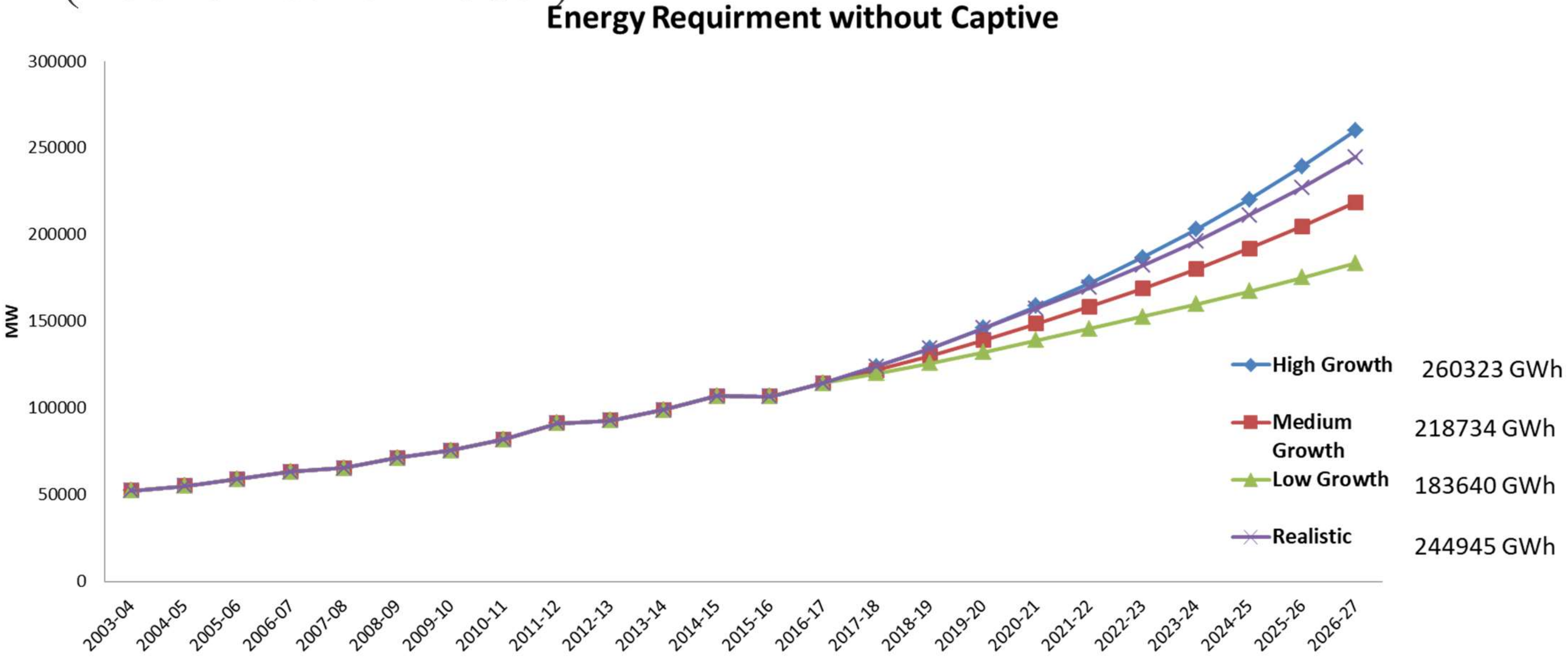
Uttar Pradesh - Projected Values at bus bar (Econometric Model)



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



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



UP’s Projected Electricity Demand - Comparison

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

Note: For utilities only
* Without Captive Generation

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

Note: Energy sold
* Without Captive and losses

Methodology

1. Projection of peak load & energy requirement
2. Load profile and load duration curve analysis
3. Expected demand for electricity (load curve) considering Solar gen. profile
4. GAMS Based optimisation model

1. Projection of peak load & energy requirement

Trend Analysis	• Study the past growth pattern
End Use method	• Study category-wise connected load, electricity consumption and growth pattern
Econometric Models	• Forecast considering economic change

2. Load profile and load duration curve analysis

- Inference from historical load profile and load duration curve
- Account for demand profile influenced by supply
- Projecting energy/peak load for future using statistical techniques

Methodology (continued)

3. Expected demand and load profile

- Solar capacity and projected addition
- Solar generation curve and it’s effect on load profile
- Impact of ToD

4. GAMS Based optimisation model

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

GAMS Optimisation Model

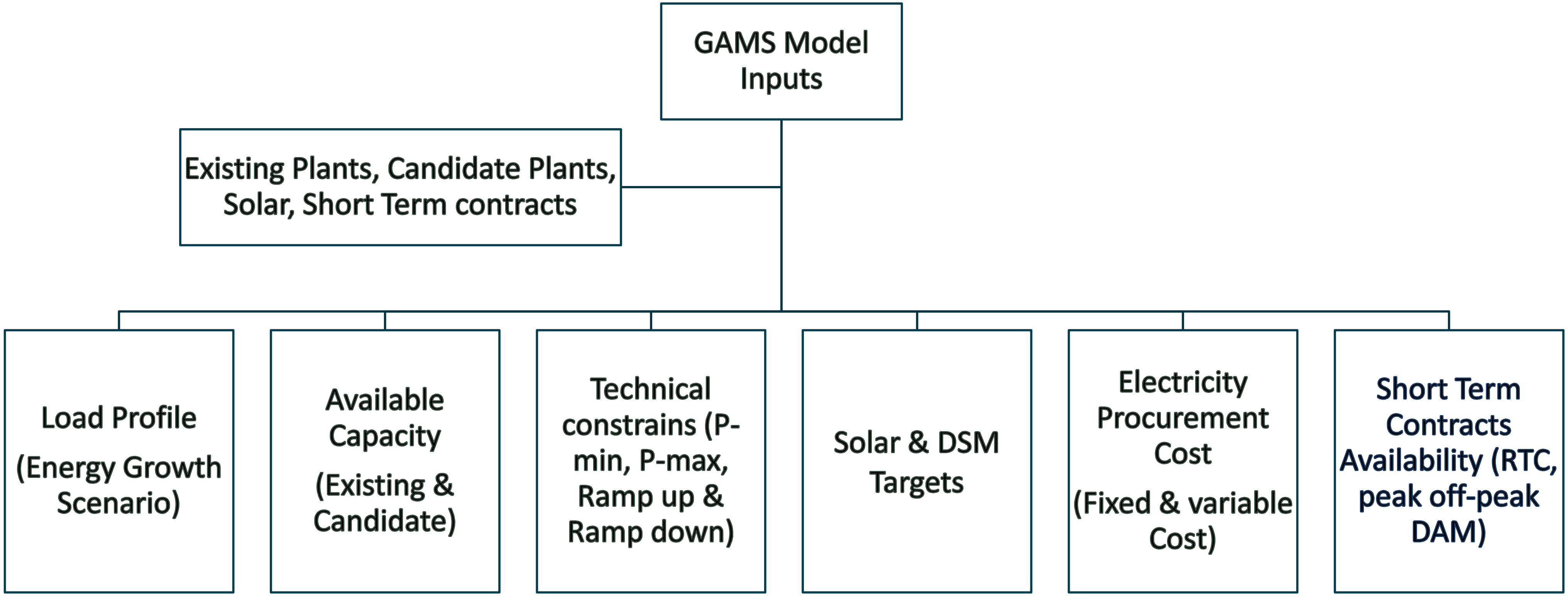
Objective:

1. Minimize total power procurement cost (Utility cost)
2. Optimum capacity utilization from available resources (Plant PLF)
3. Optimal position (year) for new capacity addition
4. Comparative study for different power procurement portfolio/scenario

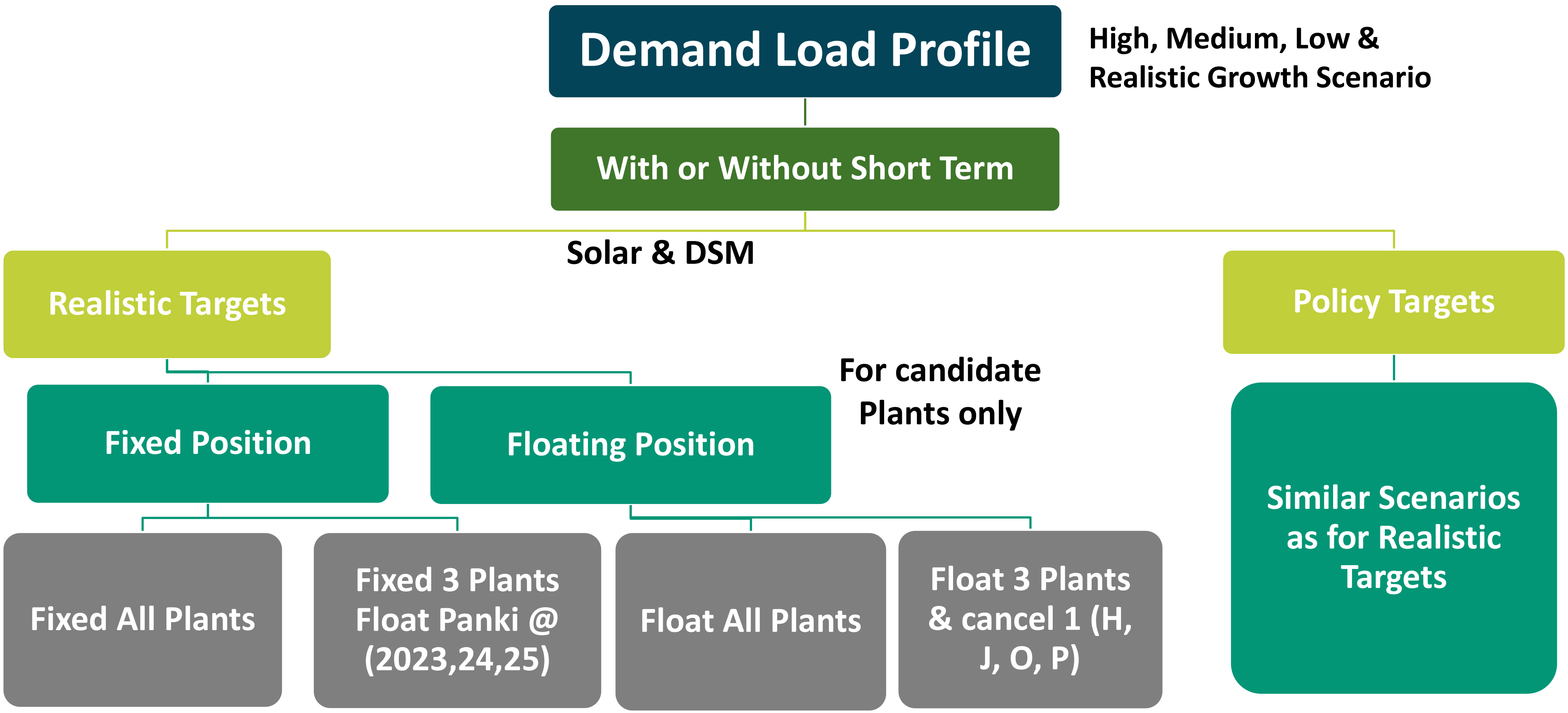
GAMS Model Inputs

1. Projected demand profiles (different scenarios)
2. Following information for existing plants and candidate plants
   a) Available capacity (Min & Max. limits, Ramp up ,Ramp down)
   b) Power procurement cost (fixed and variable cost)
   c) Duration of PPA's
3. RE/Solar projected contribution
4. Expected Short term contract availability (RTC, peak off-peak DAM) and their prices
5. DSM (Policy targets & Realistic targets)

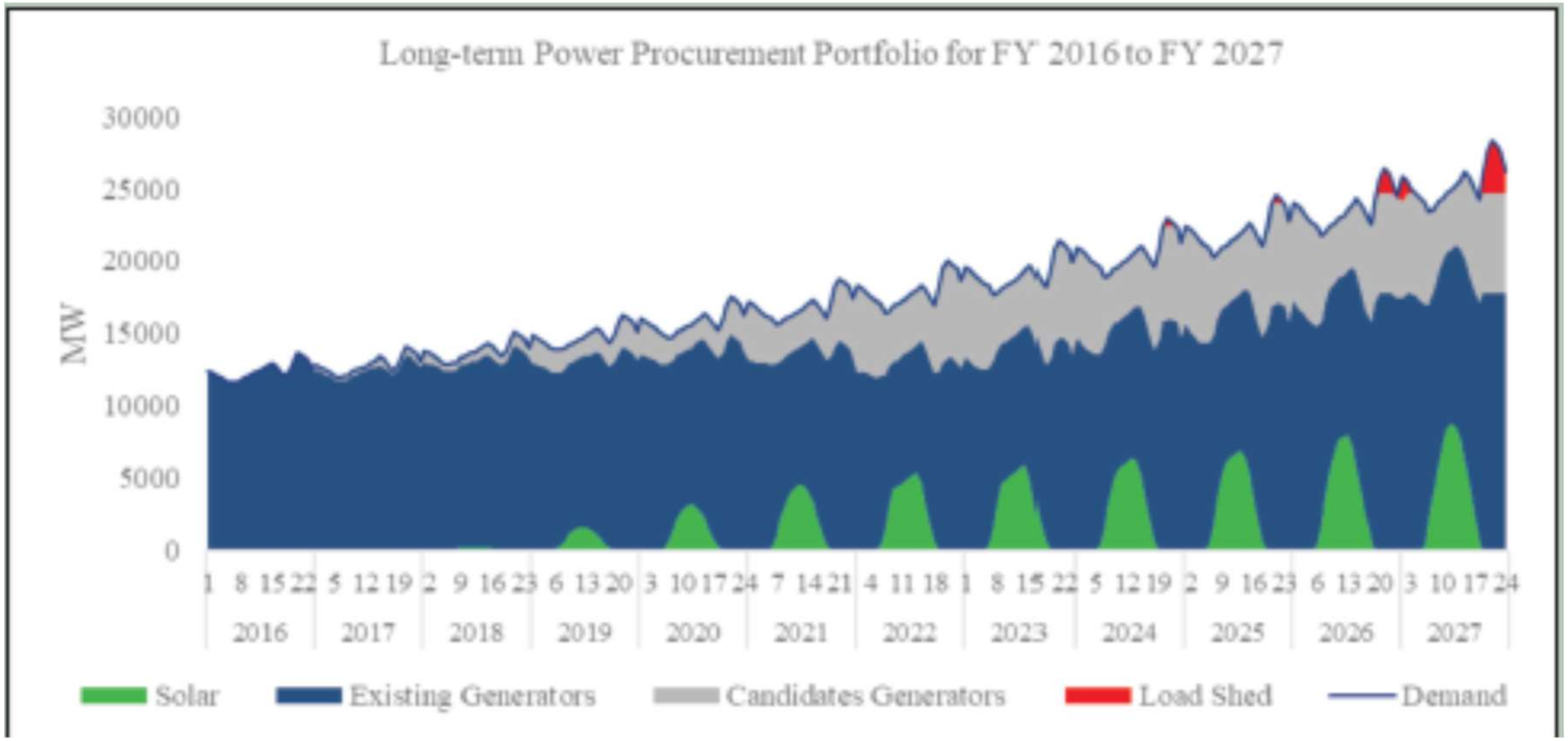
Input Variables



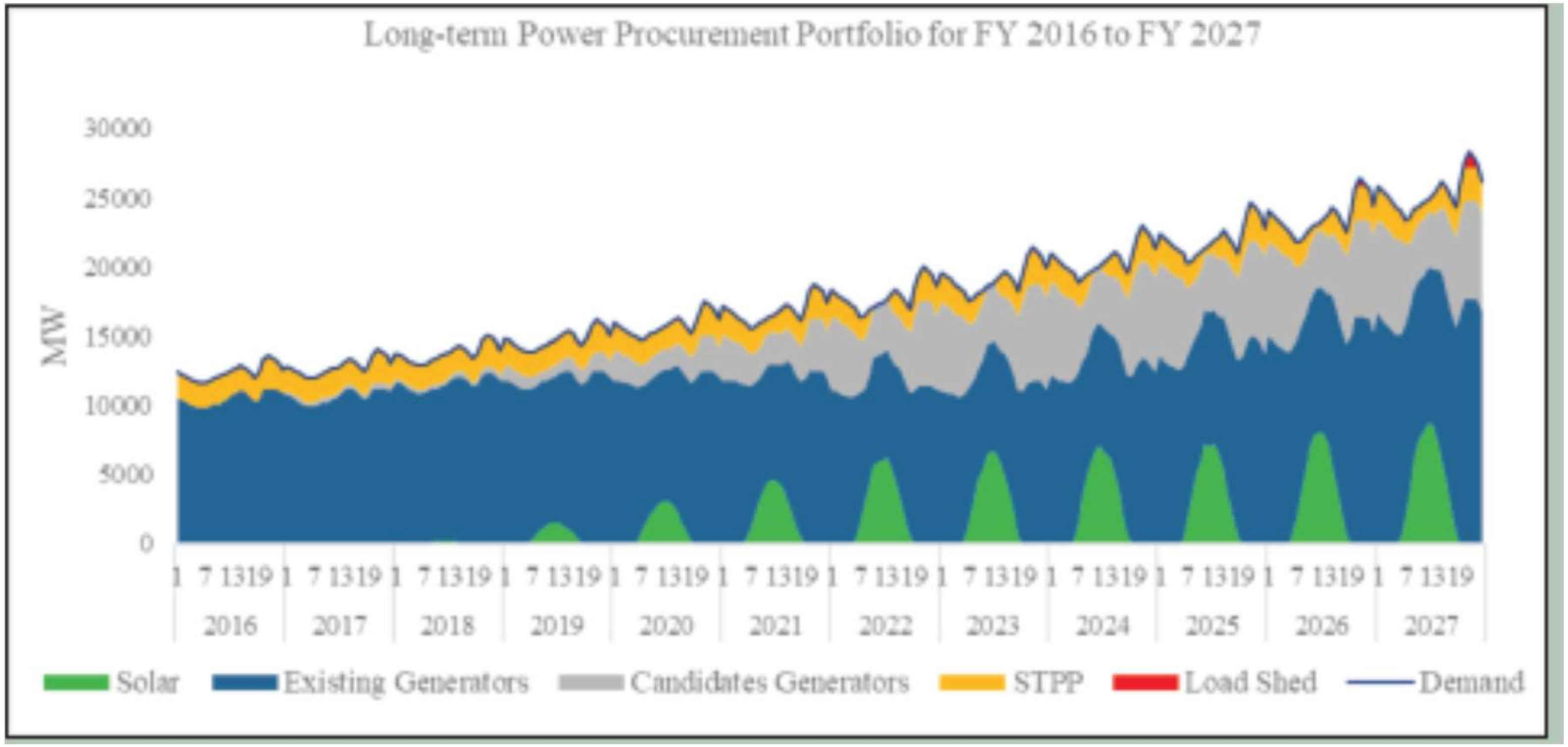
GAMS Simulation for Different Scenarios



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



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



Prevailing practices of LT demand forecasting

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

Prevailing practices of LT demand forecasting (Contd.)

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

Prevailing practices of power procurement planning

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

Recommendations on Regulatory Framework for LT Demand Forecasting

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

Key factors influencing LT demand

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

Key factors influencing LT PPP

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

Key Regulatory Takeaways

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

A healthy 'CEREAL' for the Power Sector

Centre for Energy Regulation

Energy Analytics Lab

cer.iitk.ac.in

eal.iitk.ac.in

USAID
FROM THE AMERICAN PEOPLE

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MINISTRY OF NEW
AND RENEWABLE ENERGY

BASICS OF POWER SYSTEM AND RESOURCE PLANNING

Faculty - Mr. Rakesh Kumar Goyal, Team Leader for USAID PACE-D 2.0 RE Program

Dr. Rakesh Kumar Goyal

- Serving as the Team Leader for USAID PACE-D 2.0 RE Program
- Managing Director and India country head of Tetra Tech
- Over 30 years of work experience in the power sector
- Ph.D. in Advanced Metering Infrastructure (AMI)

Contents

- Power System Operation
- Key Sector Developments focusing on IRP
- Supply and Demand Variations Past and Now
- Resource Planning
  - Data Availability and Reliability
  - How to address uncertainties
- Attributes of Resource Planning
- Case Studies

Power System Operation

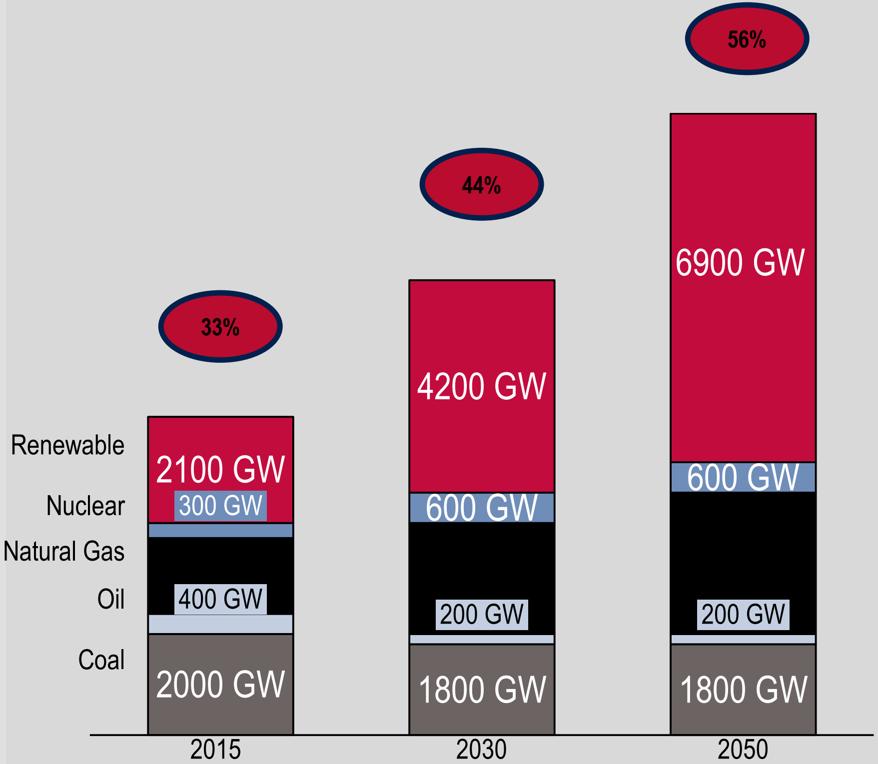
Parameter for Power System Management:

- Grid Frequency – Critical aspect of power system operations
- As per the Indian Electricity Grid Code (IEGC):
    - *Frequency band: 49.0 Hz to 50.5 Hz*
- Change in the demand and supply impact the grid frequency
    - *When demand exceeds supply, frequency falls*
    - *When supply exceeds demand, frequency rises*

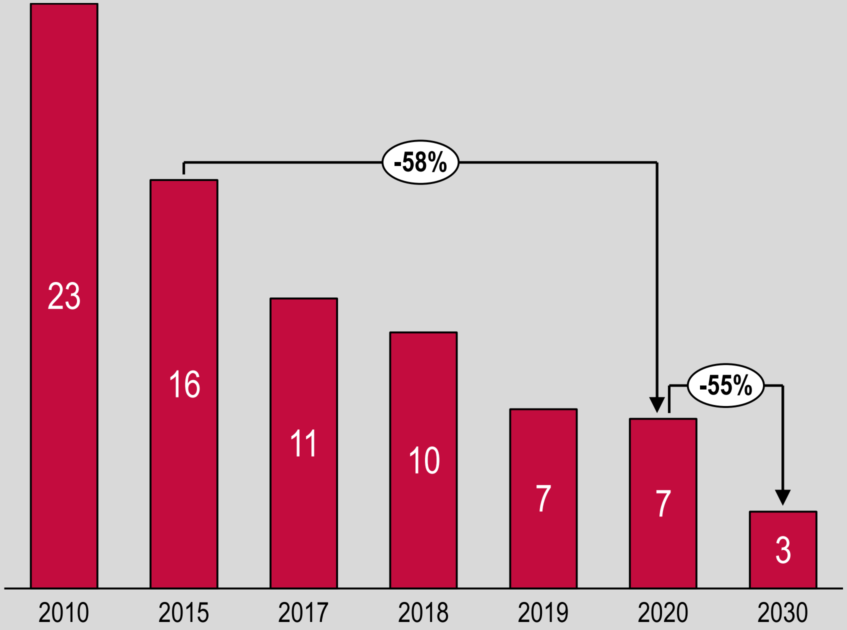
Options for Keeping the Frequency within the range:

- ➢ By governing valve operation
- ➢ By spinning reserve
- ➢ Secondary and tertiary reserves
- ➢ Storage
- ➢ Power Exchanges
- ➢ Hydro and Gas Machines
- ➢ Power aggregation

Development I : RE Vs Conventional



Installed Power Generation Capacity, Global Outlook, Source: IRENA, 2018

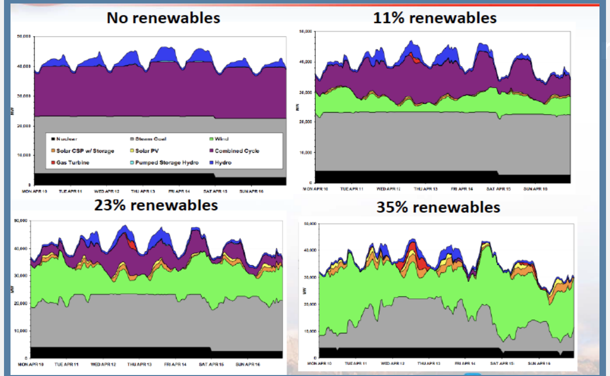


Levelized Cost of Renewable Energy (cents/kWh), IRENA, 2017

The current global **cost of thermal** is around 7 cents/ kwh which is likely to increase due to increase in coal pricing and environmental considerations

Challenges with RE (1/2)

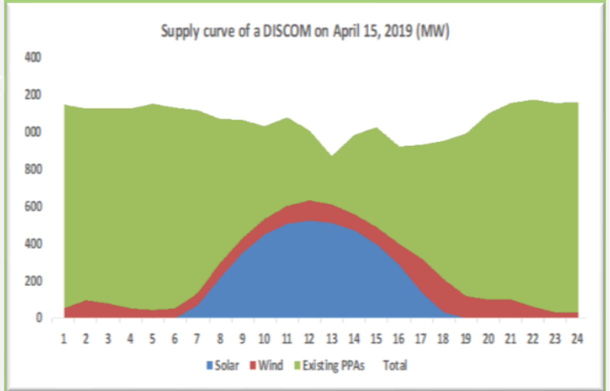
1. Higher Penetration- More Variability- High Integration Costs



2. Burden on Grid Management and Operations

- Higher cost of thermal assets
- More reserves
- High transmission capacity
- Better voltage control
- Higher system flexibility for balancing

3. Impact on Existing Resources



E.g. of a unilateral 700 MW Solar procurement by a state & its impact on the supply curve

Challenges with RE (2/2)

4. Struggle of Discom's/Consumer's in Managing RE Integration

- Limited understanding of generation profiles of various RE sources
- Managing variation in RE generation is expensive
- Demand side management approaches are not fully utilized

5. Planning for of RE Procurement

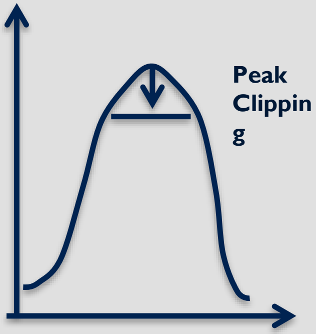
- Sizing RE to respond to present & future demand
- Identifying the best actors who can analyze, develop and supply RE to better match and manage demand

6. Focus on LCOE vs overall Cost of Supply to consumers

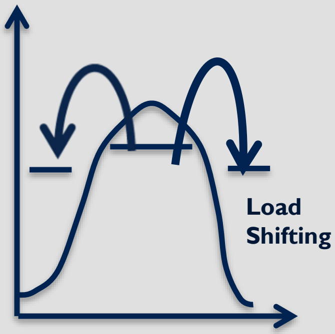
- Understanding system level costs of integrating stand alone RE critical
- Purchasing low cost single source RE does not necessarily lead to low cost of power supply

Development 2: DSM, DER and Technology Can Control Demand Variations

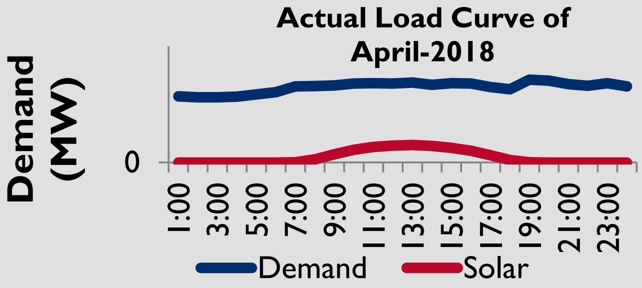
Demand Response

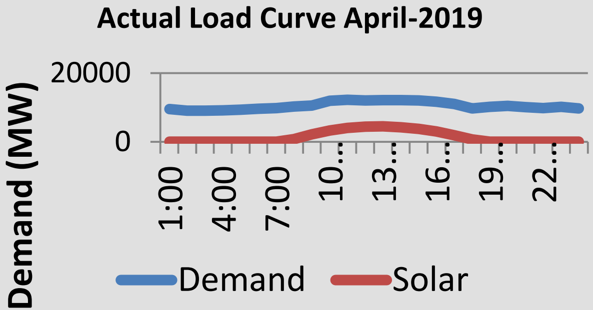


EE & Price Signals



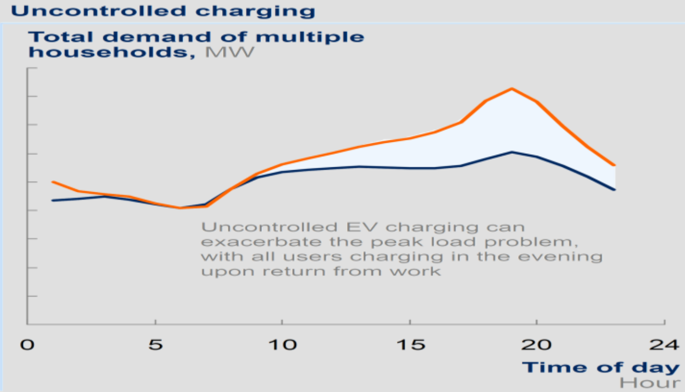
Dist. Generation

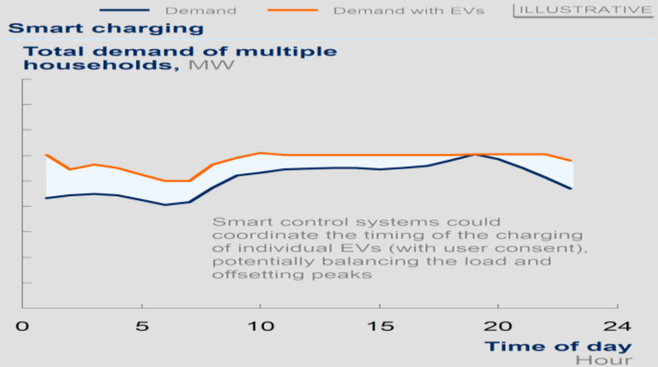




Karnataka : Due to shifting of part of Irrigation pump sets to Solar generation time. Total irrigation contributes to 1/3rd of State Energy

EE, Electric Vehicles and Price Signal



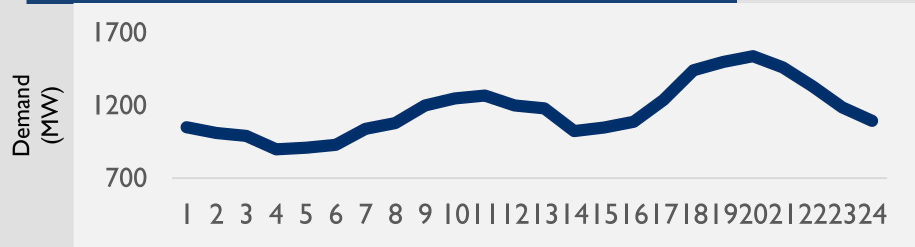


Long Term Resource Planning, with efficient Demand Forecast helps prepare Discoms for the challenges ahead

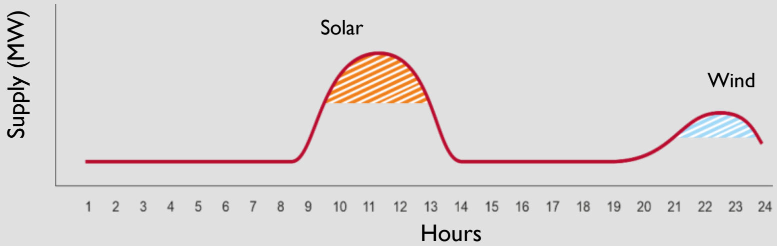
Development 3: Possibility to Match Variations in Supply with Demand across Space-Time

Supply: Thermal Generation

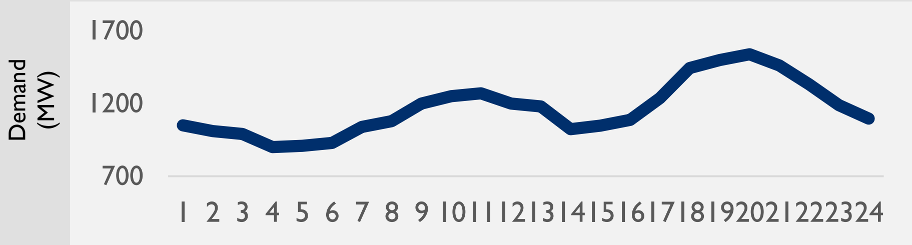
Actual Demand Curve of the State: 2019



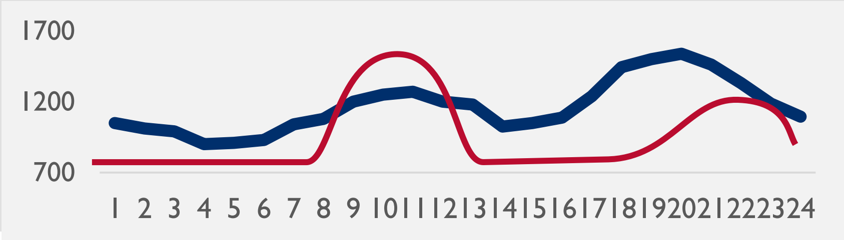
Supply: Renewable Energy Generation



Actual Demand Curve of the State: 2019



Resource Mapping can enable matching demand & Supply (Thermal & Renewable)

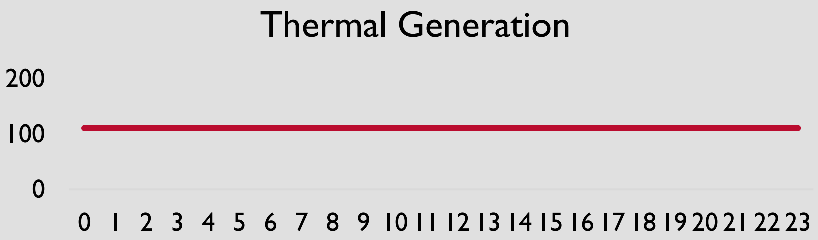


Better Forecasting, Load Shifting, Demand Response, Energy Efficiency, Pricing Signal can help matching without external support

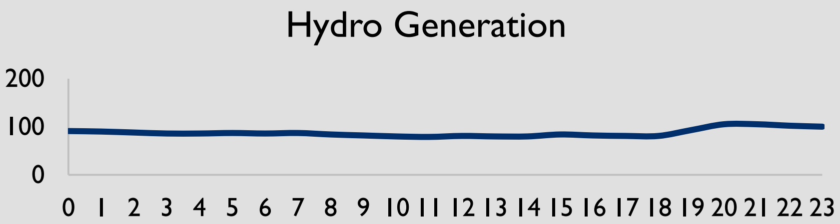
Supply Variations: Past and Now

Typical Thermal Generation

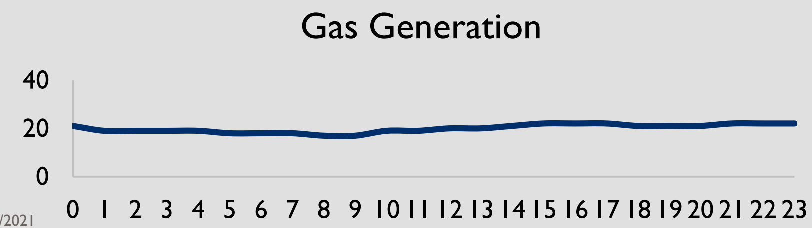
% Variation: 10-20%



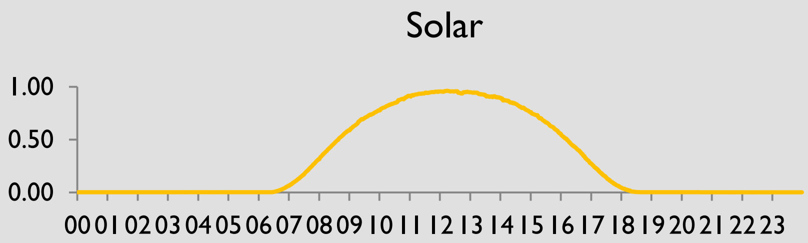
Typical Hydro Generation

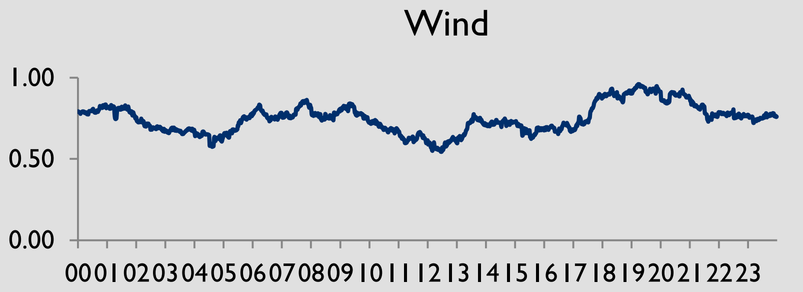


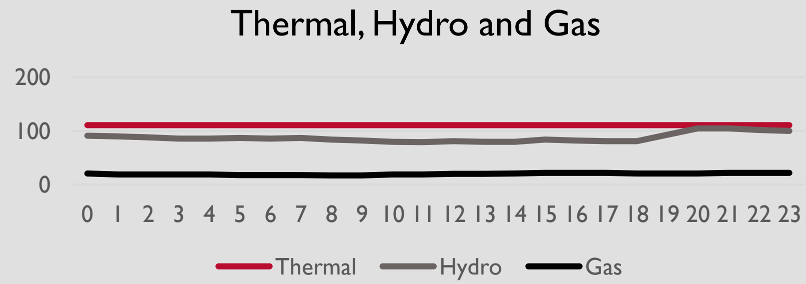
Typical Gas Generation



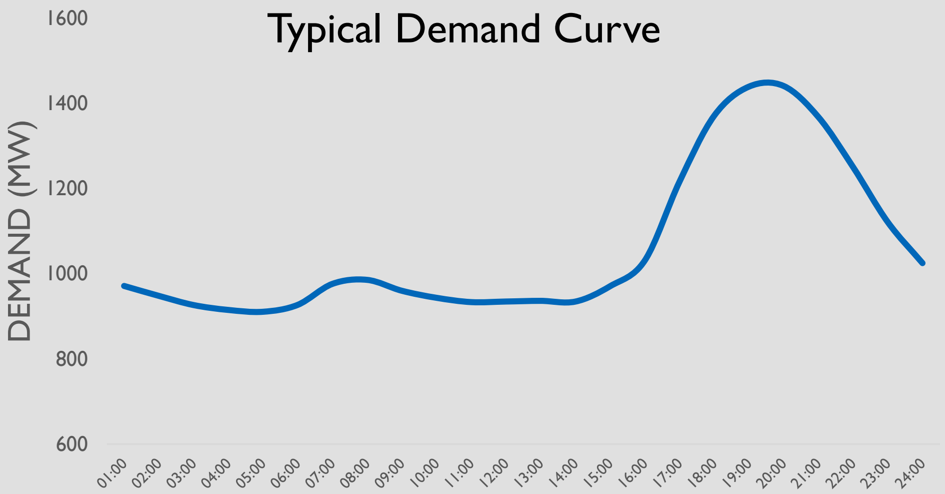
Typical Solar Generation

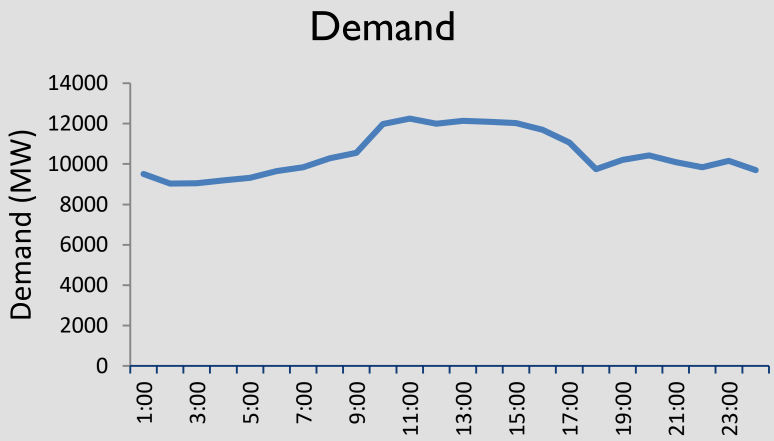






Demand Variations: Past and Now





Peak Shifting by:

- Cut-in and Cut-out of feeders
- Time of Day tariff

Demand can be varied by:

- Price signal
- Demand response
- Control over customer assets
- Distributed Generation

Journey to High Renewable Energy Future

1. Prove RE Technology Reliability

- Solar PV
- Wind
- Small Hydro
- Wind (On-shore)
- Bio-fuels

2. Attain Generation Cost Competitiveness

- Small hydro
- Wind
- Solar PV
- Biomass (still evolving)

3. Seamless Integration with the Grid

- System Friendly Procurement – RTC, Peak Supply through energy storage
- Green Energy Corridors
- Solar Parks and RE Hybrids
- Storage

4. Drive economic growth through cheaper and reliable energy

- High penetration of RE
- Generation responding to demand of grid and consumer on standalone basis

- Long term goal – 175/450 GW– we are at stage 3, with RE ready to scale but faces grid integration challenges
- One solution for managing grid integration - better manage RE procurement at the systemic level

Resource Planning

- Short Term (1 day to several weeks)
- Medium Term (1 month to 5 years)
- Long Term (5 to 20 years)

Resource planning components:

- Data Requirement
- Demand Forecasting
- Resource Mapping
- Power Procurement Optimization
- Scenario Analysis

Resources to be optimized:

- Thermal
- Renewable Energy
- Hydro
- Power Exchange, Import/Export
- Demand Response
- Distributed generation

Criterion for Optimization of Resources:

- *Least-cost power procurement*
- *Higher uptake of RE*
- *Minimum emissions*
- *Multiple*

Data Availability and Reliability

Data Set	Parameters	
Consumer Data	• Consumer categories	
Demand Data	• Category wise energy consumption • Historical annual load profile	• Load factor • Per capita energy consumption
Weather Data	• Annual maximum temperature • Annual rainfall	• Annual average humidity
Demographic Data	• Total population	• Number of households/connections
Econometric Variables	• Gross domestic product • Per capita income	• Price deflator
Policies	• Power for all • Make in India	• Saubhagya Scheme
Drivers	• Open access • CPPs • Reduction in T&D losses	• Distributed energy resources • Electric vehicles • Demand Side Management

Data Availability and Reliability

Data Set	Parameters	
Generation Data (Thermal)	• Technical minimum capacity • Auxiliary consumption • Ramp-up and ramp-down limits • Hot and cold start-ups per day • Generation cost	• Hot, warm and cold start time • Fuel availability • Specific fuel consumption • Emission levels
Generation Data (Hydro)	• Reservoir capacity • Reservoir lateral inflow • Reservoir discharge rate	• Penalty for unmet demand • Spinning reserve • Emission limits
Generation Data (RE)	• Capacity	• CUF

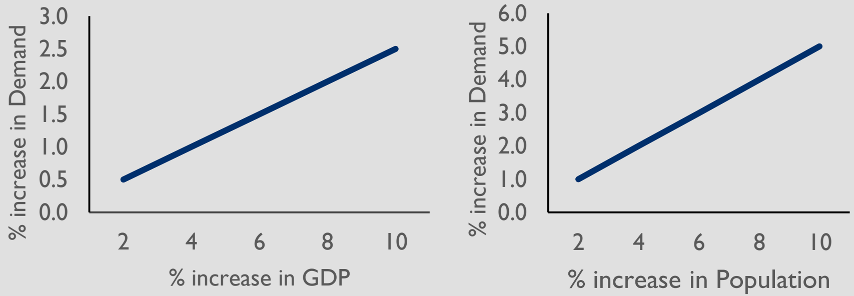
Data availability and data cleansing are critical aspects to formulate the resource plans

How to address Uncertainties

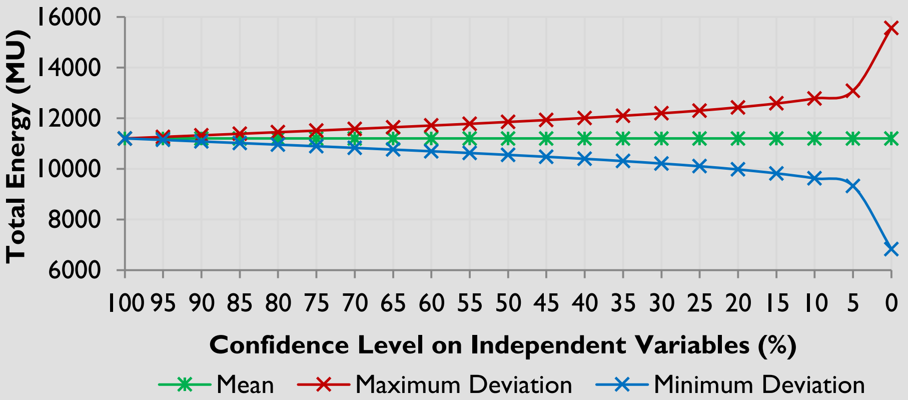
- ❖ Sensitivity Analysis to understand the impact of variable parameters on demand such as:
  - GDP
  - Population

- ❖ Probabilistic Analysis to understand the deviation in demand at different confidence intervals.

Sensitivity Analysis



Probabilistic Analysis



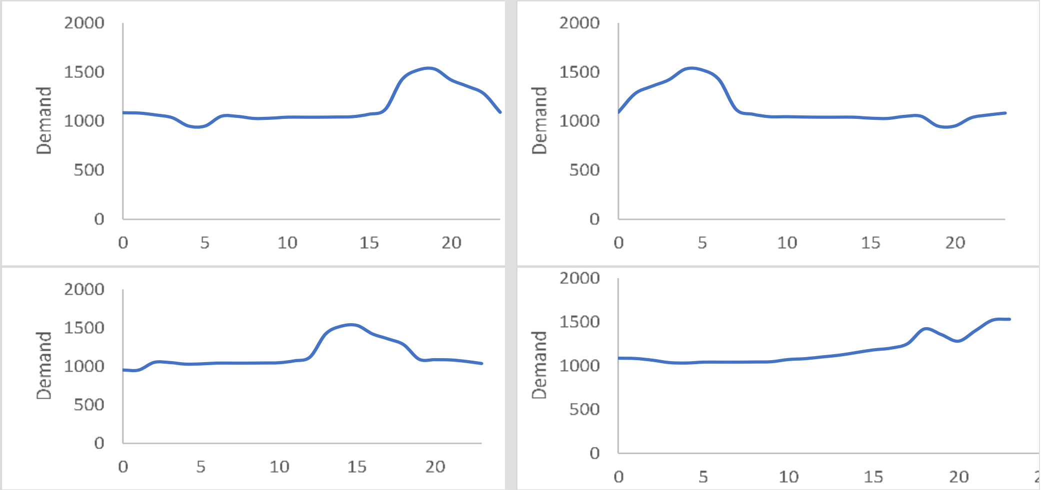
How to address Uncertainties

❖ Option analysis for different demand patterns.

Scenario Development

- Business As Usual (BAU)
- Scenario for
  - Sensitive Parameters
  - High Probability

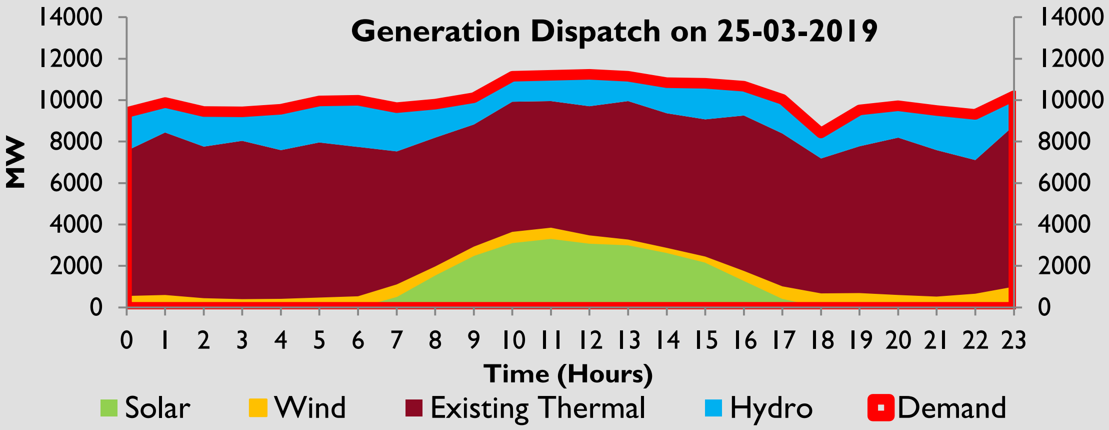
Option Analysis

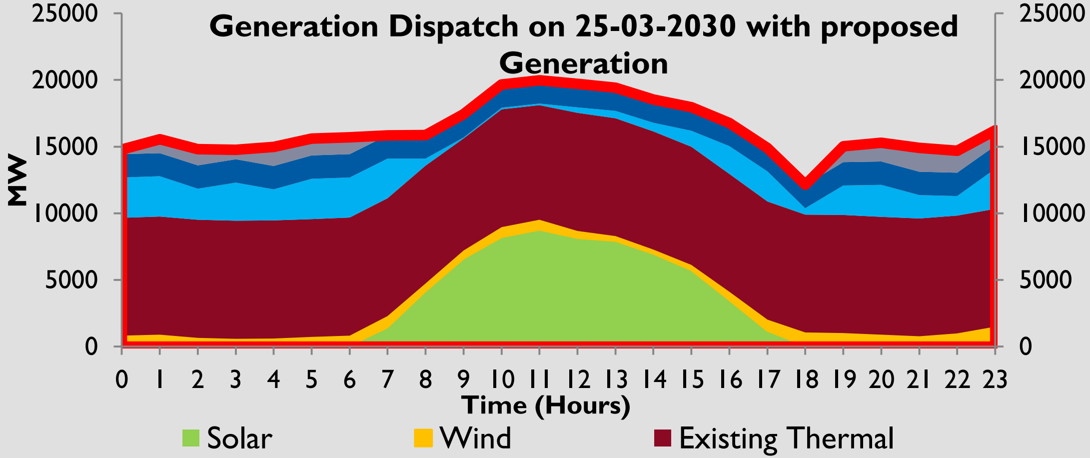


Attributes of Resource Plan

- Scenarios for uncertainties
- Planning reserve - Both on demand side and supply side
- Cost
- Share of RE, thermal and other resources.
- Expected emission level.
- Reduction in CO_2 emissions.
- Demand response considered
- Assumption-Technical and economic parameters

Simulation Study for Karnataka





2019

Peak Demand : 11245 MW

Resources : Thermal + Hydro + RE (W+S)

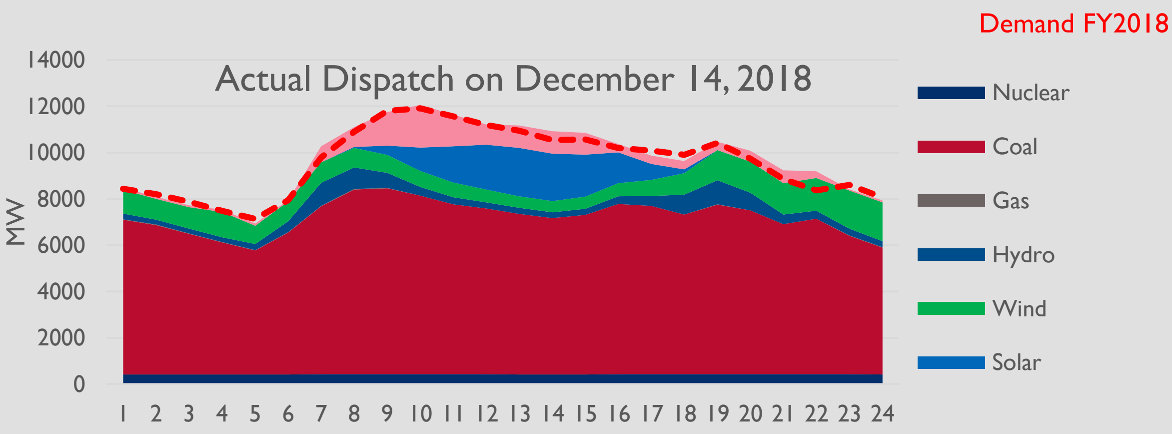
2030

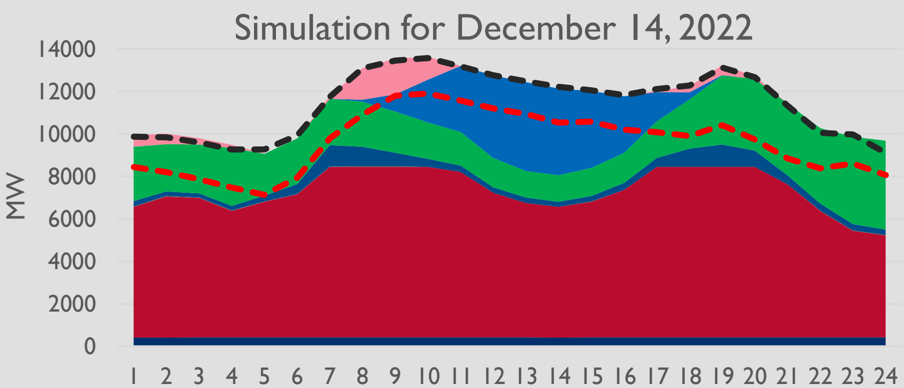
Peak Demand : 19127 MW

	Business As Usual (+)	RE Scenario (+)
Thermal	4720 MW	2670 MW
RE	0 MW	6400 MW
Storage	-	2000 MW
Cost	17,800 Cr.	16,800 Cr.

- No stranded asset created
- No grid security issues
- Savings of 1000 Crs.

Simulation Study for Rajasthan





Demand FY2022

Capacity Add.
2x Solar
2.5x Wind
Others-Nil

Dispatch on Dec. 14, 2018

- PLF of TPPs – 71%
- RE Generation Share – 15%
- Avg. Power Cost – Rs 4.88/u

Simulation for Dec. 14, 2022

- PLF of TPPs – 72%
- RE Generation Share – 30%
- Avg. Power Cost– Rs 4.63/u
  (Decrease of about 5.2%)

With better Demand Forecast & Resource Planning, RE Share can Get Doubled

Quiz

Quiz

Question 1:

1. When the demand is higher than supply, the frequency will
   a. Increase
   b. Decrease
   c. No Impact

Quiz

Question 2:

2. What are the characteristics of good resource plan?
   a. Reserve Margin
   b. Low Cost
   c. Low Emissions
   d. Higher RE

Quiz

Question 3:

3. What is the best way to minimize the system integration cost?

   a. Suitable energy storage
   b. Higher spinning reserve
   c. Higher operation of governing valve
   d. Matching the profile of demand and supply

Quiz

Question 4:

4. What is the most critical aspects of IRP?
   a. Accurate prediction of demand
   b. Accurate prediction of supply sources
   c. Reliability and availability of data
   d. Use of high-end software

DESIGNING RENEWABLE DOMINATED RESOURCE PLANS FOR FUTURE UTILITIES

Thanks!

Supported by:

- Yogeeta Sharma, Communication Specialist
- Joginder Singh, Graphic Artist
- Jayanti Mishra, Consultant
- PRDC Team

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Reference Literature

- Electrical Power System Basics by Steven W. Blume
- https://www.pace-d.com/wp-content/uploads/2020/07/Rethinking-DISCOM-Resource-Planning-White-Paper.pdf
- Pelin Yilmaz, M. Hakan Hacoglu, Alp Er S. Konukman, "A pre-feasibility case study on integrated resource planning including renewables"

MODULE II: CURRENT PRACTICES OF RESOURCE PLANNING AND INTERNATIONAL BEST PRACTICES

The goal of this module is to develop a shared understanding of the existing practices of resource planning in India and international best practices for transition of utilities to RE rich power portfolio.

- **Objectives:**
  - How is resource planning done?
  - International practices of resource planning of at least four best countries (US, Germany, Japan, UK)
  - How new developments are being incorporated in the resource planning by these countries
  - Case studies of the benefits achieved by DISCOM by better resource planning
  - Regulatory provisions for resource planning in US, Germany, Japan, and UK.
  - The process of resource planning in DISCOMs - organization, staff, processes, tools etc.
  - How uncertainty is addressed in resource planning?
- **Content:**
  - Why resource planning? Why is it more relevant as the share of RE is increasing in the supply portfolio? How it helps in saving power purchase costs?
  - Resource Planning practices followed in the United States and globally with countries that are at the leading edge of the transition to RE.
  - The popular software in use for resource planning. Features of one/two software popularly used
  - How renewable energy (RE), distributed renewable energy (DER), energy efficiency (EE), demand response (DR), electric vehicle (EV), etc. are considered in the resource planning
  - How to conduct the scenario, sensitivity, and probabilistic analysis?
  - Importance of load research. How to carry it out and how to use it in resource planning?
- **Presentation:**

DESIGNING RENEWABLE DOMINATED RESOURCE PLANS FOR FUTURE UTILITIES

– Current Practices of Resource Planning and International Best Practices

October 09, 2020; Time: 03:30 – 05:30 pm

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Agenda

Time	Session
03:30 – 03:35 pm	Welcome Address by Mr. Sumedh Agarwal, Strategic Energy Planning Lead, USAID PACE-D 2.0 RE Program
03:35 – 04:05 pm	Presentation on Methodology for Integrated Resource Planning by Ms. Ammi Toppo, Director, Central Electricity Authority (CEA)
04:05 – 04:15 pm	Quiz and Discussion
04:15 – 05: 15pm	Presentation on Current Best Practices of Resource Planning and International Best Practices, Dr. Rafael Kelman, Executive Director, PSR Consulting
05:15 – 05:25 pm	Quiz and Discussion
05:25 – 05:30 pm	Concluding Remarks

DESIGNING RENEWABLE DOMINATED RESOURCE PLANS FOR FUTURE UTILITIES

Methodology for Integrated Resource Planning

Ammi Ruhama Toppo
Director(IRP)
Central Electricity Authority

Module II

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Faculty - Ms. Ammi Ruhama Toppo, Director, Central Electricity Authority, India

Ms. Ammi Toppo

- 20 years of rich & diverse experience in power sector
- Primes formulation of National Electricity Plan (NEP)
- B.E. from Govt. Engineering College, Jabalpur and M.B.A from IIT Delhi
- Areas of interest include generation, planning studies, demand supply justification, allocation of power from Central Generating Stations, policy formulation.

Legislative framework for National Electricity Plan

Preparation of National Electricity Plan is a **statutory responsibility entrusted to CEA** under Electricity Act,2003

Electricity Act. 2003 , Section 3(4) stipulates that

- *The Authority shall prepare a National Electricity Plan in accordance with the National Electricity Policy and notify such plan* ***once in five years***
- *Provided that the Authority in preparing the National Electricity Plan shall publish the draft National Electricity Plan and* ***invite suggestions and objections*** *thereon from licensees, generating companies and the public within such time as may be prescribed:*
- *Provided further that the Authority shall - (a)* ***notify the plan after obtaining the approval of the Central Government****; (b) revise the plan incorporating therein the directions, if any, given by the Central Government while granting approval under clause (a). (5) The Authority may review or revise the National Electricity Plan in accordance with the National Electricity Policy. "*

National Electricity Policy section 3.2

- *Accordingly, the CEA shall prepare short-term and perspective plan. The National Electricity Plan would be for a short-term framework of five years while giving a 15 year perspective plan.*

National Electricity Plan

- The First National Electricity Plan(NEP) covering the review of 10th Plan, detailed plan for 11th Plan and perspective Plan for 12th Plan was notified in the Gazette in August, 2007.

- The Second NEP covering the review of 11th Plan, detailed Plan for 12th Plan and perspective Plan for 13th Plan was notified in the Gazette in December,2013 in two volumes. (Volume-I Generation and Volume-II Transmission).

- The third NEP covering review of 12th Plan (2012-17), detailed plan for period 2017-22 and perspective plan for period 2022-27 was notified in 2018 in the Gazette of India in two volumes(Vol- I- Generation & Vol- II- Transmission).

National Electricity Plan

The NEP includes :

1. Short term and long term demand forecast
2. Proposed capacity addition in generation including Renewables and its integration thereof,
3. Fuel choices based on economy, energy security and environmental considerations.
4. Key inputs viz. infrastructure requirement, fuel requirement, human resource and investment requirement etc.
5. Transmission system planning

The National Electricity Plan is used by prospective generating companies, transmission utilities and transmission /distribution licenses as reference document for future planning

Steps for long term Integrated Resource Plan

1. Defining the Objective
2. Forecasting future load
3. Existing Resources & Identify Future Resources
4. Determining Optimal Mix
5. Uncertainty Analysis
6. Comments from Stakeholders

Sequential approach of first defining the generation mix, then the optimal transmission capacity for that mix.

Defining the Objective

Supply = Demand + Reserve

Minimizing:

- Operation Cost of the existing and committed generating stations.
- CAPEX of new generating stations
- Financial implications arising out of startup cost, fuel transportation cost etc.

Constraints such as:

- Fuel availability constraints.
- Technical operational constraints viz. minimum technical load of thermal units, ramp rates, startup and shut down time etc.
- Intermittency associated with renewable energy generation.

Reliability Criteria

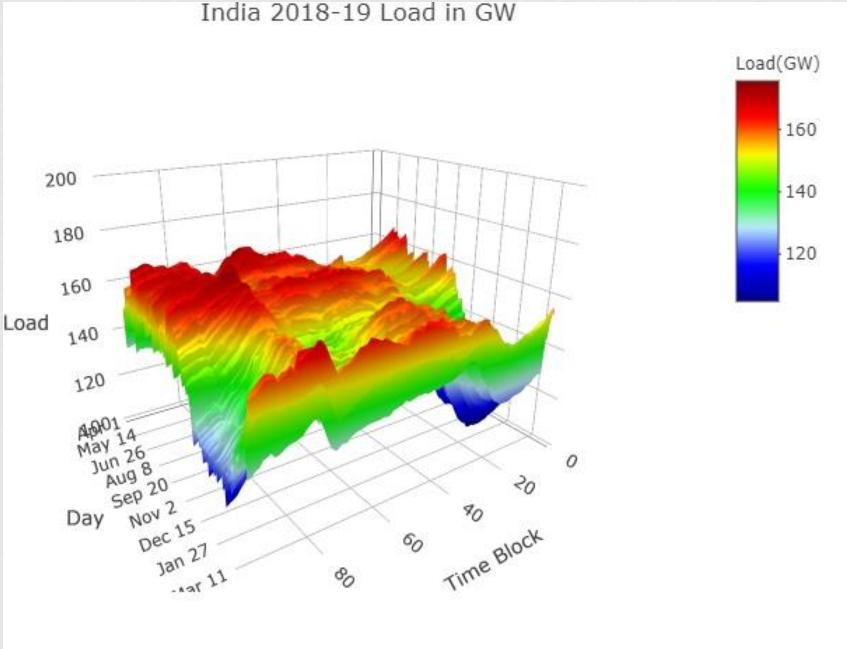
- Loss of Load Probability- It is proportion of hours per year when the available generating capacity is insufficient to serve the peak demand. (LoLP of 0.2%)

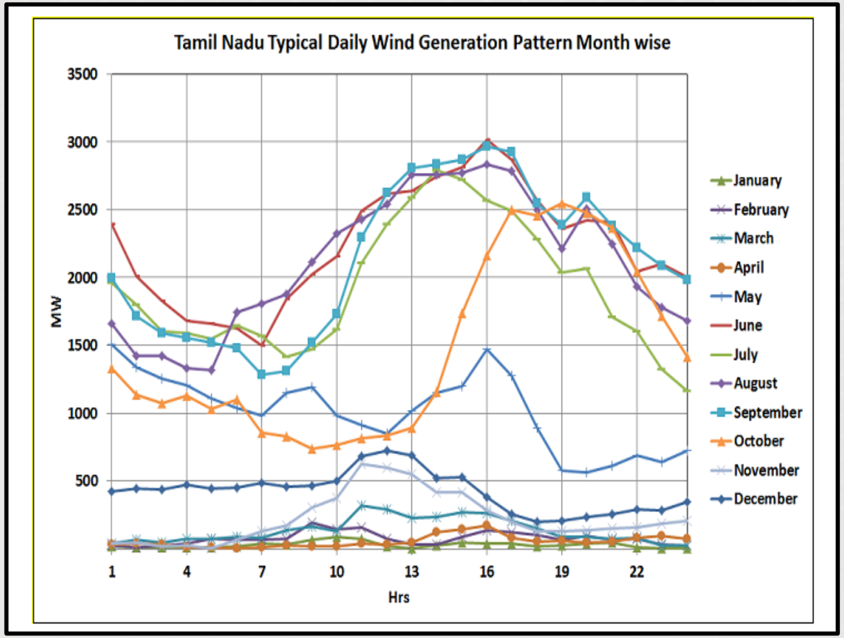
- Energy Not Served(ENS)- it is expected amount of energy which the system will be unable to supply to the consumers as a fraction of total energy requirement. (0.05%)

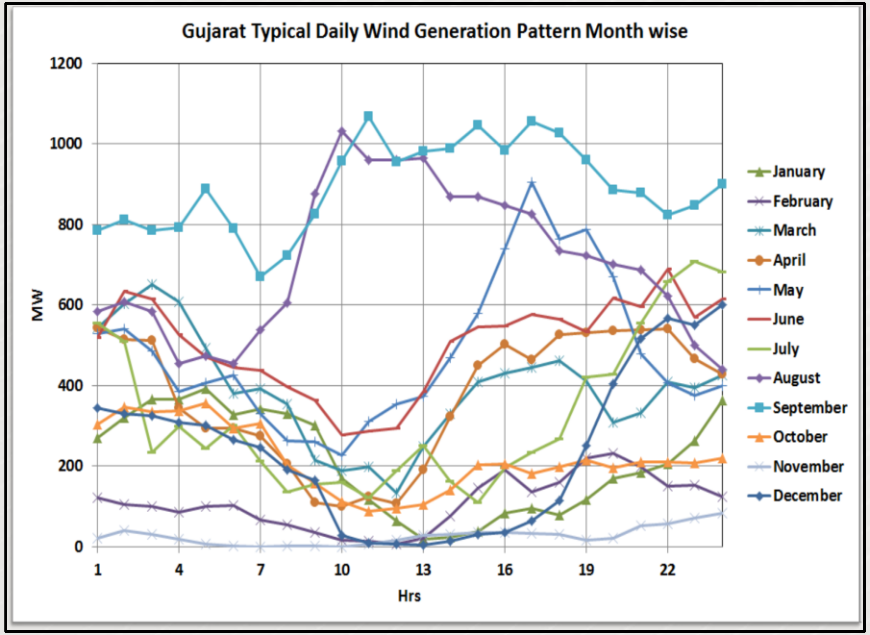
- Cost of Energy not served - It's the cost of supply from alternate source in case of no grid supply. (For ex. Cost of generation from diesel)

Forecasting Future Load

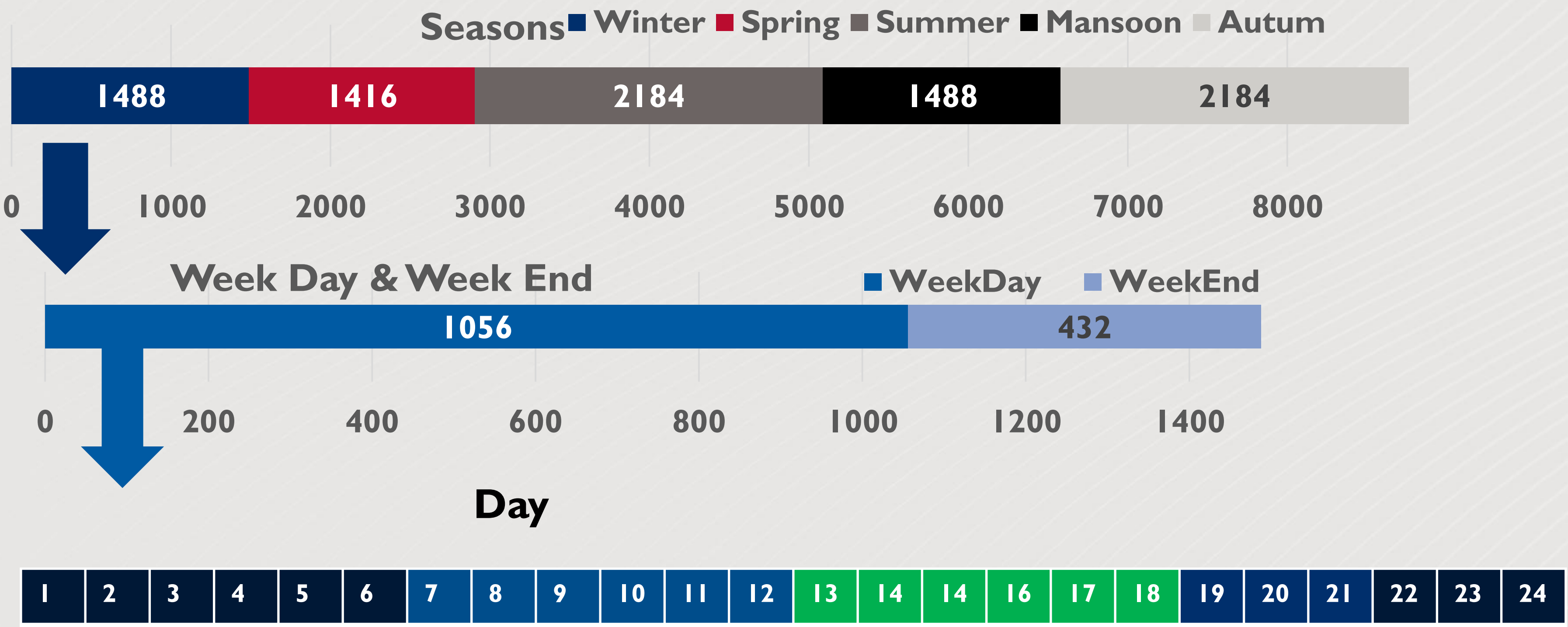
- Long term Peak and Electrical Energy Requirement are considered as per the Electric Power Survey Projections.
- Estimating Hourly demand projection for the study year.
- Long-term models with endogenous investments are computationally expensive, especially when optimizing investment decisions for multiple years simultaneously.
- To reduce the computational burden and to Capture changes in seasonal, weekly and daily demand patterns as well as wind and solar availability , 8760 hours are divided into time blocks(or time slice)




Tamil Nadu Typical Daily Wind Generation Pattern Month wise
MW
Hrs
3500
3000
2500
2000
1500
1000
500
1
4
7
10
13
16
19
22
January
February
March
April
May
June
July
August
September
October
November
December

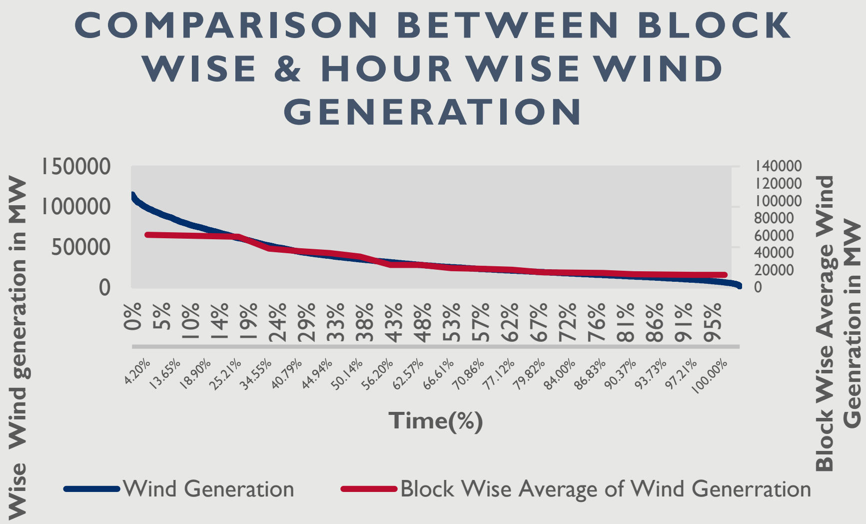

Gujarat Typical Daily Wind Generation Pattern Month wise
MW
Hrs
1200
1000
800
600
400
200
0
1
4
7
10
13
16
19
22
January
February
March
April
May
June
July
August
September
October
November
December

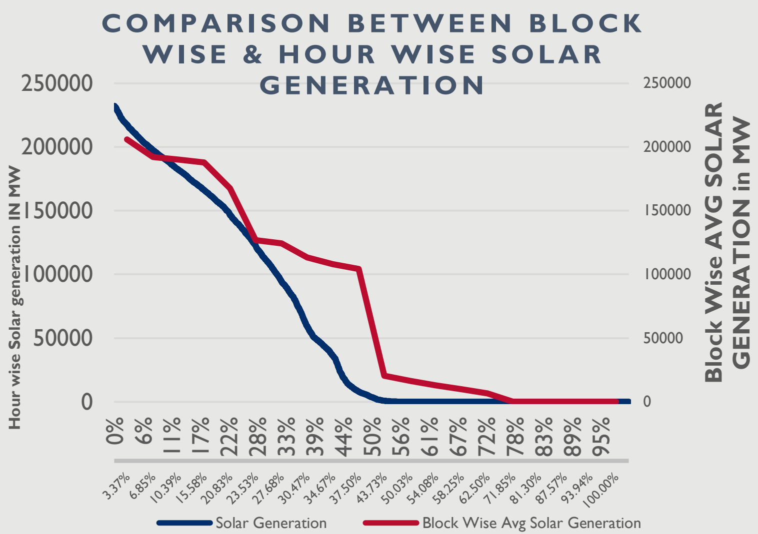
Preparation of time block

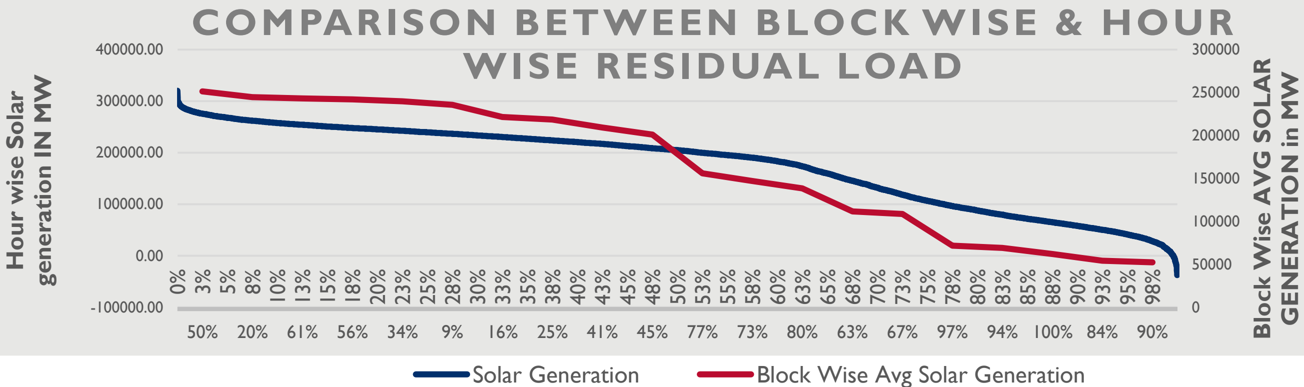


With the increase in VRE, models need to capture the variability of the supply options.

Validation of time block







Data required from Existing /Committed Resources

- Unit wise characteristics
  - Installed capacity, commissioning year, fuel type, heat rate, outage rate, maintenance duration, fuel cost, fixed O&M cost,
  - Flexible Characteristic- start up/down time and cost, ramp rates, minimum technical load, peak contribution,
  - The deterioration in operational efficiency with part loading of units of thermal plants.
  - Annual as well as Seasonal availability of fuel
  - In case of hydro- hydro storage related data, Hydro seasonal energy etc.
  - Hourly Solar and Wind Profile –data collected from the RE rich States.
  - Planned retirements

Identifying potential resource options(Candidate)

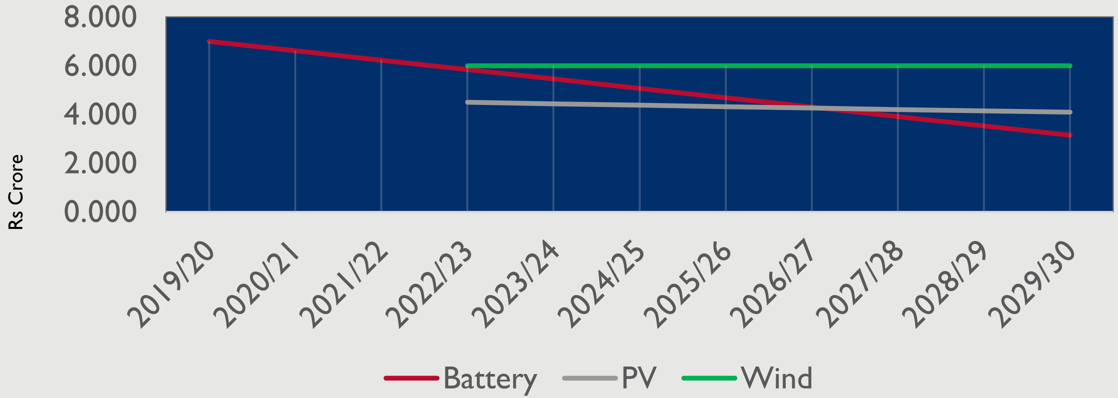
Resource choices cannot be made simply on the basis of costs (or prices).
The lower-cost resource is not always the most valuable resource.

Conventional Technologies	Renewable Technologies	Storage technologies
Coal	Solar	Pumped Storage
Gas	Wind	Battery Energy Storage
Nuclear (LWR *PHWR)	Biomass	
Large Hydro	Small Hydro	

- The generation fleet is represented by a number of different technology types, each with their own unit-wise, techno-economic parameters including the cost trends of capital cost.
- The investment constraints limit, investments based on resource, policy, or technical criteria.
- All technologies are constrained to prevent unrealistic rates of capacity growth in any particular year
- In case of hydro power projects, only those projects concurred by CEA are considered as investment option
- The Nuclear projects are considered as furnished by Department of Atomic Energy.

Cost Curve of Technology Considered

Projected reduction in capital costs over time for the RE technologies and the Battery Energy Storage system



Firm Capacity & Reserve

Firm Capacity/ Capacity Credit- It is the capacity that can serve that load all time specially during the peak time

Spinning Reserve- Spinning reserve of 5% as per the National Electricity Policy

About the Model

Input data assumptions

Demand and energy forecast , Load profile, retirements, etc.

Existing resources data

Unit capacity, auxiliary consumption, fuel type & cost, heat rate, outage rate, availability profile, O&M cost , Hourly Solar and Wind generation profile, etc.

ORDENA (Generation expansion planning software)

New resources data

Capital cost, fixed O&M cost, year of availability, availability profile, fuel type & cost, heat rate, etc.

Optimisation constraints

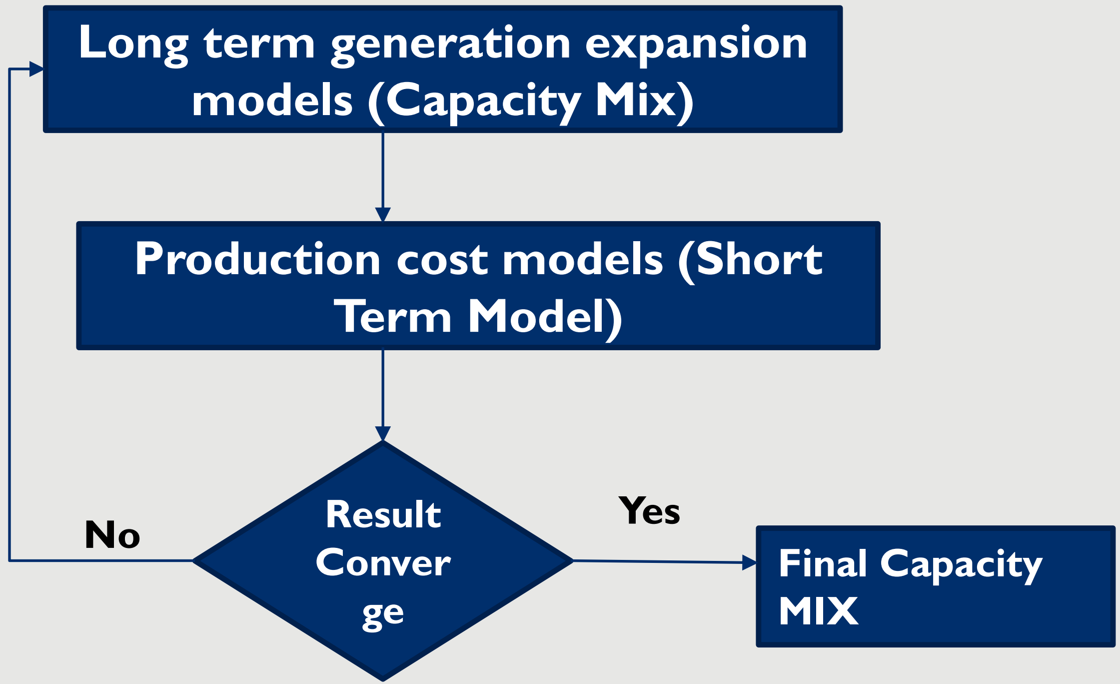
Plant availability, start up and dynamic characteristics, Ramp rates, fuel constraints etc.

Optimized resource plan

Long Term Planning:-Total system cost, annual system capacity requirement fuel wise.

Short term planning:-Hourly economic dispatch to meet the hourly demand

Validating flexibility balance with production cost models

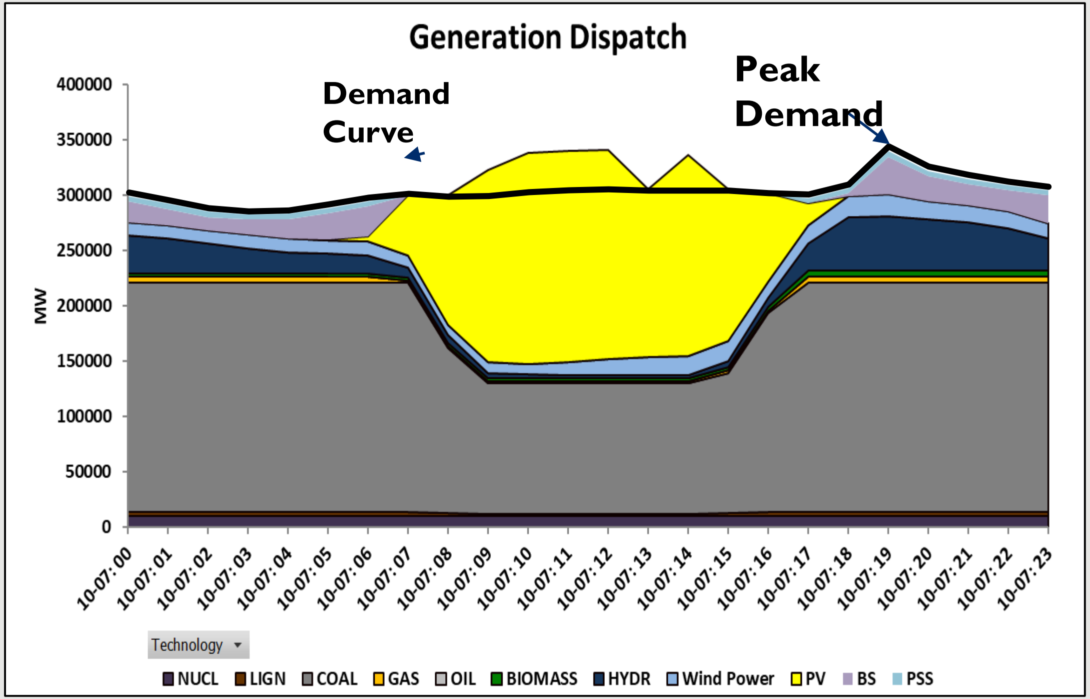


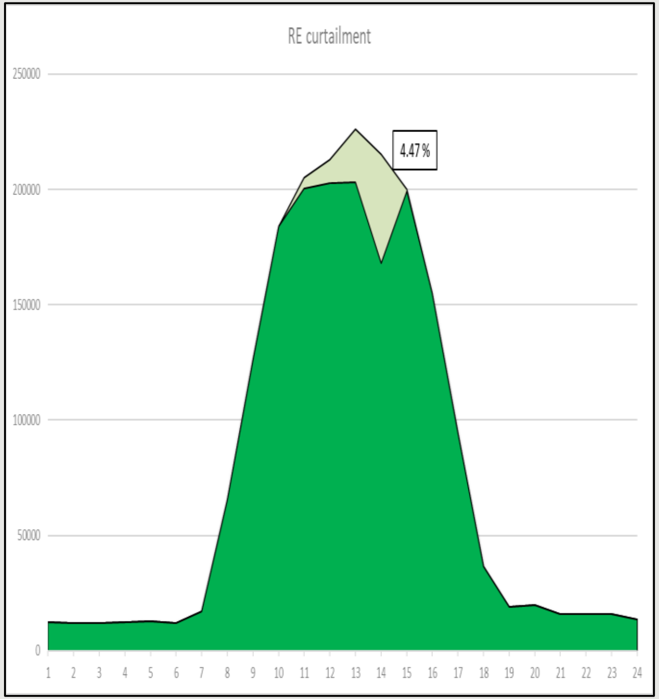
Short Term scenarios considered for Critical days

Scenario
Peak Day / Max Energy demand day
Maximum Variable RE (Wind+Solar) generation day
Maximum Solar generation day
Minimum Solar generation day
Minimum energy demand day
Minimum Variable RE (Wind+Solar) generation day
Maximum variation in demand day

Peak Demand/ Maximum Net Demand

Peak Demand – 340 GW, Energy Req- 7.21 BU

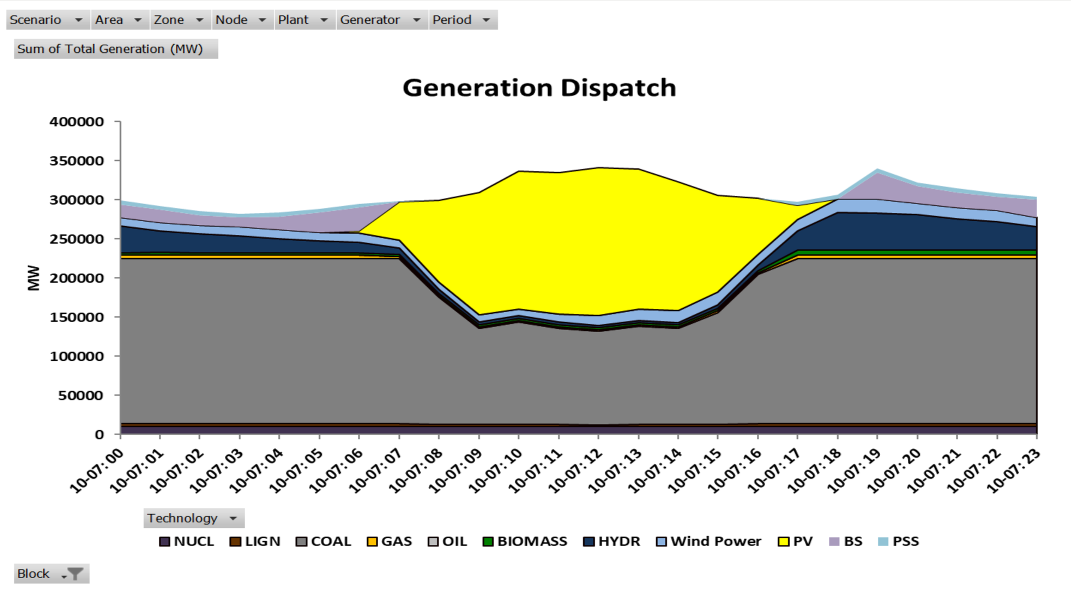


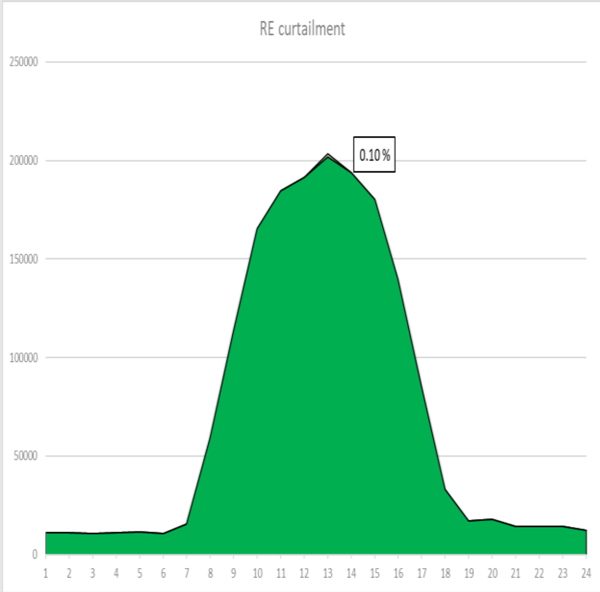


Sensitivity studies

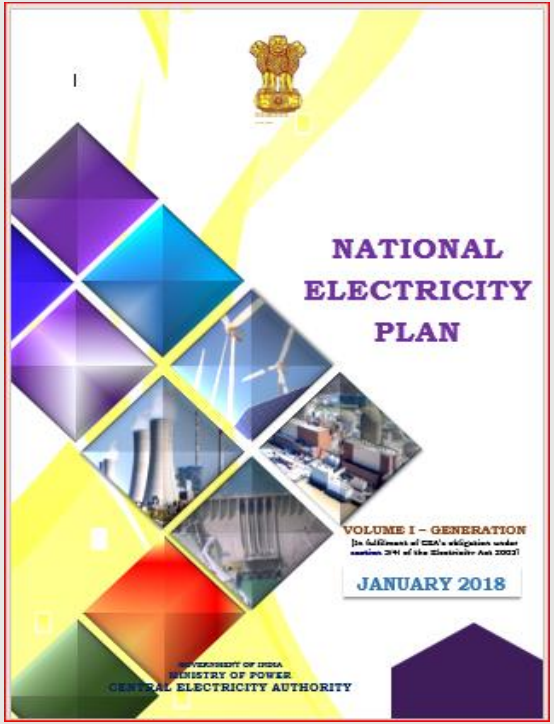
Criteria
• Demand Variation • Variation in Capital Cost • Reduction in VRE Generation • Reduction in Hydro Generation

10% reduced variable RE generation & 6% reduced Hydro generation

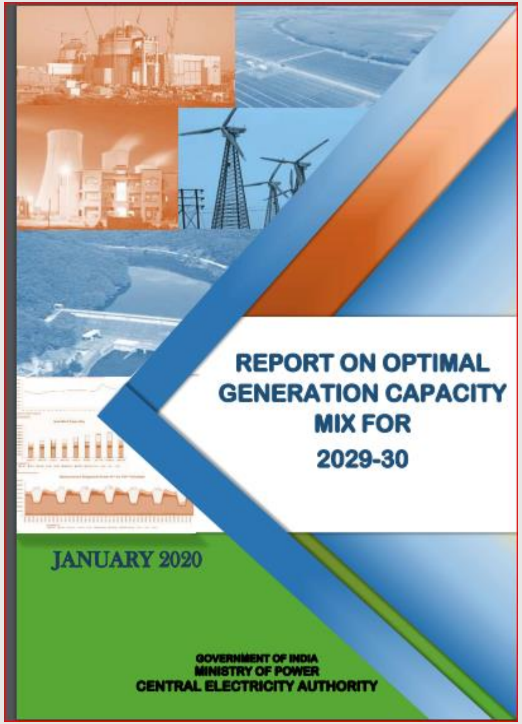




Availability of coal based power plants has to be increased by only 1.5% to fulfill the demand



https://cea.nic.in/reports/committee/nep/nep_jan_2018.pdf



https://cea.nic.in/reports/others/planning/irp/Optimal_mix_report_2029-30_FINAL.pdf

CURRENT PRACTICES OF RESOURCE PLANNING AND INTERNATIONAL BEST PRACTICES

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Faculty - Dr. Rafael Kelman, Executive Director, PSR Consulting

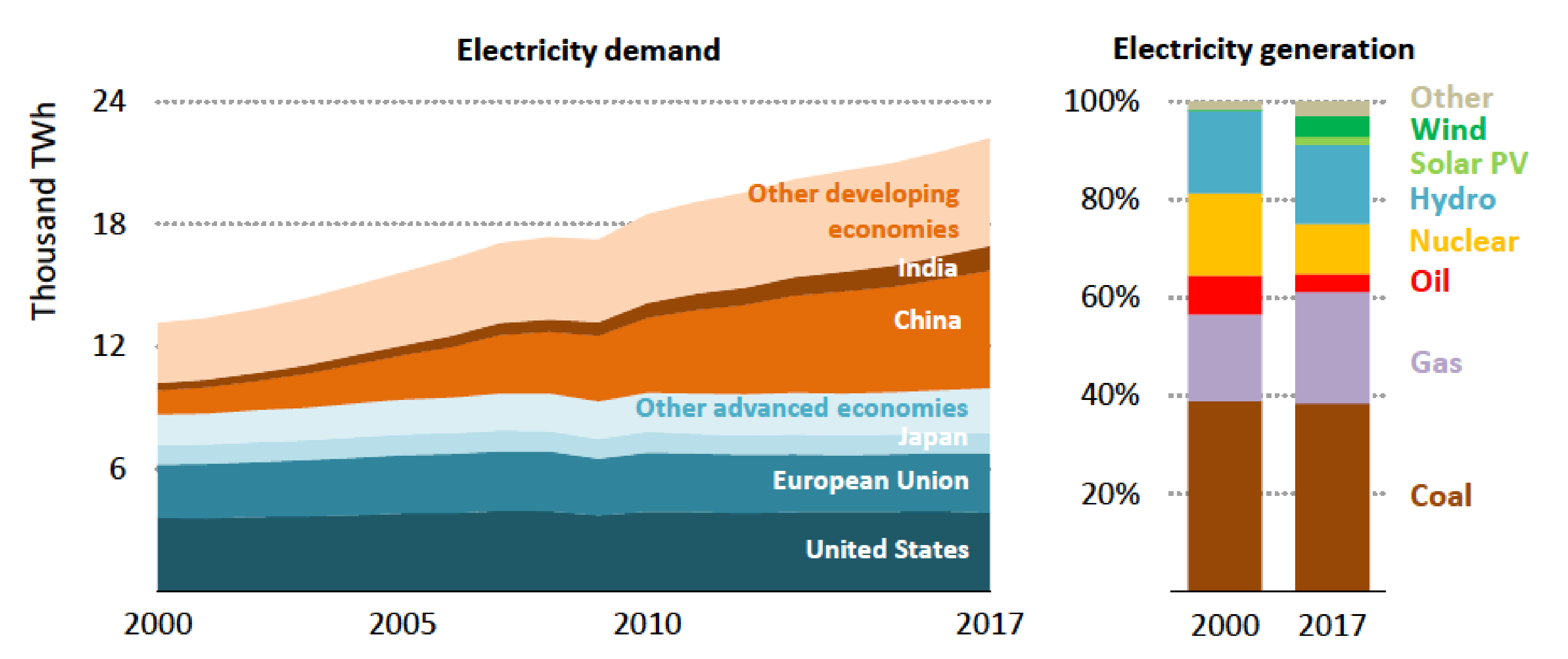
Dr. Rafael Kelman

- BSc in Civil Engineering, MSc in Water Resources and PhD in Optimization from COPPE/UFRJ.
- Dr. Kelman coordinates studies in power sector, such as the integration of renewable energy, market studies and water-energy nexus. He also participates in the development of models ranging from long-term planning to short-term scheduling of power systems.

Summary

- Background
- Integrated Resource Planning
- Models
- International experience
- The Brazil Case
- DER Cost x Benefit analysis
- DER endogenous modeling
- DER Selected cases
- References

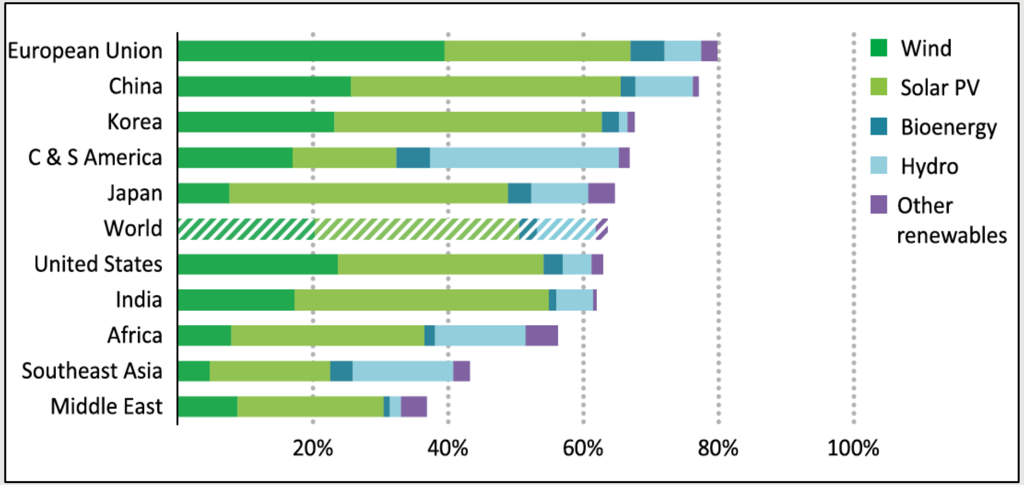
Motivation: the energy transformation



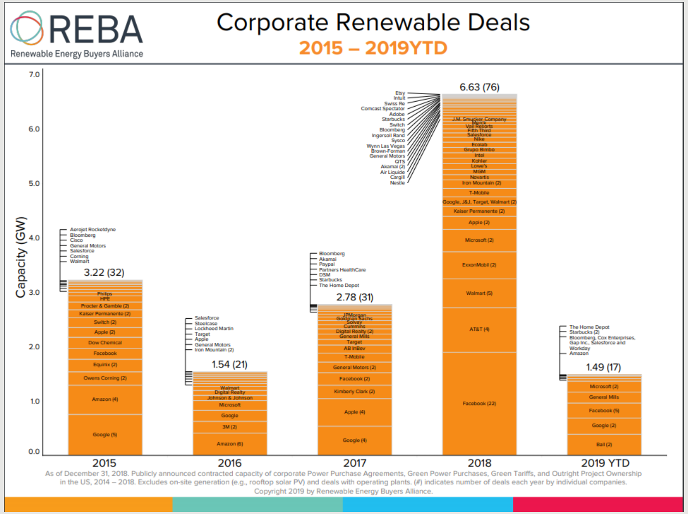
Source: IEA, 2018

Motivation: the energy transformation

RES % in capacity expansion (2018-2040)

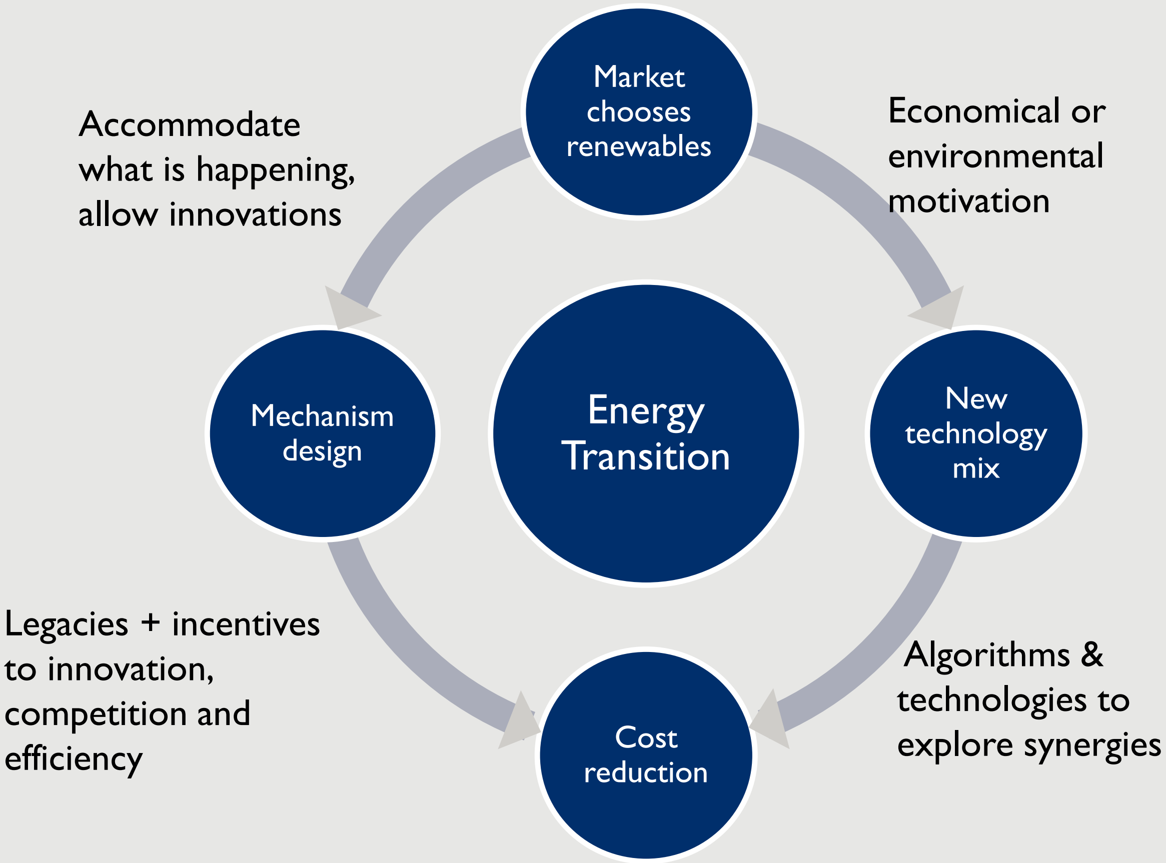


“Corporate Procurement” (voluntary) of RES



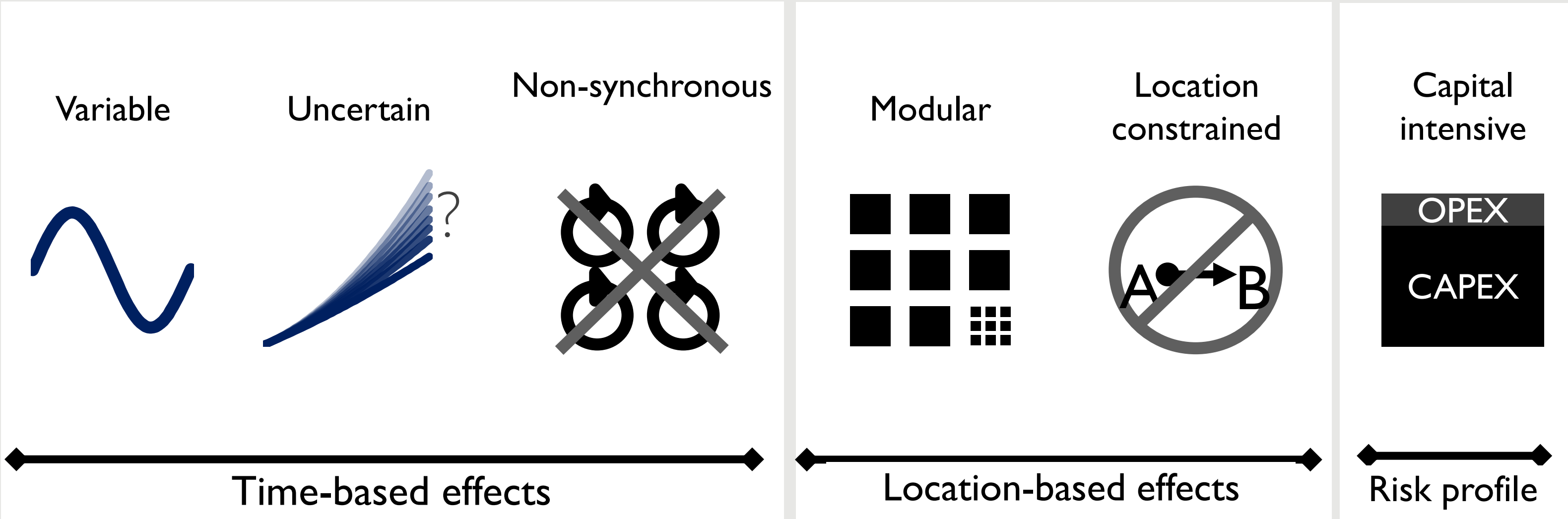
Source: IEA, 2018; REBA 2019

Motivation: the global energy transformation



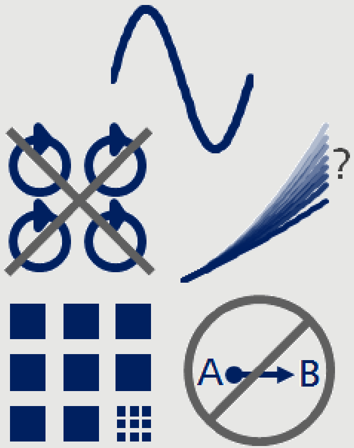
This brings the renewable integration challenge

- What makes variable renewable energy (VRE) or renewable energy sources (RES) different?



- These six properties drive all relevant techno-economic system integration effects

Flexibility is the tool for handling system integration



Technical flexibility

- Power plants that can start quickly, have a wide output range & provide many services
- Grids to connect distant and distributed VRE plants, smooth variability & pool flexibility
- Demand shaped to better match VRE availability (structurally & dynamically) and provides system services
- Storage that provides system services, reduces need for other flexibility and balances remaining surplus/deficit

Flexible markets, policy & regulation

- Rules that deliver fast system operations based on economic dispatch
- New modelling needs
- Balancing demand/supply across large geographic areas
- Level playing field for new technologies incl. for providing system services

Flexible institutions

- Processes and institutional culture to 'keep up' in a rapidly changing environment

Properties of VRE

Power system flexibility

Flexibility describes all characteristics of a power system that facilitate the reliable and cost-effective management of variability and uncertainty in supply/demand on all time and geographic scales.

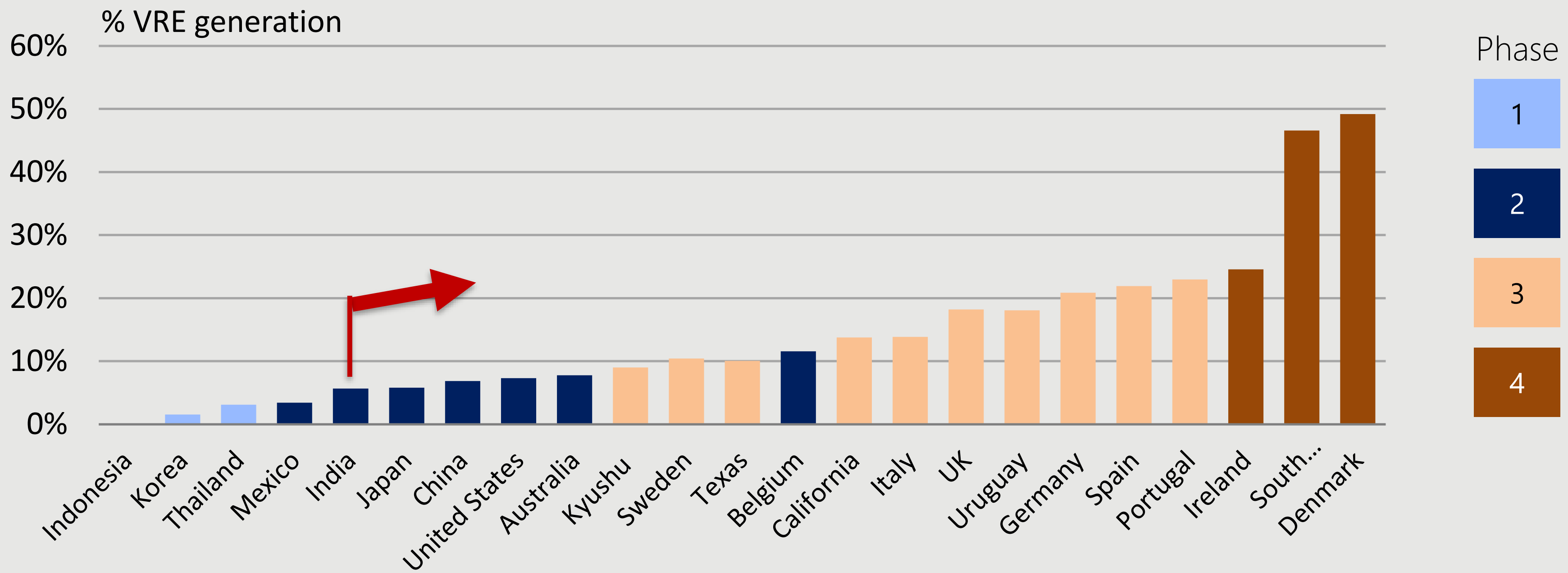
Six phases of system integration

Phase	Description
1	VRE capacity not relevant at the power system level
2	VRE capacity becomes noticeable to the system operator: operational changes and better use of existing flexibility required
3	VRE systematically determines electricity supply leading to greater swings in the supply/demand balance: additional power system flexibility required
4	VRE can supply large majority of demand at certain times: new ways to ensure system stability required
5	Structural surpluses emerge, VRE supply systematically exceeds traditional electricity demand: electrification of other sectors becomes relevant
6	VRE can meet most electricity demand except during weeks/seasons with very low availability: seasonal storage and synthetic fuels become relevant

Source: adapted from: IEA (2018) Status of Power System Transformation 2018

Where countries stand

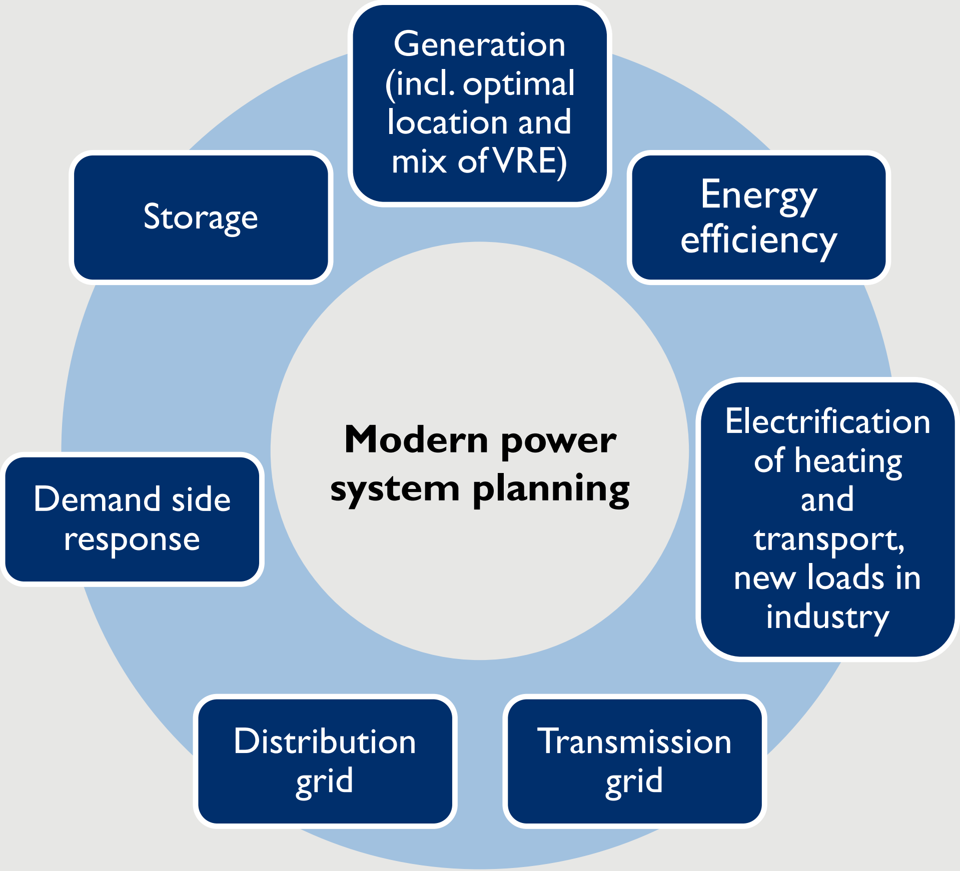
- VRE share in annual electricity generation and system integration phase, 2017



- Typical country-level integration issues determine national phase. Regions within a country can be at a different phase

Source: IEA (2018) *Renewable 2018 - Analysis and Forecasts to 2023*

Integrated planning with state-of-the-art tools is crucial

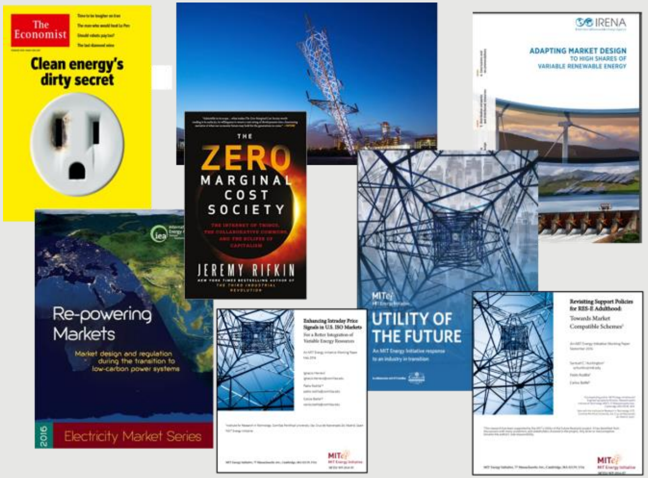


State-of-the-art (probabilistic) modeling tools are indispensible for successful VRE integration

- Need to combine long-term view on expansion with short-term view of operation
  - (sub) Hourly time steps
  - Unit commitment decisions
  - Ramping constraints
  - Hydraulic constraints in river basins
  - Variability of renewables, inflows & demand (uncertainties)
  - Energy, capacity and reserve requirements

RES penetration and market design challenges…

Efficient operation of the power system	› Ensuring least-cost dispatch › Trading close to real time › Market integration over large geographic areas
Unlocking flexibility from all resources	› **Upgrade planning and system service markets** › **Generation**, grids, demand shaping and storage
Security of electricity supply	› Adequacy: improve pricing during scarcity; possibly capacity mechanisms as safety-net › **Security: ensure appropriate tools for system operators**
Sufficient investment in clean generation capacity	› Sufficient investment certainty › Competitive procurement (with long-term contracts)
Pricing of externalities	› Reflecting the full cost (i.e. environmental impacts)



Source: IEA

Energy planning is becoming important once again…

Planning for the renewable future: Long-term modelling and tools to expand variable renewable power in emerging economies

January 2017
ISBN : 978-92-95111-06-6
Download

Ambitious national commitments, international agreements and rapid technological progress have prompted countries around the world to turn increasingly renewable energy to expand their power infrastructure. However, the variability of solar and wind energy – two key sources for renewable power generation – presents new challenges.

Proactive energy planners will address
energy (VRE) integration directly, starti
Techno-economic assessments can hel
optimal targets for renewable power u
has become a critical planning tool for
knowledge being acquired in certain m
term models.

IRENA
International Renewable Energy Agency

ABOUT OUR WORK RENEWABLES

Home

Long-term Energy Scenarios (LTES) campaign

The **Long-term Scenarios for Energy Transition (LTES)** campaign, launched at the Ninth Clean Energy Ministerial (CEM9) in Copenhagen, Denmark, aims to promote the wider adoption and improved use of long-term model-based energy scenarios to support and accelerate the energy transition among CEM countries and beyond. The campaign does not aim to develop new models or scenarios.

Focusing on three interconnected themes, the campaign will support wider and more effective use of long-term energy scenarios by:

can use energy
ps can be made more

energy scenarios
es to the energy

scenario
hance institutional

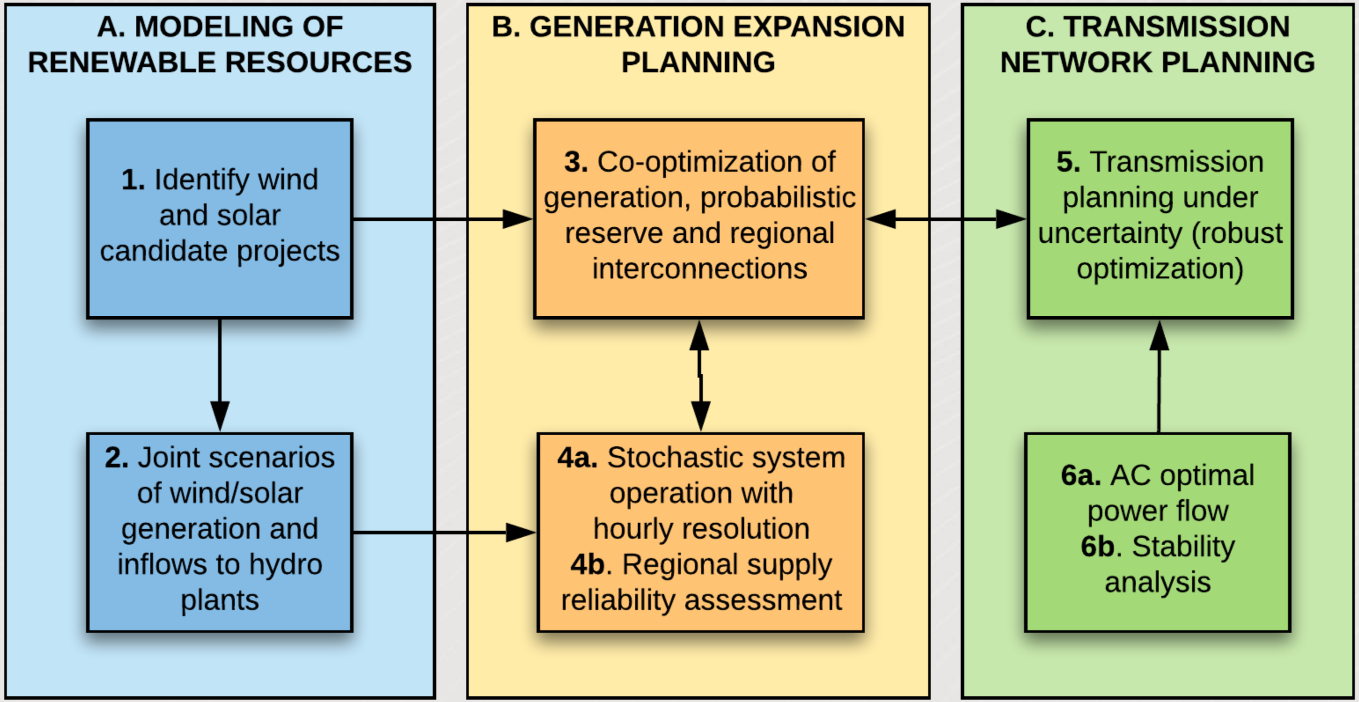
The campaign is co-led by Danish and German governments and supported by additional country members and technical partners. IRENA executes the campaign as the operating agent, organising a series of workshops to promote an exchange of insights and compile best practices among members, partners and beyond.

The campaign will have a strong presence at CEM 10 in Vancouver in May, 2019 where scenario development best practices and future recommendations will be presented to ministers and high-level participants.

The following governments have signed up to the LTES CEM campaign: Brazil, Canada, Chile, Denmark, Finland, Germany, Japan, Mexico, Netherlands, United Arab Emirates and United Kingdom.

The CEM campaign is also supported by a number of technical institutions. For more details about the campaign, visit the Clean Energy Ministerial.

G&T Expansion planning: (PSR approach)

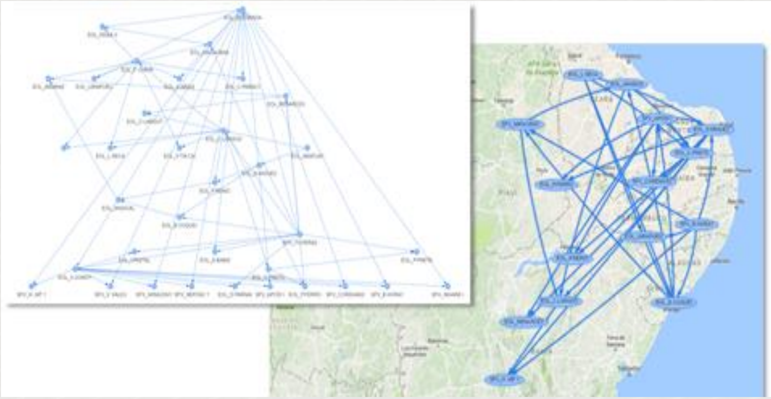


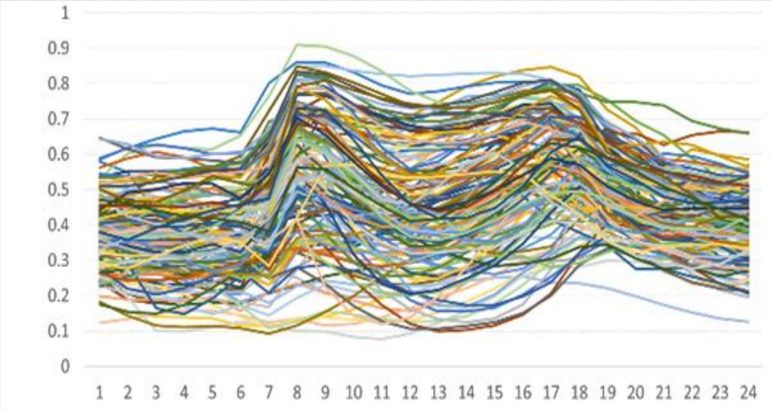
Activity A - Modeling of renewable resources

- Identify candidate projects for wind and solar generation.
  - As with hydropower projects, which require historical inflow records, each renewable candidate requires historic energy production with hourly resolution.
  - This is usually done with global databases, such as MERRA-2, which contain ~40 years of hourly wind speed and solar radiation data for the entire planet.
- Data for each candidate site is refined/calibrated based on the measured wind / solar records (usually 2-3 years) from existing neighboring plants.
- Finally, the calibrated wind speed and the solar records are transformed into 40 years of hourly energy production using the parameters of the candidate project (type of wind turbine, hub height, solar trackers, etc.).

Activity A - Modeling of renewable resources

- Generation scenarios for existing and candidate renewable sources, including hydro.
  The methodological challenges are:
  - Significant spatial correlation between wind energy and inflows in some regions.
  - Generation of scenarios must be integrated (wind, solar, and inflows to hydro plants) and with multiple time scales (hourly for wind & solar, monthly/weekly for inflows).
  - Integrated/multiscale scenarios produced by a Bayesian network, a statistical model with variables and their conditional dependencies represented through a graph



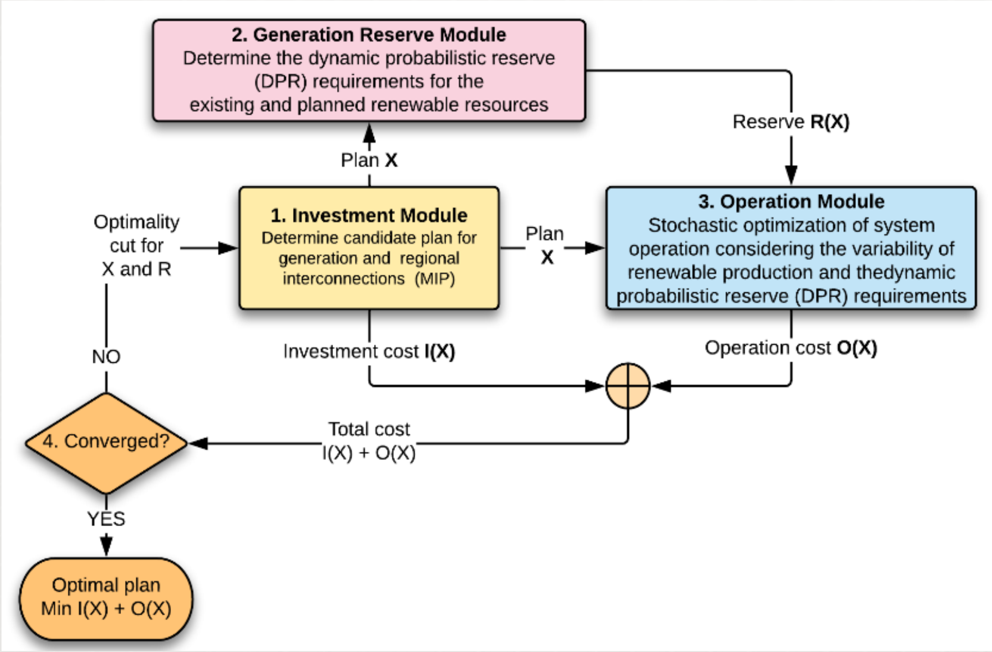


Activity B - Planning the expansion of G&T

- The objective of this activity is to determine the set of generation and regional interconnections reinforcements over the planning period that minimize the present value of the sum of investment costs and expected value of operating costs (fuel costs of thermal plants plus penalties for power supply failure).
- The amount of flexibility resources required to manage the variability of renewable sources decided with a Dynamic Probabilistic Reserve (DPR) (arXiv preprint arXiv:1910.00454).
- The DPR determines for each hour the amount of fast response generation reserves (batteries, hydro, natural gas plants etc.) necessary to compensate for the uncertainty of renewable production in consecutive hours.
- The calculation of probabilistic generation reserves for renewables is a topic of intense research worldwide. The differential of DPR in relation to other methodologies is that the required reserve automatically adjusts to the entrance of new renewable projects

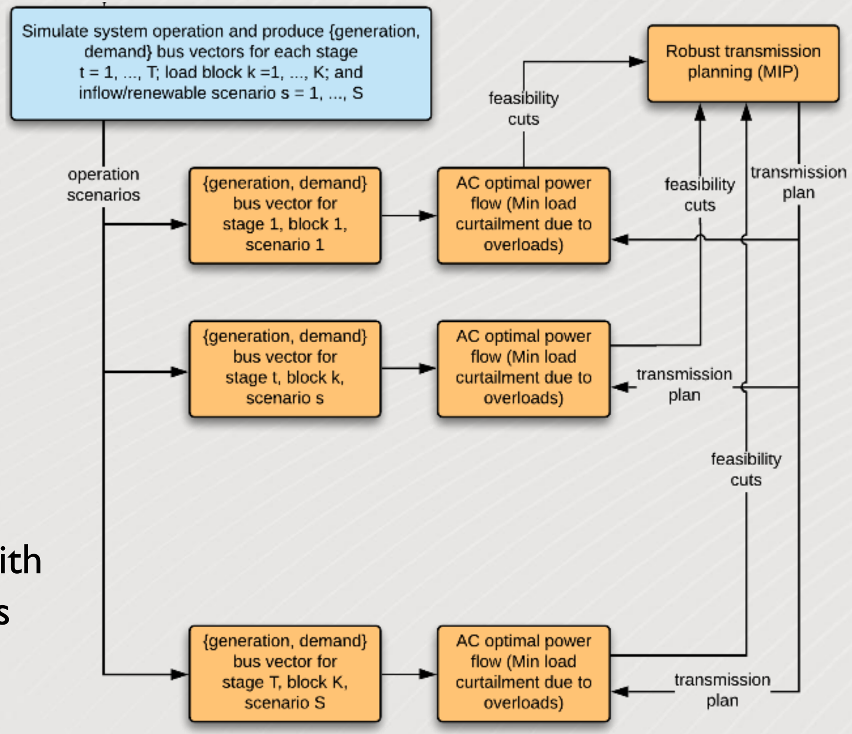
Activity B - Planning the expansion of G&T

- The optimal plan results from the iterative solution of 3 modules:
  - decision to invest in new capacity (candidate plan *X*);
  - calculation of DPR requirements R(*X*) for plan *X*;
  - stochastic system operation for plan *X* and reserve R(*X*).
- The iterative process produces the optimal plan *X** that minimizes investment costs I(*X**) + operation O(*X**).



Activity C - Transmission planning under uncertainty

- Variability of hydro, wind and solar power leads to diverse power flow patterns in the grid.
- Renewable sources often built in places with no foreseeable power injections.
- Reinforcement of transmission grid to accommodate multiple generation patterns is required to avoid dispatch of more expensive generators to alleviate overloads or avoid load shedding.
- Robust transmission plan must be feasible (i.e. with no overloads) for each of the multiple conditions that result from the probabilistic operation from the expansion plan of Activity B



Adding flexibility to transmission

- Power injection at selected nodes to alleviate overloads either with dispatchable generation or batteries / pumped-hydro-storage projects
- By modifying the circuit reactance, redistributing power flows according to Kirchhoff's law
  - FACTS (Flexible AC Transmission Systems) technologies allow the control of power flow and voltage, in addition to acting on power quality issues such as voltage compensation and current harmonics in the grid. They fit into a wide range of applications, as they are modular, reusable and have short delivery times.
  - Many of these devices provide sensors that enable real-time monitoring of operating conditions, such as power flow limits in transmission lines adjusted for temperature and wind conditions (dynamic line rating).
- Change in grid topology by (dis)connecting one or more circuits (circuit switching)
- Non-Wires Transmission: the effect of transferring X MW from point A to point B is emulated through a combination of demand response and distributed generation. Non-Wire Alternatives (NWA) have attracted attention in the United States.

Computational models

- Support IRP activities with objective of reducing cost of achieving policy goals, such as GHG reductions by mapping available resources and then selecting the portfolio of project and actions that minimize total costs while maintaining system reliability.
  - Importance of mapping resources well
  - Importance of forecasting load well for adequate planning
- Various objective, such as: Load forecasting, Capacity expansion, Production costing, Security Constrained Unit Commitment and so on. Usually more than one model is used.
- Key aspects must be addressed before deciding which computational tools to use:
  - Features and limitations (e.g. deterministic vs. probabilistic approach, full grid x sing-bus model, etc.)
  - Ability of the development team to customize the models according to client needs (flexibility),
  - If tool is user-friendly and user-support is adequate
  - If the tool can be easily integrated with other tools
  - Licensing cost and others

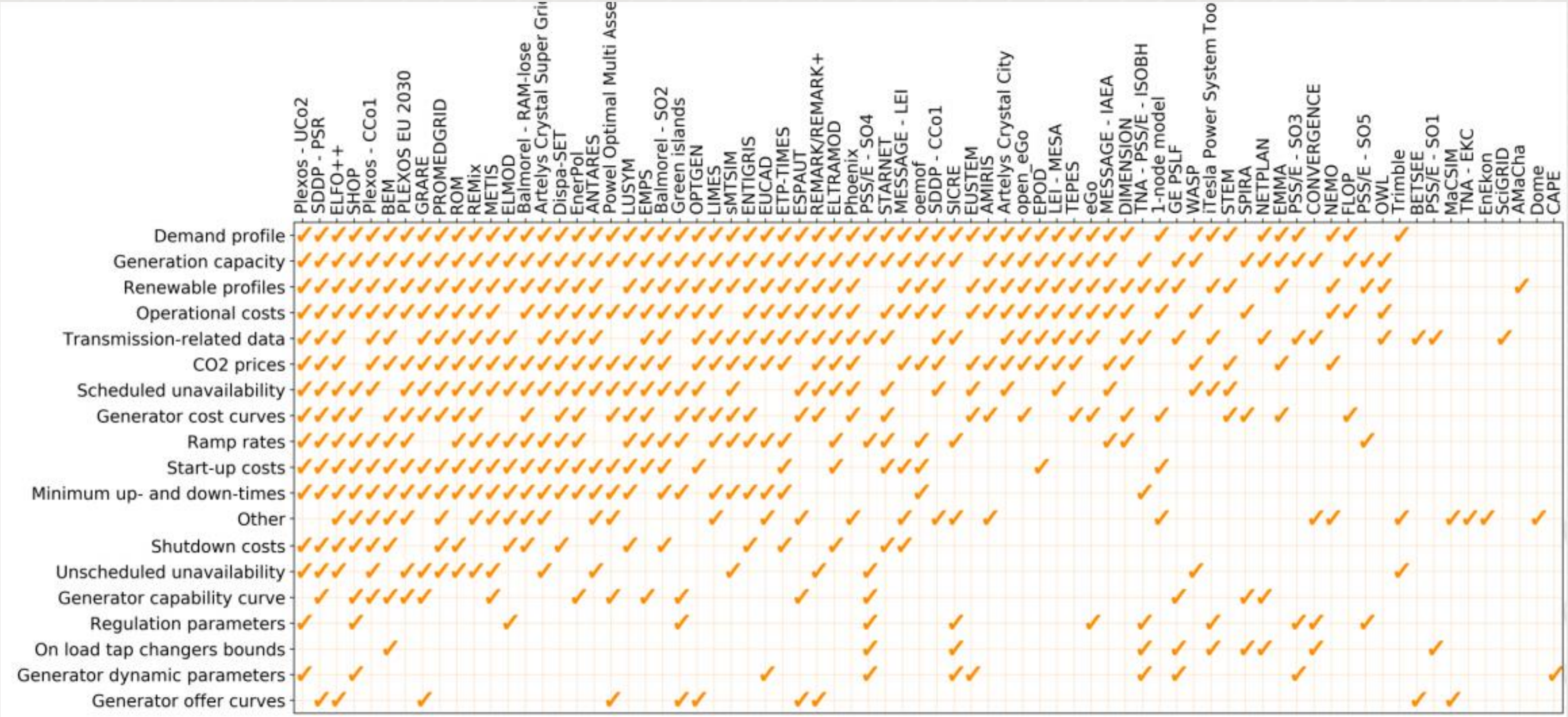
Computational models

Software-related features: about 2/3 of the models require 3rd software such as commercial optimization solvers or off-the-shelf software. Only 14% of the models are open source.
Modelling-related features: models are mostly defined as optimization problems (78%), simulation (33%) or equilibrium problems (13%). 71% of the models solve a deterministic problem while 41% solve probabilistic or stochastic problems.
Modelled power system problems: the economic dispatch problem is the most modelled problem with a share of approximately 70%, followed by generation expansion planning, unit commitment, and transmission expansion planning, with around 40–43% each. Most of the models (57%) have non-public input data while 31% of models use open input data.
Modelled technologies: hydro, wind, thermal, storage and nuclear technologies are widely considered.

Systematic mapping of power system models, JRC 2017

Computational models

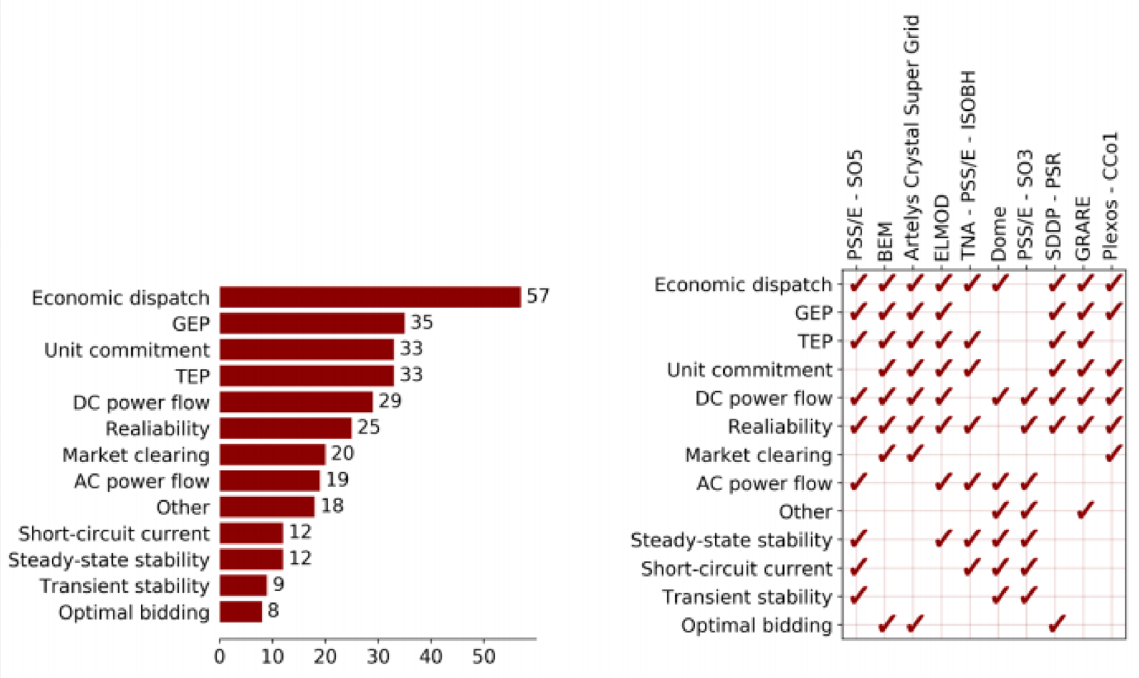
- Key input data for all models according to the survey



Source: systematic mapping of power system models, JRC 2017

Computational models

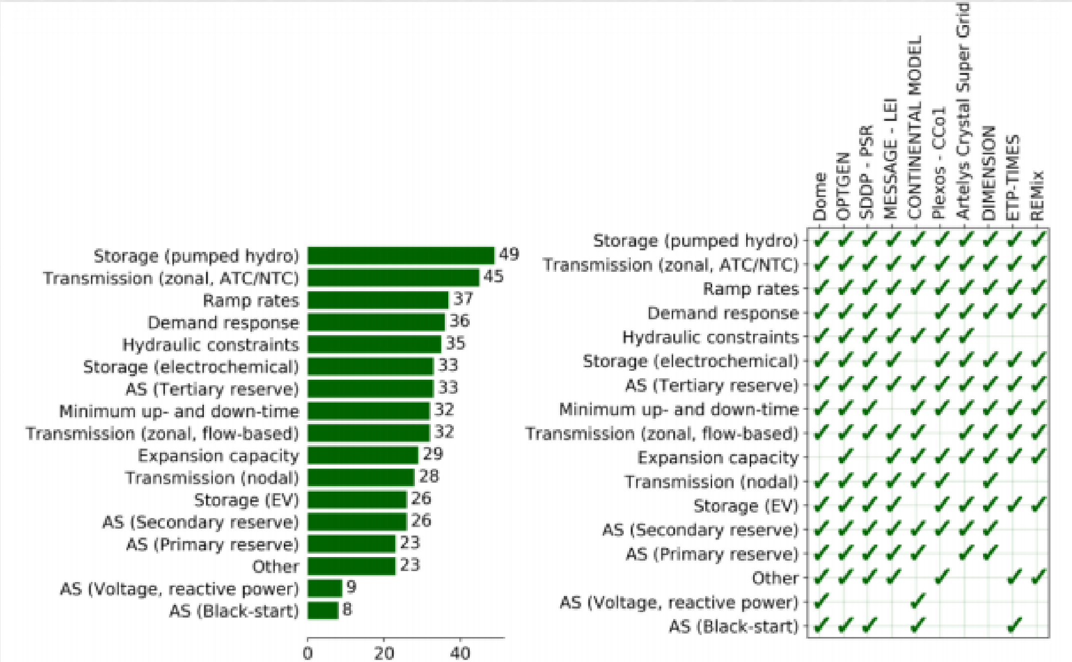
- Power system problems addressed by the tools (left plot) and mapping of the top ten tools modelling more power system problems (right plot).



Source: systematic mapping of power system models, JRC 2017

Computational models

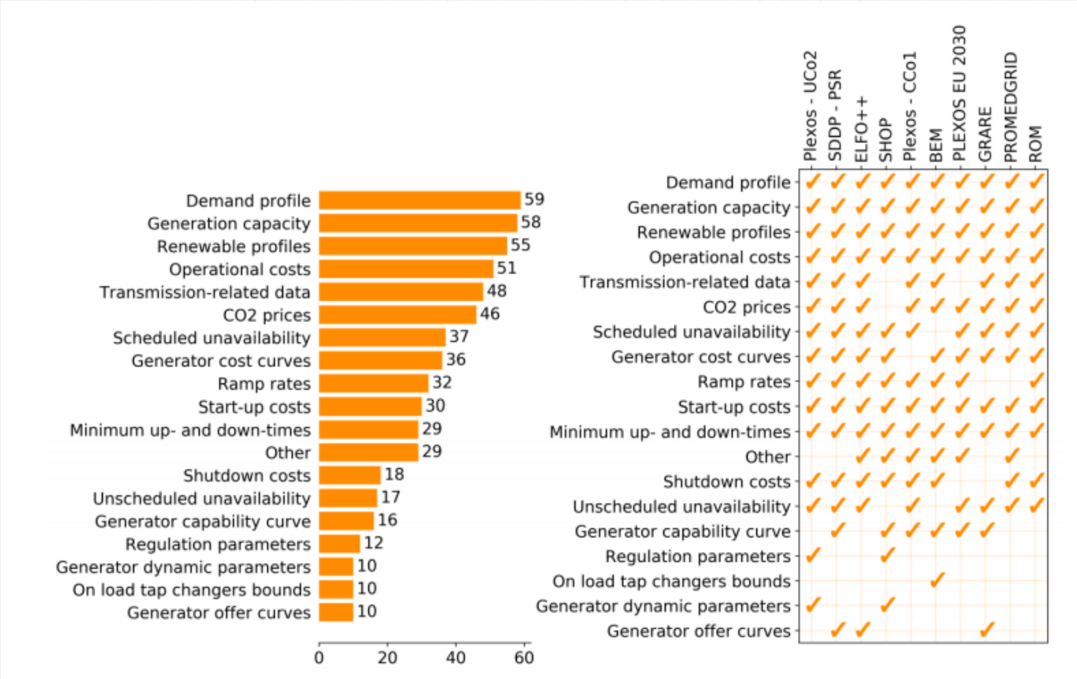
- Technical constraints considered by the participating models (left plot) and mapping of the top ten models incorporating more technical constraints (right plot).



Source: systematic mapping of power system models, JRC 2017

Computational models

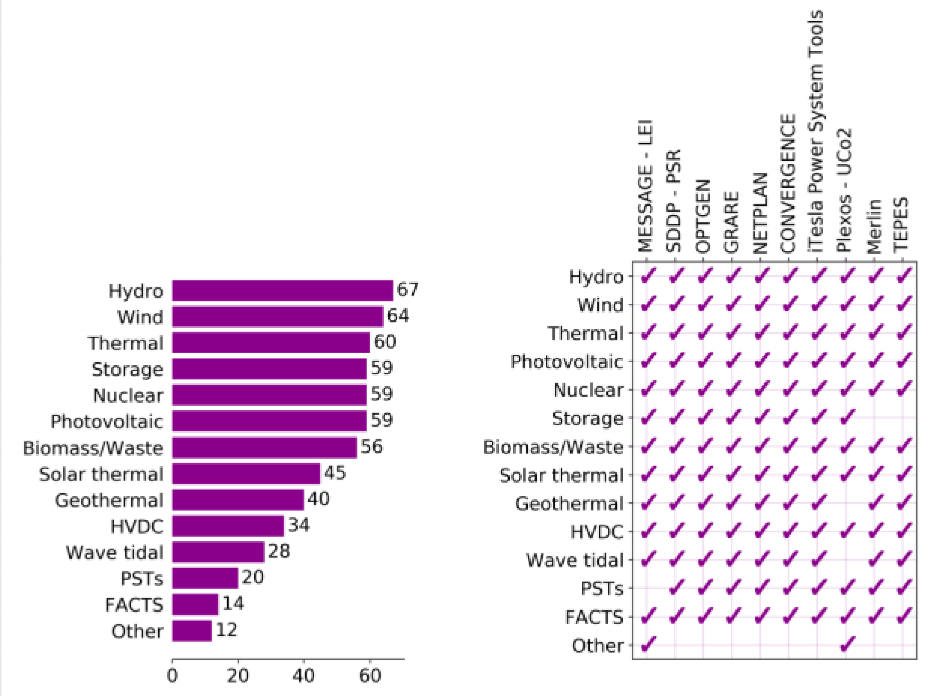
- Key input data considered by the participating models (left plot) and mapping of the top ten models incorporating more key input data (right plot)



Source: systematic mapping of power system models, JRC 2017

Computational models

- Technologies considered by the participating models (left plot) and mapping of the top ten models considering more technologies (right plot)



Source: systematic mapping of power system models, JRC 2017

United States

- Utilities follow different methodologies in Integrated Resource Planning.
- Example from CPUC 2019-2020 Proposed Reference System Plan:
  - *The value proposition of integrated resource planning is to reduce the cost of achieving GHG reductions and other policy goals by looking across individual LSE boundaries and resource types to identify solutions to reliability, cost, or other concerns that might not otherwise be found.*
- IRP from CPUC
  - Tools: capacity expansion model (RESOLVE) and production cost model (SERVM).
  - Demand forecasting and generation adequacy studies covering a period of 10 years.
  - Utilities prepare the plan based on the studies and submit the findings and plans to the public service commission: system needs, local needs and flexibility needs.
  - If needed and approved by CPUC, utilities solicit offers for capacity, energy, DSM and energy efficiency.

United States

- Example 1: 2012 LTPP authorized procurement for reliability in two transmission constrained zones of Southern California: the Western LA Basin and Venture-Big Creek local reliability areas. The decision authorized 1400-1800 MW capacity in the West Los Angeles subarea, including 1000-1200 MW of conventional gas-fired resources, 50 MW of energy storage, and 150-600 MW of preferred resources.
- Example II: Retirement of San Onofre Nuclear Generation Stations

This is the Track 4 decision in the 2012 long-term procurement proceeding. In this decision, we authorize Southern California Edison Company (SCE) to procure between 500 and 700 Megawatts (MW), and San Diego Gas & Electric Company (SDG&E) to procure between 500 and 800 MW by 2022 to meet local capacity needs stemming from the retired San Onofre Nuclear Generation Stations (SONGS). SCE is required to procure at least 400 MW, and may procure up to the full 700 MW of authorized additional capacity, from preferred resources or energy storage. SDG&E is required to procure at least 200 MW, and may procure up to the full 800 MW of authorized additional capacity, from preferred resources or energy storage.

Europe (general)

- ENTSO-E, the European Network of Transmission System Operators for Electricity, represents 43 electricity Transmission System Operators (TSOs) from 36 countries across Europe.
- ENTSO-E performs the Mid-term Adequacy Forecast (MAF) every year up to 10 years ahead. MAF evaluates power system resource adequacy with a sequential Monte Carlo probabilistic methodology using market-modeling tools.
- The Regulation further establishes that this outlook shall build on national generation adequacy outlooks prepared by each individual TSO, which implicitly is constraining the approach to bottom-up scenarios.
- The methodology for adequacy assessment is implemented in five different market modeling tools, namely, ANTARES, BID3, GRARE, PLEXOS and PowrSym.

United Kingdom

- The Electricity Capacity Report **(ECR**) summarizes the modeling analysis of the National Grid, the system operator in UK, to support Government decision on the amount of capacity to secure through Capacity Market auctions for delivery in future.
- The Government requires National Grid to provide a recommendation for each year studied based on the analysis of several scenarios.
- Demand forecasting includes energy (TWh/year) demand and electricity peak demand (GW). The drivers considered across sectors include Demand Response, Distributed Generation, Storage, Thermal efficient building, EV uptake and Energy Efficiency.
- Several scenarios are studied for supply adequacy. It is noticed that the system requires greater generation flexibility as VRE share increases. Total eligible de-rated capacity needs to be secured to achieve a reliability standard of 3 hours LOLE.

ASSAM India*

- Demand
  - ASSAM Distribution company projects demand by directly with a CAGR for up to 5 years
  - Globally, several systems demand is forecasted typically for a longer period (e.g. 10-years) with tools and forecasting methods such as time series, econometric models or Artificial Neural Networks.
- Supply
  - For supply, ASSAM considers Existing and Future Capacity from State generation, Central Generation Share (CGS), Renewables and Procurements.
  - Globally, several systems are using integrated resource planning models to guide new investments (either centralized or by the market, through auctions).
  - Variable renewable energy and distributed energy resources increase complexity and pose methodological challenges in the integration of utility scale (high voltage) planning with distribution response. (Sub) hourly load and scenarios of non-dispatchable generation are used together with flexible resources to identify supply adequacy in the long-term.

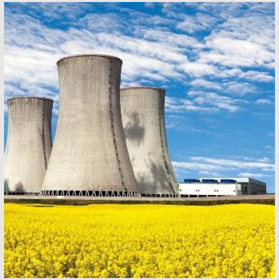
* India load forecasting and resource optimization Gap analysis report - Assam

1. Brazil IRP case: candidate projects

- Candidate project preparation per technology resulted from discussions between Consultants and EPE based on market references (mainly auctions)
- Coal, open cycle and combined cycle natural gas, nuclear, biomass, wind, solar PV, storage devices, no hydropower after 2026.
- Technical parameters (such as ramps, startup costs and possible dispatch models)
- Economic parameters, such as CAPEX and OPEX (fixed and variable) and fuel prices
- Expected technological advances considered (e.g. increase in turbine size, decrease of costs for solar, wind and storage)
- Utility scale optimized; exogenous DG scenario used.



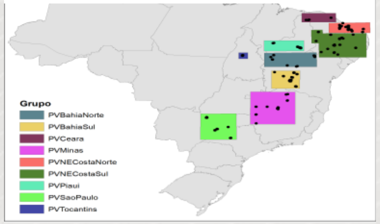


Wind candidates

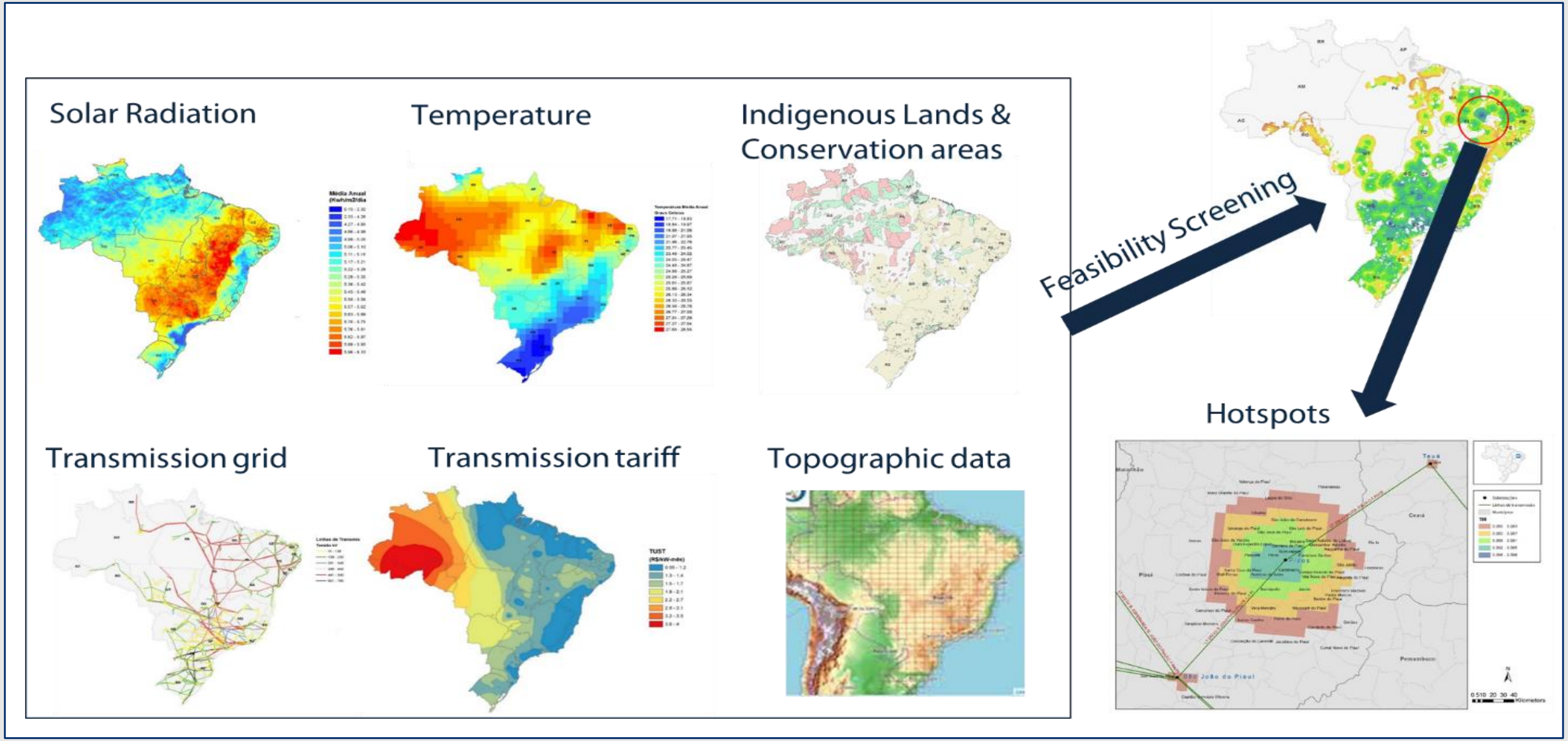
- Candidate projects from energy auctions (~800 wind projects and 400 solar projects totaling or 22 GW)
- Known data: bus connection and capacity
- Investment cost, fixed O&M cost and lifetime based on market values
- Wind velocity / solar irradiation time series taken from reanalysis data (MERRA2 / NASA)
- Classification attributes: intraday and seasonal wind velocities using a minimum spanning tree algorithm resulted in 22 wind regions and 9 solar regions
- Calibration of simulated (model-based) production based on historical production

Solar PV regions



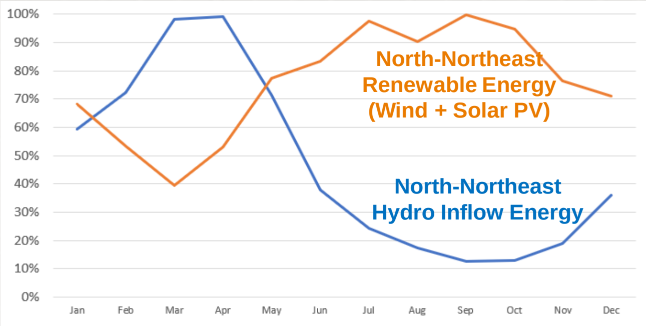
Wind regions

Solar PV project preparation

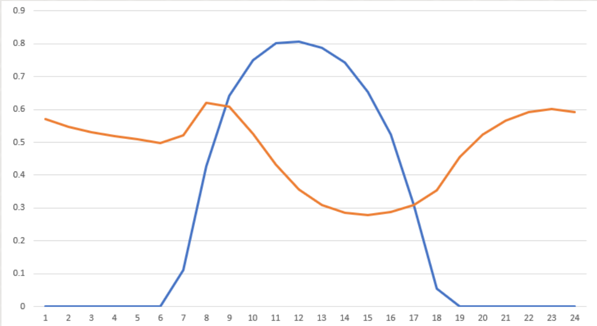


Hydro, wind and solar complementatities need to be captured

Wind-hydro seasonal complementarity



Wind-solar daily complementarity



Wind parks location

Wind-wind correlation matrix

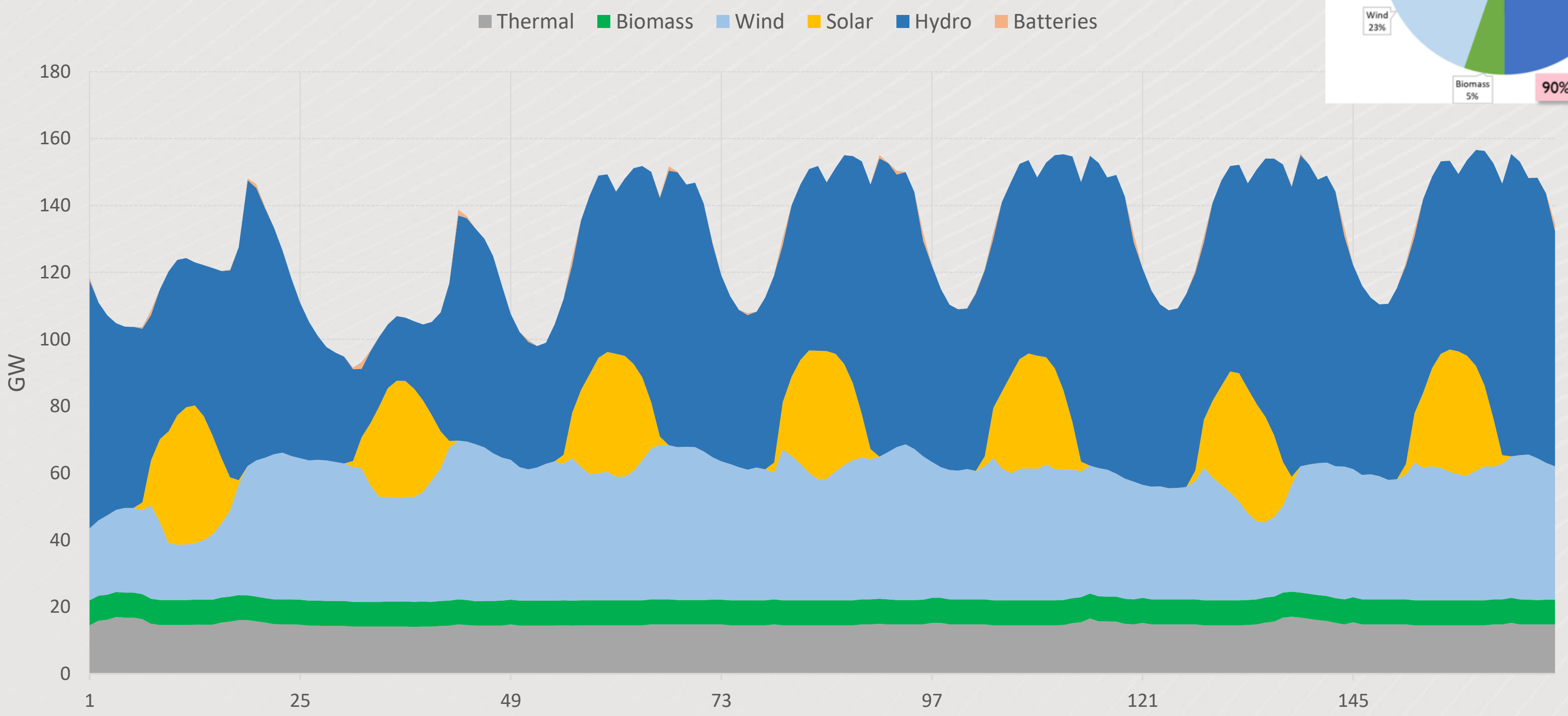
	W110	W175	W124	W136	W282	W426	W458
W110	1.00						
W175	0.93	1.00					
W124	1.00	0.95	1.00				
W136	0.98	0.97	0.99	1.00			
W282	0.41	0.26	0.39	0.35	1.00		
W426	0.25	0.17	0.24	0.24	0.54	1.00	
W458	0.17	0.20	0.18	0.19	0.35	0.65	1.00

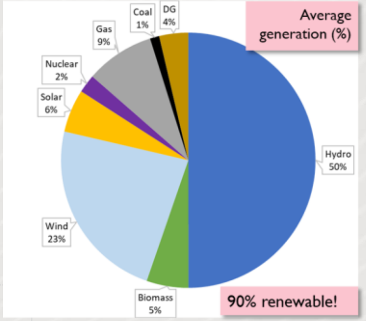
Wind-hydro correlation matrix

	W110	W175	W124	W136	W282	W426	W458
ROSANA	0.34	0.40	0.35	0.38	0.20	0.48	0.43
BARRA GRANDE	0.32	0.34	0.32	0.35	0.36	0.35	0.13
MACHADINHO	0.32	0.33	0.32	0.34	0.41	0.40	0.18
TAQUARUCU	0.31	0.38	0.32	0.36	0.16	0.47	0.43
CAPIVARA	0.31	0.38	0.31	0.35	0.15	0.45	0.41
OURINHOS	0.30	0.37	0.31	0.34	0.02	0.35	0.31
CHAVANTES	0.30	0.36	0.31	0.34	0.02	0.35	0.30
CAMPOS NOVOS	0.30	0.29	0.30	0.31	0.43	0.41	0.24
GARIBALDI	0.30	0.29	0.30	0.31	0.44	0.42	0.25
ITA	0.29	0.29	0.29	0.31	0.40	0.37	0.14
QUEBRA QUEIX	0.29	0.30	0.30	0.31	0.31	0.41	0.28
L.N. GARCEZ	0.28	0.34	0.28	0.32	0.06	0.37	0.33
CANOAS II	0.28	0.34	0.28	0.32	0.06	0.37	0.33
CANOAS I	0.28	0.33	0.28	0.32	0.07	0.37	0.34
FOZ CHAPECO	0.27	0.26	0.27	0.28	0.38	0.36	0.10
STA CLARA PR	0.27	0.31	0.27	0.30	0.32	0.37	0.40
JORDAO	0.27	0.30	0.27	0.29	0.32	0.37	0.39
FUNDAO	0.27	0.31	0.27	0.29	0.32	0.37	0.40
ERNESTINA	0.26	0.26	0.25	0.25	0.40	0.43	0.21
PASSO FUNDO	0.26	0.25	0.25	0.26	0.40	0.43	0.09

	W110	W175	W124	W136	W282	W426	W458
B. ESPERANCA	-0.66	-0.58	-0.66	-0.65	-0.32	-0.32	-0.24
CURUA-UNA	-0.56	-0.56	-0.55	-0.55	-0.37	-0.26	-0.26
MANSO	-0.52	-0.41	-0.52	-0.49	-0.57	-0.39	-0.13
ESPORA	-0.45	-0.42	-0.45	-0.44	-0.33	-0.35	-0.14
JIRAU	-0.40	-0.41	-0.40	-0.39	-0.33	-0.03	0.00
STO ANTONIO	-0.40	-0.41	-0.40	-0.38	-0.33	-0.03	0.00
BELO MONTE A	-0.40	-0.43	-0.40	-0.41	-0.48	-0.46	-0.44
DARDANELOS	-0.38	-0.35	-0.39	-0.37	-0.41	-0.29	-0.29
ESTREITO TOC	-0.38	-0.36	-0.39	-0.40	-0.55	-0.47	-0.40
SAO MANOEL	-0.37	-0.38	-0.37	-0.38	-0.64	-0.37	-0.38
TELES PIRES	-0.37	-0.38	-0.37	-0.38	-0.64	-0.37	-0.38
SALTO DO RIO	-0.37	-0.38	-0.38	-0.39	-0.18	-0.21	-0.10
SALTO	-0.35	-0.38	-0.37	-0.38	-0.16	-0.20	-0.09
JAURU	-0.35	-0.42	-0.38	-0.38	0.12	0.14	0.14
TUCURUI	-0.35	-0.41	-0.36	-0.39	-0.37	-0.32	-0.35
SAMUEL	-0.34	-0.35	-0.36	-0.35	-0.35	-0.30	-0.41
COLIDER	-0.33	-0.32	-0.33	-0.34	-0.62	-0.41	-0.33
SINOP	-0.33	-0.32	-0.33	-0.34	-0.61	-0.37	-0.30
RONDON II	-0.31	-0.26	-0.32	-0.30	-0.39	-0.45	-0.56
ROSAL	-0.31	-0.26	-0.30	-0.30	-0.25	-0.37	-0.41

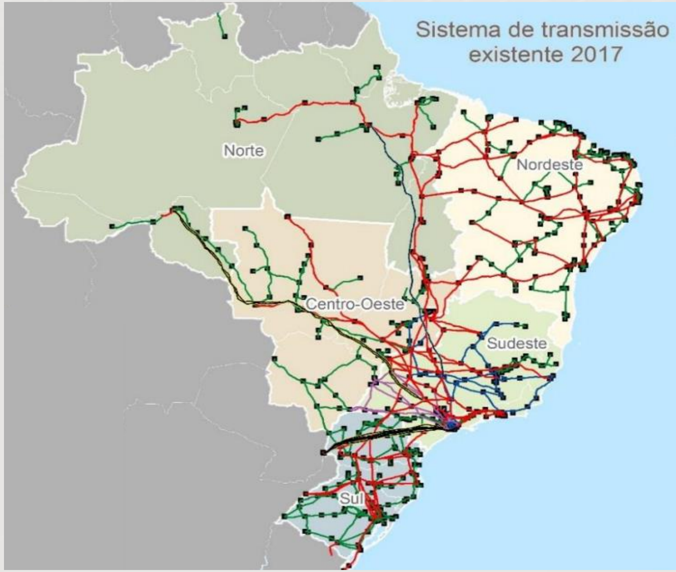
Weekly operation at end-of-horizon (August)

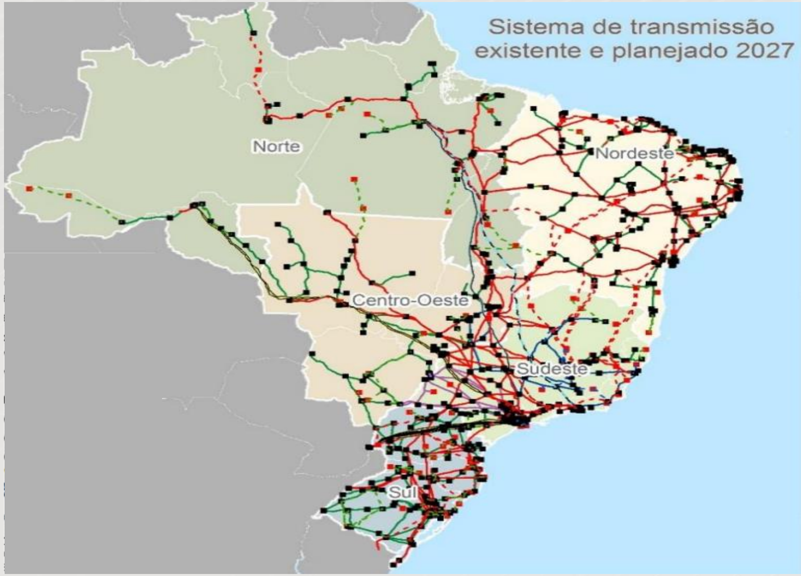




Transmission reinforcements

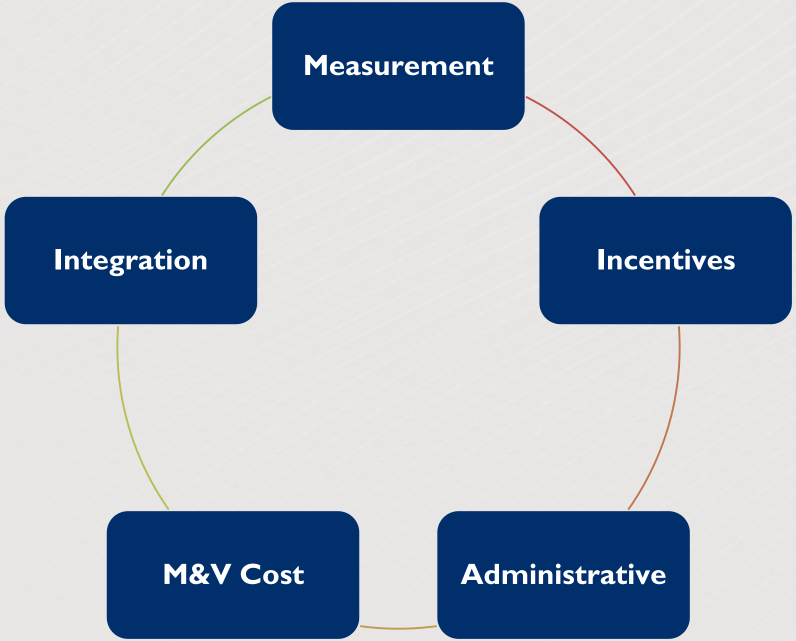
System	Number of circuits	Total length [km]	Investment [billion US$]
NE	140	14397	3.14
SE	41	2063	0.64
N	33	1748	1.79
CW	8	242	0.05
S	7	112	0.26
HVAC Tie Line	4	1100	1.39
HVDC Tie Line	1 bi-pole	3600	2.18
SIN	**234**	**23262**	**9.45**





Cost and benefits of DER

Costs



Benefits

Avoided costs with traditional assets that provide energy & capacity services

Avoided costs with transmission and distribution networks

- DG: local supply of demand can reduce ginvestments on utility scale generation and transmission
- Storage can avoid overload and investments on grid
- EV: can postpone investments on grid depending on recharge and provide generation services V2G)
- DR: can avoid overloads and investments on grid

DER Benefits

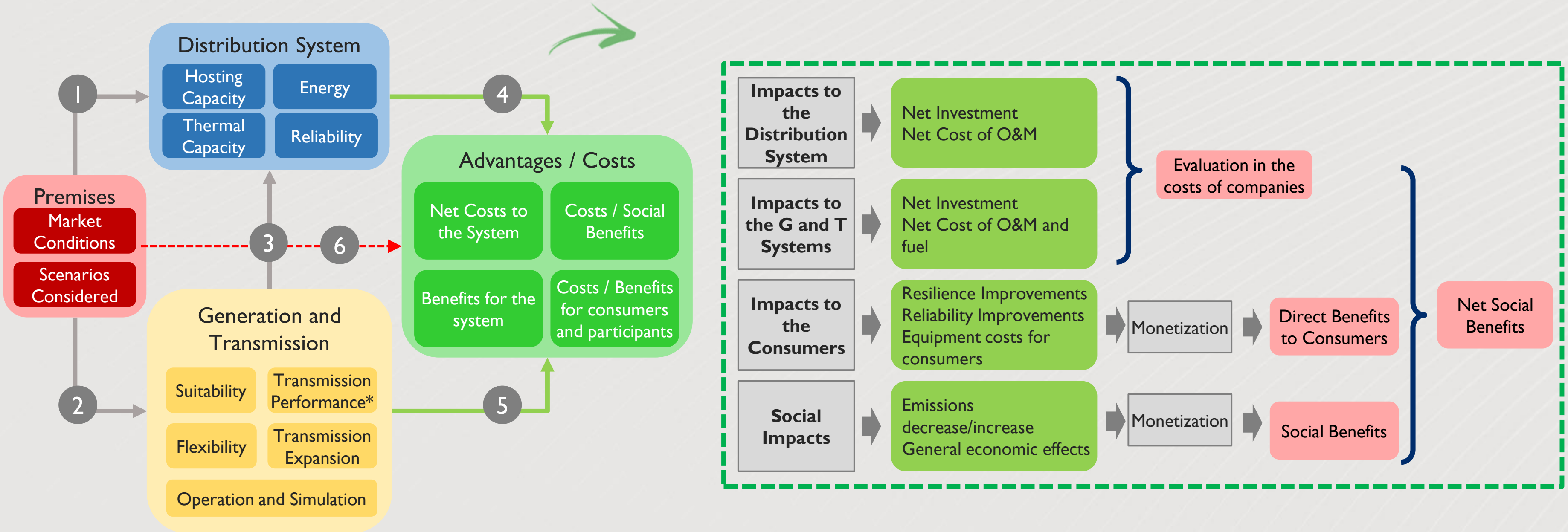
		Flexibility	Voltage control	Frequency control	Operating reserve	Black-Start	Reliability / Resilience	Emissions Reduction	Loss reduction
	Demand Response	✓ (green)	⊗	✓ (yellow)	✓ (green)	⊗	✓ (green)	✓ (yellow)	✓ (yellow)
	Distributed Generation	⊗	✓ (yellow)	⊗	⊗	⊗	⊗	✓ (green)	✓ (yellow)
	Distributed Storage	✓ (yellow)	✓ (green)	✓ (green)	✓ (green)	✓ (green)	✓ (yellow)	✓ (yellow)	⊗
	Electric Vehicle	✓ (yellow)	✓ (green)	✓ (green)	✓ (yellow)	⊗	✓ (yellow)	✓ (yellow)	✓ (yellow)

How to measure costs and benefits?

- There is no consensus on the best way to assess the costs and benefits of DER
- Methodologies that **explicitly** calculate the costs and benefits of DER
  - System implementation and maintenance costs and benefits through **avoided costs** (B/C > 1) though several tests. *Participant Cost Test* (do DER users have savings?), *Ratepayer Impact Measure* (are there added costs to non-users of DER?), *Utility Cost* (are benefits of DER higher than their costs?), *Total Resource Cost* (are benefits of DER for utility and consumers higher than their costs) and *Societal Cost* (broader than previous, as it includes tradeoffs to Society)
  - Evaluation of costs & benefits of DER in planning and operation
- Methodologies that **implicitly** develop a cost x benefit analysis by incorporating REDs into optimization models.

Evaluation of costs & benefits of DER in planning and operation

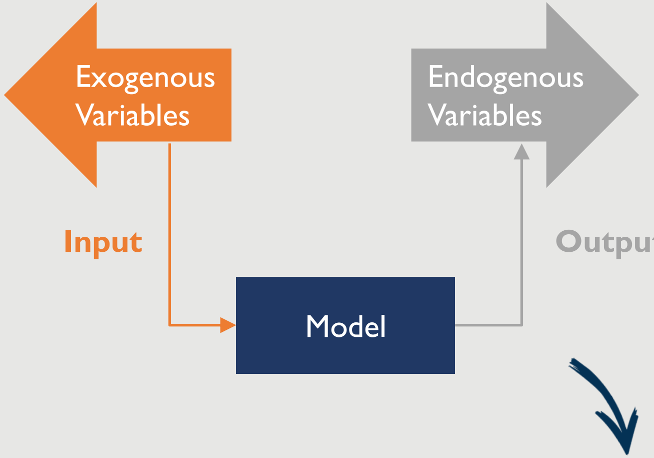
- EPRI: bottom-up methodology for evaluating impacts of different DER scenarios in planning and operation, followed by cost-benefit analysis.



Approaches to model DER insertion endogenously

- **Endogenous** methodologies to forecast DER diffusion
  - Generation
  - Transmission
  - Distribution

- Approaches for DER modeling



Challenges for DER representation in the resource planning model

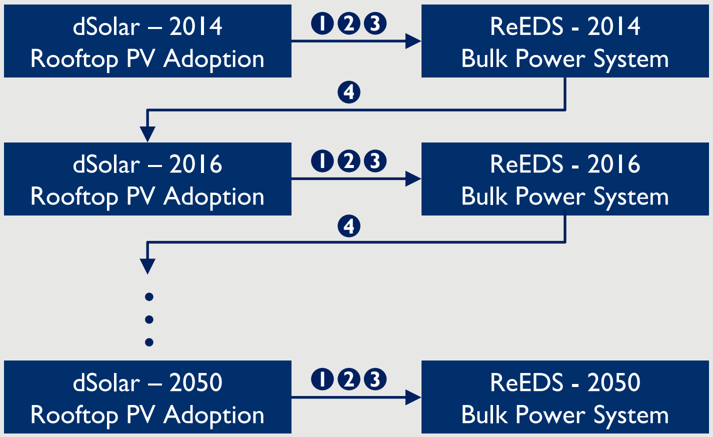
Hybrid Model

Assess interaction between:

NREL Transforming ENERGY

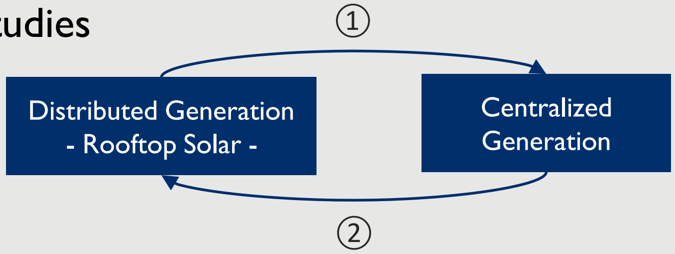
"centralized" solar (T & D) → ReEDS

PV DG - *rooftop* → dSolar



❶ Rooftop PV capacity per region
❷ Capacity factor by time slice
❸ Retail electricity prices of adopters
❹ Rooftop PV marginal curtailment rate

Case studies



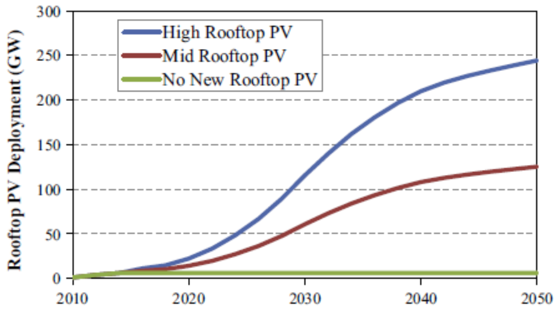
Scenarios

	①	②
ReEDS Configurations	**dSolar Configurations**	**dSolar Configurations**
Low PV Cost	High Rooftop PV	No curtailment
	Mid Rooftop PV	Net curtailment
	No New Rooftop PV	Full curtailment
SunShot Cost	High Rooftop PV	No curtailment
	Mid Rooftop PV	Net curtailment
	No New Rooftop PV	Full curtailment
Low Natural Gas Cost	High Rooftop PV	No curtailment
	Mid Rooftop PV	Net curtailment
	No New Rooftop PV	Full curtailment
Low Wind Cost	High Rooftop PV	No curtailment
	Mid Rooftop PV	Net curtailment
	No New Rooftop PV	Full curtailment

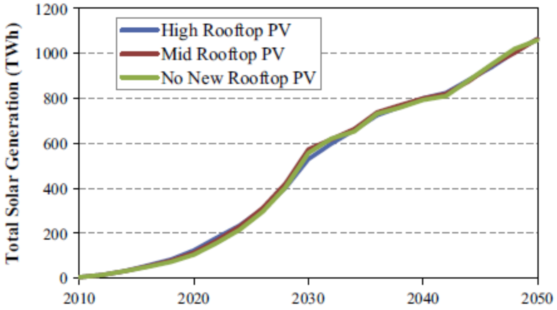
Hybrid Model Results

- Impact of *rooftop* PV installation on the centralized generation expansion
- Impact of centralized generation expansion on *rooftop* PV installation

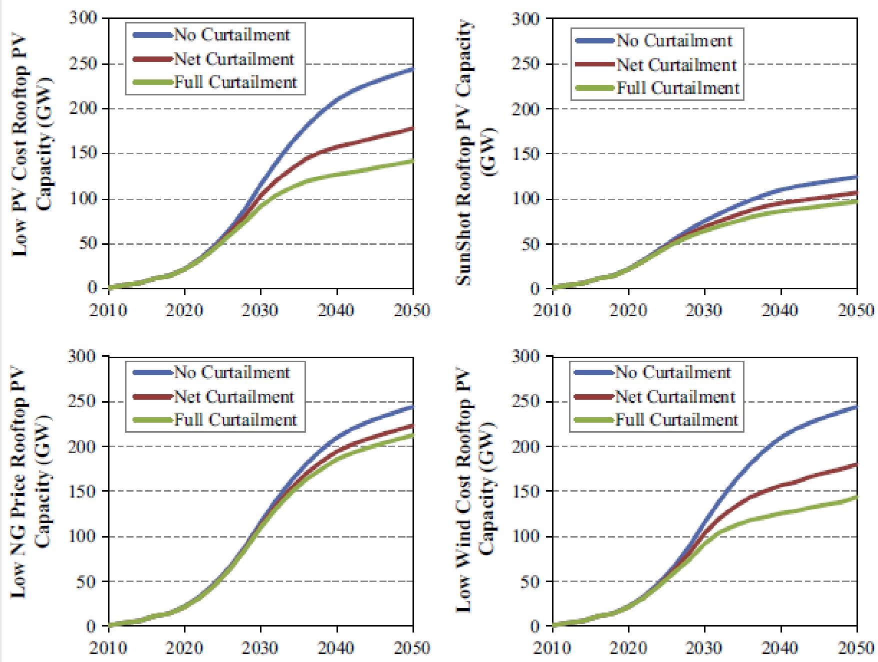
Low PV Cost



Rooftop PV Installation



The total solar generation is not influenced by the instaled capacity of PV rooftop



Hybrid Model Asssessment

- Main Conclusions
  - Model allows the integration of "centralized" solar expansion (T & D) with *rooftop* PV.
  - Shows that *rooftop* PV is competitive with utility-scale solar generation (T & D).

- Assessment

	- Detailed representação of *rooftop* PV - Captures dynamical (time-varying) system expansion
	- No explicit representation of PV generation uncertainty - No feedback loop between DER and centralized solar decisions in the same year

Gen X Model

√ Hourly Operation √ Unit Commitment √ Transmission network, Distribution, Losses

- Minimizes investment and operation costs (considering DERs) for **one year**.

- The model was extended in a PhD thesis (*Jesse Jenkins*) to allow assessment of DER services to the system.

HV network and DistCo Mid-voltage network not represented explicitly

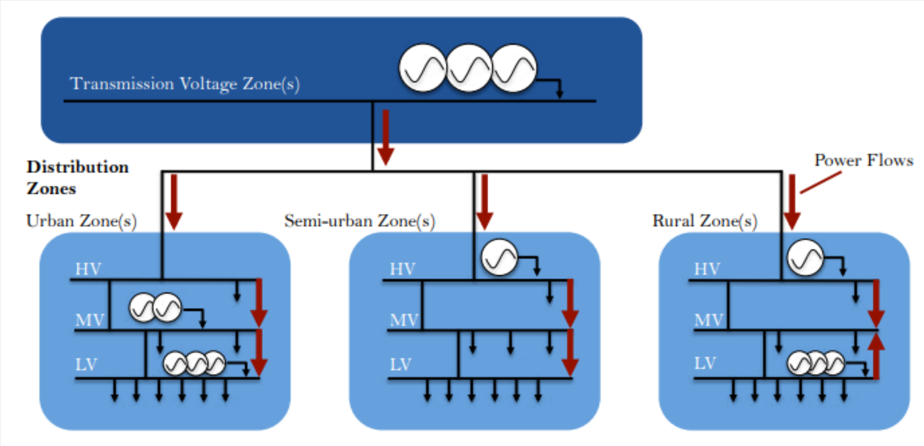
- Depending on the system, detailed representation of the transmission and distribution networks may not be feasible.

These networks are represented implicitly as constraints and equations obtained from preprocessing

Distribution losses | Operational Reserve | Reinforcements

Gen X Model Pre-Processing

Transmission and Distribution Network



Losses in the distribution network

1. Run power flows for the distribution network for randomly sampled generation/load configurations;
2. For each sampled configuration add the load and generation values for mid- and low-voltage levels.
3. Obtain a scatter gram of load and generation points (mid- and low-voltage) versus losses for the scenarios.
4. Adjust a quadratic expression of losses as a function of the load and generation points.
5. Build a piecewise linear approximation of the quadratic expression.

Operational Constraints

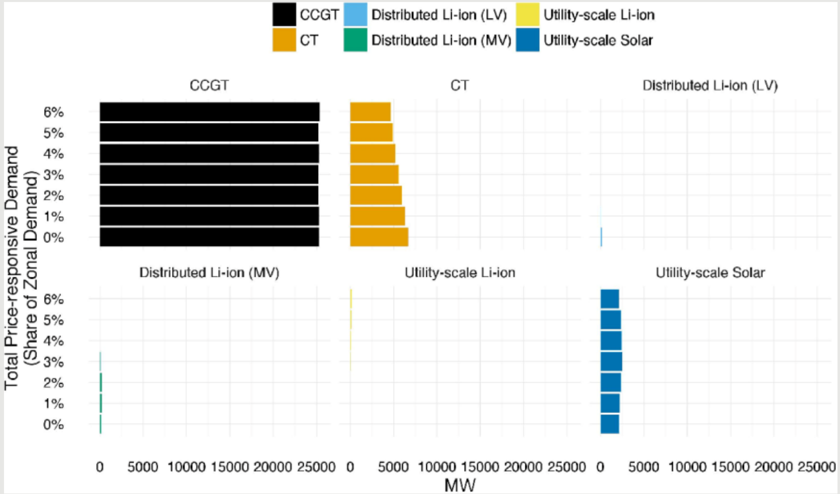
Distribution network reinforcements

Analytical Expressions

Gen X Model Application

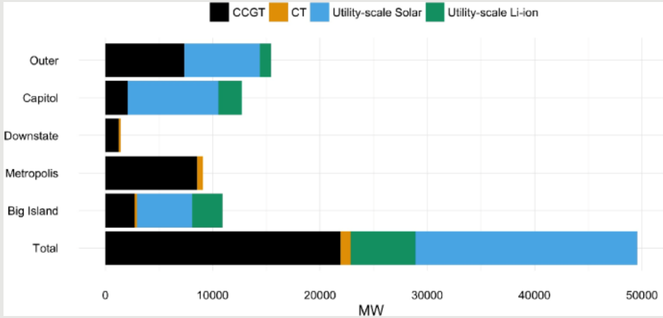
- Sample system based on NYISO

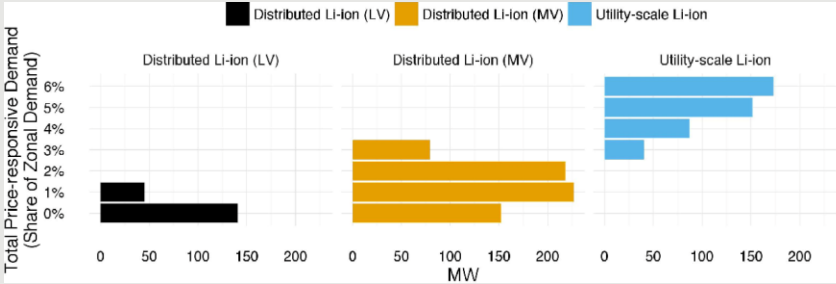
Payment for cutoff level	DER (Base Case)	Limit DER 1	Limit DER 2	Limit DER 3	Limit DER 4	Limit DER 5	No DER
$1000/MWh	3.0 %	2.5 %	2.0 %	1.5 %	1.0 %	0.5 %	0%
$500/MWh	2.0 %	1.7 %	1.3 %	1.0 %	0.7 %	0.3 %	0%
$250/MWh	1.0 %	0.8 %	0.7 %	0.5 %	0.3 %	0.2 %	0%
Total DER	6.0 %	5.0 %	4.0 %	3.0 %	2.0 %	1.0 %	0%



Expansion Plan – Base Case

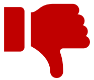
Transmission Zones





Gen X Model Assessment

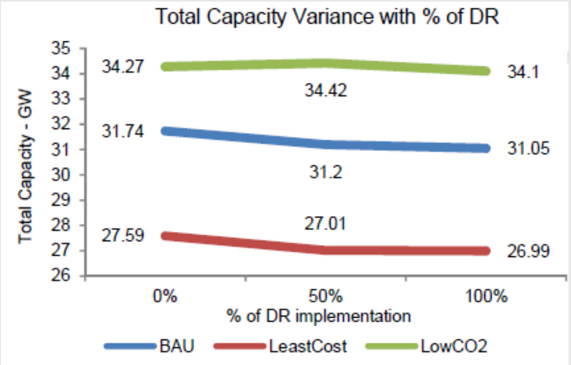
- Assessment of the methodology

	- Detailed modeling of the HV system - Implicit modeling of the distribution network (pre-processing)
	- One-year horizon – does not capture dynamical system evolution. - No representation of DER/renewable production uncertainty.

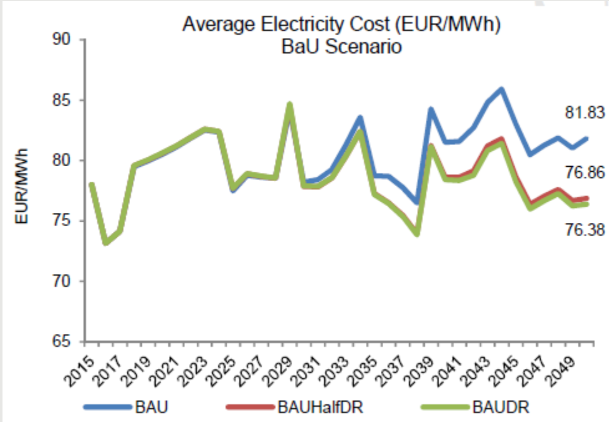
OSeMOSYS Model

- Impact of Demand Response on Long-Term Planning
- DR potential in different voltage levels (*bottom-up* approach)

- Expansion scenarios: BAU, LOW CO_2 and Least Cost
- DER Scenarios: 0%, 50% and 100%



Trend of DR contribution to the reduction of total installed capacity



Trend of DR to reduce average energy cost

OSeMOSYS Assessment

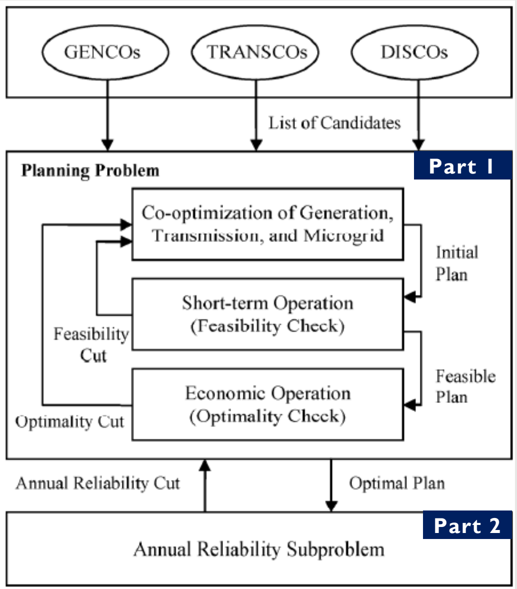
- Main Conclusions
  - Flexible loads are important for the system.
  - The study did not consider costs related to demand response.

- Assessment

	- Dynamical system expansion - Demand Response with detailed modeling of flexible loads
	- No representation of the transmission network - No representation of the stochastic aspects of intermittent sources.

Microgrids in Planning

- Microgrids in planning as an alternative to co-optimization of generation and transmission.
- Problem decomposition



Scenarios:

Case 0 : $G_{centralized}$ Candidates

Caso 1: $G_{centralized}$ Candidates + Transmission

Caso 2: $G_{centralized}$ Candidates + DERs (Microgrids)

Caso 3: $G_{centralized}$ Candidates + T + DERs (Microgrids)

Cost ($Billion	Case 1			Case 2			Case 3		
	G	T	Micro grids	G	T	Micro grids	G	T	Micro grids
investiment Cost	0.225	0.052	-	0.062	-	0.435	0.115	0.036	0.221
Operation Cost	4.215	-	-	3.916	-	0.017	4.045	-	0.009
Cost of Energy not Supplied	0.004			0.005			0.003		
Total planned cost	4.496			**4.435**			**4.429**		

Microgrids can contribute to the reduction of total planning cost

Microgrids in Planning Assessment

- Assessment of the methodology

	- Represents system dynamics in planning - Represents the transmission network - (Partial) representation of uncertainty (outages)
	- Losses are not considered - Simplified representation of the distribution network

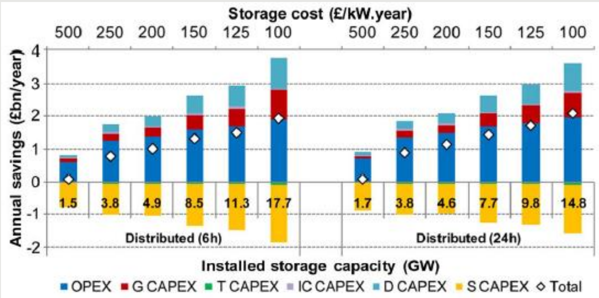
WeSIM Model

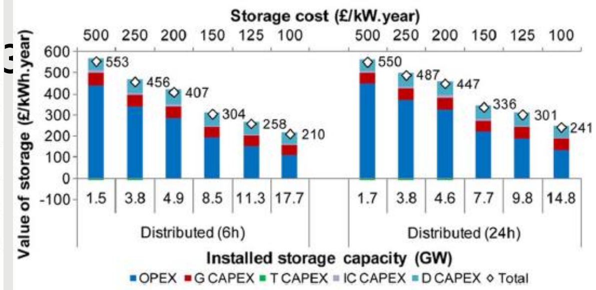
- *Whole-Electricity System Model*
- Minimizes investment and operation costs (considering DERs) for **one year**
- This model has evolved with time
  - [2018] Model captures uncertainty, stochasticity

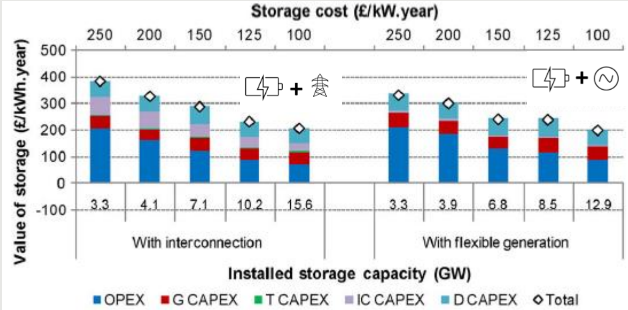
    ***Stochastic unit commitment model* (SUCM)**

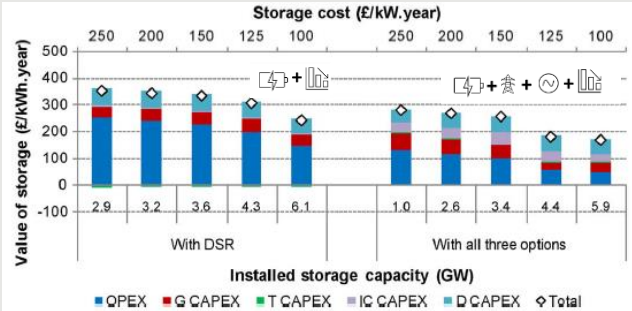
    - WeSIM → Optimal G and T expansion (simplified operation)
    - SUCM → Detailed system operation
  - [2014, 2017, 2018] Model to evaluate the distribution network and peak supply reinforcements

WeSIM Model Application to Batteries - UK









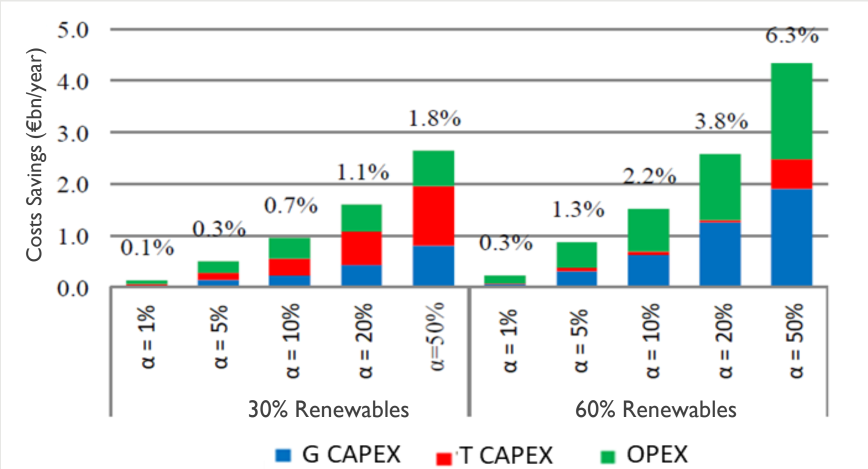
Scenarios:

- Case 1: Increased interconnection capacity
- Case 2: Increased flexibility of existing generators
- Case 3: Demand Response
- Case 4: Case 1 + 2 + 3

WeSIM Model Industrial Demand Response - Europe

- Industrial Demand Response in 2030 – Europe

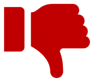
- Expansion Scenarios: 30% and 60% of energy supplied by renewables
- DR Scenarios: 1%, 5%, 10%, 20%, 50%



Scenario with higher participation of renewables, DR brings highest benefits

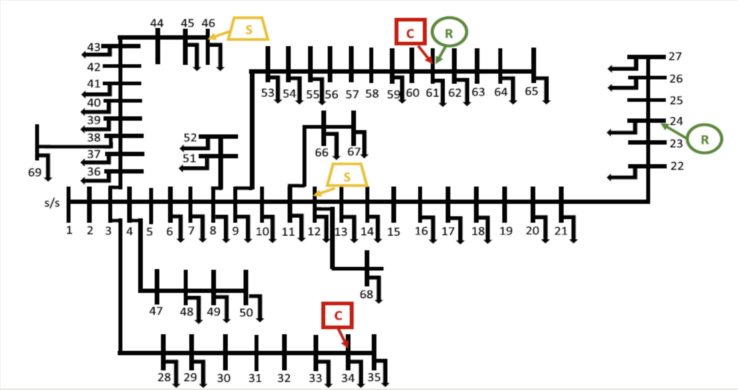
WeSIM Model Assessment

- Assessment of methodology

	- Simultaneous modeling of G + T + D (approximated) - Endogenous modeling of DERs; captures synergies/competitivenesss
	- one-year horizon – does not capture dynamical system evolution. - Does not represent uncertainty of renewable generation. - Does not represent network losses.

Expansion planning of Distribution: EV, Batteries and PV

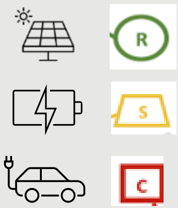
- Optimal investment in DERs, considering uncertainties in long-term peak load, amount of electric vehicles, energy purchase/sale prices at the HV voltage level.



- Scenarios: Limit on energy purchase
  - Unlimited energy purchase (UEP)
  - Limited energy purchase (LEP)

Deterministic

	#Recharge stations		Solar capacity (kW)		Storage capacity (kW)		Load curtailment (kW)		Total cost ($)	
	UEP	LEP	UEP	LEP	UEP	L.EP	UEP	L.EP	UEP	L.EP
$\Lambda^G = \Lambda^L = \Lambda^{EV} = 0$	91	81	0	90	0	790	0	0.332	427.398	484.761



With uncertainties on demand, recharging stations and energy prices

Λ^G	#Recharge stations		Solar capacity (kW)		Storage capacity (kW)		Load curtailment (kW)		Total cost ($)	
	UEP	LEP.	UEP	LEP	UEP	LEP	UEP	LEP	UEP	**LEP**
I	80	24	0	1750	0	800	0	96.43	678.415	1.064.651

Robust expansion planning of the Distribution - Assessment

- Assessment of methodology

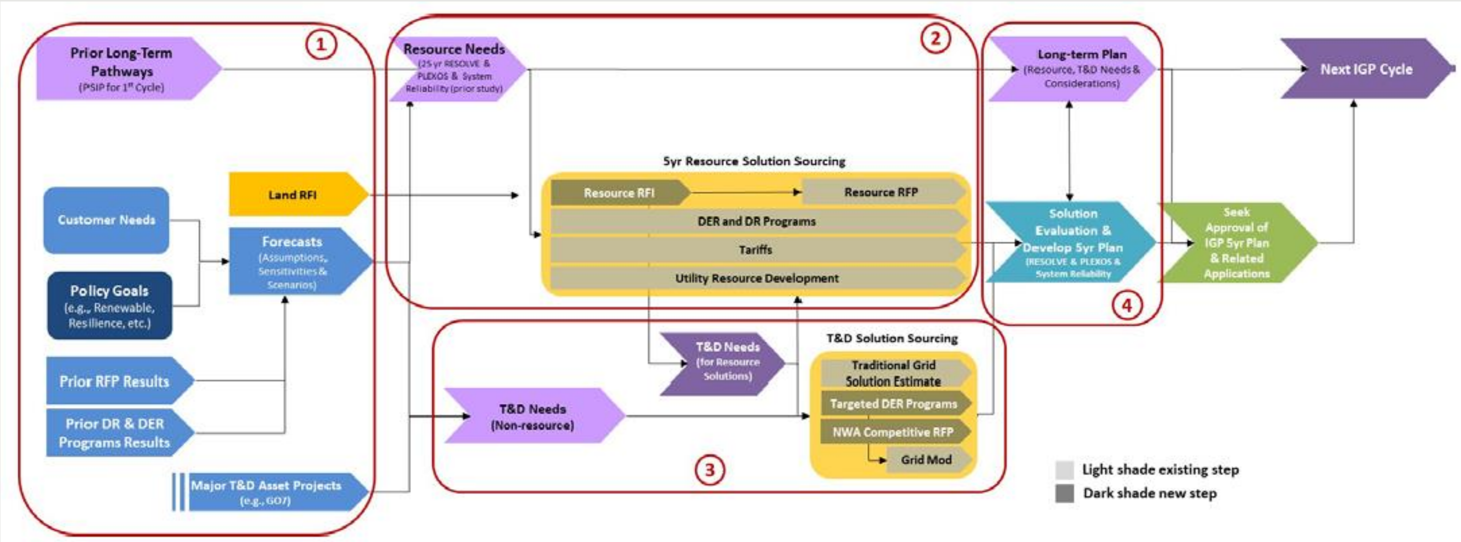
👍	- Long-term uncertainties in planning
👎	- Does not represent uncertainty in renewable generation. - Does not assess investments in G + T + D

Integrated Planning: Hawaii

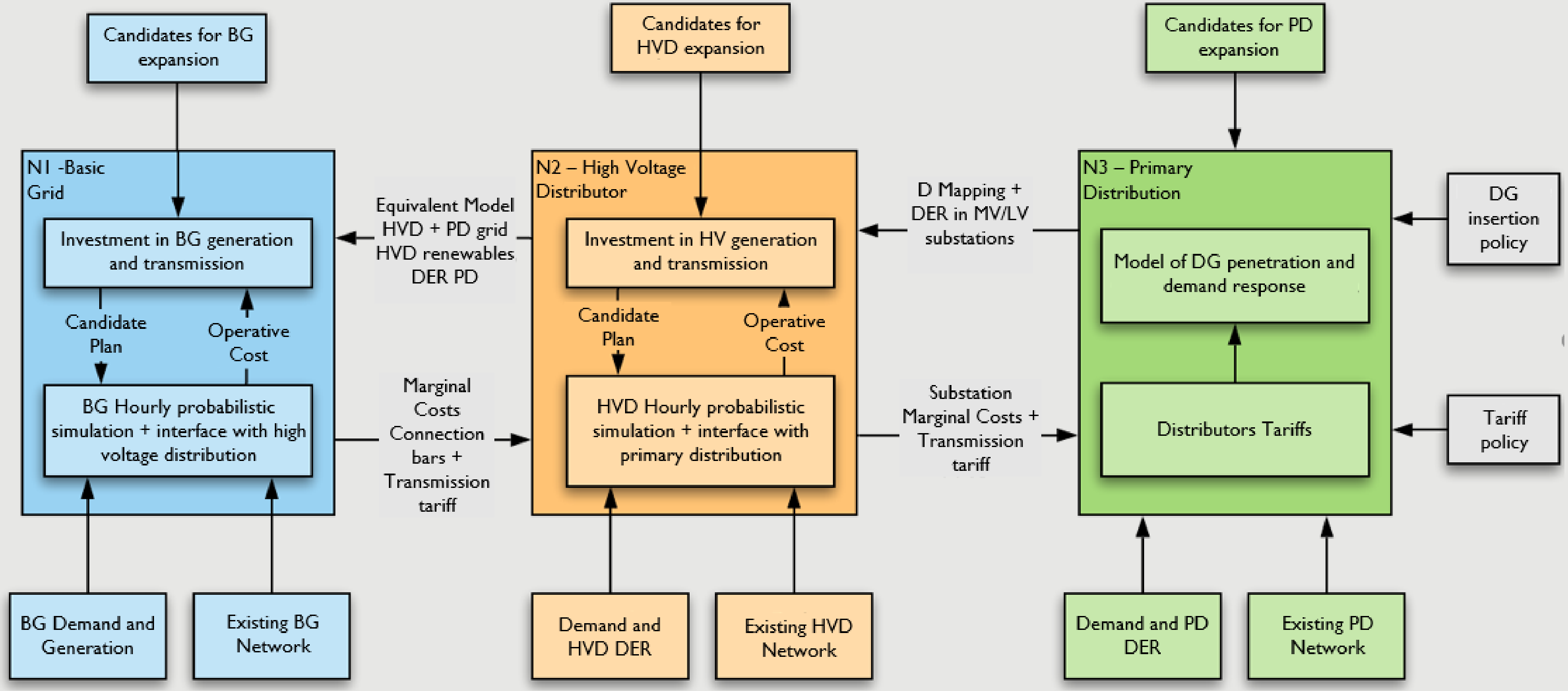
- Hawaii electric utility wishes to identify the **optimal resource mix**.
- Integrated planning methodology, with multiple stages, identifying required system services.

Technology neutrality

- Planning Premises and projections
- Identification system needs and sources of services
- Identification of transmission and distribution alternatives
- Medium-long term planning



Proposed methodology (PSR)



Proposed methodology

Expansion planning with endogenous representation of DERs

- Hierarchical planning model composed of three levels (L)

N1 – Module corresponding to high voltage systems (Transmission)

It considers every element of the centralized grid, generation and basic grid (BG)

N2 – *n* modules corresponding to high voltage distributors (HVD) network

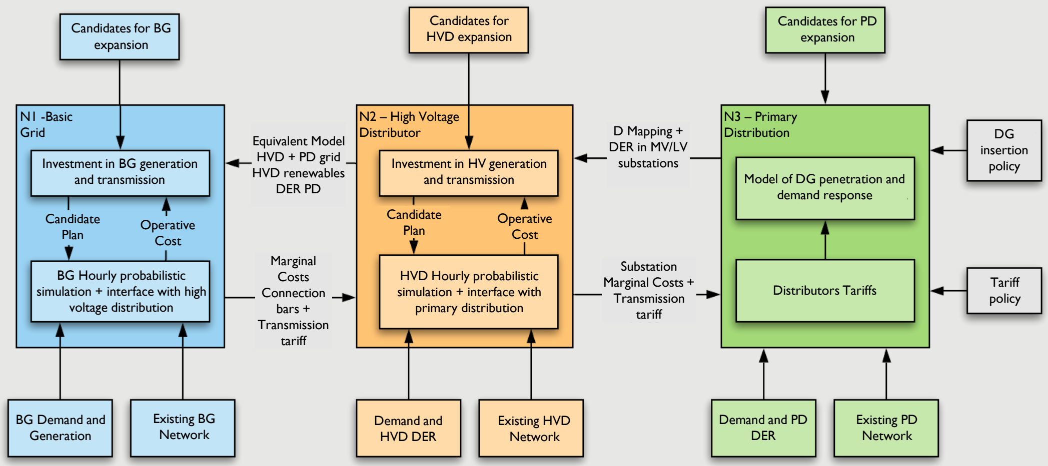
N3 – *n x m* modules of Primary-Secondary Distribution (PSD), corresponding to systems that originate from each distributor substation (MV/LV).

It is not computationally feasible to represent the three levels in a single optimization model

Hierarchical levels

Integrated and iterative process

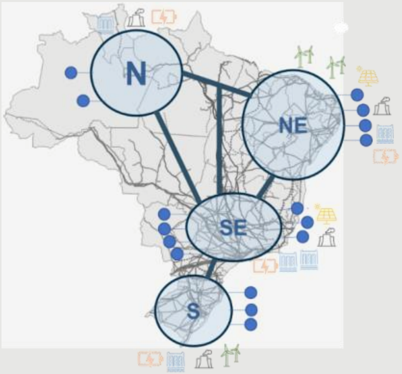
Main components of the methodology



Expansion planning: L1

- Centralized system: detailed G,T, storage (S)
- Simplified distribution system (*n* network equivalents of the distribution networks)

Hourly injection scenarios

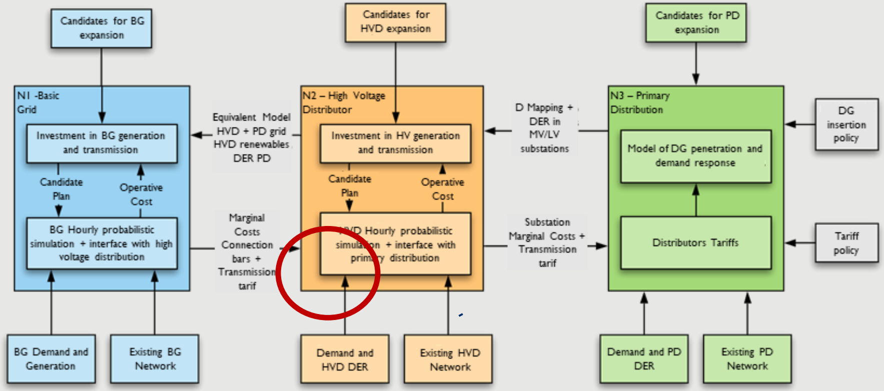


● N equivalent networks

Obj.F.: Min [Inv Cost G+T+S + E (Operation cost)]

- Economic signals from L1 to L2

Step 1	Step 2	Step 3	Step 4	Step 5
Given optimum G&T expansion plan	Simulate system hourly operation, many scenarios of inflows & VRE power using a detailed transmission network	Obtain marginal costs from frontier busbars between HV and *n* systems.	Add a term to the marginal cost related to the location economic signal (wire tariff).	Start planning L2



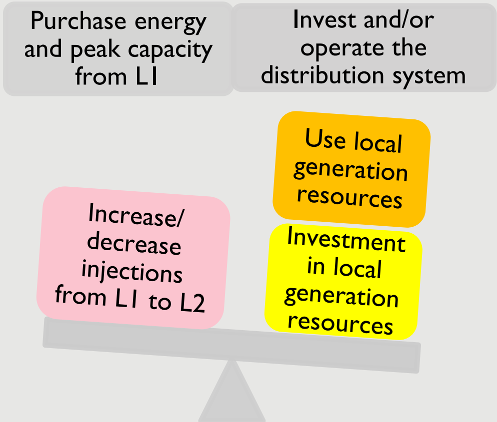
Expansion planning L2

- Planning of "HV" level of the Distribution grid (HVDdist):

Obj.F: Min [Investment costs in G+T+S at HVD$_{Dist}$
+ operation costs of local resources +
costs of acquiring services from L1]

Dummy generators at the buses connecting L1 to L2

Tradeoff



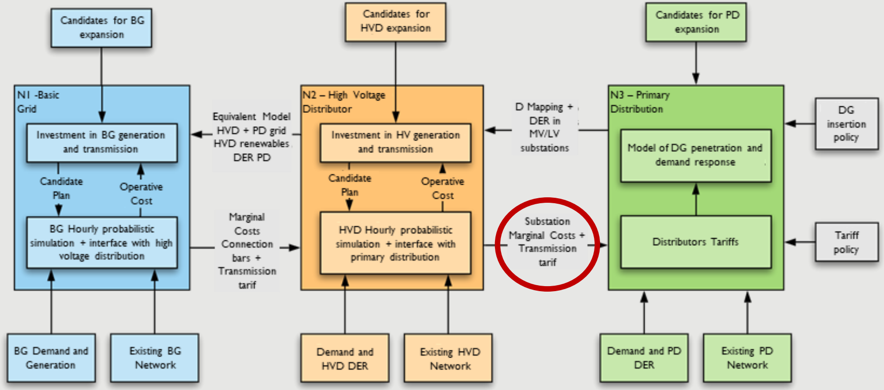
- Economic signals from L2 to L3

Step 1 Given optimum expansion plan N2

Step 2 Retrieve marginal costs for high voltage distribution system for all simulated hours.

Step 3 Add to marginal cost term related to transmission / distribution locational tariff TUST/TUSD

Step 4 Start planning L3



Expansion planning: L3

- Decision to install DERs is taken by consumer based on:
  - Supply tariff and RED cost

Decentralized vision

Step 1 Emulate consumer decision making. It can insert GD, batteries or change its demand curve.

Step 2 With the result of step 1, expand the distribution system

Step 3 Within the expansion process, simulate the distribution system using OpenDss, a three-phase distribution power flow model.

OBS.:

Economic DER optimization from consumer standpoint

New DER, impact system requirements and **planning**

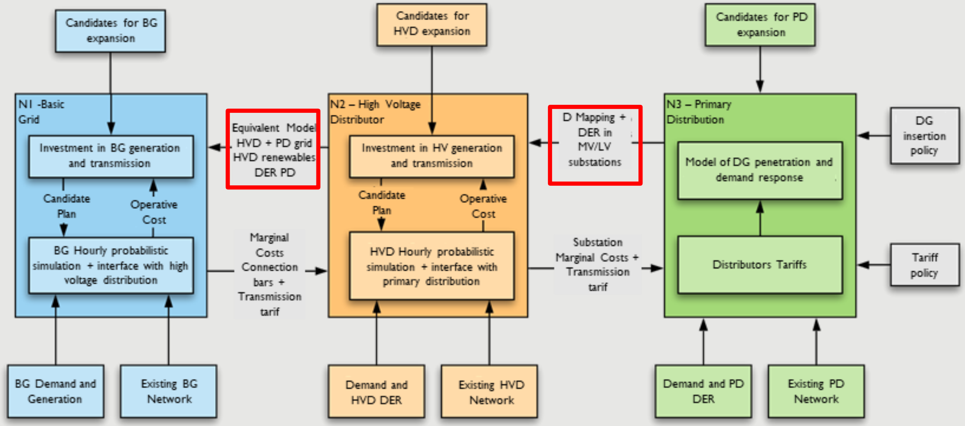
Centralized vision

Verify whether the economic signals to consumers induce maximum benefits

Optimization model like L2, considering rooftop solar panel candidates.

Obj.F: Min [Investment costs in distribution + operation costs of local resources + costs of acquiring services from L2]

Feedback (L3 → L2 and L2 → L1)



Detail of 1st feedback

L3 – Primary distribution

- Output data -

Investment in solar generation, DR, batteries etc.

L2 – "HV" Distribution

- Input data -

New demand and generation injections mapped to the substations

L2 Expansion

- Output data -

New set of generations and reinforcements in L2

L1 – HV network

- Input data -

New network equivalent

L1 Expansion

Texas

- A 2019 study presents a method to quantify the benefit of deferred investment in T&D in Texas with a methodology based on approximate cost and directly monetized benefit.
- How can DER reduce T&D cost? It reduces investments related to the supply of peak demand
- How much of T&D cost relates to load growth that can be avoided? 10%-30% of T&D costs
- For how long can DER defer T&D investments? Load growth compared with DER growth data
- What is the value of postponing investments on T&D? Wire costs are for the next 10 years are compared in cases with or without DER (20% penetration)
- Results: (US$ 2019 million).
  - Present value without postponement: $1,045
  - Present value with postponement due do DER: $700
  - Annual savings (DER Benefit): $345
  - Saved over next 10 years: $2,452

Texas

- The study also provides a method to quantify short-term price reductions in the Texas market
- The study considers that DER reduces peak demand
- Methodology based on Market Price Appreciation, which requires simulation
  - Adds DER if applicable in given hour in the supply stack curve
  - Updates prices of electricity
  - Reduces the new price from the original price (higher)
  - Multiplies this difference by the load to compute total savings
- Results indicate savings of US$3.35 billion over 10 years for 1000 MW of DER.
- The methodology can also compute the *incremental* benefit of DER, based on it use in peak hours during summer (15h-19h from Jun. to Sep.) and winter (7h-10h,, from Dec. to Mar)
- The unitary yearly savings are roughly: US$ 500/kW for DER <100 MW, US$ 400/kW for DER<1000 MW and reduce sharply for DER penetration > 1000 MW.

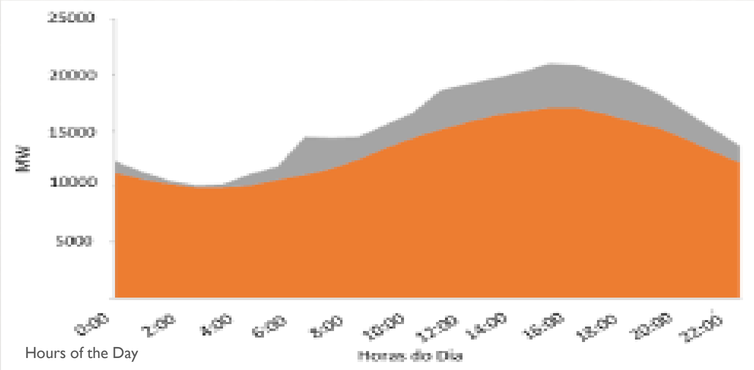
Electric vehicles in Arizona

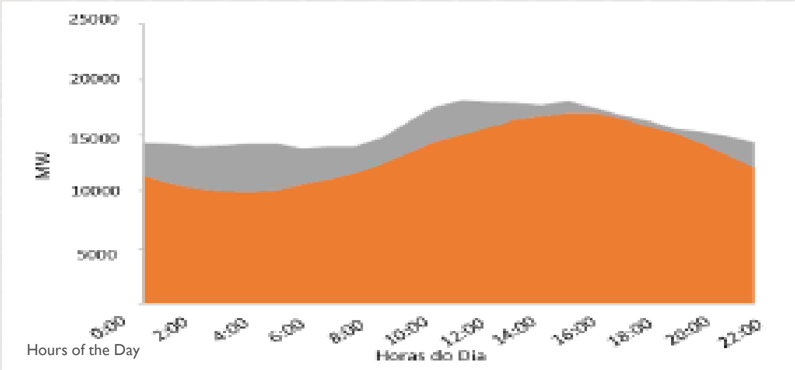
- The State of Arizona created incentive policies for the adoption of battery-electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV).
- A study* evaluate costs and benefits from the utility net revenue perspective and the impact to consumers for two scenarios of EV penetration and for two charging regimes
  - Reference: vehicles are recharged when users arrive home
  - Off-peak: 92% of recharge happens from 9pm to 4am in response to economic signal provided by utility to owners of vehicles.
- Two scenarios for EV penetration are considered :
  - Moderate: 1m EVs (12% of total) by 2050
  - High (7.5m) EVs (90% of total) by 2050 and 50% of total by 2040

* [65] M.J. Bradley & Associates, "Electric Vehicle Cost-Benefit Analysis. Plug-in Electric Vehicle Cost-Benefit Analysis: Arizona" 2018, Available at: https://www.swenergy.org/pubs/azevstudy (Access:04/06/2020)

Electric vehicles in Arizona

- The graphs show 2016 hourly P95% daily demand in orange and the 2040 EV demand in grey for year 2040, high penetration scenario of EV (50%) considering Reference recharge (left) and off-peak recharge (right).

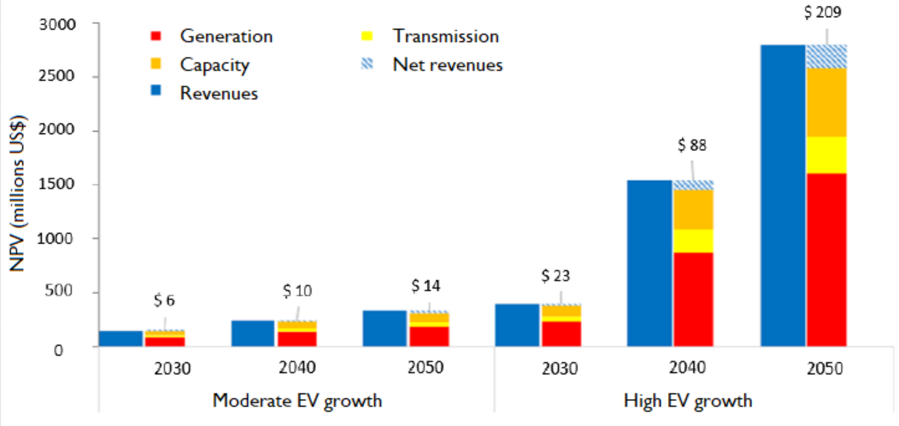


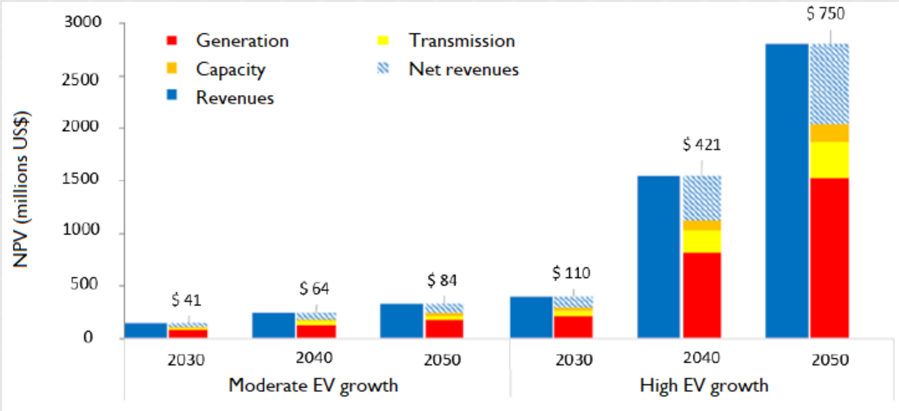


- Increased peak (left) requires more investments and costs of energy purchase at higher prices.
- Savings are originated from tariff design and expected response by EV users

Electric vehicles in Arizona

- Net revenues increase from US$209 to US$750 million due to reduced costs in 2050 for the high EV growth scenario, mostly due smaller capacity costs.
- According to local regulation, most of these excess revenues are transferred to consumers through tariff reduction of about 5% in 2030
- Other benefits to society: reduction of NOx and greenhouse gases





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MINISTRY OF NEW
AND RENEWABLE ENERGY

Models

Software	Capability	Methods	Input Parameters	Output	Countries
AleaDemand	Energy forecasting	Genetic Algorithms, Neural, Networks and Statistics	Explanatory variables include calendar days, weather, temperature thresholds, socioeconomic indicators, climatology and seasons.		Belgium, France, Italy, Germany, Netherlands, Poland, Spain and UK
Alyuda	Energy Forecasting	Logistic regression, Decision trees, Decision rules, Neural Networks	GDP, Population density, Prices of fossil energy carriers, consumer sector sales expectations	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	Generation Adequacy	Monte Carlo Simulations, Stochastic models	Technical and meteorological parameters	LOLP, LOLE, LOEE / EENS	Germany, Luxembourg, The Netherlands, Belgium and France
AURORA	Energy Forecast, Resource Valuation and Net Power Costs	Resource capacity or generation, zone demand, net flows, fuel usage	LP and MIP		North America

Models

Software	Capability	Methods	Input Parameters	Output	Countries
BID3	Power Procurement	Stochastic Dynamic Programming, Detailed modeling of intermittent RE generation	Fuel prices and operational constraints, Detailed and consistent historical wind speed and solar radiation.	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	Generation Adequacy	Dynamic Program (DP), Generalized Bender‟s Decomposition, Screening Curve Option, Pre-specified Pathway Option	Planning Reserve Margin, emission constraint, Resource availability, Demand and energy forecast, Fuel forecasts, Retirements, CO_2 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	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	Generation Adequacy	Time series, Statistical sampling, Probabilistic Monte Carlo analysis		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

Models

Software	Capability	Methods	Input Parameters	Output	Countries
OPTGEN & SDDP	Power Procurement and Operation Planning	Benders Decomposition and Mixed Integer Programming (MIP)	Energy balance constraints, Operation reserve constraints, Generator and contract constraints: unit commitment, detailed hydro modeliong, capacity & energy limits, transmission modeling, fuel contraints, grid security constraints and emission limits	More than 200 results including operational variables, economic variables (marginal costs) and others	~60 countries of all continents
PLEXOS	Energy Forecasting, Power Procurement	Advanced Mixed Integer Programming (MIP)	Energy balance constraints, Operation reserve constraints, Generator and contract constraints: ramp, min capacity, energy limits, Transmission limits, Fuel limits and Emission limits	Optimal planning solution in the medium term. Short-term unit commitment and economic dispatch. Hourly electricity spot prices	Europe, Middle East and Australia
PowrSym	Generation Adequacy	Cost data and system operating parameters, hourly load data and maintenance data	Monte Carlo Scenarios and Climate Dependent Time series	Capacity factor, Emissions, Fuel burn, Electric energy generated , Costs (fuel; operation and maintenance, O&M; start up; emissions; total), Number of unit starts, Operating hour	Japan, South Korea, Europe and North America

References

[1] Rogers E., 1962. "Diffusion of Innovations". New York: Free Press of Glencoe (1st ed). OCLC 254636
[2] Vernon R., 1966. "International Investment and International Trade in the Product Cycle". International Business Strategy (pp. 35-46). Routledge.
[3] Gartner Inc, 2001. "The Gartner Glossary of Information Technology Acronyms and Terms".
[4] Dedehayir O., Steinert M., 2016. "The hype cycle model: A review and future directions". Technological Forecasting and Social Change 108 (2016): 28-41.
[5] Moore, G. A., 1999. "Crossing the chasm: Marketing and Selling Technology Products to Mainstream Consumers". Collins Business Essentials, 290p.
[6] International Energy Agency (IEA) – Tracking Energy Integration – Disponível em: https://www.iea.org/reports/tracking-energy-integration/energy-storage (Acessado em 28 de Maio de 2020)
[7] Bass F., 1969. "A New Product Growth Model for Consumer Durables". Management Science 15, p 215-227
[8] Bass F., Krishnan T., Jain D., 1994. "Why the Bass model fits without decision variables". Marketing Science 3, volume 13, p 203-223
[9] Meade N., Islam T., 2006. "Modelling and forecasting the diffusion of innovation – A 25-year review". International Journal of Forecasting 22 (2006) 519– 545
[10] Sigrin B., Gleason M. et al, 2016. "The Distributed Generation Market Demand Model (dGen): Documentation". Technical Report NREL/TP-6A20-65231
[11] Sigrin B., Drury E., 2014. "Diffusion into New Markets: Economic Returns Required by Households to Adopt Rooftop Photovoltaics". Energy Market Prediction: Papers from the 2014 AAAI Fall Symposium.
[12] Konzen G., 2014. "Difusão de sistemas fotovoltaicos residenciais conectados à rede no Brasil: Uma simulação via modelo de Bass". Dissertação de Mestrado – Instituto de Energia e Ambiente da Universidade de São Paulo.
[13] EPE, 2019. "Modelo de Mercado da Micro e Minigeração Distribuída (4MD): Metodologia – Versão PDE 2029". Nota Técnica DEA 016/2019
[14] Dong C., Sigrin B., Brinkman G., 2017. "Forecasting residential solar photovoltaic deployment in California". Technological Forecasting & Social Change 117 (2017) 251–265
[15] Kurdgelashvili L., Shih C. et al, 2019. "An empirical analysis of county-level residential PV adoption in California". Technological Forecasting & Social Change 139 (2019) 321–333
[16] Trachuk A., Linde N., 2019. "Dissemination of Distributed Energy Technologies". DOI: 10.5772/intechopen.88604
[17] Assunção J., Schutze A., 2017. "Developing Brazil's Market for Distributed Solar Generation". Núcleo de Avaliação de Políticas Climáticas – PUC-Rio
[18] Prießner, Alfons & Sposato, Robert & Hampl, Nina. (2018). Predictors of Electric Vehicle Adoption: An Analysis of Potential Electric Vehicle Drivers in Austria. Energy Policy. 122. 701-714. 10.1016/j.enpol.2018.07.058.

References

[19] McDermott, Ethan G., "Examining the effects of policy interventions on increasing electric vehicle adoption in California" (2017). Master's Projects and Capstones. 567.
[20] Danielis, Romeo & Scorrano, Mariangela & Giansoldati, Marco & Rotaris, Lucia, 2019. "A meta-analysis of the importance of the driving range in consumers' preference studies for battery electric vehicles," Working Papers 19_2, SIET Società Italiana di Economia dei Trasporti e della Logistica.
[21] Srivastava, A., Van Passel, S., & Laes, E. (2018). Assessing the success of electricity demand response programs: A meta-analysis. Energy Research & Social Science, 40, 110–117. doi:10.1016/j.erss.2017.12.005
[22] Van Dam, Michiel. 2017, "Adoption of battery storage by household consumers Using agent based modeling to improve electricity distribution network models". TU Delft
[23] Milis, K., Peremans, H., & Van Passel, S. (2018). Steering the adoption of battery storage through electricity tariff design. Renewable and Sustainable Energy Reviews, 98, 125–139.
[24] Ito K., Ida T., Tanaka M., 2018. "Moral Suasion and Economic Incentives: Field Experimental Evidence from Energy Demand". American Economic Journal: Economic Policy 2018, 10(1): 240–267
[25] Dutra J. (Coordenadora), 2019. "Metodologia de Elaboração da Função de Custo do Déficit". P&D Estratégico ANEEL PD-0642-002/2015. Colaboradores FGV CERI, Thymos.
[26] Berry S., Levinsohn J., Pakes A., 1995. "Automobile Prices in Market Equilibrium". Econometrica, Vol. 63, No. 4 (Jul., 1995), pp. 841-890.
[27] IEA, 2019. "Global EV Outlook 2019". Acessado em https://www.iea.org/reports/global-ev-outlook-2019
[28] Berlotti M.L., Brunner J., Modanese G., 2016. The Bass diffusion model on networks with correlations and inhomogeneous advertising". Chaos, Solitons and Fractals, 90 (2015) pp. 55-63. arXiv:1605.06308 [physics.soc-ph]
[29] Nevo A., 2000. "A Practitioner's Guide to Estimation of Random-Coefficients Logit Models of Demand". Journal of Economics & Management Strategy, Volume 9, Number 4, Winter 2000, 513–548
[30] Meade R., 2019. "Measuring Prosumer Welfare: Modelling Household Demand for Distributed Energy Resources and Residual Electricity Supply". Presentation at the EPOC Winter Workshop 2019, University of Auckland.
[31] Zhang Y., Zhong M., Geng N., Jiang Y., 2017. "Forecasting electric vehicles sales with univariate and multivariate time series models: The case of China". PLoS ONE 12(5): e0176729. https:// doi.org/10.1371/journal.pone.0176729

References

[32] Srinivasran V., Mason C. H., 1986. “Technical Note—Nonlinear Least Squares Estimation of New Product Diffusion Models”. Marketing Science 5(2):169-178. https://doi.org/10.1287/mksc.5.2.169
[33] Bemmaor A.C., 1994. “Modeling the diffusion of new durable goods: Word-of-mouth effect versus consumer heterogeneity”. Research Traditions in Marketing (Kluwer Academic Publishers, Boston), 221–229.
[34] Boswijk H.P.,Franses P.H., 2005. “On the Econometrics of the Bass Diffusion Model”, Journal of Business and Economic Statistics, 25, 255–268.
[35] Sterman J. D., 2001. “Systems dynamics modeling: tools for learning in a complex world”, California management review, Vol 43 no 1, Summer 2001
[36] Coelho M.D.P., Saraiva J.T., Konzen G., Araujo M.C., Pereira A.J.C., 2019. “Modelling the Growth of DG Market and the Impact of Incentives on its Deployment: Comparing Fixed Adoption and System Dynamics Methods in Brazil”. 2019 IEEE Milan PowerTech conference. DOI: 10.1109/PTC.2019.8810994
[37] ANEEL, 2020. Base de dados de unidades de geração distribuída. Acessado em http://www2.aneel.gov.br/scg/gd/VerGD.asp, março de 2020.
[38] Department Of Energy, 2018. “Global Energy Storage Database”. Office of Electricity Delivery & Energy Reliability. Acessado em https://www.energystorageexchange.org/, junho de 2018.
[39] Jackson, M., 2008. “Social and Economic Networks”. Princeton University Press.
[40] Van der Bulte, C., Stremersch, S., 2004. “Social Contagion and Income Heterogeneity in New Product Diffusion: A Meta-Analytic Test”. Marketing Science Vol. 23, No. 4, Fall 2004, pp. 530–544
[41] Kiesling, E., Guenther, M., Stummer, C., Wakolbinger, L.M., 2012. “Agent-based simulation of innovation diffusion: a review”. Central European Journal of Operations Research 20.2 (2012): 183-230.

MODULE III: DEMAND FORECASTING

The goal of the module is to understand the importance of demand forecasting in resource planning and build learning on ways to forecast demand in a granular and robust manner.

- **Objectives:**
  - What is demand?
  - Why utility requires long term, medium term and short-term demand forecasting?
  - Development of accurate energy forecasts for distribution companies (DISCOMs)
  - What is role of econometric parameters in long-term load forecasting?
  - Creation of dynamic models considering economic drivers, demographics, policies, and game-changing technologies such as DER, EVs, etc.
  - Understand advanced statistical methods such as multi-regression, ARIMA & ANN to forecast the demand.
  - Demand Forecasting in RE rich environment
- **Content:**
  - What is Demand Forecasting
  - Short term, medium term and long-term demand forecasting
  - Necessity of forecasting demand, impact of higher/lower demand forecast
  - How demand can be controlled?
  - Methodologies for demand estimation (Econometric, compound annual growth rate (CAGR), partial end use method (PEUM), etc.) and their pros and cons.
  - New development/complexities in demand forecasting
  - How and why it is important to develop profile-based demand forecasting in RE rich environment?
  - How demand control can be used to reduce cost of supply side resources?
- **Presentation:**

USAID FROM THE AMERICAN PEOPLE

GOVERNMENT OF INDIA
MINISTRY OF NEW
AND RENEWABLE ENERGY

Agenda

Time	Session
02:30 – 02:35 pm	Recap of the previous sessions and update on next sessions, Mr. Amarjeet Hira, Chief Moderator
02:35 – 02:40 pm	Feedback and Discussion by Mr. Anurag Mishra, Energy Team Leader, USAID/India
02:40 – 03:00 pm	Introduction to Demand Forecasting and Practices of Forecasting in India at Central and State Level – Mr. Manoranjan Kalita, CGM, Assam Power Distribution Company Limited
03:00 – 03:40 pm	Methodology of Demand Forecasting and Emerging Best Practices - Mr. Sumedh Agarwal, Strategic Energy Planning Lead, USAID PACE-D 2.0 RE Program
03:40 – 03:45 pm	Quiz and Discussion
03:45 – 04:25 pm	Demonstration of Demand Forecasting Module, Mr. Kashyap Vasudevan, Software Specialist, PRDC
04:25 – 04:30 pm	Concluding Remarks

Introduction to Demand Forecasting and practices of forecasting in India at Central and State level

Faculty - Mr. Manoranjan Kalita, CGM (Com & EE), Assam Power Distribution Company Limited

Mr. Manoranjan Kalita

- Chief General Manager (Com & E.E.) at Assam Power Distribution Company Ltd. (APDCL)
- 30 years of experience in Electricity Transmission and Distribution
- He has a background of electrical engineering, along with an Advanced Diploma in Management, Finance and Engineering

Demand Forecasting

- The demand forecast is used as a basis for system development, and for power procurement planning.
- Over-forecasts lead to more generation resources than is required – Unnecessary capital expenditure
- Under-forecasts prevent optimal economic tariffs – Lead to purchase of power from costly units or high cost power form markets.
- Prediction of future energy demand requires an **intuitive** and **wise judgment**

Why Long Term and Medium-Term Forecasting is Important

Long Term Forecasting:

- Plays a fundamental role in economic planning of new generating capacity and transmission networks.
- Spans over 5 to 20 years.

Medium Term Forecasting:

- Used mainly for the scheduling of fuel supplies, maintenance program, financial planning and tariff formulation
- Spans over 1 month to 5 years

Short term

- Provides the basis for planning start-up and shut down schedules of generating units, reserve planning and the study of transmission constraints
- Spans over 1 day to several weeks

Very short term

- Used in economic load dispatching and security assessment
- Spans over some minutes to several hours

Demand Forecasting – At Central Level and State Level

19th Electric Power Survey (EPS) - Overview

1. Demand Forecasting at Central Level - CEA

Every Five Years

End-Use Categories (Discom Level Annual Consumption Data) Past 12 Years + Policy Initiatives (Central & State Govt Targets) → CEA (EPS) PEUM → Demand Forecast (National/State/Discom) 10 years ahead

Partial End Use Approach

Forecasts Based on State's Estimates

Annual Peak & Energy Forecasts

2. Demand Forecasting at State / DISCOM Level

Annual

End-Use Categories (Discom Level Annual Consumption Data) Past 5-8 Years + Policy Initiatives (Central & State Govt Targets) → DISCOM CAGR → Demand Forecast (National/State/Discom) 5-10 years ahead

Mostly Based on Trend Analysis

STU/SLDC Supplements with Peak Estimates

Annual Peak & Energy Forecast

Monthly Peak Estimates based on past trend

Methods of Demand Forecasting

- Time Series
- Econometric
- End-Use
- Partial End Use (Combination of Time Series and End Use)

Case of Assam State, India

Power Scenario in Assam

Maximum Demand Met and Gross Demand of Assam		
FY	Max Demand met (MW)	Max Gross Demand (MW)
2017-18	1740	1823
2018-19	1808	1895
2019-20	1956	2051
2020-21	1964	2073

* The difference between the Demand Met and the Gross Demand is because of some Distribution and Transmission Line Constraint and Line Fault.

Demand of Assam at present	
Summer	1200 MW to 1964 MW
Winter	750 MW to 1450 MW

Demand Forecasting of APDCL

Long Term Demand Forecasting (Year on Year basis)

- *To decide upon the requirement of entering into any long-term agreement for power procurement and Infrastructure Development.*

Forecasting done by CEA in Electric Power Survey

- In *19th EPS, forecasting was done from FY 16-17 to FY 26-27.*
- *Also, perspective projections was done for FY 31-32 and FY 36-37.*

Forecasting done by consultant

- *PRDC was engaged 2013 to do the forecasting from Year 2013 to 2022.*

Forecasting done by APDCL's in-house team

- *The trend of last 10 years' maximum peak demand and avg off-peak demand are studied.*
- *The forecasted Demand is compared with the availability from existing LTA.*
- *The calculation is done on excel sheet and basically CAGR type of method.*

Medium Demand Forecasting (Month on month basis)

- *To decide upon the requirement of entering into any Bilateral agreement for power procurement or Banking of Power arrangement.*

Forecasting done for next 3 years

- *Similar to Long Term forecasting, but data is more accurate.*
- *Decision for any Bilateral arrangement is taken.*
- *3 years' Merchant Power Agreement with OTPC for FY 18-19 to FY 20-21.*

Forecasting done on Month wise basis for next Financial Year (LGBR)

- *Trend of last 5 years' month wise both peak and avg Demand are studied .*
- *Seasonal variation is also seen.*
- *Decision for Banking of Power for next FY is taken.*
- *The calculation is done on excel sheet and basically CAGR type of method.*

Assam's Power Demand vs Availability scenario

FY	Forecasted Peak Hour Demand (MW) (as per own study)	Forecasted Peak Hour Demand (MW) (as per 19th EPS)	Forecasted Peak Hour Availability from existing long term agreement (LTA) (MW)	Shortfall (MW) (as per own study)	Shortfall (MW) (as per 19th EPS)	Upcoming Stations
2020-21	2078	2502	1780	298	722	SPV Assam – 100 MW (25 MW already commissioned)
2021-22	2173	2713	1780	393	933	NHPC (Tawang): 49 MW, Amguri SPV- 70 MW, Nikachhu: 80 MW
2022-23	2244	2979	1780	464	1199	Punatsangchhu-I: 204 MW, Punatsangchhu-II: 173 MW
2023-24	2320	3271	1780	540	1491	
2024-25	2403	3590	1780	623	1810	
2025-26	2492	3868	1780	712	2088	

APDCL's Existing methodology and USAID's software module

- It is expected that USAID's Demand Forecasting module will yield more accurate results than APDCL.
- While APDCL's existing methodology is Excel based, USAID's software module handle much more historical, econometric, weather and demographic data along with new drivers.
- The result in the software module is calculated based on many techniques like CAGR, trend, econometric, partial end use method, artificial neural network, ARIMA etc. The best fitted curve can be selected out of these techniques.

Methodologies of Demand Forecasting and Emerging Best Practices

Faculty - Mr. Sumedh Agarwal, Strategic Energy Planning Lead for USAID PACE-D 2.0 RE Program

Mr. Sumedh Agarwal

- Mr. Agarwal leads the development of resource planning software for distribution utilities (DISCOMs)
- Worked as Utility Planning Engineer - Designed Smart Grid Program for Dubai Electricity and Water Authority (DEWA), Dubai and AMR for Tata Power Delhi Distribution Limited, India.
- Mr. Sumedh has managed donor funded reform project with USAID, ADB, World Bank working in more than 12+ countries in Asia, Middle East and United States.
- He has a background in Electrical Engineering, and Masters (Gold Medalist) in Business from BITS Pilani.
- Coauthored two books and an international white paper on distribution practices and power sector planning.

Contents

- Summary of learnings
- Methods of Demand Forecasting
- Data Needed for Demand Forecasting
- Recommended Framework for Demand Forecasting)

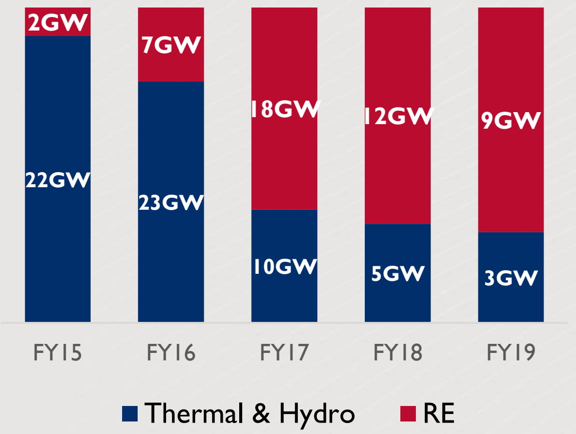
Summary of Learnings : Demand Forecasting

Conventional

- Mostly 5-10-year Forecast Horizon
- Typically CAGR
- Excel Based
- Yearly Resolution with Peak and Energy Forecasts
- Primarily dependent on historical energy sales
- Conducted Annual as part of Regulatory Compliance

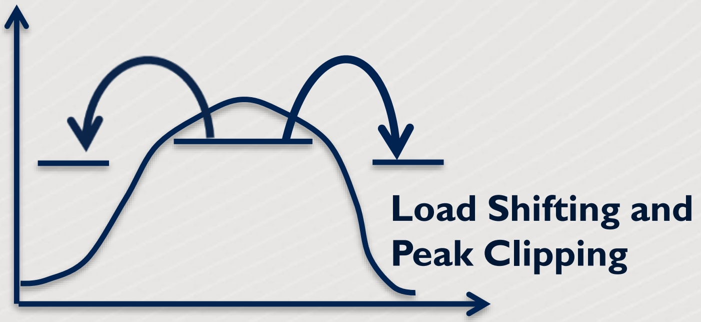
But Conventional Forecasting Approach Requires Rethinking

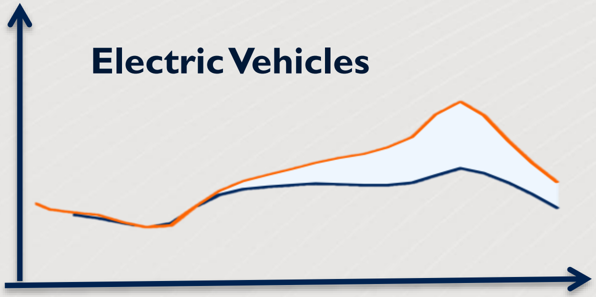
RE Capacity addition



There is an rising share of renewable capacity addition v/s conventional **in Indian power portfolio**

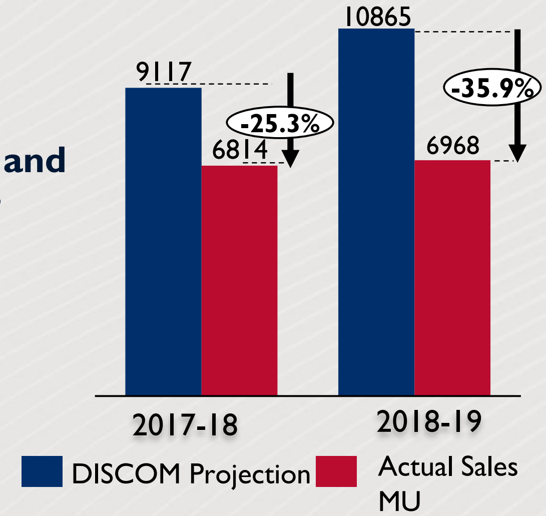
New Drivers : DSM and EV





Uncontrolled EV charging can exacerbate problems if done during peak hours of the day

Demand Forecasts : Impacts



Demand Overestimation resulted additional cost burden to DISCOM **1740 crores in FY 2018-19.**

Proposed Approach for Demand Forecasting

- High degree of spatial and temporal granularity in demand forecasts
- Improve accuracy of forecasts and develop cognizance of new realities. (RE, DER, EV and EE)
- Recognition of Uncertainty and Best Practice in Risk Management
- Use of better computing models and software's to manage mid-term and long-term resource plans.

- What comprise of scientifically advanced techniques of DF
- Recommended Framework for Demand Forecasting – Curve Fitting

- What comprise of more scientifically advanced techniques of DF

METHODS OF DEMAND FORECASTING

Demand Forecasting Methods

Parametric Methods	Artificial Intelligence Based Methods
• **Subjective** • Judgment • Intuition • Commercial knowledge • Any other relevant information. • **Uni-Variate (CAGR, Trend)** • Based entirely on past observation in a given time series. • Naive or projection forecasting technique. • **Multi-Variate (Econometric)** • Establishes casual or explanatory relationship with other variables • Whether variables co-relate or move in relation to each other in some clearly established way. • Regression models, econometric models • **End Use** • Usage of the electricity in residential, commercial and industrial sectors. • Specific energy consumption in lighting, heating, air-conditioning, refrigeration, manufacturing etc.	• **Neural networks** • Support vector machines • Genetic algorithms • Wavelet networks • Fuzzy logics • Expert system

Demand Forecast Methods

- Compound Average Growth Rate (CAGR)
- Trend Analysis
- Econometric Method
- Partial End Use Method (PEUM)
- Auto Regressive Integrated Moving Average (ARIMA)
- Artificial Neural Networks (ANN)

Compound Average Growth Rate

- CAGR is a specific term for the geometric progression ration that provides a constant growth rate over the time period.
- It is a useful measure of growth over multiple time periods.
- This method dampens the effect of volatility of periodic changes that can render arithmetic means irrelevant.

$$Y = \{(\text{Current value}/\text{Base value})^{[1/(\text{no of years}-1)]}\}-1$$

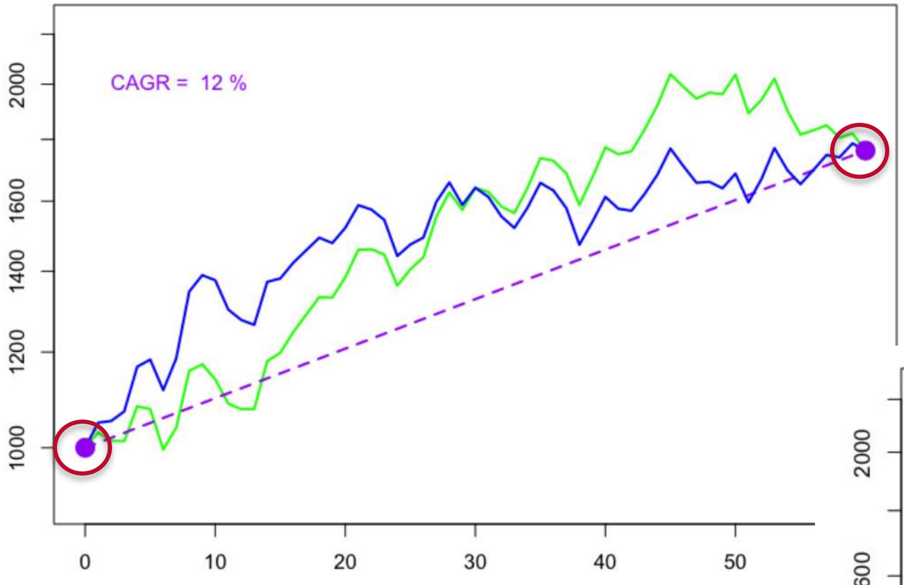
This method best suits data which has seen a uniform growth / decline over time.
Sudden impacts are not best captured by this method.

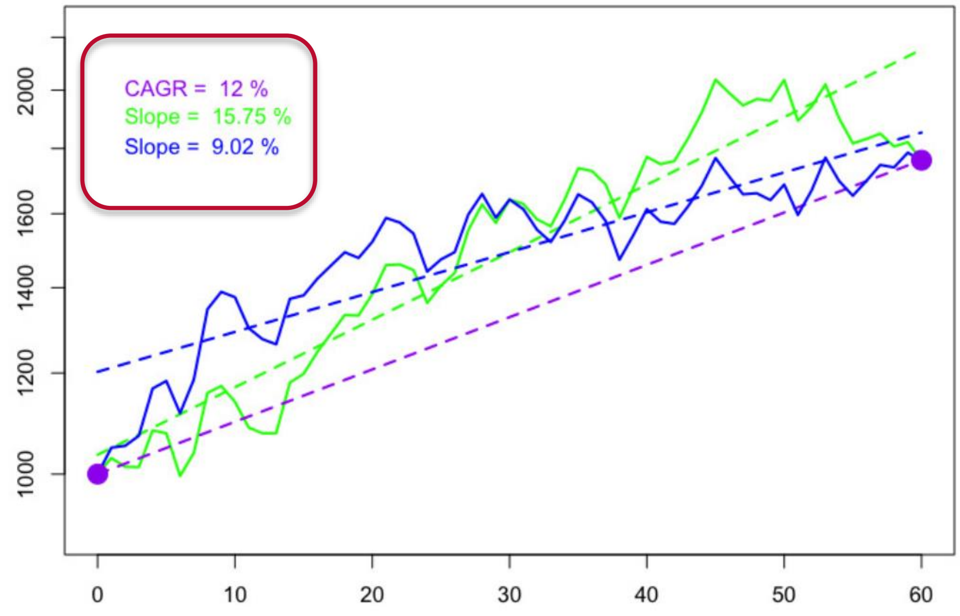
Trend Analysis

- Trending methods are widely used as a tool for forecasting which works with historical data, extrapolating past load growth patterns into future.
- Typical trends

Straight line	Parabola	S Curve	Exponential	Gompertz
$Y = a + bx$	$Y = a + bx + cx^2$	$Y = a + bx + cx^2 + dx^3$	$Y = ce^{dx}$	$Y = \ln^{-1}(a + ce^{dx})$

Trend Analysis v/s CAGR



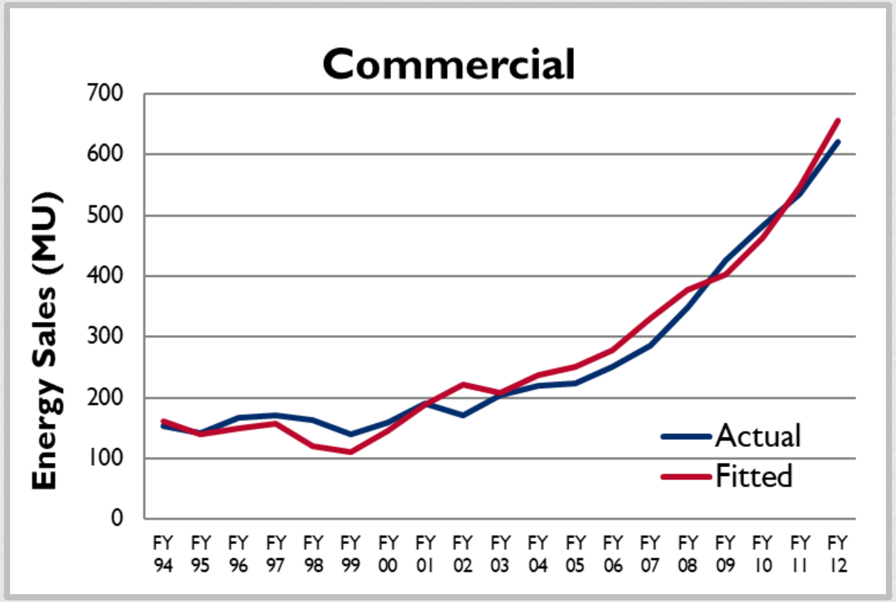


Trend Analysis help absorbs the volatility, the drawdowns on the way.

Econometric Method

$$Demand_{Commercial} = a * GDP_{Tertiary} + b * Price\ Deflator + c$$

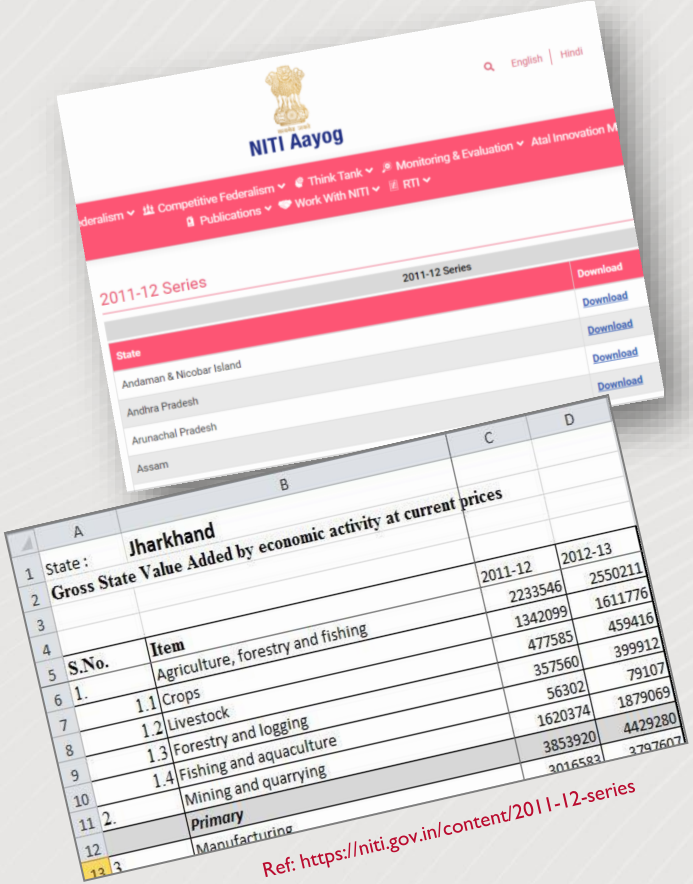
- a: 0.000327
- b: -510.859
- c: -56.4218 (constant term)



- Include behaviour of economic variables that lead to growth of the different sectors of economy
- Mostly Top Down Models
- Useful when large and predictable changes are expected.
- Different Models such as Partial Adjustment Model and Seemingly Unrelated Regression to calculate long term demand.

Demand Forecast – Econometric Variables

Gross Domestic Product	Measure of economic growth of the people living in an area
	GDP of different sector gives an insight on the possible demand from the corresponding consumer categories
Per Capita Income	Represents the average income of an individual
	Calculated based on the GDP value and the population forecasted
Price Deflator	Measure of price inflation/deflation with respect to a specific base year
	This variable explains the effect of prices in the demand equation



Ref: https://niti.gov.in/content/2011-12-series

End-Use Model

- Electricity Demand is a derived demand that arises from demand of energy services such as space conditioning, cooking, lighting, irrigation which require electrical equipment.
- "Bottom-Up Approach" focuses on final electrical energy needs of different categories of consumers such as domestic, commercial, irrigation, industries and railway traction.
- Estimate future demand in considerable detail by type, category, and size likely be demanded in the future.
- End-use data comes from **load research** carried out by DISCOMs

MEGA CITY SURVEY FOR 18TH ELECTRICI POWER SURVEY FORECAST

Name of Public Utility/ S E B/Licensee/ Elect. Deptt. …………………………………………………………..

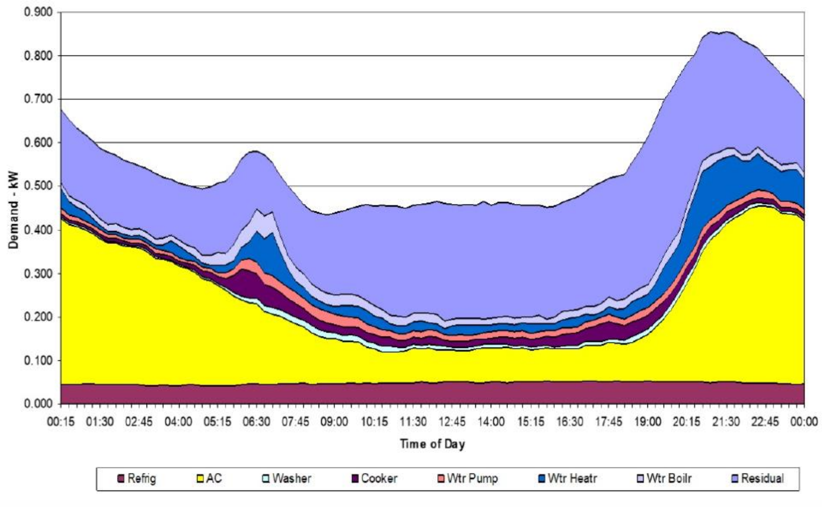
Name of City ……………………………...………………

Category: **PUBLIC WATER WORKS (LT)**

Year		Connected Load (KW)				Hours of operation		Energy Consumption	
		End Year	Mid Year	Addition during the Year	% age AGR of (1)	in Numbers (7/2)	Addition during the year	MUs	% age AGR of (7)
		1	2	3	4	5	6	7	8
1998-99	ACTUAL								
1999-00									
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									
2007-08									
2008-09									
2009-10									
2010-11	prov.								
2011-12									
2012-13									

CEA in India uses Partial End-Use and Econometric Methods for forecasting

Load Research



- Helps Utilities to understand how various consumer categories (residential, commercial, industrial, etc.) use electricity in a day
- How diversity in their usage helps flatten the demand curve.
- Conventional meter are read once in a month and there are no segregation of category-based feeders.
- AMI helps utilities to obtain load research data directly from smart meters.
- Typically include
  - Understanding consumer's load shapes: day-to-day and across seasons
  - Identify peak coincidence: consumer load against DISCOM's peak load
  - Evaluate fall in demand during off-peak hours

ARIMA – Auto Regressive Integrated Moving Average

What?

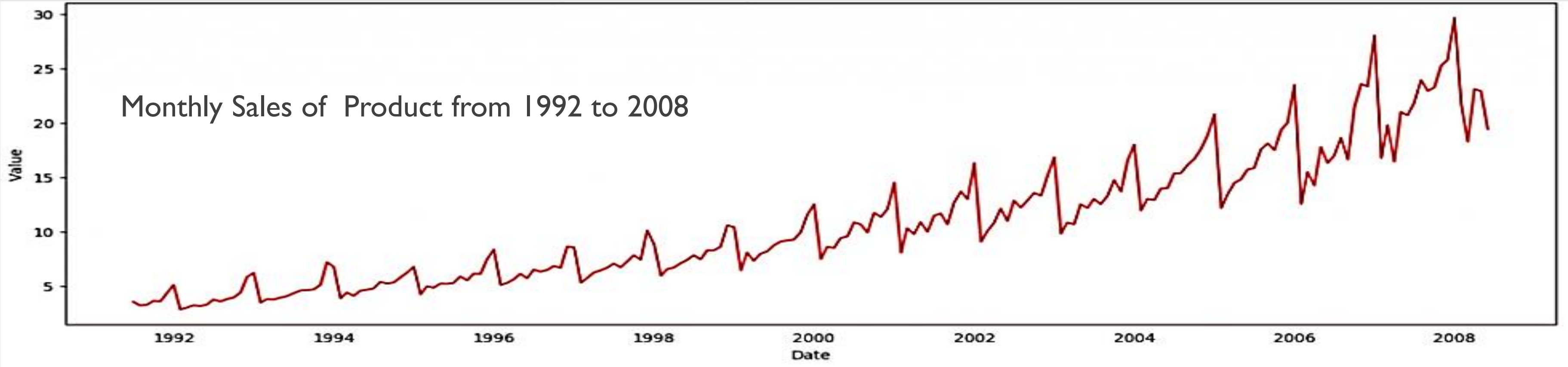
- A time series is a sequence where a metric is recorded over regular time intervals.

Why?

- Analyzing a time series is the preparatory step before forecasting of the series.

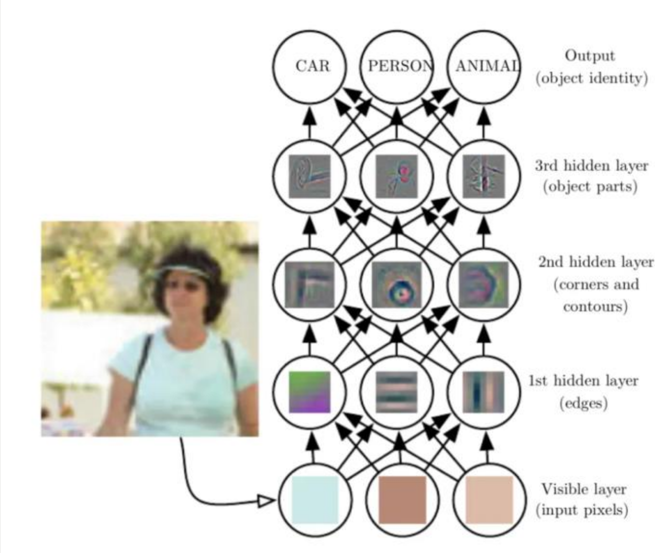
Range?

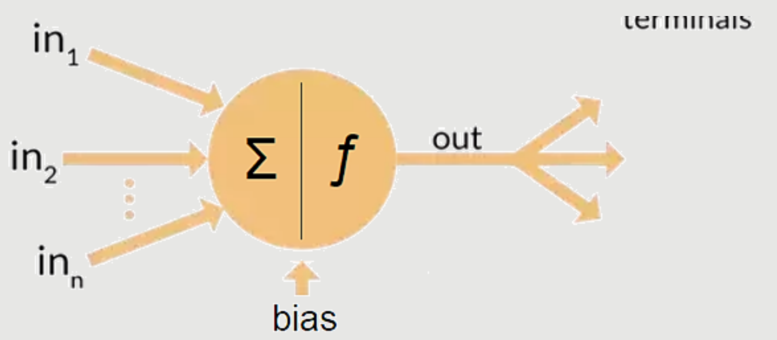
- Depending on the frequency of observations, a time series may typically be annual, quarterly, seasonal, monthly, weekly, daily, hourly



Artificial Neural Networks

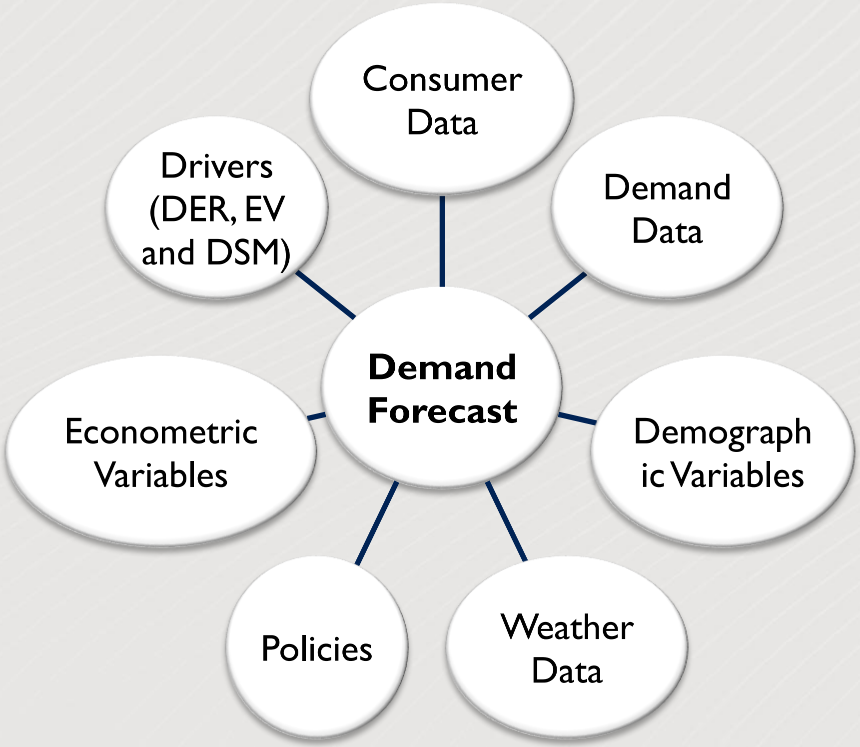
- Artificial Neural Networks (ANN) is a computational model based on the structure and functions of biological neural networks.
- Each link is associated with weight. ANNs are capable of learning, which takes place by altering weight values.
- Together, the neurons can provide accurate answers to some complex problems, such as Forecasting, Language Processing, computer vision and AI.





DATA NEEDS FOR DEMAND FORECASTING

Demand Forecasting in RE Rich Environment: Key Elements



Type of Data Used for Demand Forecasting

- **Dependent variable**: Category-wise historical annual energy & peak power.
- **Independent Variables**: Historical and predicted GDP, population, per capita income, policies, etc. (MW)

Long Term Load Forecast

- Energy forecast up to 20 years on yearly basis
- Peak demand estimations as per load factor

- **Dependent variable**: Historical monthly energy & peak power with hourly resolution.
- **Independent Variables**: Historical and predicted weather parameters, seasonality, locality

Medium Term Load Forecast

- Forecast values of dependent variable i.e. monthly energy in MU and load (MW) for up to 3 years with hourly resolution.

Demand Forecast - Demand Data

DATA SET	VARIABLES	IMPACT ON FORECAST	INDICATIVE SOURCE
Demand Data	Category-wise annual **energy consumption**	The historical energy consumption is considered category-wise to understand the inherent trend of each category.	Distribution Licensee
	DISCOM-wise annual **load profile**	The projected load profile required for resource planning is derived based on the historical load profile.	SLDC
	Load Factor	Historical load factor is vital to compute the peak demand from the forecasted energy consumption for future years.	Distribution Licensee or computation from annual load profile data

Demand Forecast – Weather Data

DATA SET TYPE	DATA VARIABLES	IMPACT ON FORECAST	INDICATIVE SOURCE(S)	ASSUMPTIONS
Weather Data	Seasons of the year	The variation in demand due to seasonal variations can be captured for better projections.	India Meteorological Department	The future seasonal trends will remain consistent
	Annual / Seasonal Max Temperature	The annual variations in weather like rise in temperature due to global warming, increase/decrease in rainfall and changes in humidity due to environmental aspects will lead to a shift in demand	Public websites for weather data like accuweather	Future trend based on user-defined projections
	Annual/Seasonal Rainfall			
	Annual/ Seasonal Average Humidity			
	Water Table	A measure of the level of underground water, which is receding year-on-year	Reports from Central and State Boards	

Weather Data Samples

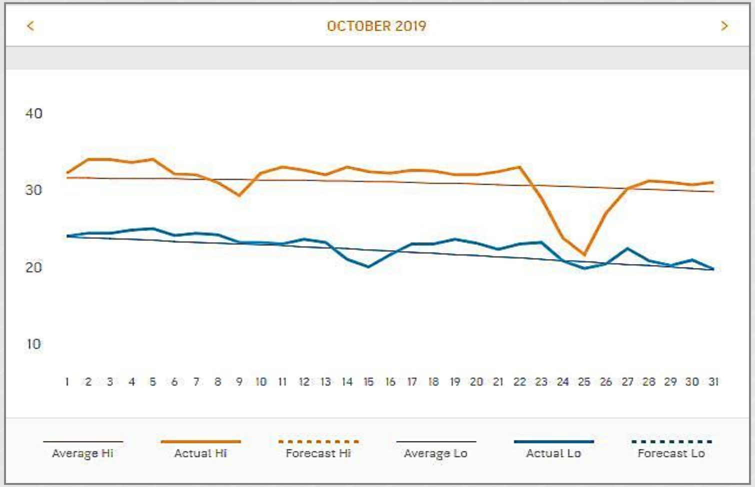
SEASONS

What are the seasons defined by the India Meteorological Department?

Meteorological seasons over India are:

- Winter Season: January – February
- Pre Monsoon Season: March – May
- Southwest Monsoon Season: June - September
- Post Monsoon Season: October - December

Ref: FAQ Document, National Weather Forecasting Centre, Indian Metrological Department



Ref: Monthly weather by Accuweather.com

Annual / Seasonal / Monthly Maximum Temperature,

Total Rainfall and

Average Humidity

Key indicators of year-on-year variation in weather

Demand Forecast – Demographic Variables

State Population

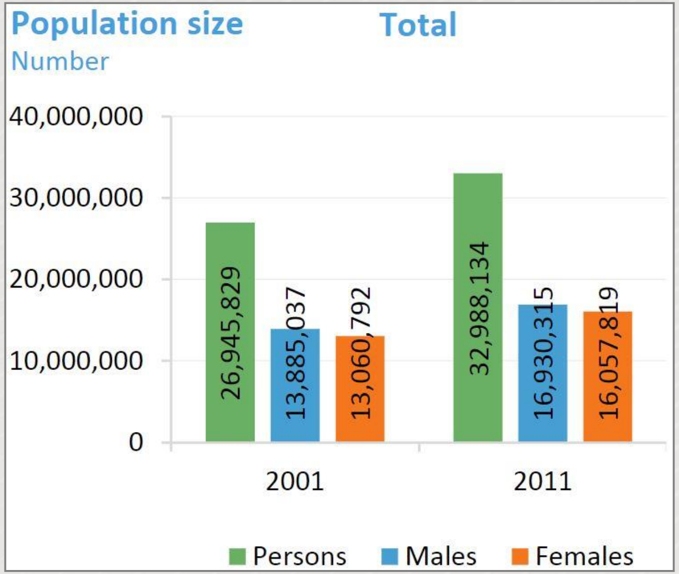
- Population of a region will have a positive correlation with the demand of that region
- With growing per capita consumption, population has a direct impact on demand

Number of households

- Due to socio-economic factors, number of persons per household is coming down, which is also a reason for increase in number of households.
- With continued improvements in quality of life, demand for energy will continue to soar

Number of connections / installations

- From the population growth estimates, the estimates on the number of installations can be apportioned
- This number is a function of the demographic growth



Ref: http://censusindia.gov.in/

Demand forecasting – Business Process

Data Set
- Consumer Data
- Demand Data
- Weather Data
- Demographic Variables
- Econometric Variables
- Policies & Drivers

Data Cleansing
- Provision to discover inaccurate or incomplete data, prior to studies and further analysis

Model Selection
- Choose one or more statistical methods to arrive at the best forecast values
  - CAGR
  - Trend
  - Econometric
  - ARIMA
  - ANN
  - PEUM

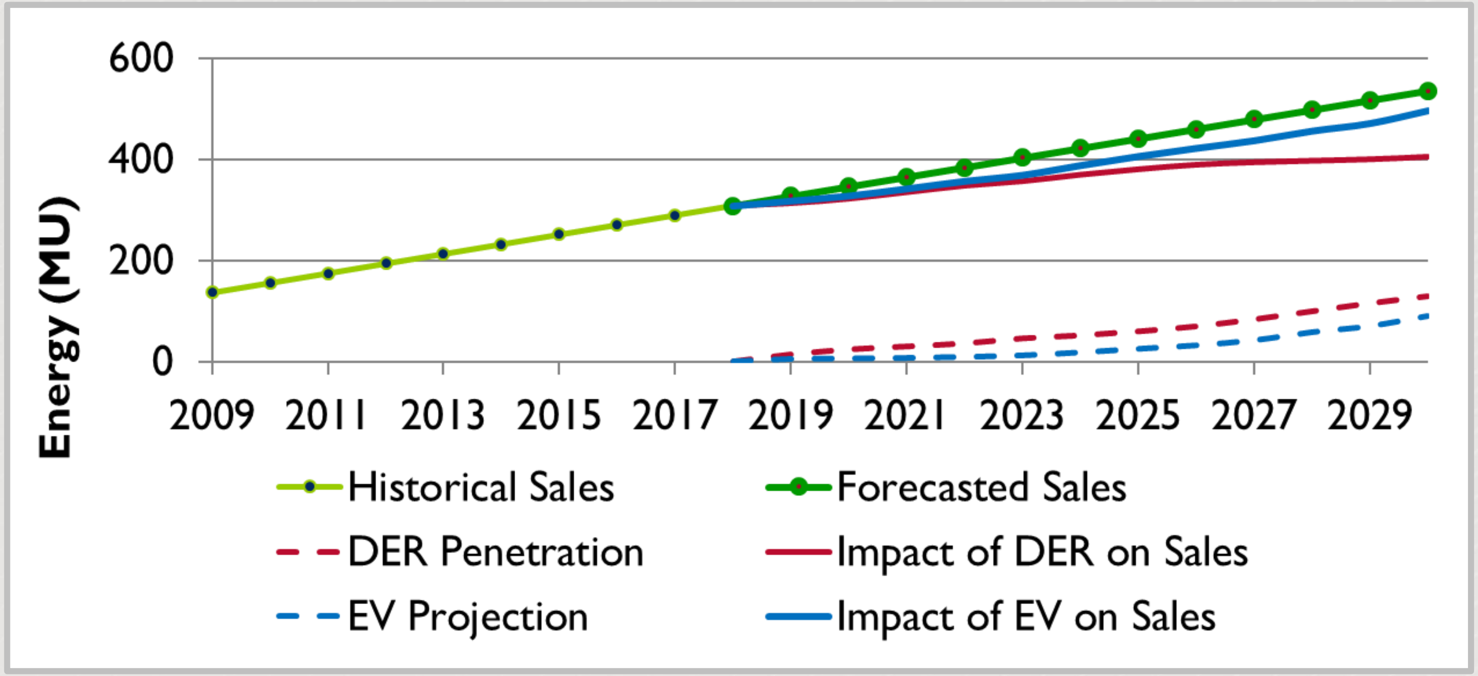
Test Analysis
- Confidence levels of the forecasted results, which get impacted by the variation of several influencing parameters, can be analysed

Output
- Forecasted results can be categorized and visualized

Recommended Framework for Demand Forecasting

Step 1 : Consideration to New Drivers

Superimposition of Impacts on Projections



Impact of EV superimposed on the forecasted demand to arrive at reliable demand projections

Electric Vehicles – Assessment of Impact

EV Categories

- 2-wheelers include Motorcycle, Scooter and Moped
- 3-wheelers include personal, passenger and e-rickshaws
- 4-wheelers include private & commercial cars
- Bus includes normal buses and omni bus

Battery Characteristics

- Average battery size (kWh per vehicle)
- Full charging cycle
- Complete charging cycle efficiency
- Energy requirement per km (kWh)

Vehicle Statistics

- Total number of vehicles on road - YoY
- Number of EV as a percent of total vehicles on road – YoY
- Average kms driven per day

Demand Forecast – Policies

Power For All

- Reliable 24x7 supply to domestic, industrial, etc
- Adequate power supply to agricultural consumers
- Provide electricity to all households by FY22

Make In India

- Ease of doing business
- Availability of modern and facilitating infrastructure
- New sectors in manufacturing, infrastructure, etc
- Government as facilitator and not regulator

Saubhagya Scheme

- Free electricity connections to households in rural areas and select families in urban areas.
- Providing Solar based standalone system for un-electrified households located in remote areas

Deendayal Upadhyaya Gram Jyoti Yojana

- GoI initiative for rural electrification
- provide continuous power supply to rural India
- Feeder separation (rural households & agricultural) and strengthening infrastructure

Energy Conservation Building Code

- Aims at establishing minimum energy performance standards for buildings in India
- Includes parameters related to RE integration

Smart Cities Mission

- Promote sustainable and inclusive cities
- Provide core infrastructure and give a decent quality of life to its citizens

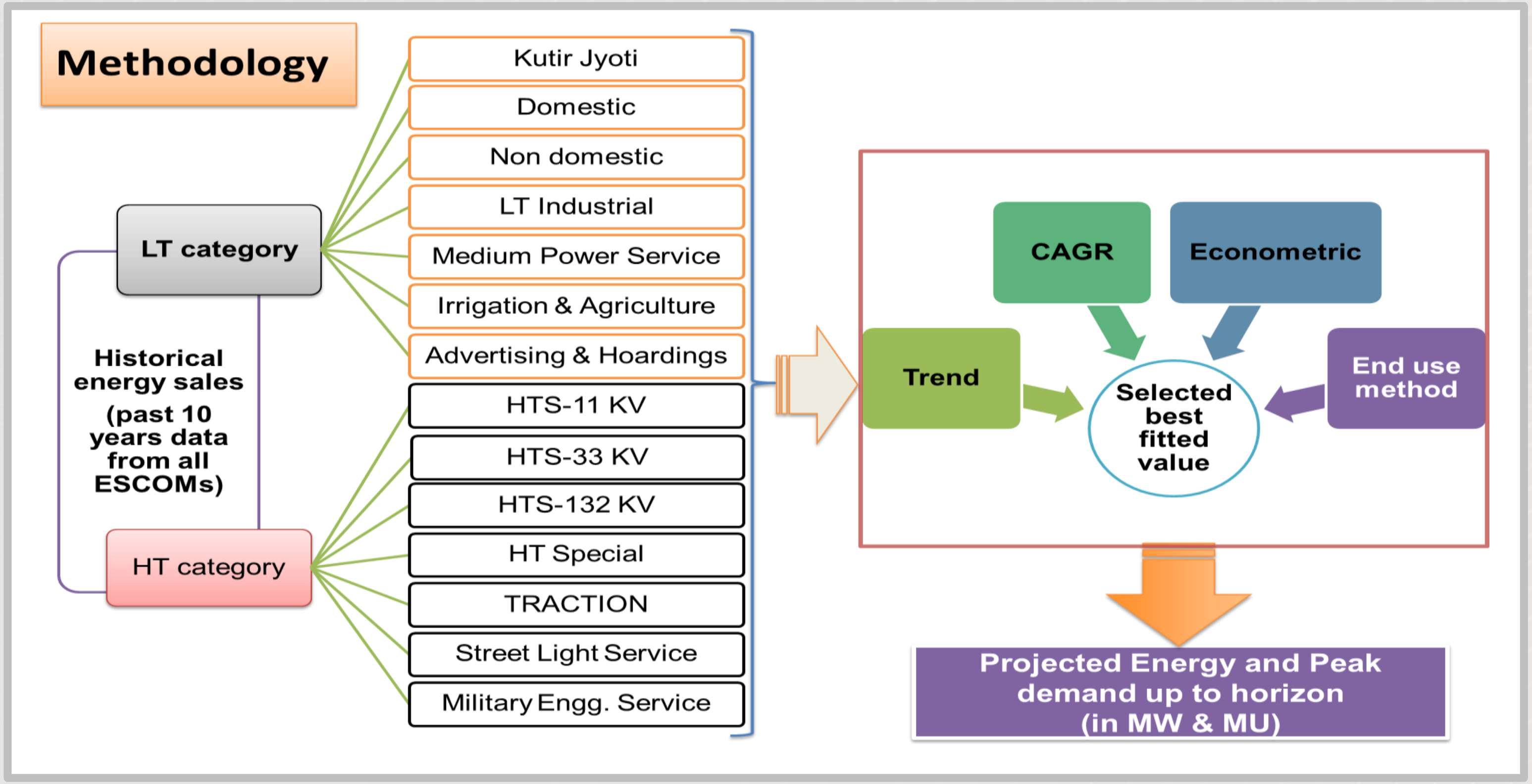
Demand Forecast – Drivers

DATA SET	DATA VARIABLES	IMPACT ON FORECAST	INDICATIVE SOURCE(S)	ASSUMPTIONS
Drivers	OA CPP	Total demand on the utility will reduce with increase in OA & CPP	Distribution Licensee	Projection based on a user-defined growth rate
	DER	Penetration of consumer level DERs reduce the total power sold by utility	State RE Development Agencies	Project DERs based on associated policy targets
	EV	Penetration of EV is expected to raise the State Demand	Documents from transport department, FAME, etc	Target number of EVs, Average kms driven
	DSM	DSM measures (Energy Efficiency and Demand Response) will target a reduction in demand.	Targets from regulatory documents or potentials assessed by BEE, etc	NIL

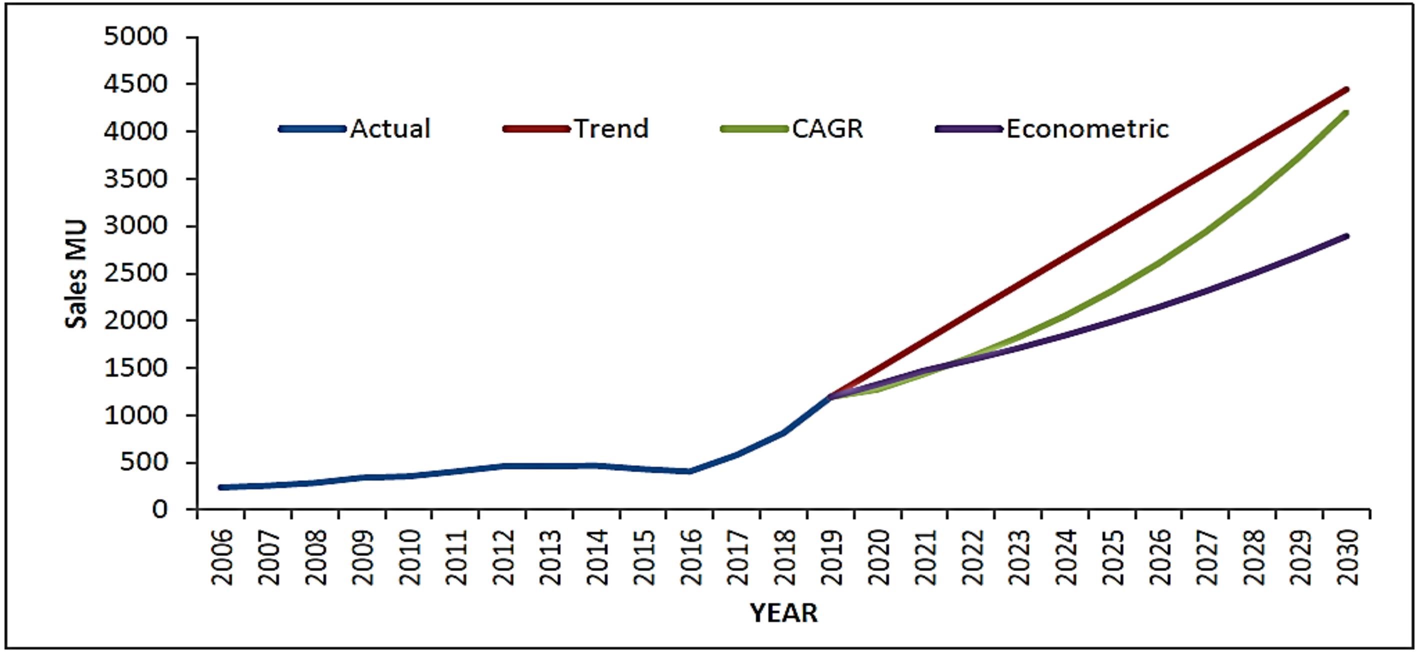
Recommended Framework for Demand Forecasting

Step 2 : Model Selection and How Curve Fitting is Done

Demand Forecast – For each consumer category

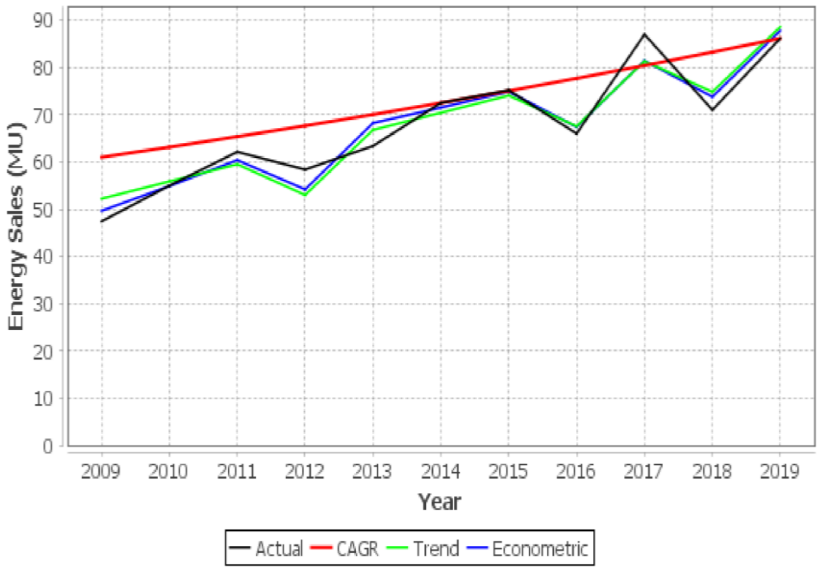


Historical Energy Consumption (MU) – Curve Fitting



The best fitting curve will be chosen as the one with which the sum of the squares of the differences between the fit values and the corresponding past input sample values is minimum.

This is then used to predict the future trend of the corresponding economic or energy consumption data.

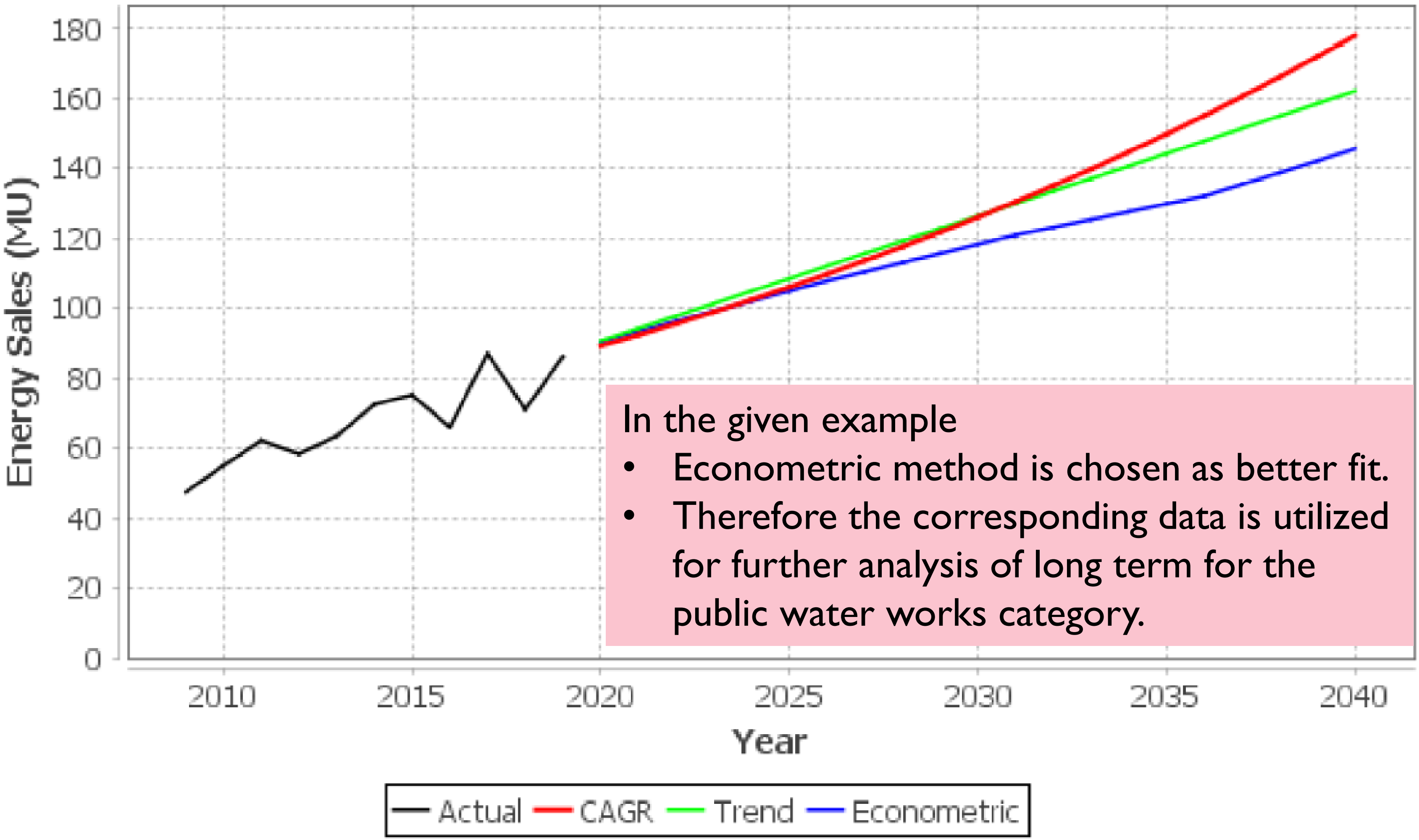


Public Water Works for DISCOM values in MU

YEAR	Actual	CAGR	Trend	Econometric
2009	47.410	60.996	52.229	49.643
2010	54.984	63.140	55.865	54.888
2011	62.125	65.359	59.501	60.383
2012	58.385	67.656	53.008	54.182
2013	63.380	70.033	66.774	68.229
2014	72.494	72.494	70.410	71.501
2015	75.180	75.042	74.046	74.869
2016	66.000	77.679	67.552	67.417
2017	87.000	80.409	81.319	81.418
2018	71.000	83.235	74.825	73.786
2019	86.160	86.160	88.591	87.801
Equation		Growth: 3.514 %	$Y = -7253.009756+3.636256*X1-10.129872*X2^2$	Y= -193.698293+0.000008*X1+0.000059*X2-10.819846*X3
Indices		R^2 :0.238 Se :8.303	R^2 :0.913 Se :4.065	R^2 :0.938 Se :3.663

Best Fitting of Curve

Coefficient of Correlation (R^2) is maximum and standard deviation Se is minimum is chosen as a method to forecast the demand for future years



In the given example

- Econometric method is chosen as better fit.
- Therefore the corresponding data is utilized for further analysis of long term for the public water works category.

Recommended Framework for Demand Forecasting

Step 3 : Converting the Energy (MU) into Demand (MW)

T & D Loss Projections

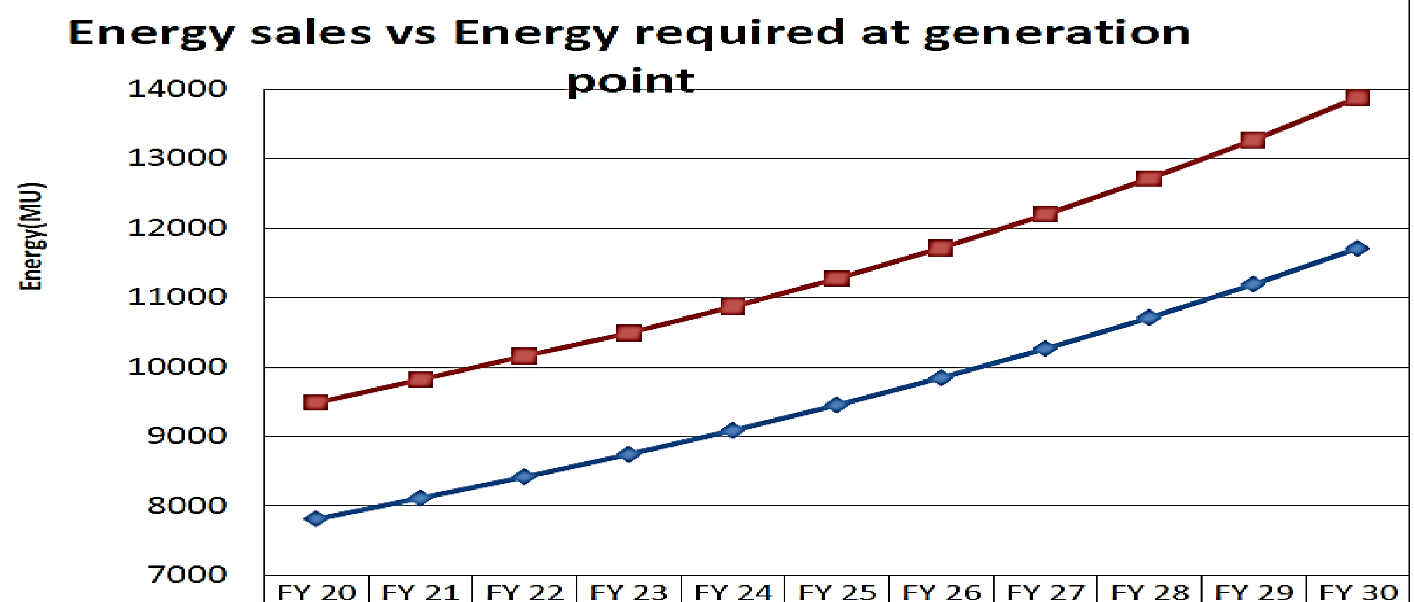
Each DISCOMs develop a loss reduction trajectory

Steps involved:	
	Historical recorded T & D losses
	Targets set by Utility / Policies
	Realization of future T & D losses
	Superimposition on projections

Total Demand = Energy Sales + T & D Losses

Initiatives like IPDS in India aims at reducing the AT&C losses by Strengthening of sub-transmission and distribution network and by metering of distribution transformers /feeders / consumers in the urban areas

Ex-Bus Generation (MU)



	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30
Total Energy Projected (HT+LT)	7810	8110	8415	8740	9085	9452	9843	10262	10710	11191	11708
Projected Energy at gen. point (MU)	9485	9819	10159	10487	10868	11274	11713	12196	12714	13269	13882

Demand Forecasting – Output Summary

Summation of Category Wise Energy MUs at DISCOM level

↓

Adding / Subtracting the Values of Energy Forecast due to New Drivers

↓

Ex Bus Energy Considering T&D losses

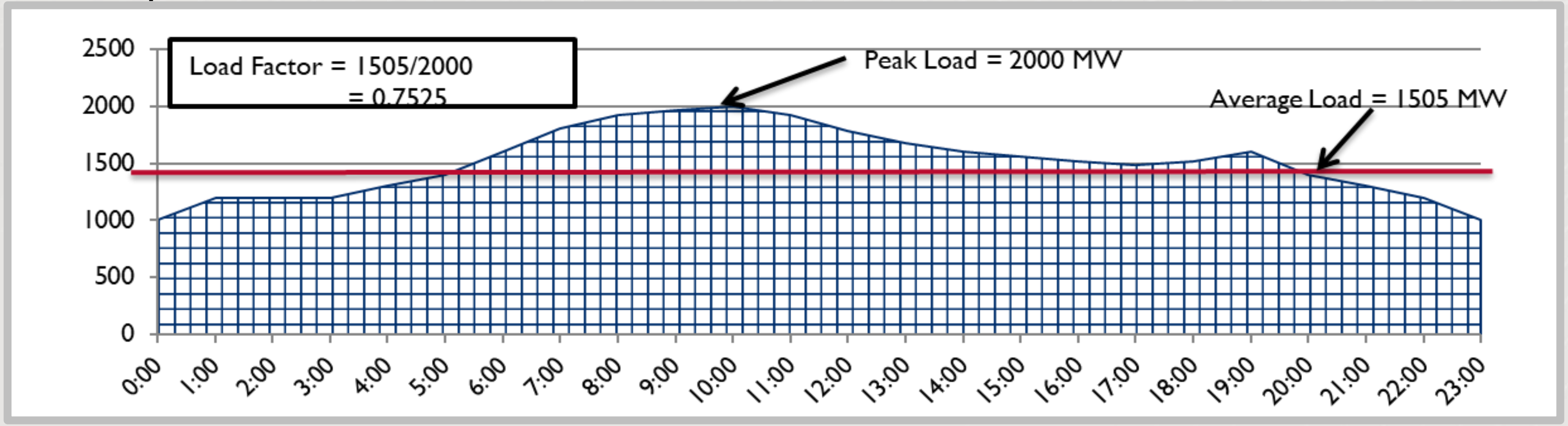
↓

Convert Energy Input Determined to Peak Demand by dividing it with load factor

Historical Load Factor Computation

Peak Demand Forecasting

- Forecasting should be done for electrical energy.
- Annual peak demand is obtained by annual load factor as –
  - Peak demand MW = (Energy sales in MU *1000)/(Load factor * 8760)
  - A reliable load factor value is required. Therefore average of past 3-4 years hourly load profile data is used.

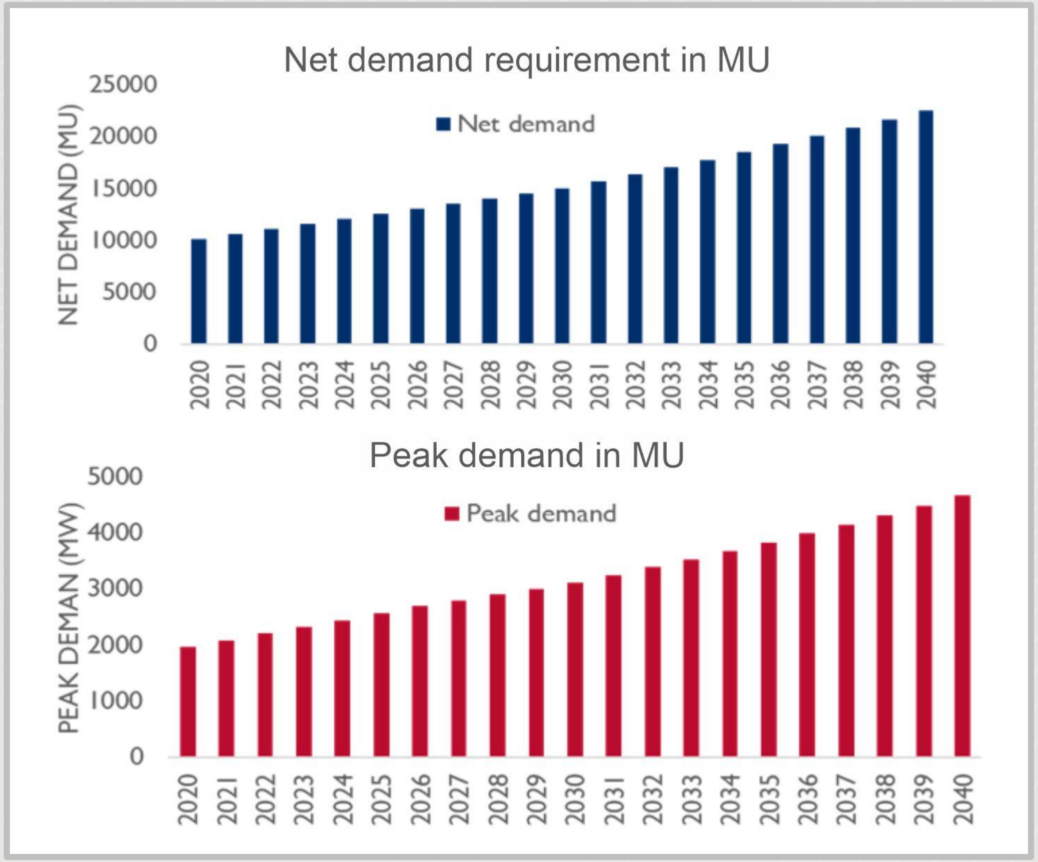


Recommended Framework for Demand Forecasting

Step 4 : Developing Profiles and Further Analysis

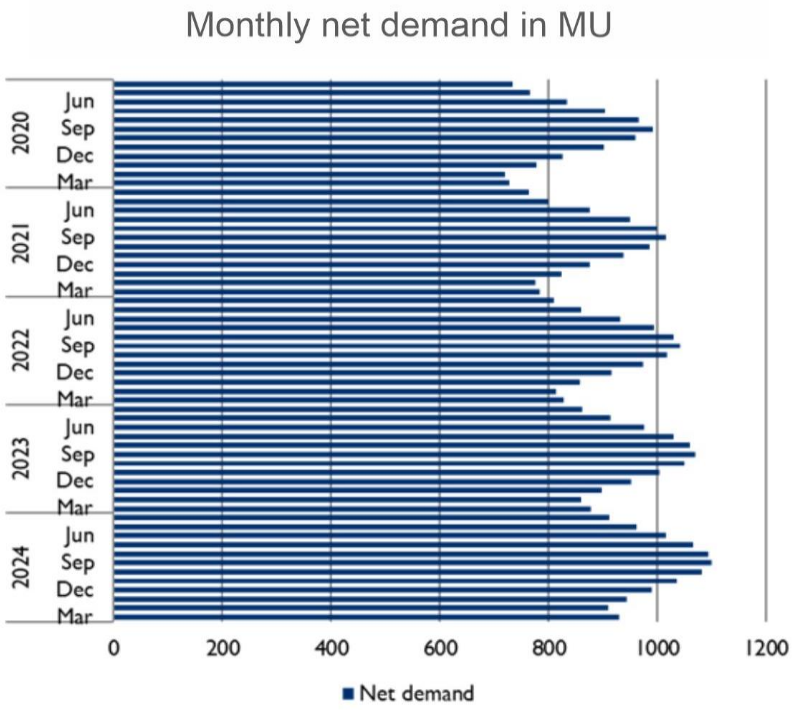
Results: Long Term Forecasting

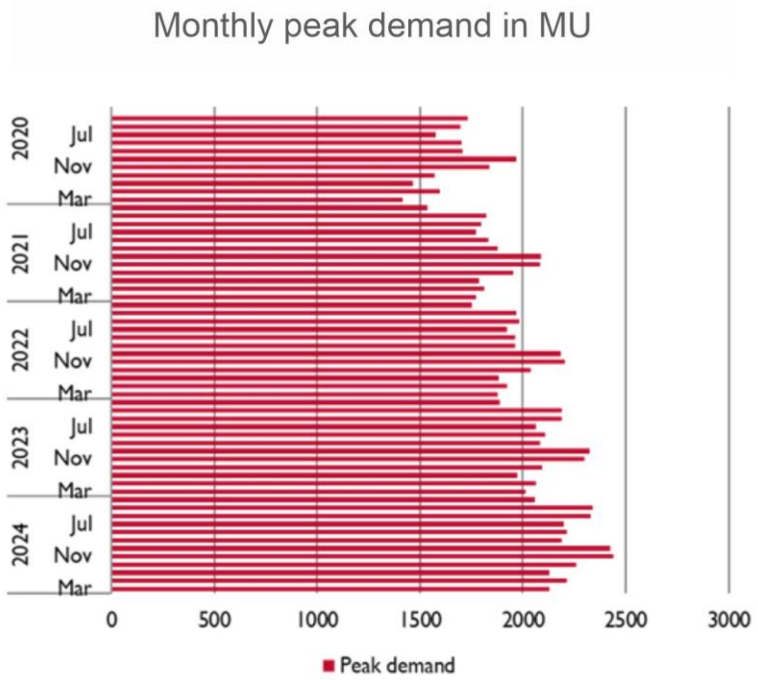
- Long term demand forecasting: 2020 to 2040
- Based on the average load factor of previous 3 years, the peak demand is estimated.
- On an average, % deviation of demand projections w.r.t energy sales approved is **4.8% for partner Discom in program**



Source: BAU Report

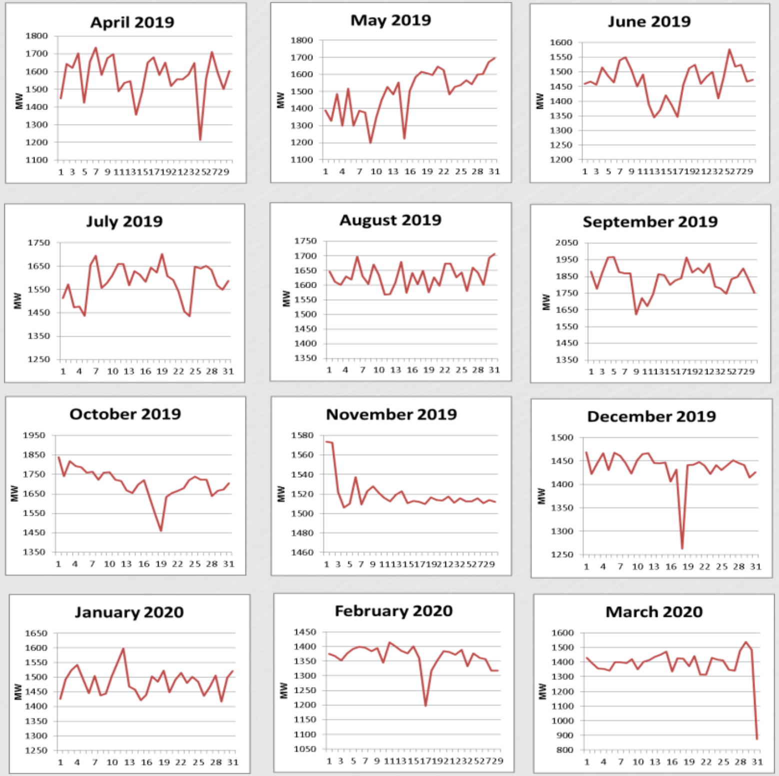
Results: Medium Term Forecasting



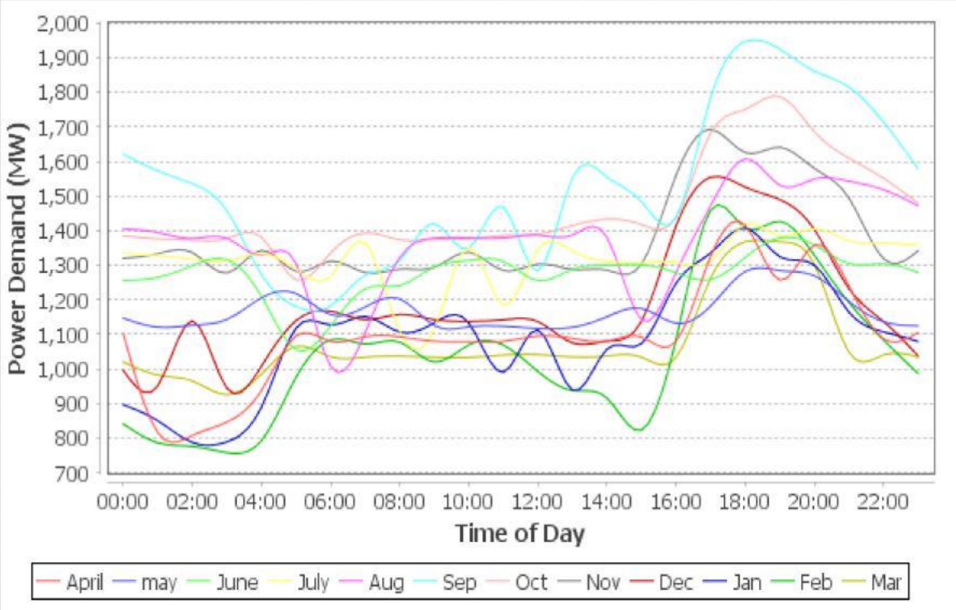


Source: BAU Report

Results: Hourly Load Profiles



The load profile for the day of each month having peak demand is shown for the year 2020.



Source: BAU Report

Demand Forecasting – Output Summary

Category-Wise Long Term Annual Demand Forecast

Category-Wise Medium Term Annual Demand Forecast

Medium Term Hourly Demand Forecast for the State

Sensitivity Studies

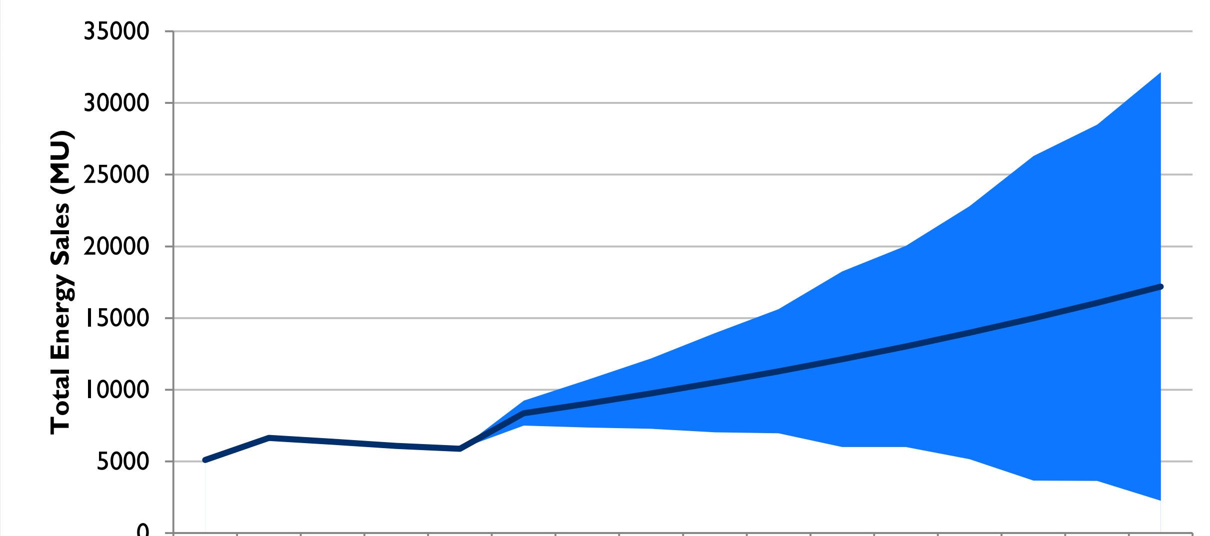
- Increasing/ Shifting irrigation supply
- Excluding the impact of one or more parameters
- Addition of one or more parameters
- Impact of Policy Changes

Scenario Building

- Business-As-Usual Scenario
- High Demand Scenario
- Low Demand Scenario
- Other User-Defined Scenarios

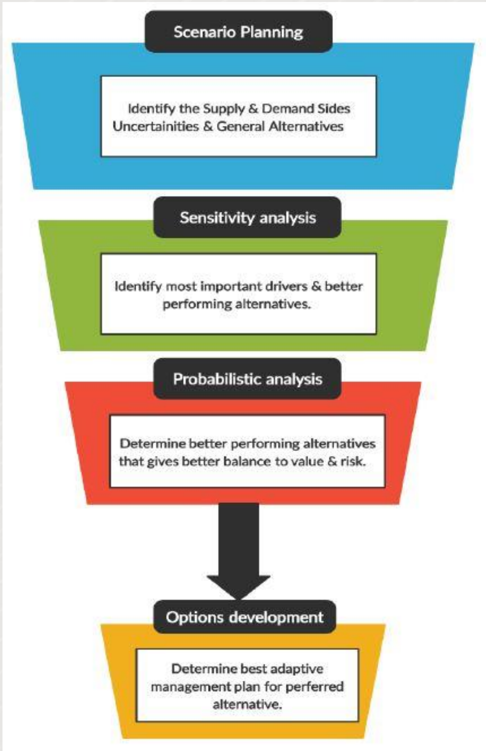
Probabilistic Analysis

Probabilistic Energy Sales at Varying Standard Deviation of Independent Variable for the Year 2030.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Upper limit	5098	6640	6362	6085	5877	9232	10694	12191	13941	15610	18255	20040	22801	26302	28487	32147
Lower limit	5098	6640	6362	6085	5877	7488	7364	7281	7034	6958	6004	6014	5153	3671	3630	2250
Mean	5098	6640	6362	6085	5877	8360	9029	9736	10487	11284	12129	13027	13977	14986	16059	17199

Source: Probabilistic Analysis Report



Risk Based Resource Plan Identification

Recommended Framework for Demand Forecasting

Step 5 : About the DISCOM REPOSE Software
Demand Forecasting Module

Faculty – Mr. Kashyap Vasudevan, Domain Lead at Power Research and Development Consultants Pvt. Ltd. (PRDC)

Mr. Kashyap Vasudevan

- 10 years of rich experience in electrical power system domain
- Domain expertise in developing algorithms for generation dispatch support system, Mixed Integer Linear Programming and in concepts of distribution system strengthening.
- B.E. (Electrical and Electronics Engineering) and M.Sc. by research in Power System

Parameters Considered for Demand Forecasting

- Demand is forecasted under two scenarios:
  - ✓ Business As Usual
  - ✓ Scenario with Drivers

Business As Usual	Scenario with Drivers
• Based on the energy sales and econometric data, the demand is forecasted for all the consumer categories. • CAGR, Trend, and Econometric for long term forecasting • ARIMA and ANN for medium term forecasting	• In this impact of drivers is considered on BAU scenario to forecast the demand. • Drivers: Open Access (OA), Captive Power Plants (CPP), Distributed Energy Sources (DER), and Electric Vehicles (EVs).

Further, sensitivity and probabilistic analysis is done to study the variation in demand.

About Tool

- The demand forecasting can be performed at DISCOM level for all categories.
- The various consumer categories, like residential, commercial, industrial etc., can be considered for forecasting.

The methods that have been provided in the software to arrive at the best forecast values are:

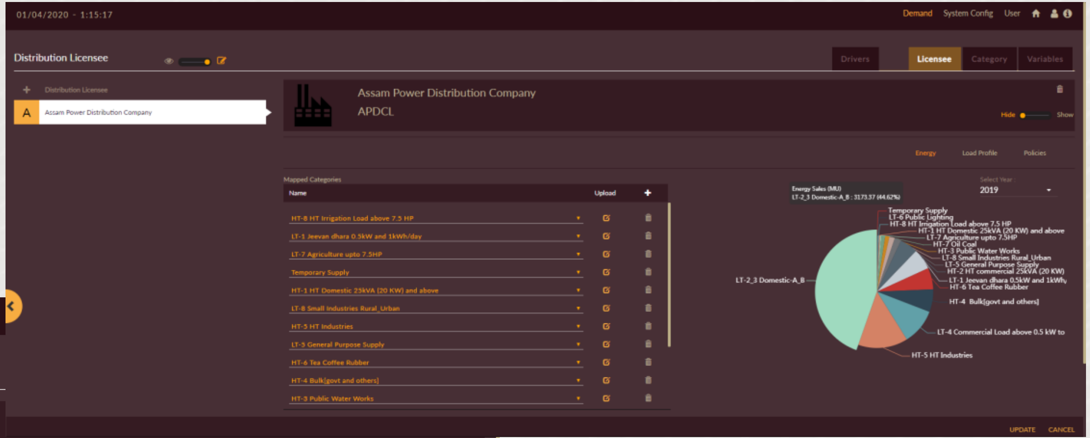
Univariate:
- CAGR
- Trend Analysis

Multivariate:
- Econometric Method
- ARIMA
- ANN

PEUM:
Decomposes the sales of electricity into its elemental component of consumption

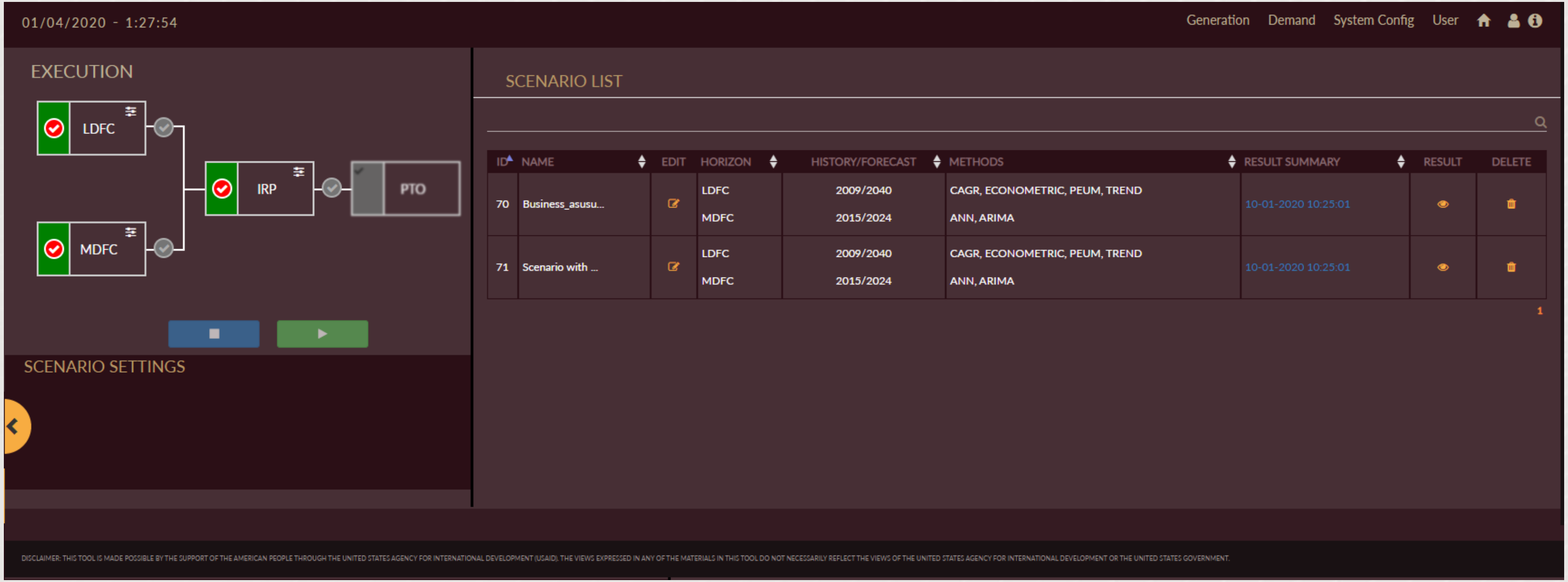
Tool Highlights: Configuration of DISCOM

- The DISCOM and associated consumer categories can be configured as a one-time activity.
- The historical energy sales observed for each consumer category can be uploaded into the tool.



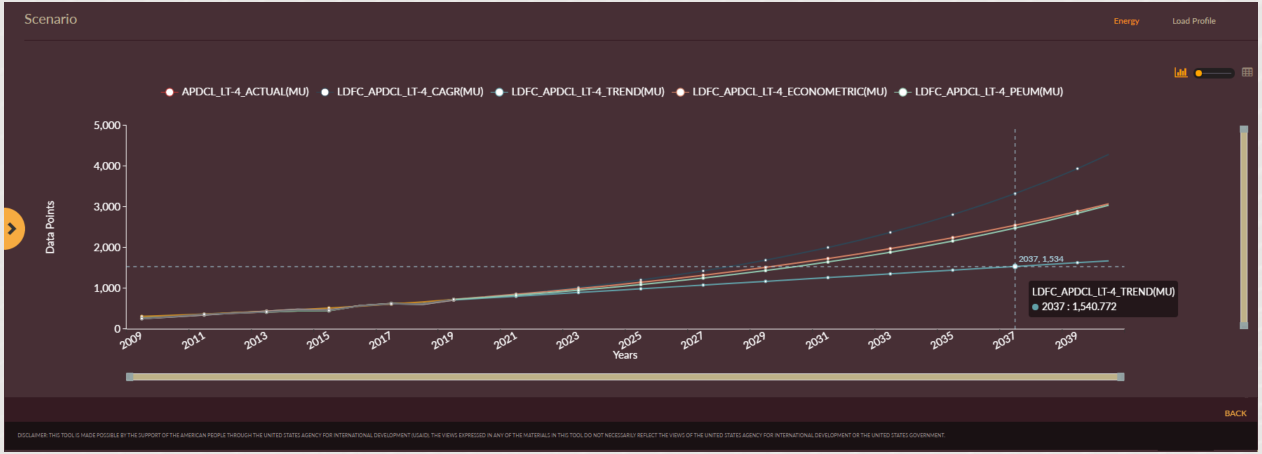
- The SCADA data can be directly imported into the tool for capturing the hourly load profile and the load factor observed.

Tool Highlights: Scenario Creation



Several scenarios can be created in the tool to analyse various aspects and carry out sensitivity studies to understand the impact of various policies and drivers on the total demand.

Tool Highlights: Forecast Results



The results obtained for each category by different forecasting methods can be visualized both graphically and in tabular form to identify the most suitable forecast results

Year	APDCL				
	LT-4				
	APDCL_LT-4_ACTUAL(MU)	LDFC_APDCL_LT-4_CAGR(MU)	LDFC_APDCL_LT-4_TREND(MU)	LDFC_APDCL_LT-4_ECONOMETRIC(MU)	LDFC_APDCL_LT-4_PEUM(MU)
2009	274.53	312.847	257.556	260.653	274.53
2010	315.159	340.418	303.386	310.595	315.159
2011	353.928	370.418	349.215	367.167	353.928
2012	403.062	403.062	395.044	393.79	403.062
2013	417.217	438.583	440.873	423.841	417.217
2014	449.977	477.234	486.702	471.471	449.977
2015	451.24	519.292	470.376	459.326	451.24
2016	578.3	565.056	578.36	571.237	578.3

Results obtained for LT4 Commercial category

DESIGNING RENEWABLE DOMINATED RESOURCE PLANS FOR FUTURE UTILITIES

Thanks!

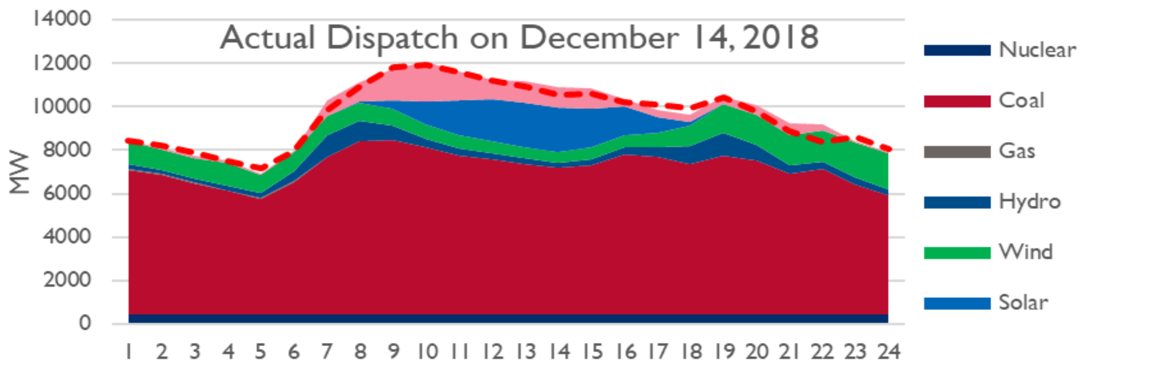
Module III

USAID FROM THE AMERICAN PEOPLE

GOVERNMENT OF INDIA MINISTRY OF NEW AND RENEWABLE ENERGY

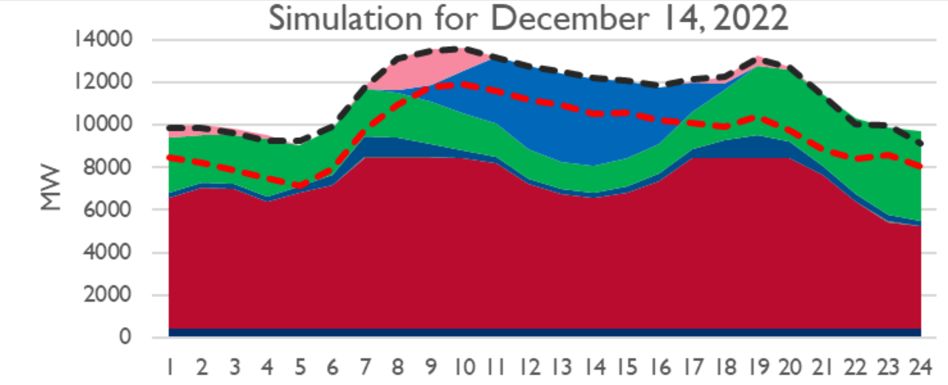
How Supply and Demand Curve Matching Helps Higher RE Uptake ? – A Simulation Study for Rajasthan

Demand FY2018



Dispatch on Dec. 14, 2018

- PLF of TPPs – 71%
- RE Generation Share – 15%
- Avg. Power Cost – Rs 4.88/u



Demand FY2022

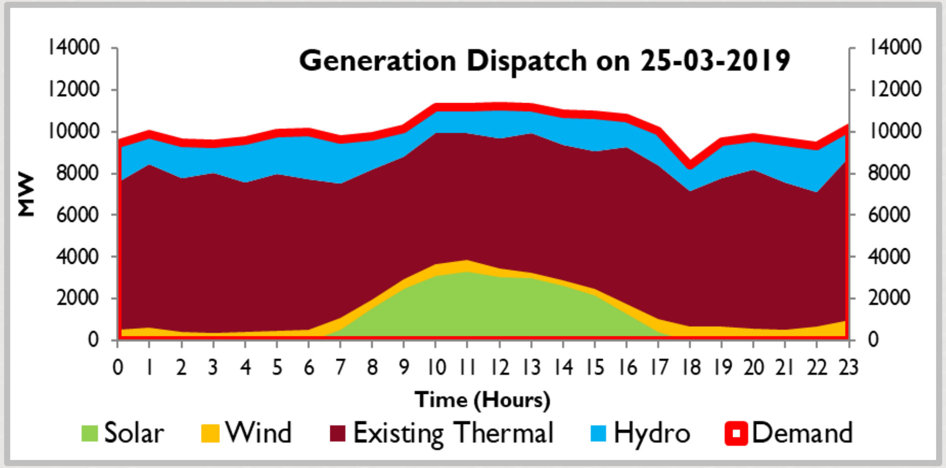
Capacity Add.
2x Solar
2.5x Wind
Others- Nil

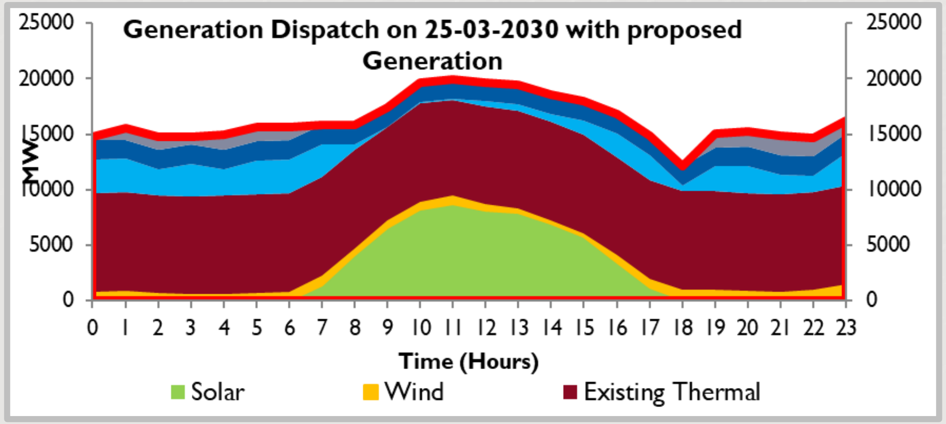
Simulation for Dec. 14, 2022

- PLF of TPPs – 72%
- RE Generation Share – 30%
- Avg. Power Cost– Rs 4.63/u (Decrease of about 5.2%)

With better Demand Forecast & Resource Planning, RE Share can Get Doubled

Karnataka : Resources Optimization using Simulation Tool





2019

Peak Demand : 11245 MW

Resources : Thermal + Hydro + RE (W+S)

2030

Peak Demand : 19127 MW

	Business As Usual (+)	**RE Scenario (+)**
Thermal	4720 MW	2670 MW
RE	0 MW	6400 MW
Storage	-	2000 MW
Cost	17,800 Cr.	16,800 Cr.

No stranded asset created

No system level grid security issues

Savings of 1000 Crs/annum

Assam's Power Demand vs Availability scenario

FY	Forecasted Peak Hour Demand (MW) (as per own study)	Forecasted Peak Hour Demand (MW) (as per 19th EPS)	Forecasted Peak Hour Availability from existing long term agreement (LTA) (MW)	Shortfall (MW) (as per own study)	Shortfall (MW) (as per 19th EPS)	Upcoming Stations
2020-21	2078	2502	1780	298	722	SPV Assam – 100 MW (25 MW already commissioned)
2021-22	2173	2713	1780	393	933	NHPC (Tawang): 49 MW, Amguri SPV- 70 MW, Nikachhu: 80 MW
2022-23	2244	2979	1780	464	1199	Punatsangchhu-I: 204 MW, Punatsangchhu-II: 173 MW
2023-24	2320	3271	1780	540	1491	
2024-25	2403	3590	1780	623	1810	
2025-26	2492	3868	1780	712	2088	

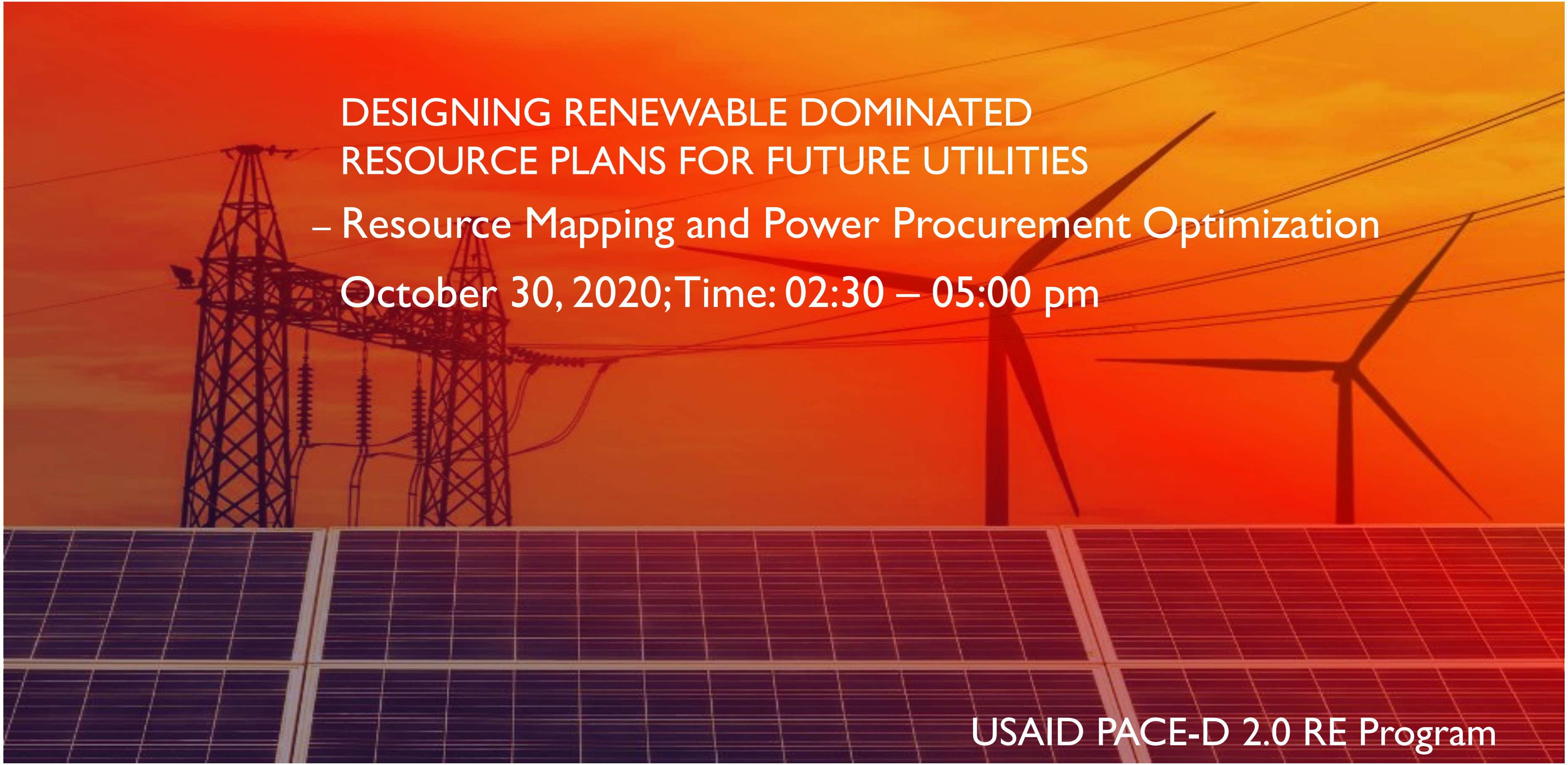
Global Practices for Demand Forecasting

	Demand forecast Model	Periodicity	Tool
Europe	Econometric and End Use are most prevalent	Annually evaluated for a period of about 10 years by most Utilities.	Mostly ANTARES. Other tools include PLEXOS, GRARE, BID3, and PowrSym
America	Econometric, End Use and Statistically Adjusted End Use (SAE) are most prevalent models	Annually evaluated for a 20 year period by most Utilities.	Strategist, PROVIEW, Metrix, LoadMAP-R and PLEXOS
Australia & New Zealand	Econometric Method	Annually evaluated for a 20 year period	PLEXOS
Malaysia	Time Series, Regression Analysis	Evaluated for upto 20 years	Not Available

MODULE IV: RESOURCE MAPPING AND POWER PROCUREMENT OPTIMIZATION

The goal of this module is to identify the best resource (renewable, thermal, , and others) and its quantity to match the demand with minimum grid integration cost.

- **Objectives:**
  - Understand how to map the generation resources to meet the demand
  - Understanding of linear programming to determine the optimal output
  - Understand how to choose optimal energy mix considering higher uptake of renewable energy
  - Development of power procurement plans
- **Content:**
  - Why integrated resource mapping?
  - Characteristics of resources (thermal, hydro, RE etc.)
  - What generation parameters are to be considered for resource mapping?
  - How to select correct generation mix?
  - How to deal with uncertainties in generation forecast?
  - What is Mixed Integer Linear Programming (MILP)
  - Methodology of Integrated Resource Mapping (IRM)
  - How to develop load generation balance at weekly and hourly intervals
  - Outputs and benefits of IRM to state
  - Utility power procurement process
  - Attributes of power procurement, how utility decides procurement plan?
  - How to optimize power procurement plan? What parameters are to be considered for optimizations?
  - What is planning reserve? How it should be included in power procurement?
  - Power procurement optimization
  - Outcomes
- **Presentation:**



DESIGNING RENEWABLE DOMINATED RESOURCE PLANS FOR FUTURE UTILITIES

– Resource Mapping and Power Procurement Optimization

October 30, 2020; Time: 02:30 – 05:00 pm

USAID PACE-D 2.0 RE Program

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GOVERNMENT OF INDIA MINISTRY OF NEW AND RENEWABLE ENERGY

Agenda

Time	Session
02:30 – 02:35 pm	Recap of the previous sessions and update on next sessions, Mr. Sumedh Agarwal, Strategic Energy Planning Lead, USAID PACE-D 2.0 RE Program
02:35 – 02:50 pm	Introduction to Resource Mapping – Mr. Rishi Nandan, GM, Jharkhand Bijli Vitran Nigam Limited
02:50 – 03:50 pm	Resource Mapping and Power Procurement Optimization – Dr. Nagaraja and Dr. Chandrasekhar Atla, PRDC
03:50 – 04:00 pm	Q/A and Quiz
04:00 – 04:50 pm	Demonstration of Resource Mapping and Power Procurement Optimization Module
04:50 – 04-55 pm	Plan for Tutorial on November 04, 2020
04:55 – 05:00 pm	Concluding Remarks

Resource Mapping and Power Procurement Optimization

DESIGNING RENEWABLE DOMINATED RESOURCE PLANS FOR FUTURE UTILITIES

Resource Mapping and Power Procurement Optimization

Mr. Rishi Nandan

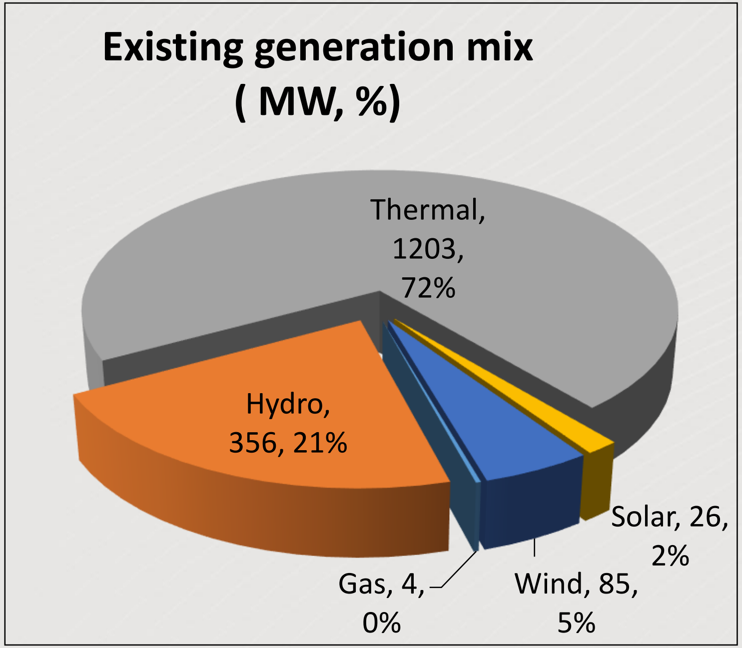
General Manager,

Commercial dept. – JBVNL

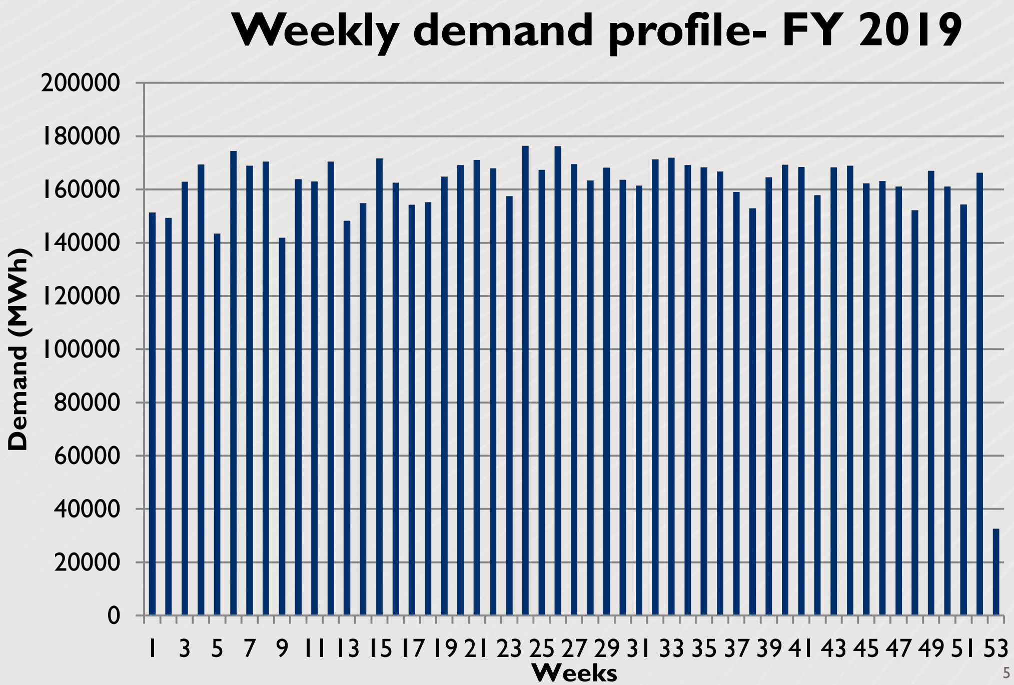
Mr. Rishi Nandan has 20 years of experience in power sector, leading a team of 20 people involved in day to day power operation in coordination with SLDC, Power resource optimization through long term and short-term planning, integration of renewables in power portfolio of JBVNL, and conceptualization and implementation of project to increase penetration of renewable energy in the state of Jharkhand.

Bachelor of Engineering in Electrical from MSRIT, Post Graduate Diploma in Management from IIM, Ranchi. At present, pursuing PhD from The Institute of Chartered Financial Analysts of India (ICFAI) with research title being "Effect of Power management on economic growth of Small and Medium Industrial Sector in Jharkhand“.

Jharkhand Power Sector at a glance(Non - DVC area)



FY 2019 JBNVL summary	Energy (MU)	8521.2
	Peak demand (MW)	1319



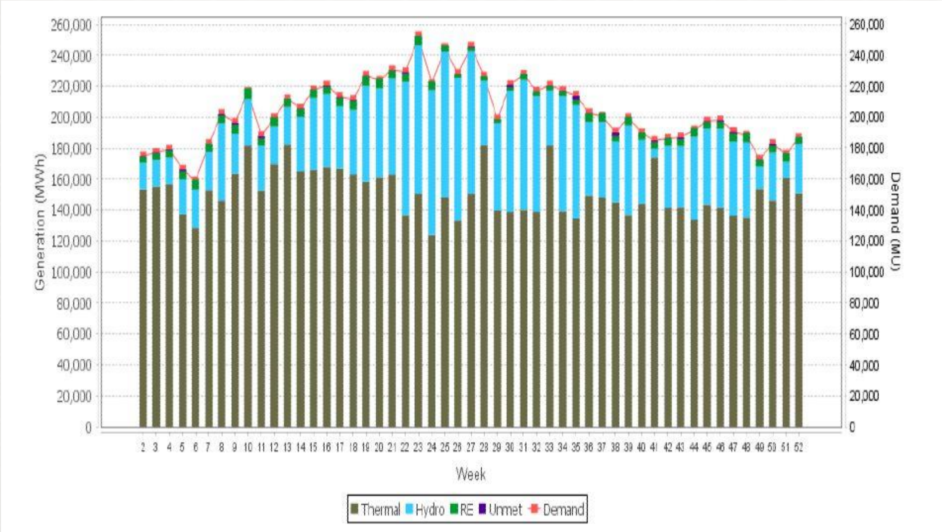
Introduction – Resource Mapping

- Resource Adequacy is the ability of the diverse generating resources in the power system to match the load on the power system. It is based upon a state-of-the-art probabilistic analysis conducted using sophisticated market-modeling tools.
- The planning analysis is important to assess whether the electricity supply will be able to remain secure and available when needed.
- It facilitates the planning process of new energy supply facilities to deliver energy while avoiding overinvestments.

Resource mapping is an increasingly prominent issue that requires advanced methodologies to capture and analyse rare events with adverse consequences for the supply of electric power. It describes the continuous balance between net available generation on the one hand and net load levels on the other

Introduction – Resource Mapping

- Matching available generation (based on predetermined PLF) with total energy consumption does not guarantee adequate resource planning. Several operational constraints also need to be factored before arriving at generation.
- Globally, adequacy assessment is a key aspect of Resource mapping.

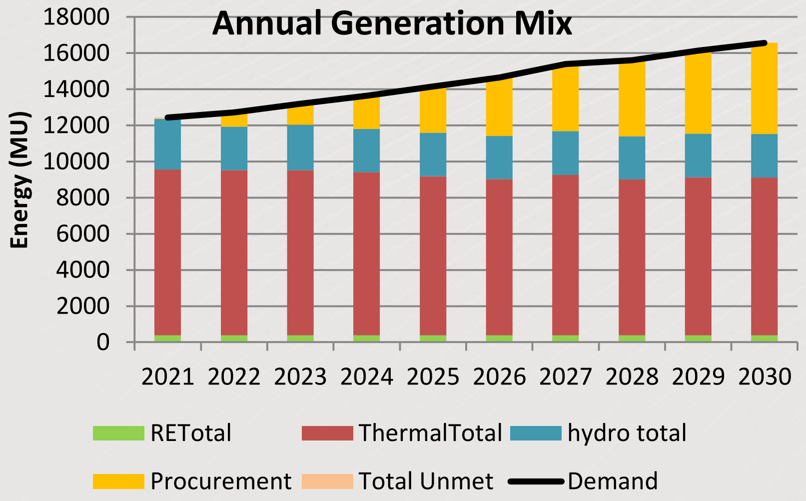


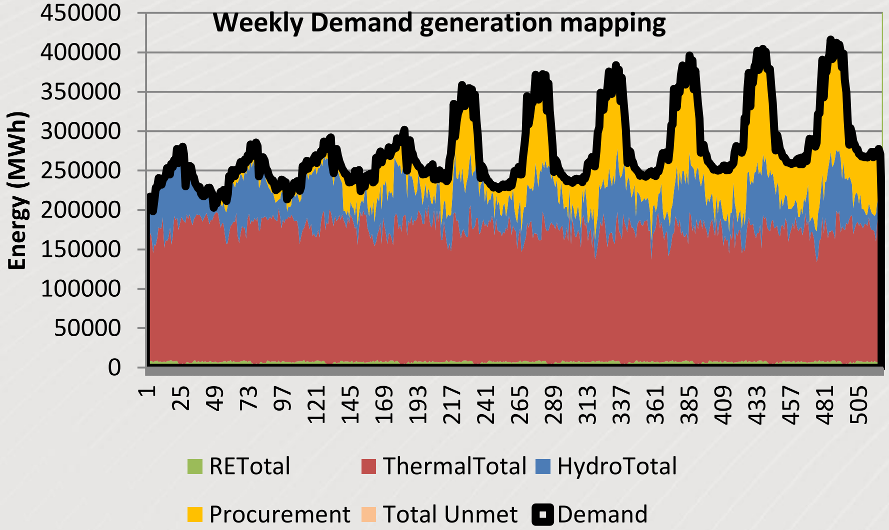
Importance – Resource Mapping for Utilities

- It's crucial to create a plan that identifies risks and issues as early as possible in the project so resolution or mitigation options can be executed to reduce the potential risks.
- The utilities need to minimize the total cost under constraints for all types of generations.
- Identification of optimal generation mix to meet the forecasted demand.
- Developing a generation expansion plan to meet the unmet demand across the study horizon.
- Formulating a reliable generation plan considering the inherent uncertainties in demand and generation.

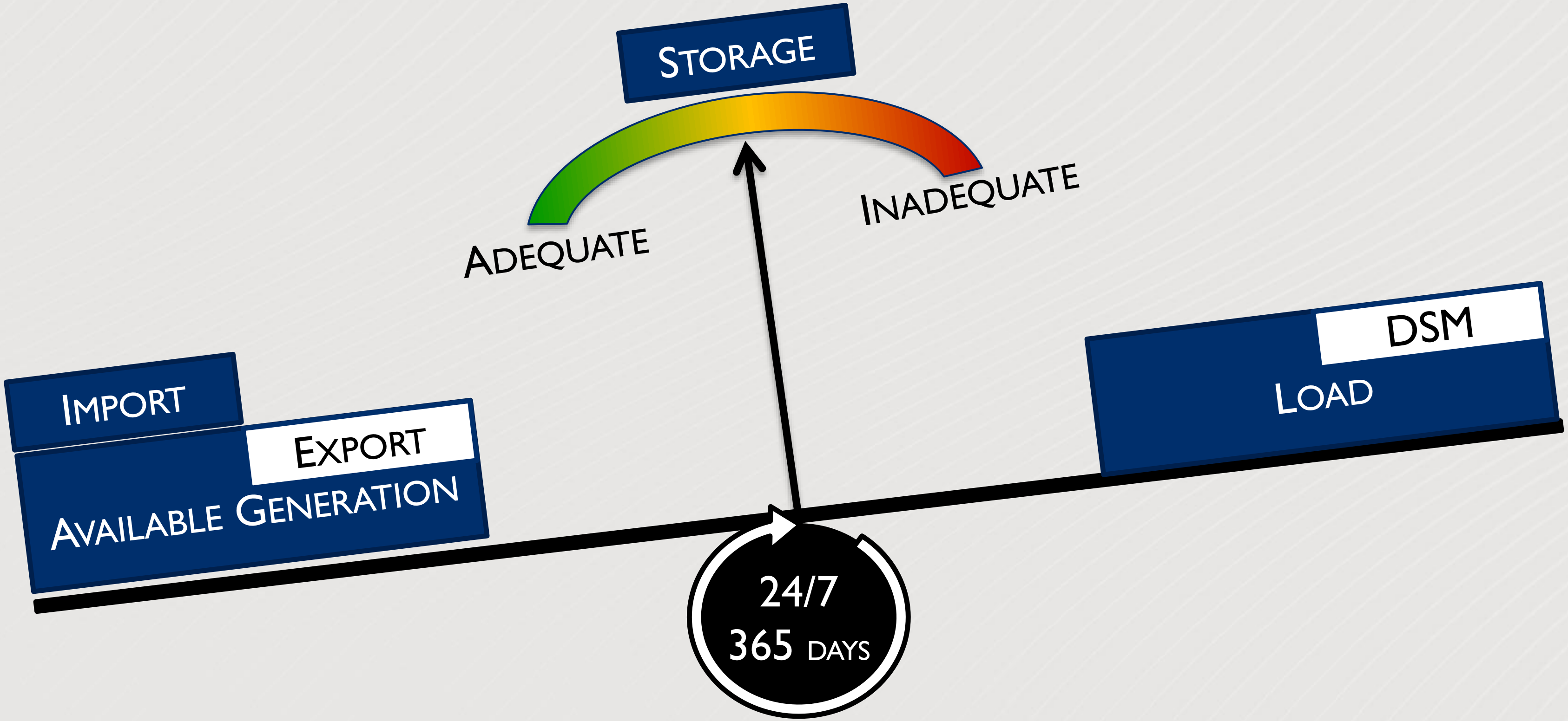
Importance – Resource Mapping for Utilities

- **Integrating renewable energy sources :** While power systems have been designed to handle the variable nature of loads, the additional supply-side variability and uncertainty can pose new challenges for utilities and system operators. The tool will help for decision making to allow maximum possible renewables with least cost.





The Big Picture



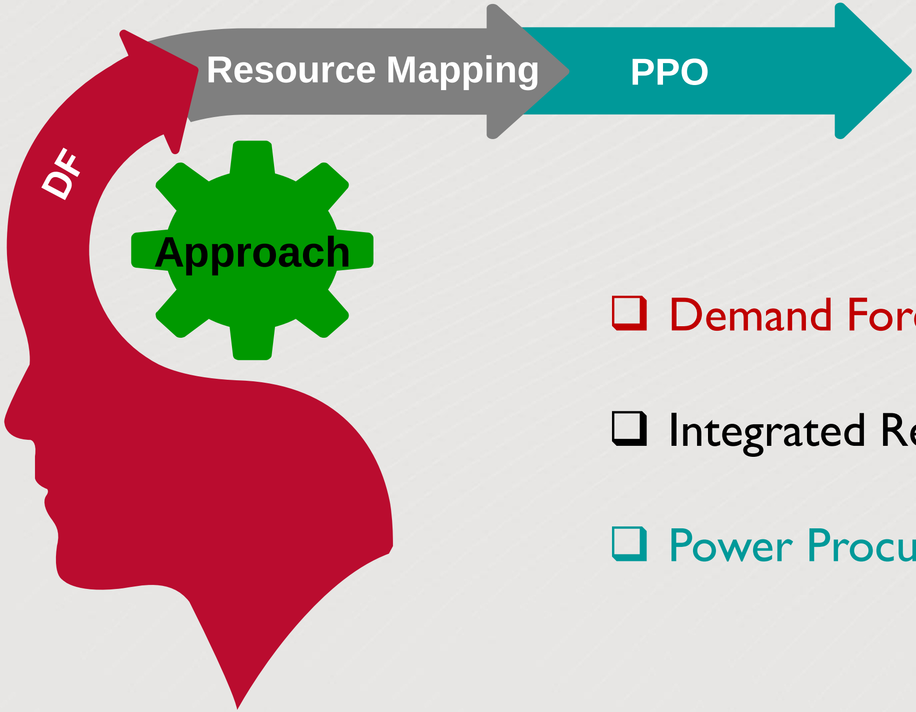
Resource Mapping and Power Procurement Optimization

Dr. Nagaraja

Founder & Managing Director , PRDC.

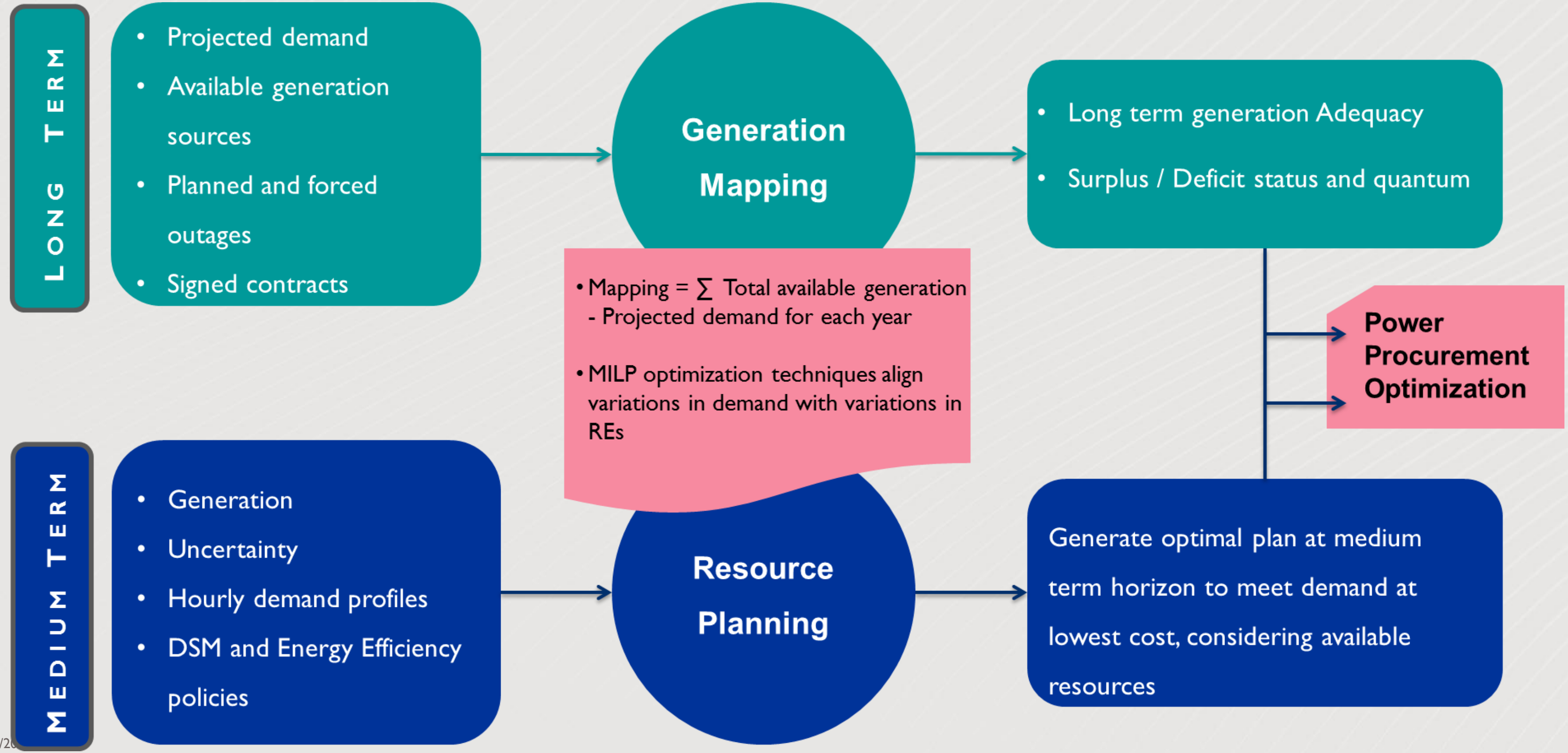
Nagaraja R has done his electrical engineering degree from University of Mysore in 1986 and did his masters (M.E) and doctoral (PhD) degrees from Indian Institute of Science, Bangalore, India. He is Promoter and Managing Director of Power Research Development Consultants Pvt. Ltd., Bengaluru, INDIA. He is specialized in design, implementation and project management of power system analysis, power plant training simulators, design simulators, SCADA and Energy Management Systems. He has provided consultancy services to large number of utilities and industries across the world.

Approach for Power Sector Planning

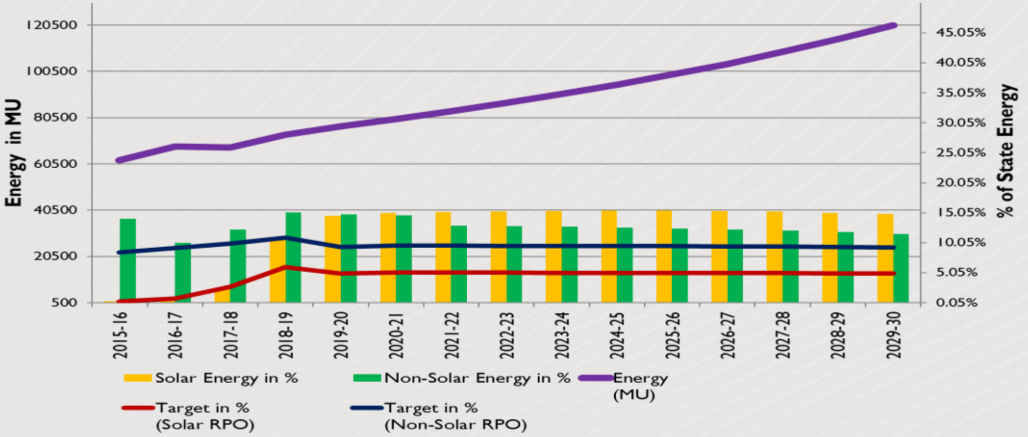


- ❑ Demand Forecast Module
- ❑ Integrated Resource Mapping Module
- ❑ Power Procurement Optimization Module

Approach for Resource Mapping

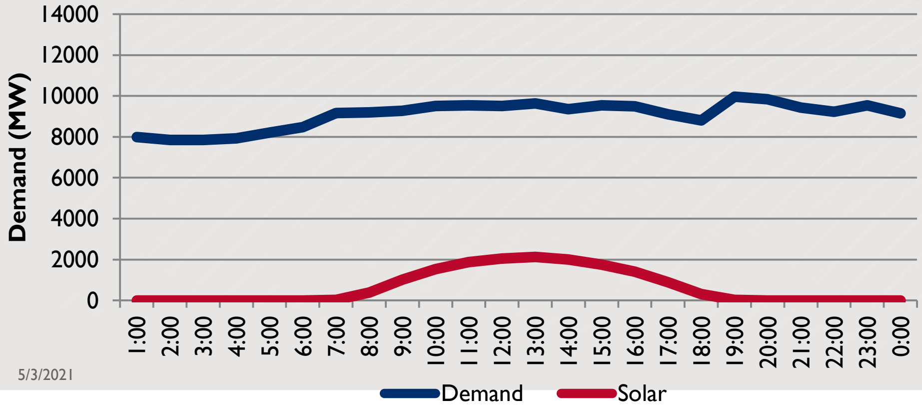


How Karnataka Exceeded RPO Target?

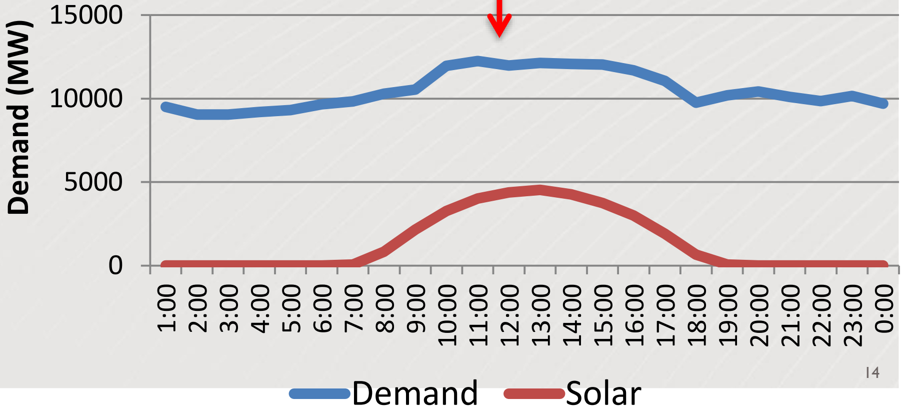


Due to shifting of part of Irrigation pump sets to Solar generation time. Total irrigation contributes to 1/3rd of State Energy

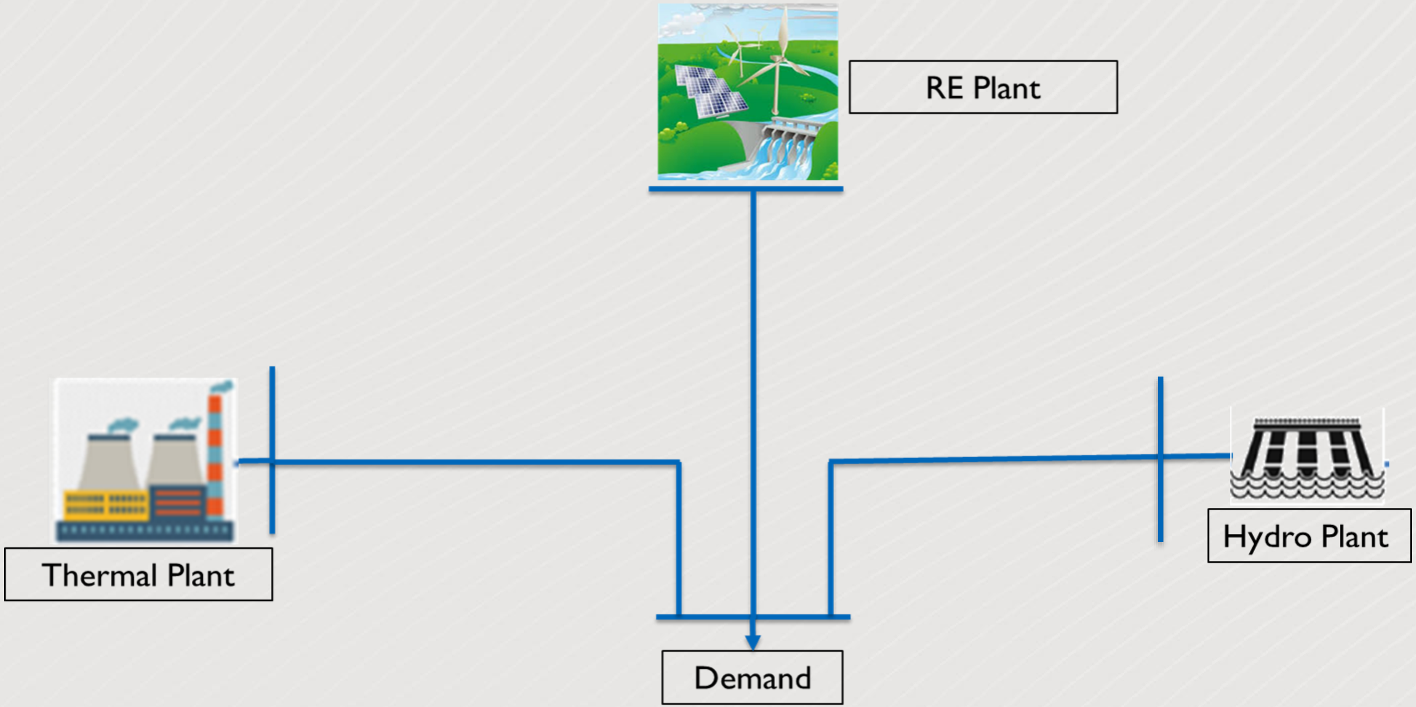
Actual Load Curve of - April-2018



Actual Load Curve April-2019



Scheduling and Optimization



The objective of Resource Mapping is to optimally dispatch and control the generating units to satisfy the demand subject to thermal and hydro constraints and operating constraints of all generating units considering the effect of RE in the system

Resource Mapping Parameters

All Generators

- Unit minimum & maximum generation
- Plant auxiliary consumption
- Unit commitment
- Ramp Constraints
- Station Constraints
- Maintenance Profiles
- Forced Outages
- Reserve Contribution
- Unit initial conditions
- Maximum number of startups

Thermal Generators

- Thermal Cost Function
- Startup / Shutdown time & costs
- Minimum up / down time
- Minimum operating time
- Fuel constraints
- Emission levels

Hydro Generators

- Unit power production curve
- Hydro Cost function
- Weekly hydro energy profile

Unconventional Generation

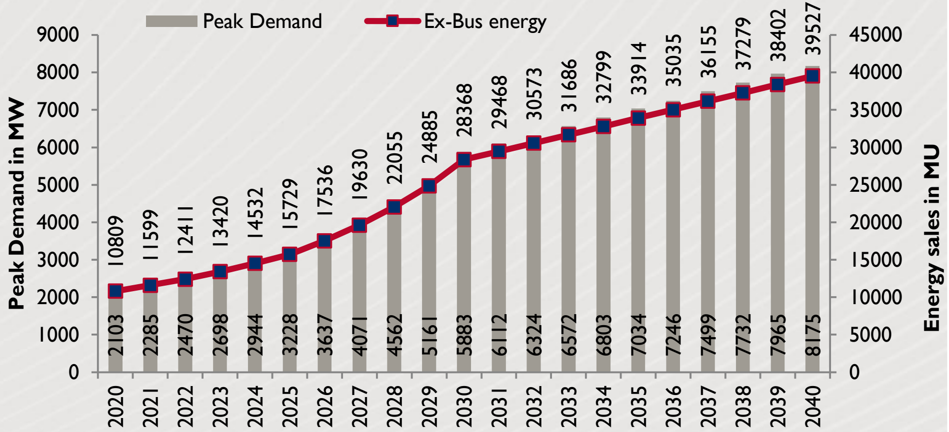
- Uncertainty
- Must-run status
- Utilization Factor

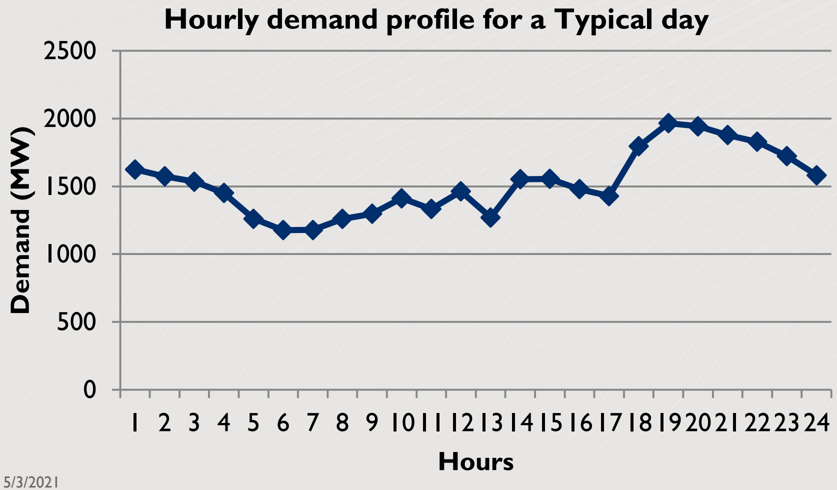
System Constraints

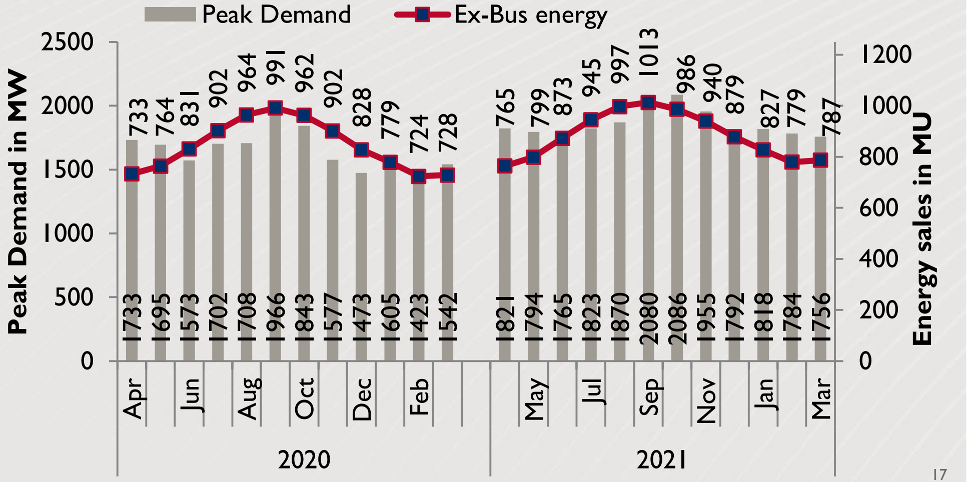
- Load-Supply balance
- System reserve requirements
- Imports and export agreements
- System emission limits
- RPO Targets

Resource Mapping Prerequisite

- Demand forecast
  - Long term
  - Medium term
- Hourly Demand profile

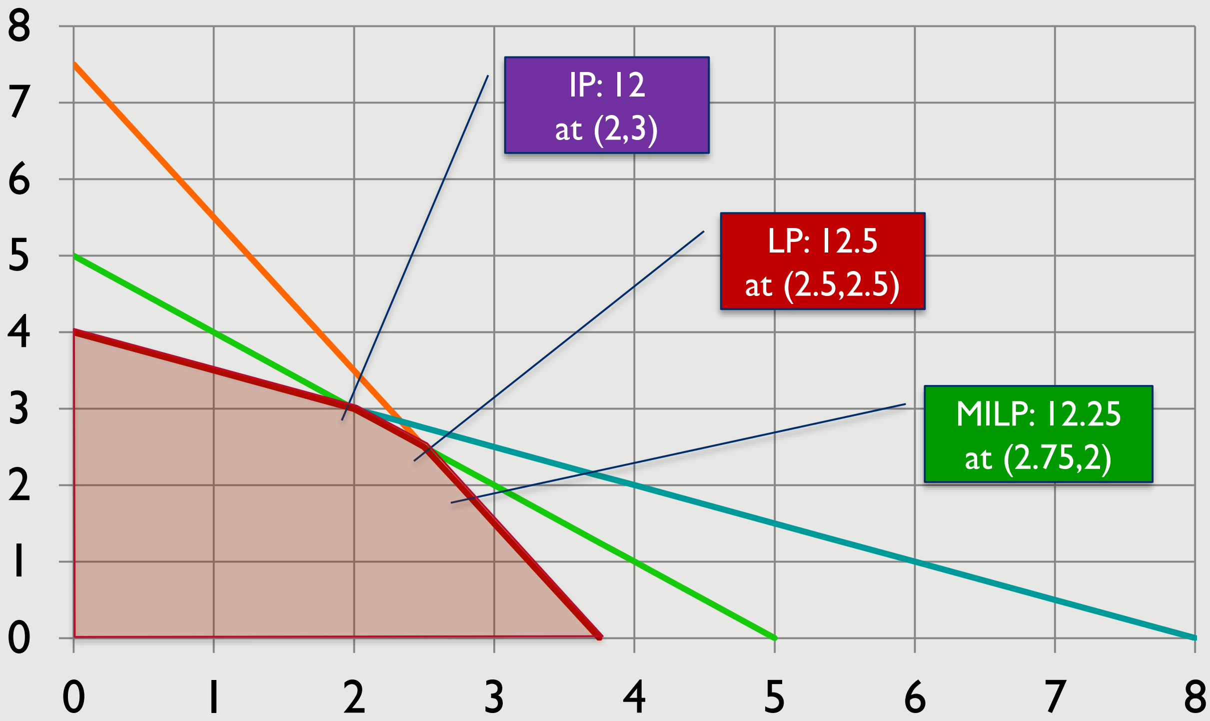






Methodology: Mixed Integer Linear Programming

- Objective function
  maximize 3x + 2y
- Constraints (such that)
  $4x + 2y \leq 15$
  $x + 2y \leq 8$
  $x + y \leq 5$
- Bounds (while)
  $x \geq 0$
  $y \geq 0$
- Criteria (where)
  - IP => x & y are integers
  - LP => x & y are real numbers
  - MILP => x is real number while y is integer



Methodology: MILP Horizon & Resolution

The size of the problem is immense i.e. includes thousands of variables & constraints, which further scales with optimization time horizon and resolution.

Typical time horizon -> Weekly

- The optimal values for each hour of the whole year are calculated, with the optimization problem broken up on a weekly basis, to reduce computation time.

Typical resolution -> Hourly

- The results such as generation output of the thermal and hydro plants, marginal costs, etc. are provided per hour.

The total system cost is minimized for each week on an hourly basis

Risk Assessment

Conventional approach includes **DETERMINISTIC APPROACH** of resource mapping.

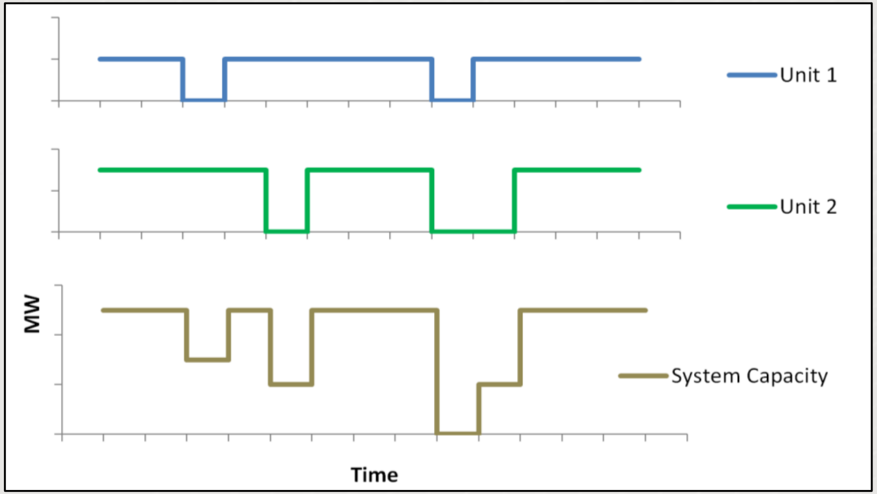
For RE rich States, assessment of the inherent risks and its impact becomes more important.

Risk assessment relies on a **PROBABILISTIC APPROACH** in which supply is matched against demand by simulating the operations of the power system on an hourly basis over an entire year.

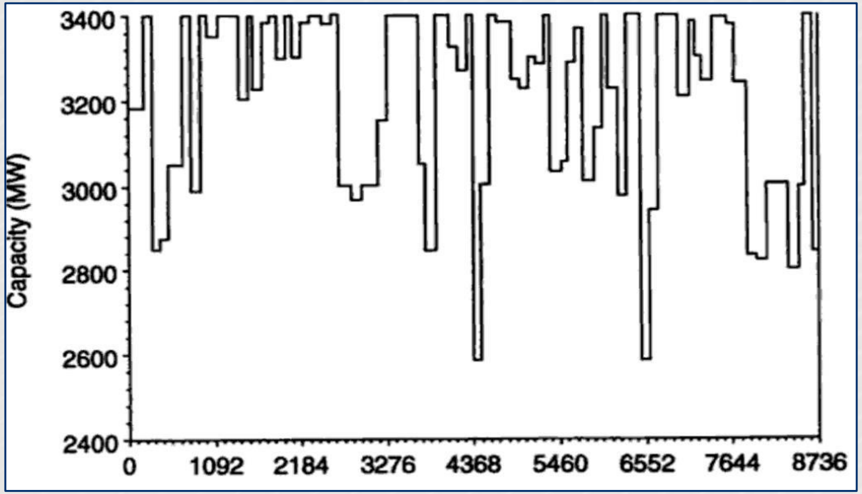
Probabilistic Analysis for Risk Assessment include the following aspects

- Significant swings in power demand
- Unforeseen unavailability of generation facilities can reduce available capacity
- RE generations dependent on Wind speed and Solar Irradiation, which are variable

Generation availability by Monte Carlo Simulation

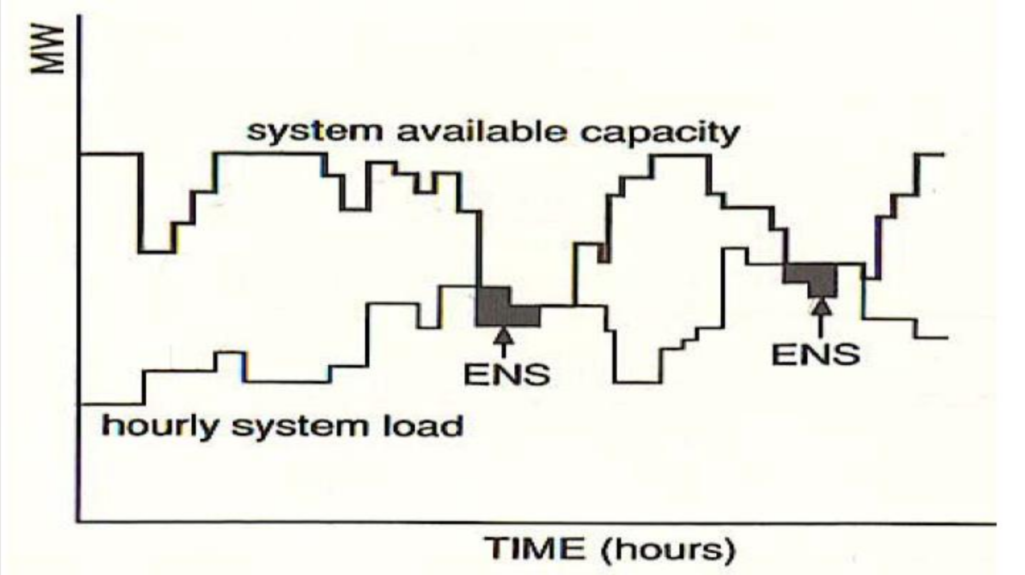


Available capacity model of each unit and the system



System available capacity model in a typical sample year

Demand – Generation mapping by Monte Carlo Simulation

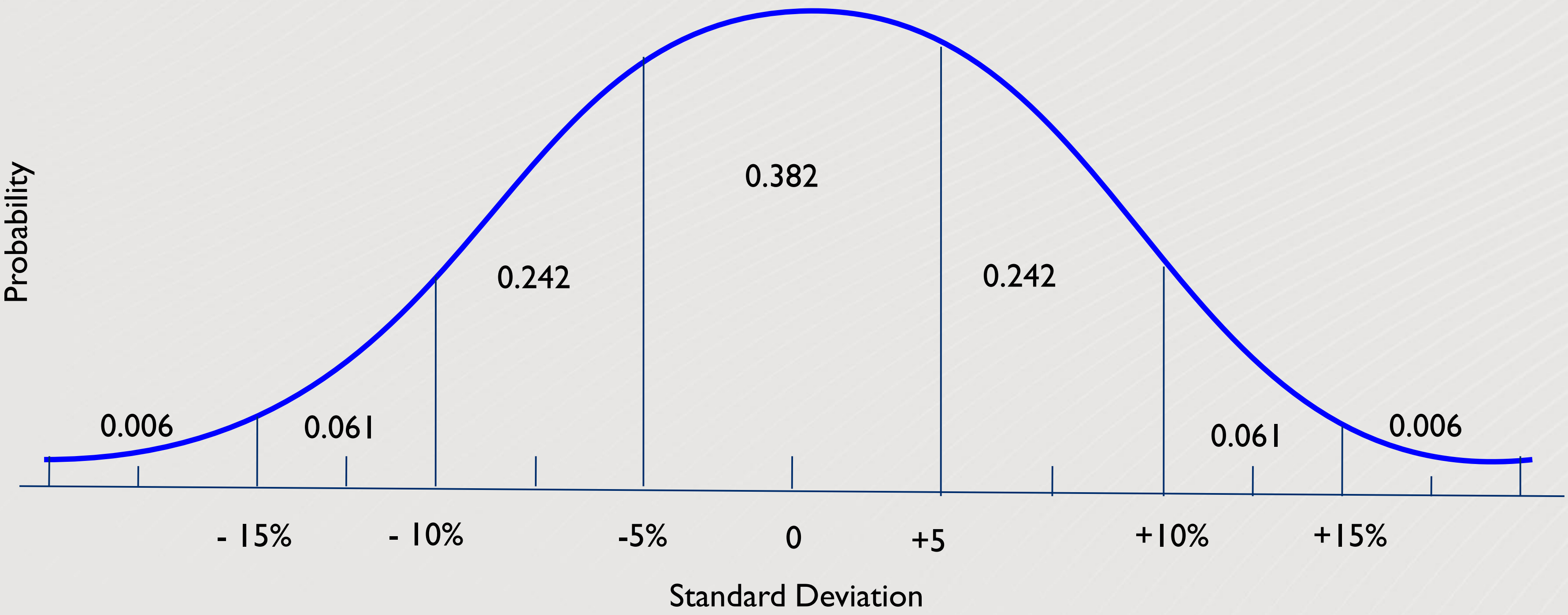


Superimposition of the available capacity on the load

- **LOLP:** Loss of Load Probability
- **LOLE:** Loss of Load Expectation
- **ENS:** Energy Not Served

As per National Electricity Plan (NEP), the adequacy standard is ~17 hours LOLE/ annum

Demand / RE uncertainty by Monte Carlo Simulation



Power Procurement Optimization

- Projected demand & available generation.
- Penalty for unmet demand
- Contract obligations
- Variable RE generation portfolio
- Power Markets data

Power Procurement Optimization

Application provides the best possible energy mix, considering power procurement from contracts, including the following:

- Strategy support, which includes all types of contracts, for the forecast horizon
- Surplus/shortfall optimization if the quantum is to be absorbed
- Surplus / deficit in terms of MU and MW with time slots.
- Seasonal power procurement assessment.
- Revision of existing PPAs
- Cost benefit analysis by comparing new PPAs/ existing PPAs / power from markets

- **Risk-based procurement strategy assistance to manage price and volume risk associated with procurement in the market or by contracts applying MILP optimization techniques**

What-if-scenarios:

- Define different pricing rules, or
- Remove or add some constraints to increase or limit some contractual flexibilities,
- To measure and compare the effect on the cash flow, and pricing.
- Bilateral power procurement portfolio with the lowest energy procurement cost, taking into account buy-sell opportunities in and out of the spot market possibilities

Role of Flexible Sources

System Status:

- Is State in Surplus?
- Is State in deficit?
- Is State in deficit in Summer and Surplus in other seasons?
- What are the planned PPA's?

Cost factors:

- Cost of Renewables
- Cost of Conventional units
- Cost of Flexible Sources
- Strategy for buying and selling at different seasons/weeks?

Technical Limitations:

- How much maximum RE mix can be allowed with existing flexibility in the system?
- Ramping constraints
- How much RE can be further added with additional flexible sources?
- Is the cost of Resource Mix optimal?

Storages: Grid Connected

Utility-scale storage is a straight forward flexibility option, however, its modeling is significantly more complex than modeling conventional generation.

As its cost is typically higher than generation or DR, its deployment must be planned carefully.

Storage technologies primarily include

- Pumped hydro
- Batteries
- Flywheels etc.

These storage devices are characterized by an energy capacity, a round-trip efficiency and a time-varying storage level.

The various motivations to install storage technologies range from

A need for reserves	A need for capacity	A need for enabling increased renewables

The storage may also be a preferred option over procurement, if economically feasible

Selection of storage option

Reduction in surplus generation in non-summer seasons as surplus generation during high renewable time will be used for pumping the water or charging the Battery

Reduction in overall annual power purchase cost by accommodating more renewables in the grid with the support of Storage services

Avoid huge surplus in non-summer seasons due to addition of firm capacity

Minimal usage of reservoir based hydro units in non-summer season by best utilization of storage units. This will enable maximum reservoir levels to operate the hydro units during summer season to meet peak demand.

Ramping support to grid operation due to high penetration of Renewables

Ancillary reserve support like primary and secondary reserves.

Power Portfolio Alternatives

Alternate 1 :
Fixed amount of firm power throughout the year

Firm capacity to be contracted to meet the peak demand occurring in summer season. However, this may results in high surplus in non-summer season

Alternate 2:
Storage based generation (Pumped storage / Battery storage)

Storage will help to meet the peak demand in all seasons including summer. Utilizing the pumped storage plant in high wind season instead of hydro power plant will make more hydro energy availability during summer season.

Alternate 3 :
Short term power procurement during peak season

For any change in system conditions and plans, short term power procurement can be used as remedial solution to meet the peak demand in summer season and to sell surplus generation in non-summer season.

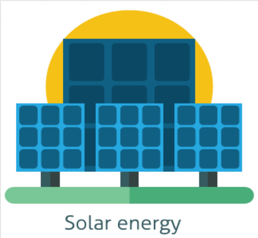
Resource Mapping and Power Procurement Optimization

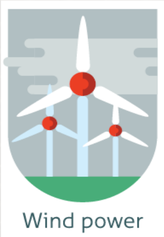
Dr. Chandrasekhar Reddy Atla

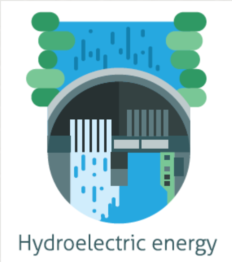
Principal Engineer, PRDC

Chandrasekhar Reddy Atla, has done his electrical engineering degree from Sri Venkateswara University in 2003 and did his masters (M.Tech) from National Institute of Technology-Karnataka and PhD from Visvesvaraya Technological University, INDIA. Currently working with PRDC, Bengaluru, INDIA. His areas of interest are power system planning and operation, power system reliability, generation and transmission planning, renewable integration and forecasting etc.

Power Procurement Optimization– What & Why?







- ❑ Utilities are obligated to source a certain percentage of their requirements from renewable energy

- ❑ Optimal Generation planning to reduce cost of generation

- ❑ PPA planning

Power Portfolio Optimization

Objective Function:

- Minimization of overall cost of power procurement over a year (emissions, reserves, RE targets etc)

Constraints:

- Load Profile Changes
- Existing Generation & Proposed Generation
- Technical Constraints of various generation mix: Technical minimum, maximum, ramp up, ramp down, minimum up time, minimum down time, fuel availability etc.
- DERs and DSM aspects
- Economical constraints; cost details of all types of generation units, emission constraints, storage cost details
- Long term PPAs

Methodology: Optimal Unit Commitment & Economic Dispatch

Calculate the marginal cost as part of outcome of a system cost-minimization problem.

Formulated as a large-scale Mixed Integer Linear Programming (MILP) Problem

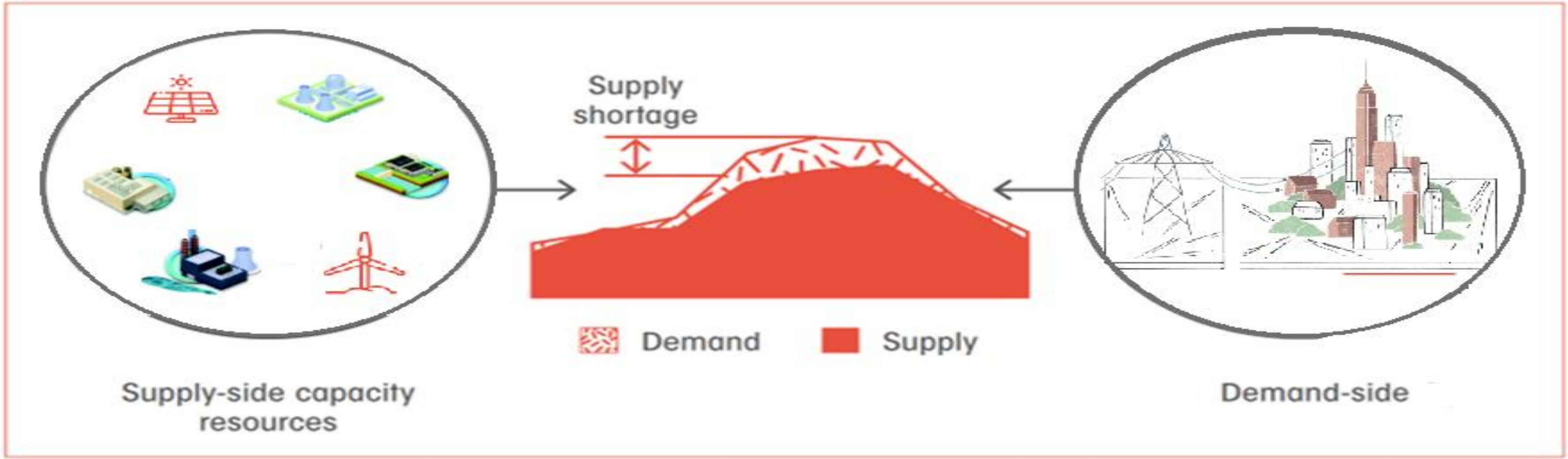
The MILP problem attempts to find the least-cost solution while respecting all configured constraints.

To avoid infeasible solutions, the constrains are modeled as soft constraints i.e. constraints can potentially be violated at the expense of high penalty cost.

Hard Constraint	G1 + G2 + G3 = Load	Min ($Cost_{G1}$+$Cost_{G2}$+$Cost_{G3}$+C_e) and C_e = $10e^6$
Soft Constraint	G1 + G2 + G3 + e >= Load	

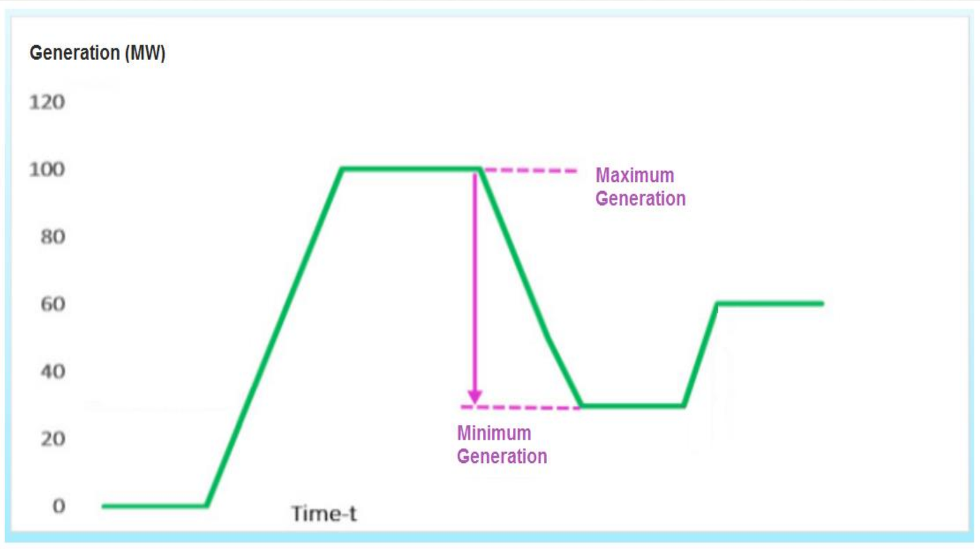
Load Generation Balance

The electricity energy demand is represented through a constraint that the sum of energy generated must be equal to the load at each hour



$$Thermal\ Generation + Hydro\ Generation + RE\ Generation + Unmet\ Demand = Demand + Losses$$

Parameter: Generator Unit Commitment & Operating Limits



If a unit is committed,

$$Minimum\ Generation\ Limit \leq Unit\ Generation \leq Maximum\ Generation\ Limit$$

Else,

$$Unit\ Generation = 0$$

Methodology: Mixed Integer Linear Programming: Example

Gen	Tech Min	Max	Cost (INR/MWh)
U1 (MW)	50	100	5000
U2 (MW)	30	100	6000
U3 (MW)	70	100	3000

How thermal unit technical minimum works?

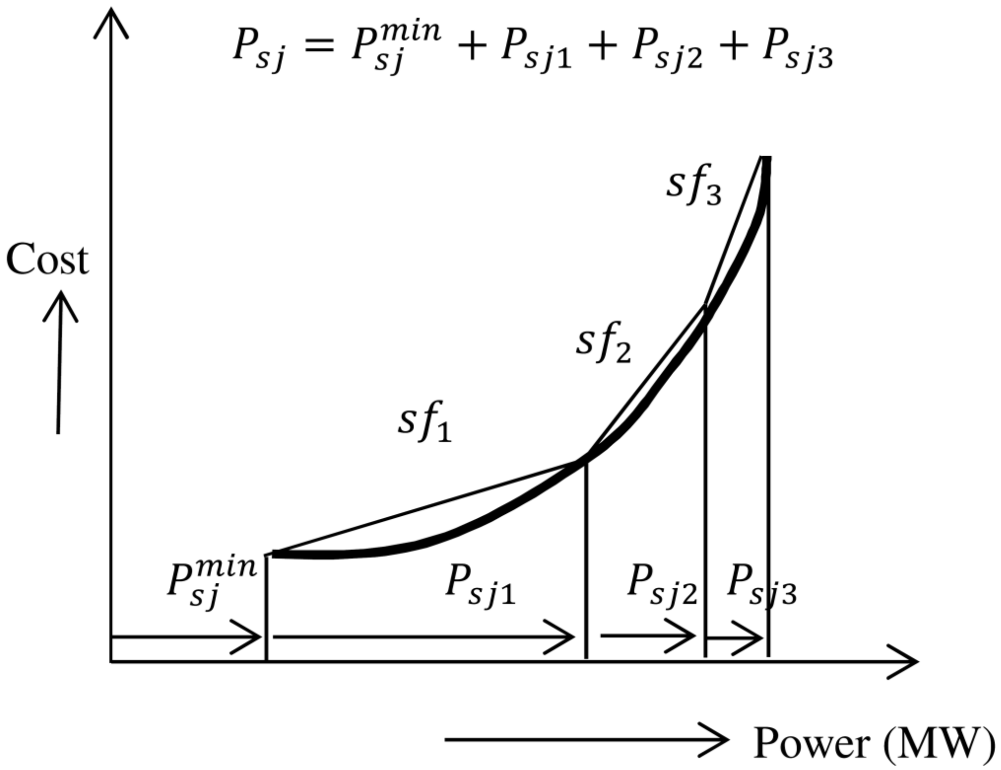
Load shed cost & its impact?

hours	1	2	3	4	
Demand (MW)	100	120	150	180	Cost (INR/MWh)
U1 (MW)					0
					0
U2 (MW)	30	30	30	30	720000
			20	50	420000
U3 (MW)	70	70	70	70	840000
		20	30	30	240000
				Total cost	22,20,000
Total demand	550	MWh		Average INR/MWh	4,036.36

hours	1	2	3	4	
Demand (MW)	80	120	150	130	Cost (INR/MWh)
U1 (MW)	50	50	50	50	1000000
		40	50	50	700000
U2 (MW)	30	30	30	30	720000
			20		120000
U3 (MW)					0
				Total cost	25,40,000
Total Demand	480	MWh		Average INR/MWh	5,291.67

Parameter: Generation Cost Function

The thermal plant/unit will be modeled with a piecewise linear cost function i.e. the sum of the fixed and operating costs of all thermal plants, at all hours



Where,

P_{sjk} Power in the segment 'k', measured from the start of the kth segment

sf_k Designated slope of kth segment

Methodology: Mixed Integer Linear Programming: Example

How incremental cost works?

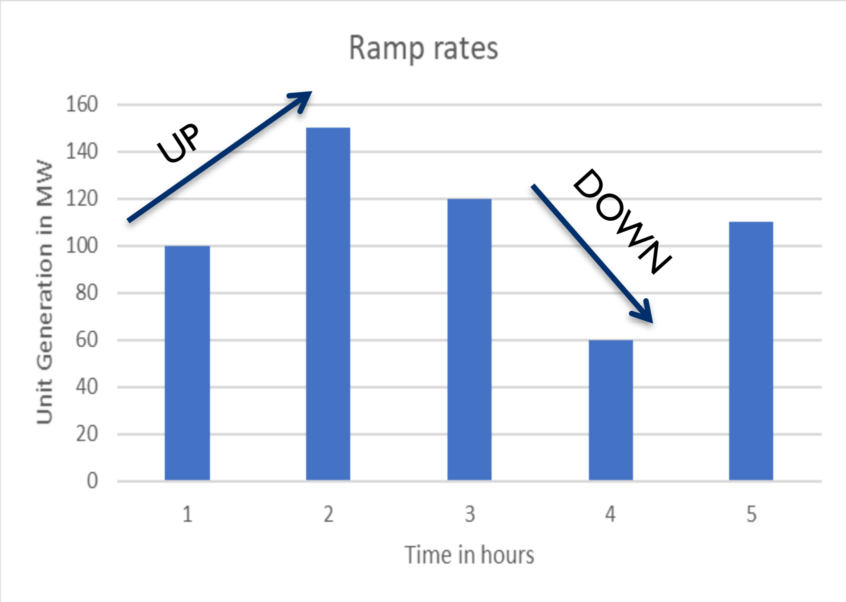
Gen	Tech Min	Max	Cost (INR/MWh)		
			FC	VC1 (<50 MW)	VC2 (>50 MW)
			INR/MW	INR/MWh	INR/MWh
U1 (MW)	0	100	3000	3000	3500
U2 (MW)	0	100	2500	2750	4500

hours	1	2	3	4			
Demand (MW)	50	60	70	80	FC (INR)	VC (INR)	Cost INR
U1 (MW)					1200000		2010000
	50	50	50	50		600000	
		10	20	30		210000	
U2 (MW)					1000000	0	1000000
						0	
					Total cost (INR)		3010000
					Average INR/MWh		11577

hours	1	2	3	4			
Demand (MW)	50	60	70	80	FC (INR)	VC (INR)	Cost (INR)
U1 (MW)					1200000		1200000
						0	
						0	
U2 (MW)	50	50	50	50	1000000	550000	1820000
		10	20	30		270000	
					Total cost (INR)		3020000
					Average INR/MWh		11615

Parameter: Ramping Limits

Any increase/decrease in power production in successive hours must lie within a permissible range



Ramp Up Rate: 50 MW/hr

Ramp down rate: 60 MW/hr

If generator is ramped up,

Current generation – Previous generation <= Ramp-up limit

i.e. $Generation_t - Generation_{t-1} \leq \overline{r}(j) \qquad t = 1, 2, \ldots, T$

if generator is ramped down,

Previous generation – Current generation <= Ramp-down limit

i.e. $Generation_{t-1} - Generation_t \leq \underline{r}(j) \qquad t = 1, 2, \ldots, T$

Methodology: Mixed Integer Linear Programming: Example

Gen	Tech Min	Max	Cost (INR/MWh)	Ramp UP/DOWN Rate (MW/h)
U1 (MW)	50	100	5000	20
U2 (MW)	30	100	6000	30
U3 (MW)	70	100	3000	10

hours	1	2	3	4	
Demand (MW)	100	120	150	180	Cost (INR/MWh)
U1 (MW)					0
					0
U2 (MW)	30	40	40	40	900000
			20	40	360000
U3 (MW)	70	70	70	70	840000
		10	20	30	180000
				Total cost	22,80,000
				Average INR/MWh	4,145.45

How Ramp rates works?

System operation! How complex?
Role of Flexible source…

hours	1	2	3	4	
Demand (MW)	70	80	150	130	Cost (INR/MWh)
U1 (MW)	No Feasible solution				
U2 (MW)					
U3 (MW)					

Parameter: Must-run Units and Outage Units

A must-run unit will remain committed at all times, even if it is not an economical decision taken by the model. Conversely, an outage unit (forced or under maintenance) will remain uncommitted for the duration of outage

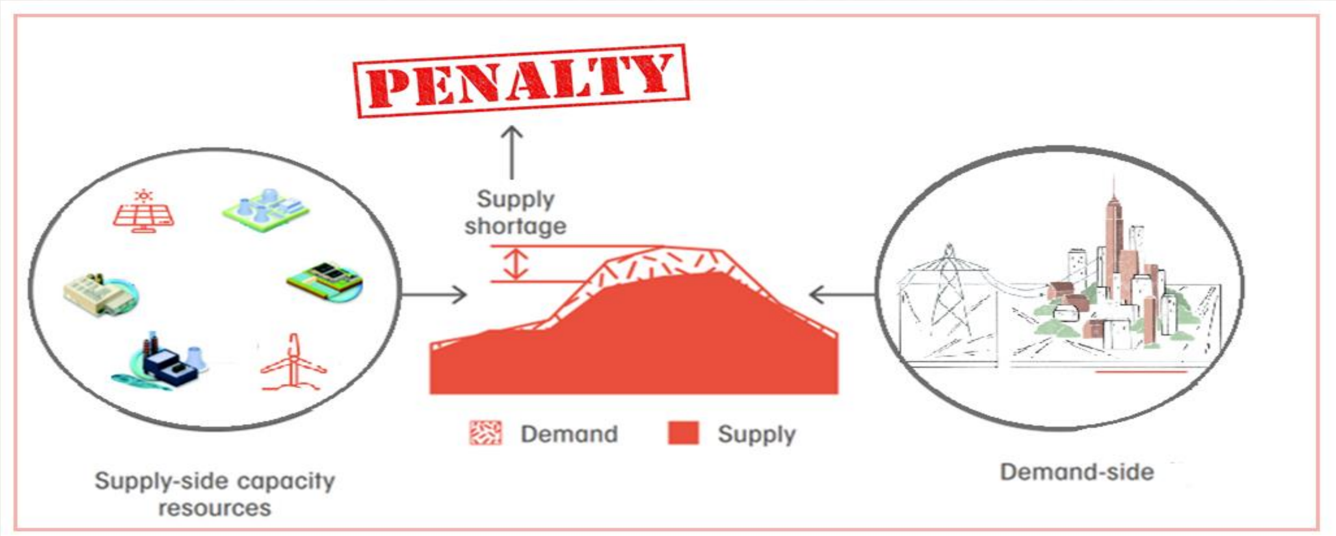
$x(j_m, t) = 1$ i.e. for must-run units, commitment remains 1 for all 't'

$x(j_o, t_o) = 0$ i.e. for outage units, commitment is forced to 0 for the outage period

https://www.google.com/url?sa=i&url=http%3A%2F%2Ftrainingyogyakarta.com%2Fpratical-operation-maintenance-testing-of-diesel-power-generating-plants%2F&psig=AOvVaw2W5fXgd_gO1Wwq6vykei6N&ust=1603982116585000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCJDmr4bC1-wCFQAAAAAdAAAAABAD
https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.power-grid.com%2F2015%2F09%2F21%2Fwatts-bar-unit-1-begins-nuclear-refueling-maintenance-outage%2F&psig=AOvVaw1vKPESVk2c4tvp3qsl-r--&ust=1603981913947000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCICvvrnB1-wCFQAAAAAdAAAAABAD
https://www.google.com/imgres?imgurl=https%3A%2F%2Fmedia.noria.com%2Fsites%2FUploads%2F2018%2F12%2F20%2F77f079a4-5793-491e-b6f5-06cc808113a8_Images_ProactiveMaintenanceApproach_31035_1234x694_extra_large.jpeg&imgrefurl=https%3A%2F%2Fwww.reliableplant.com%2FRead%2F31035%2Fproactive-maintenance-approach&tbnid=Hckba4smQgLOhM&vet=10CA4QxiAoBGoXChMIkMn99sjX7AIVAAAAAB0AAAAAECY..i&docid=ImQ5f6MFChMHDM&w=1234&h=694&itg=1&q=maintenance%20operation&ved=0CA4QxiAoBGoXChMIkMn99sjX7AIVAAAAAB0AAAAAECY

System Specific : Penalty for Unmet Demand

Based on the system demand and available generators, the load-supply balance equation is set for mapping the resources. To avoid any infeasible solution, this equation is set as a soft constraint.



$$\sum_{j \in T} \mathbf{g}_{j,t} + \sum_{k \in P} \mathbf{c}_{k,t} + S_t + U_t = L_t$$

Thermal Specific Parameter: Fuel Limits

Total annual generation from a thermal unit must be a function of the annual fuel availability for the plant.

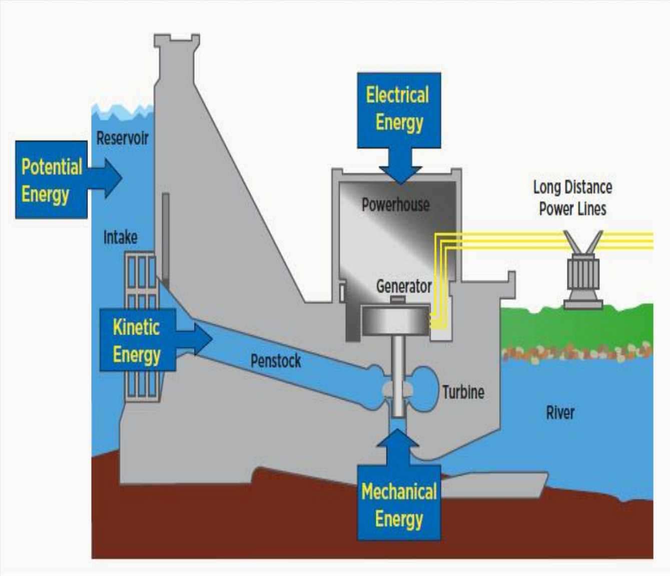
$$\sum_{j=1}^{J} SFC_j * Total\ Generation_j \leq Maximum\ Fuel$$

Where SFC is the specific fuel consumption of each unit 'j' within the plant

https://encrypted-tbn0.gstatic.com/images?q=tbn%3AANd9GcR-YZ1feGJTzalN1rPx6K2u1zfzl4ZYcc64yw&usqp=CAU
https://www.ft.com/__origami/service/image/v2/images/raw/http%3A%2F%2Fcom.ft.imagepublish.prod.s3.amazonaws.com%2Ff0d6bb02-9d26-11e7-8b50-0b9f565a23e1?fit=scale-down&source=next&width=700

Hydro specific Parameter: Generation based on Availability

Total weekly generation from a hydro unit must be a function of the weekly water availability in terms of energy (MU) for a hydro plant



$$\sum_{j=1}^{J} Total\ Generation \leq Maximum\ Available\ Water\ for\ the\ plant$$

https://cleanleap.com/sites/default/files/documents/1598/images/fig07_0.jpg

Parameter: Maximum number of start-ups

The number of times a unit is shutdown and started must be limited to ensure longer life of the machine

$$Sum\ of\ all\ startups\ subjected\ on\ a\ unit\ 'j' \leq \overline{A}(j)$$

Where,

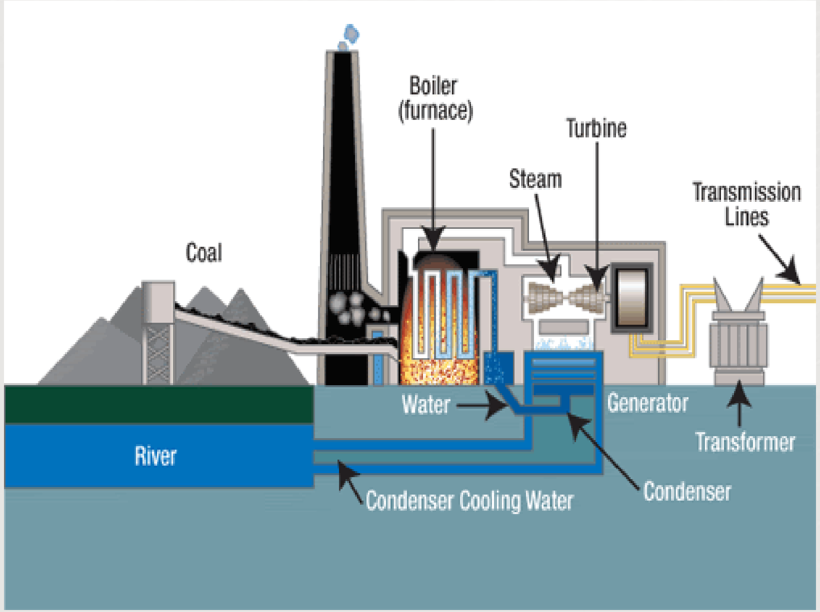
Unit startup binary variable =

$$\begin{Bmatrix} 1\ if\ unit\ 'j'\ started\ to\ operate\ at\ hour\ 't' \\ 0\ otherwise \end{Bmatrix}$$

https://www.powermag.com/wp-content/uploads/2016/10/westfalen-d-and-e_rwe.jpg
https://encrypted-tbn0.gstatic.com/images?q=tbn%3AANd9GcQ-xle_2LQ0hZvrADK22RGVnFRBuA9YSgKO3Q&usqp=CAU

Thermal Specific Parameter: Startup Cost

The total cost of thermal unit's start-up is calculated by the product of unit start-up costs (hot, warm and cold start-ups) in Rs and start-up binary of each unit .



$$TSC = \sum_{t=1}^{T}\sum_{j=1}^{J} Cp_{j,t}\, y_{j,t}$$

Where,

$y_{j,t}$ – Unit startup binary variable

$$\begin{Bmatrix} 1\ if\ unit\ 'j'\ started\ to\ operate\ at\ hour\ 't' \\ 0\ otherwise \end{Bmatrix}$$

$Cp_{j,t}$ – Startup cost of unit j at hour t, such that

$$Cp_{j,t} = Cp_{j,t}{}^{h}.y_{j,t,h} + Cp_{j,t}{}^{w}.y_{j,t,w} + Cp_{j,t}{}^{c}.y_{j,t,c}$$

$y_{j,t,h} = 1; \quad for\ 0 \le T_j^{off} < T_j^{w}$

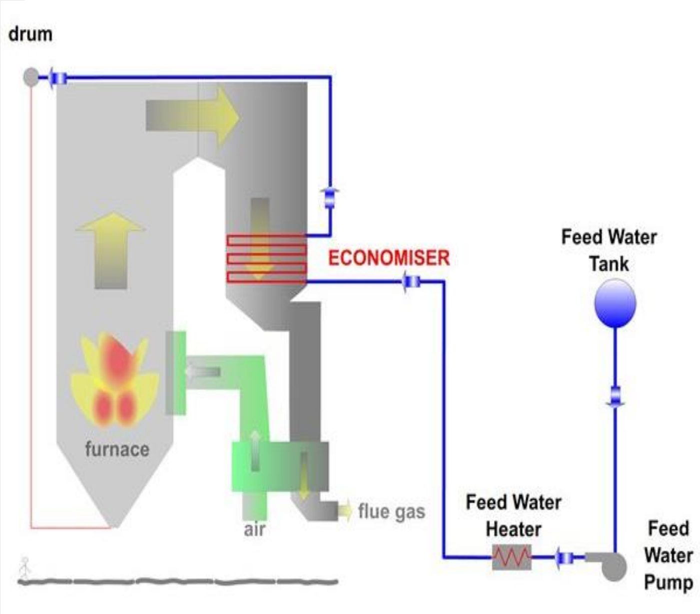
$y_{j,t,w} = 1; \quad for\ T_j^{w} \le T_j^{off} < T_j^{c}$

$y_{j,t,c} = 1; \quad for\ T_j^{c} \le T_j^{off} < T_j^{-}$

https://i.pinimg.com/originals/d5/65/26/d5652657ad3b03b27fa2dae0a7575126.jpg

Parameter: Minimum Up & Down time

The minimum time (hours) that a unit should remain disconnected before being allowed to resume operation



$$CommitmentStatus_{t-1} - CommitmentStatus_{t} + CommitmentStatus_{k} \leq 1$$

https://img.bhs4.com/83/B/83B71A89C11FD79BEF71EA83964D5C77E957B67F_large.jpg

Thermal Specific Parameter: Limit on Emission Levels

Total green-house gases emitted from all thermal generators in the study area must be within the permissible emission limit.

$$\sum_{p=1}^{P} Emission_p \leq Maximum\ Allowable\ Emission$$

https://powerinsight.vision-media.co.in/wp-content/uploads/2019/02/Power-Plant.jpg

Objective Function

Objective of Resource Mapping is to find the least-cost hourly generation schedule for the study horizon

$$Z = \min \left(\mathit{Unit\ Cost\ Function} + \mathit{Startup\ and\ Shutdown\ Cost} + \mathit{Cost\ of\ Unmet\ Demand} \right)$$

Illustrative Example

Demand Data			
Hour	Demand MW	Hour	Demand MW
1	150	13	420
2	150	14	410
3	160	15	410
4	170	16	400
5	180	17	380
6	200	18	400
7	240	19	430
8	280	20	420
9	320	21	380
10	400	22	300
11	410	23	200
12	410	24	150

Generation data

G1 cost: (652.32+2000*PG1) Rs/hour; PG1: G1 generation in MW
G2 cost: (1881.68+100*PG2) Rs/hour; PG2: G2 generation in MW

G1: 210 MW; Aux. consumption: 20 MW, PG1_min: 126, when run
G2: 250 MW; Aux. consumption: 2.5 MW, PG2_min: 20 MW, when run

G1, if running, minimum number of hours of run: 4 hour
G1, if off, minimum number of hours of off: 3 hour

G2, if running, minimum number of hours of run: 2hour
G2, if off, minimum number of hours of off: 1 hour

G1: Daily maximum energy output: 4560 MWh
G2: Daily maximum energy output: 3089 MWh

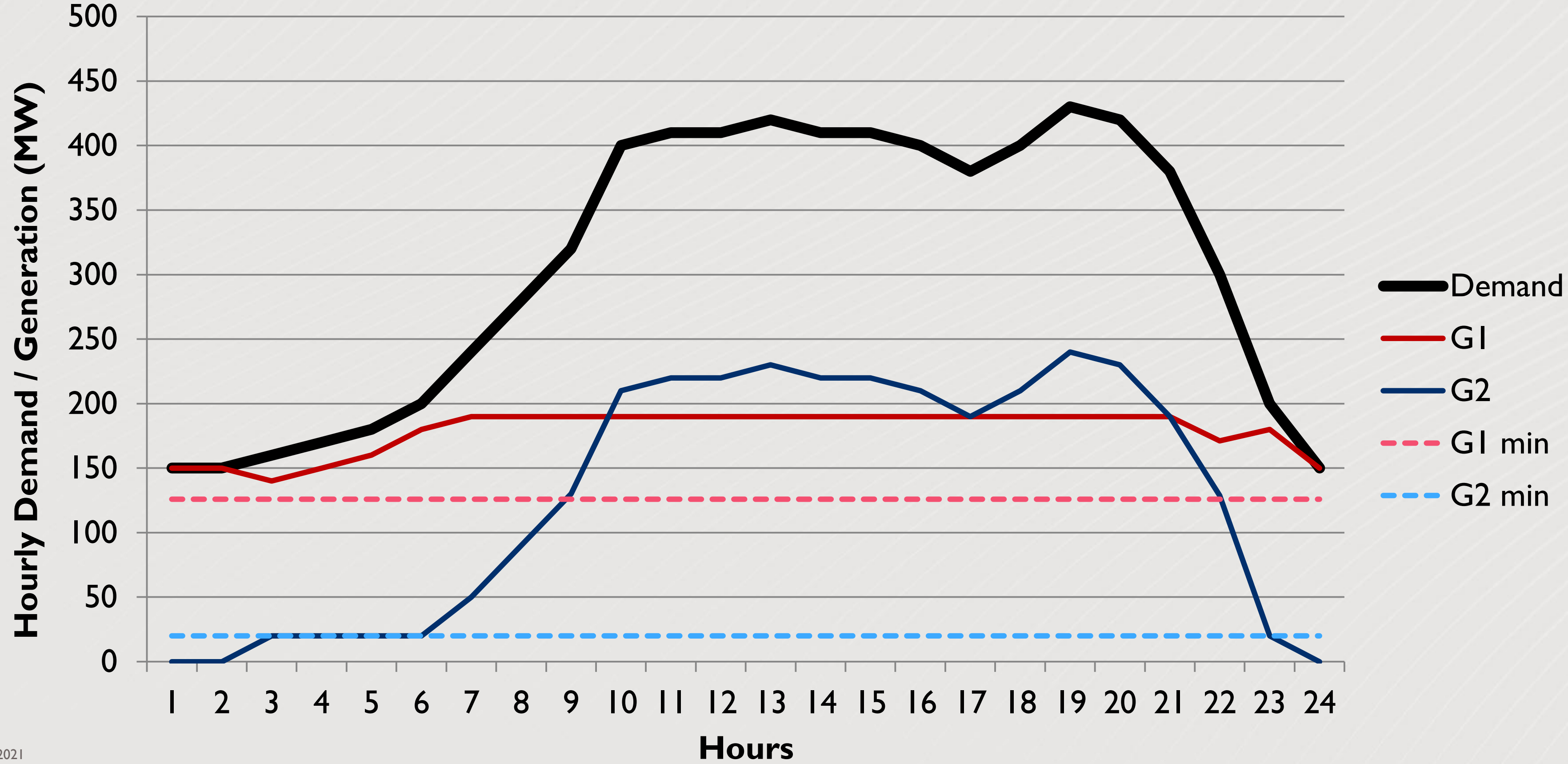
G1: Maximum ramp rate: +/- 30 MW/hour
G2: Maximum ramp rate: +/- 250 MW/hour

Illustrative Example

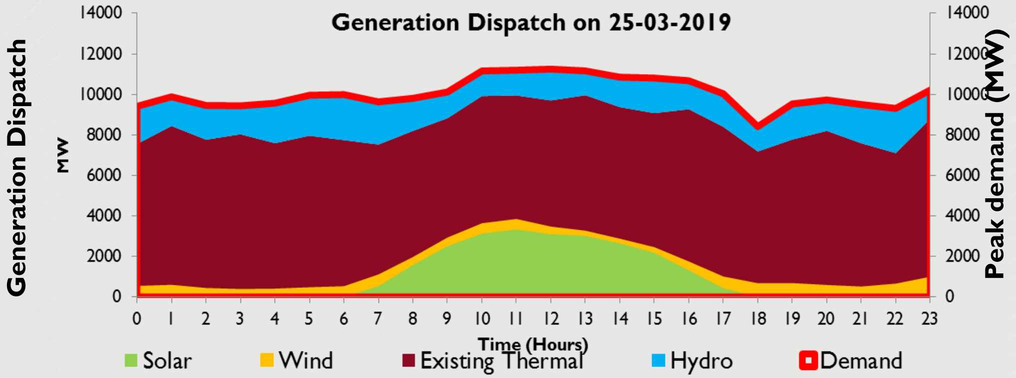
Hours	1	2	3	4	5	6	7	8	9	10	11	12
Demand MW	150	150	160	170	180	200	240	280	320	400	410	410
G1(t2) - G1(t1) - MW	0	0	-10	10	10	20	10	0	0	0	0	0
G1 MW	150	150	140	150	160	180	190	190	190	190	190	190
G2 MW	0	0	20	20	20	20	50	90	130	210	220	220
G1 min MW	126	126	126	126	126	126	126	126	126	126	126	126
G2 min MW	20	20	20	20	20	20	20	20	20	20	20	20
G1 cost Rs	300652	300652	280652	300652	320652	360652	380652	380652	380652	380652	380652	380652
G2 cost Rs	1882	1882	3882	3882	3882	3882	6882	10882	14882	22882	23882	23882
Cost_total Rs	302534	302534	284534	304534	324534	364534	387534	391534	395534	403534	404534	404534

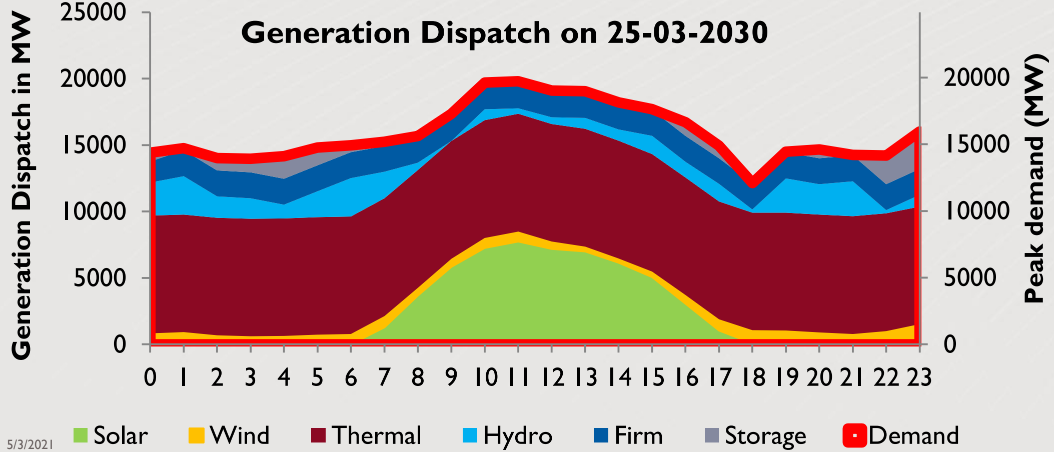
Hours	13	14	15	16	17	18	19	20	21	22	23	24	Total
Demand MW	420	410	410	400	380	400	430	420	380	300	200	150	7370
G1(t2) - G1(t1) - MW	0	0	0	0	0	0	0	0	0	-19	9	-30	0
G1 MW	190	190	190	190	190	190	190	190	190	171	180	150	4281
G2 MW	230	220	220	210	190	210	240	230	190	129	20	0	3089
G1 min MW	126	126	126	126	126	126	126	126	126	126	126	126	3024
G2 min MW	20	20	20	20	20	20	20	20	20	20	20	20	480
G1 cost Rs	380652	380652	380652	380652	380652	380652	380652	380652	380652	342652	360652	300652	8577656
G2 cost Rs	24882	23882	23882	22882	20882	22882	25882	24882	20882	14782	3882	1882	354060
Cost_total Rs	405534	404534	404534	403534	401534	403534	406534	405534	401534	357434	364534	302534	8931716

Illustrative Example



Karnataka : Resources Optimization using Simulation Tool





2019

Peak Demand : 11245 MW

Resources : Thermal + Hydro + RE (W+S)
(55%) (14%) (31%)

2030

Peak Demand : 19127 MW

	Business As Usual (+)	RE Scenario (+)
New Thermal	4500 MW	2400 MW
RE	0 MW	6400 MW
Storage	-	2000 MW
Cost	18,500 Cr.	17000 Cr.

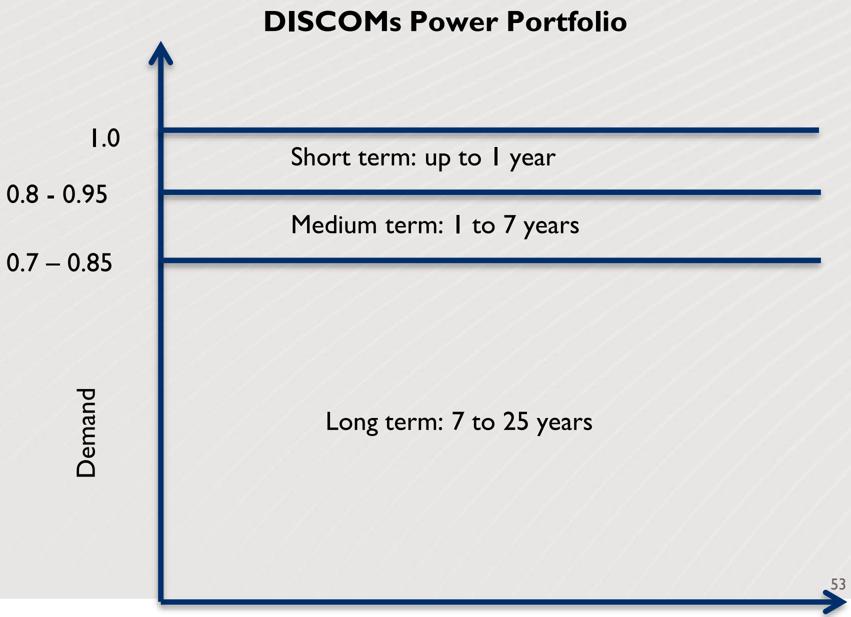
No stranded asset created
No system level grid security issues
Savings of 1500 Crs/annum

Power portfolio

Long term contracts	Short term contracts
Help to bring certainty of cash flow and are necessary for making projects bankable	Highly uncertain on cash flow
Utilities are stuck to a technology	Utilities freely can adopt the different technologies for flexibility in resources mix
High costly if low cost power is available in market	More economical when low cost power is available.
Surplus power from long term PPAs can be traded in short term market	High in cost when short term market operates at high market prices when power required by State.
System Operation: When planned with scientific methods, system operation is smooth even with high RE penetration due to planned flexible sources in the system	System Operation: Large volume of short-term transaction creates congestion in transmission due to unplanned power flow

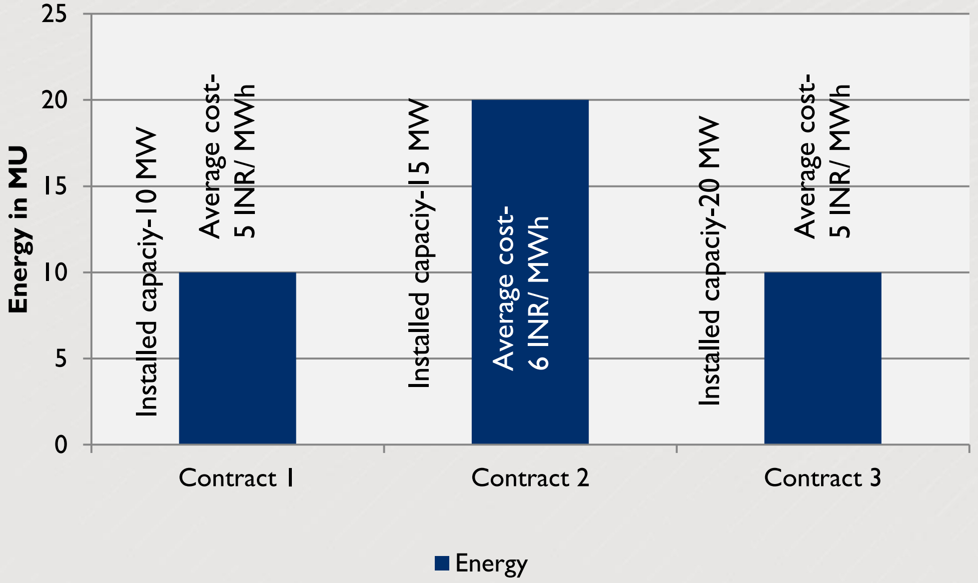
High RE and low cost of power can be achieved by improving

- Existing planning tools
- Methodologies
- Capacities of power sector planners



Contract Specific : Contract selection

For the generating units having committed contracts, the total generation from all contracts must be between generator minimum and maximum operating limits and total energy procured annually from each contract will be within the user-defined annual share



$$\underline{g}_{j,t} \leq \sum_{c \in j} g_{c,t} \leq \overline{g}_{j,t}$$

Objective Function

Objective of Power Procurement Optimization is to find the least-cost hourly generation schedule for the study horizon

$$Z = \min \begin{pmatrix} Unit\ Cost\ Function + Startup\ and\ Shutdown\ Cost + \\ Cost\ of\ Unmet\ Demand + contract\ cost\ function \end{pmatrix}$$

In addition to the Resource Mapping constraint the constraints mentioned in the power procurement optimization is considered

Outcomes

Quiz

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MODULE V: REGULATORY FRAMEWORK FOR RESOURCE PLANNING

The goal of this module is to discuss the requirements of regulations to examine power procurement, i.e. 80% cost of DISCOM business.

- **Objectives:**
  Understand the role of regulatory framework for resource planning
- **Content:**
  - Importance of Regulatory Framework in RE rich environment
  - Model Regulations
- **Presentation:**

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Agenda

Time	Session	Speaker
02:30 – 02:35 pm	Welcome Address and Recap	Mr. Sumedh Agarwal, Strategic Energy Planning Lead, USAID PACE-D 2.0 RE Program
02:35 – 03:20 pm	Presentation on Regulatory Framework for Resource Planning	Dr. Rakesh Kumar Goyal, Team Leader and Mr. Amarjeet Singh, Research Analyst; USAID PACE-D 2.0 RE Program
03:20 – 03:30 pm	Quiz and Q&A Session	
03:30 – 03:35 pm	Address	Ms. Karen Klimowski, Director Indo-Pacific Office, and Acting Dy. Mission Director USAID
03:35 – 03:40 pm	Felicitation of Faculty Members and Review Committee – PACE-D program	
03:40 – 04:00 pm	Certificate Distribution to participants	
03:40 – 04:05 pm	Final Words from Ms. Karen Klimowski, USAID	
04:05 – 04:30 pm	Feedback from Participants	Mr. Anurag Mishra, Energy Team Leader, USAID/India

Regulatory Framework for Resource Planning

Faculty - Mr. Rakesh Kumar Goyal, Team Leader for USAID PACE-D 2.0 RE Program

Dr. Rakesh Kumar Goyal

- Serving as the Team Leader for USAID PACE-D 2.0 RE Program
- Managing Director and India country head of Tetra Tech
- Over 30 years of work experience in the power sector
- Worked for five years with UP Electricity Regulatory Commission and interacted with more that 20 regulatory commissions in India and outside India

Contents

- Why Regulatory Framework for Resource Planning?
    - Resource Planning is a Complex Process
    - Financial and economic consideration
- Development of Regulatory Framework for Resource Planning
    - Methodology
    - Primary Research
    - Secondary Research
- Model Regulations for Resource Planning

Why Regulatory Framework for Resource Planning ?

Resource Planning is a Complex Process

Resource Planning is a process that helps DISCOMs to **optimize** their supply resources to meet long-term and medium-term demand based on **least cost** and maximum renewable energy in its power portfolio. Key attributes of resource planning are as follows:

- Demand Forecasting
- Resource Mapping
- Estimating Additional Resources
- Developing Alternate Resource Portfolios
  - Combinations of RE, Demand Side and Conventional
  - Develop Options (Managing Risk and Uncertainty)

Resource Planning is a Complex Process

Formulation of a good resource plan depends on the following:

- Data quality
- Advanced statistical methods
- Software tool
- Load research
- Incorporation of new realities such as EVs, EE, DSM etc.

*Resource planning is a **complex process**, it is therefore important to have **guidelines** that mandates the development of efficient resource plans.*

Financial and Economic Consideration

Overestimation of demand

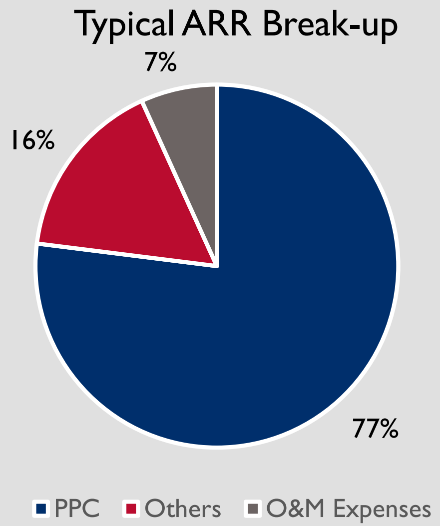
- An indication of poor planning
- Lead to undue burden of fixed and minimum commitment charges
- Unutilized capacity
- Sunk capital cost

Underestimation of demand

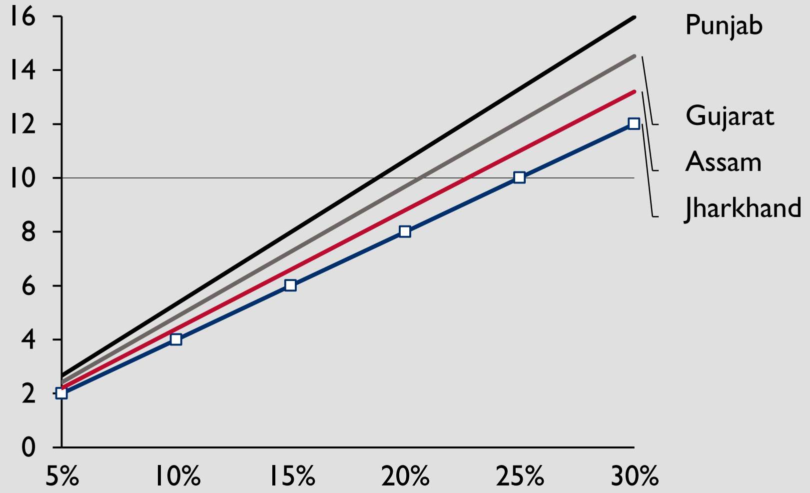
- Lead to power shortages and load shedding
- Economic losses due to lower production.
- Law and order problems
- Social impact

Financial and Economic Consideration

- Power Procurement Cost is around 60-80% of ARR filed by DISCOMs
- Incorporation of RE and accurate estimation of demand will result in significant savings for DISCOMs



Source: JSERC ARR and Tariff for 2019-20

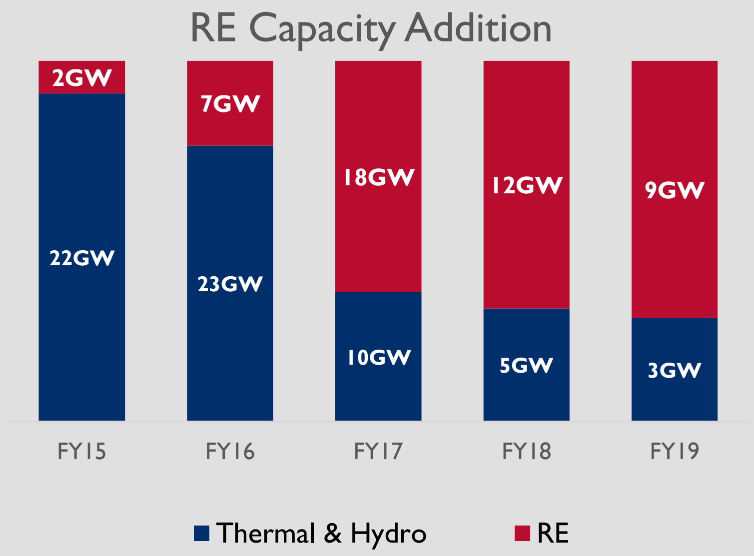


10% reduction in PPC @25% RE in power portfolio
Savings: 550 Crores annually

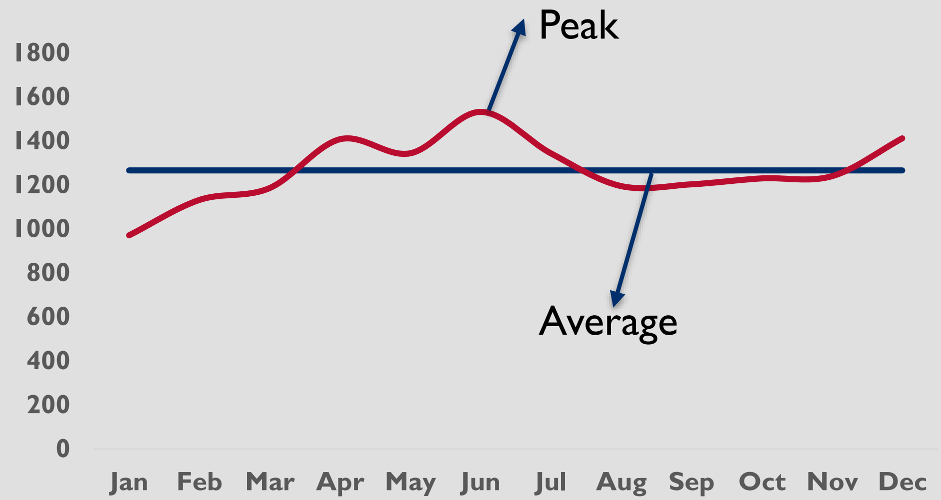
It is important for DISCOMs and regulators to carefully examine the power purchase cost.

Financial and Economic Consideration

RE Installed	RE Target by Y2022	Falling RE Prices	Discoms' Avg. Procurement Cost
87 GW (23% of Installed Cap. Mar'20)	**175 GW** Aiming for 225GW	**Wind ₹ 2.5 -2.85/kWh** **Solar ₹ 2.4 -2.65/kWh**	**₹ 3.6/kWh** (APPC FY18-19)



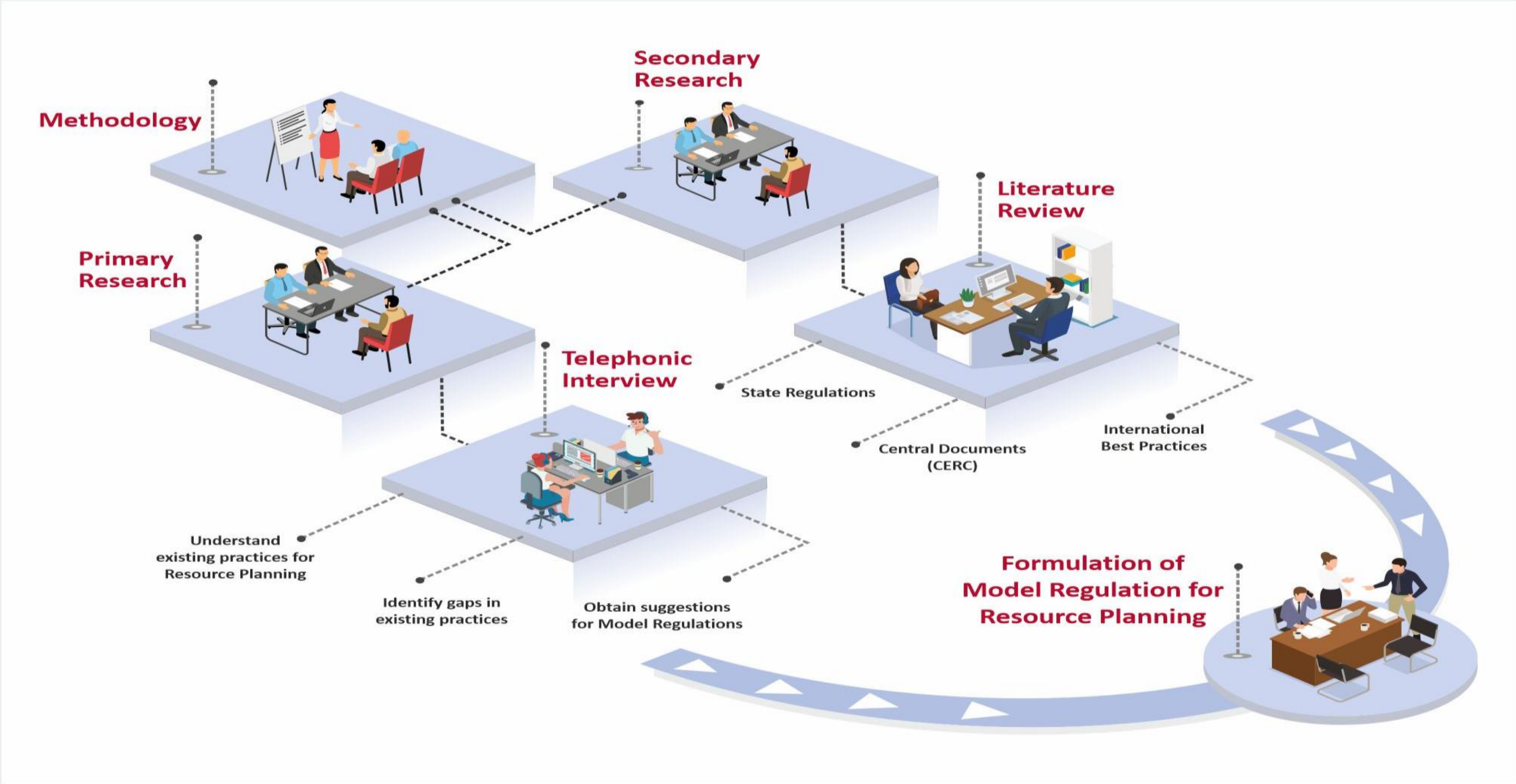
Increasing share of RE in total capacity addition and the inclusion of same in power portfolio



It is possible to better match variations in supply with demand across space-time with technologies such as demand response, energy efficiency and demand side management

Development of Regulatory Framework

Develop Regulatory Framework for Resource Planning: Methodology



Primary Research:

STAGE 1: SELECTION OF STATES: The parameters that were adopted for State Selection is presented in the next slide

STAGE 2: DRAFTING OF QUESTIONAIRE AND INTERVIEW CHECKLIST: Questionnaires is presented in later slides

STAGE 3: TELEPHONIC INTERVIEW OF DISCOM EPLOYEES AND REGULATORS

STAGE 4: ANALYSIS AND EVALUATION OF FINDINGS: The Gap Analysis is mentioned in the 'Summarization of Findings' slide

Secondary Research: Existing Regulations

Guidelines/Regulations of 12 Indian States were studied to understand the importance provided to resource plans by reviewing following documents:

I. For Load Forecasts, Resource Plans, And Power Procurement

II. Tariff Methodology and Regulatory Tariff orders

III. Multi Year Tariff Regulations

IV. Central and State Grid Code

V. Electricity Supply Code-

The 12 States that have been selected are: **Assam, Andhra Pradesh, Punjab, Delhi, Gujarat, Jharkhand, Rajasthan, Tamil Nadu, Karnataka, Bihar, Meghalaya and Haryana**

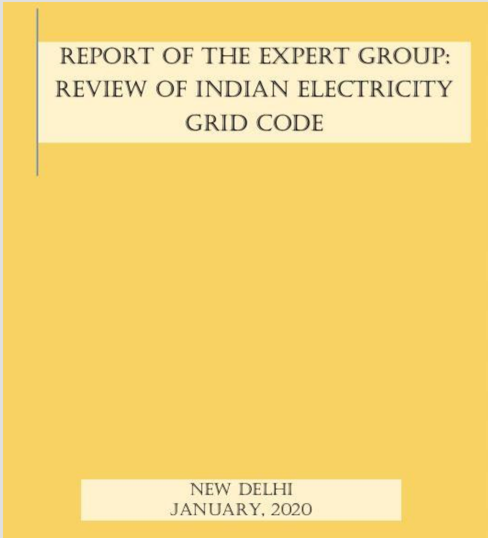
Secondary Research: CERC Planning Code

(a) Demand forecasting by State

i. Timeline to submit the demand forecast by September 30 every year.
ii. Submission to: STU
iii. Methodology: Trend, Time Series, Econometric
iv. Develop daily load curve (hourly basis) for a typical day for each month.

(b) Generation Resource Planning

i. Demonstrable resource adequacy with list of resources along with associated capacities shall be submitted to the respective STU and SERC.
ii. Emphasis on:
   - Generation Flexibility
   - Demand Response
   - Economic Dispatch



Source: Report of the Expert Group: Review of Indian Electricity Grid Code

Secondary Research: International Best Practices

	RESOURCE PLANNING	FINDINGS	SOURCE
United States	• Econometric, End Use and Statistically Adjusted End Use (SAE) are most prevalent models • Approaches combining Deterministic and probabilistic outlook	• Strong Regulatory Framework for resource planning • Recognition of Uncertainty and Best practice management.	*"Resource Planning Guidelines for Electric Utilities" by Arkansas Public Service Commission*
Europe	• Econometric and End Use are most prevalent • Typically, Sequential Probabilistic Monte Carlo Method including deterministic constraints	• Improve forecasts using LR and develop cognizance of new realities. (RE, DER, EV and EE). • Engagement of stakeholders	*"Grid Development Plan" by TSOs*
Australia	• Econometric Method • Two Year Probability of Supply Adequacy Shortfall (2YRPSAS)	• Regular updates of Resource planning • Modelling and Software use	*"Integrated System Plan" for the National Electricity Market by AEMO*
UK	• Bottom-Up Approach for forecasting down till postal code • Strong regulatory framework	• High degree of temporal and spatial granularity • Development of options based on multiple scenarios	*"Distribution Future Electricity Scenarios" by Electricity North West*

Summary of Findings

S.No	Key Findings
1.	Basic preliminary regulations does exist in very few SERCs, but they are about 15 years old and not amended since. **Before unbundling**, the State Electricity Boards had strong planning departments and all investments in a state's power sector were based on the projections made in the plan. **Post unbundling**, the importance of long-term and medium-term planning was diluted, and focus shifted to managing short term causalities No detailed Specific Regulations for Resource Planning are in force.
2.	Regulations lack mention of methodology to develop resource plans.
3.	None of the Regulations provide specific timelines for submission, approval and modification of Resource Plans.

Summary of Findings

S.No	Key Findings
4.	No Scenario building exercise based on sensitivity, and probability analysis is done.
5.	No emphasis on conducting Load Research
6.	None of the Regulations support development of hourly demand profile which is important attribute to consider in RE rich environment.
7.	Methodology to include impact of new drivers such as EE, DER, EV, etc. on demand forecasting, other than DSM is absent.
8.	Very limited use of software tools based on algorithm
9.	DISCOMs do not have any specific department for planning. Generally, Resource Planning is carried out by commercial/finance department of the DISCOM
10.	DISCOM and Regulators do not have trained staff to develop/examine resource plan

The findings revealed a need to have well defined regulatory framework to examine the 80% cost of DISCOM business.

Model Regulations

Faculty - Mr. Amarjeet Singh, Research Analyst, USAID PACE-D 2.0 RE Program

Amarjeet Singh

- *Postgraduate in Energy Systems Engineering from IIT Bombay*
- *Experience of working with countries such as India, Ghana, Liberia and Bhutan*
- *Four years of experience in renewable energy*
- *Worked with donors such as USAID, World Bank, UNDP etc.*

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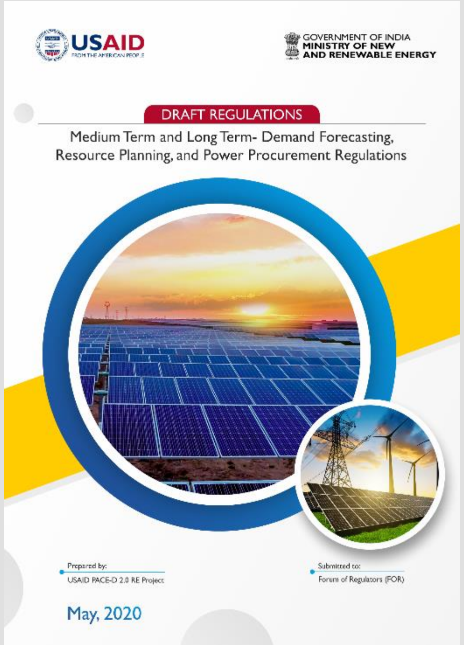
Model Regulations: Content

- **Chapter 1:** Title: "*Medium Term and Long-Term Demand Forecasting, Resource Planning and Power Procurement Regulations*", Commencement and Applicability
- **Chapter 2:** Definitions of such terms as Act, Area of Supply, Availability Factor, etc.
- **Chapter 3:** General Instructions Regarding Resource Plan Submission
- **Chapter 4:** Demand Forecast
- **Chapter 5:** Resource Plan
- **Chapter 6:** Power Procurement
- **Chapter 7:** Miscellaneous
  - ✓ Removal of difficulties
  - ✓ Power to Relax
  - ✓ Power to Amend
  - ✓ Savings



Demand Forecast

- Consumer category wise demand forecast
- Methodology:
  - *Compounded Average Growth Rate (CAGR)*
  - *End Use; Trend; Partial End Use*
  - *Econometric (Specifying the parameters used, algorithm, and source of data).*
- Impact of policies and drivers such as:
  - *Open Access; Demand Side Management*
  - *Distributive Sources; Electric Vehicles*
  - *Tariff Signals; Availability of Supply*
  - *Policies such as 24*7 power supply*
- Computation of net demand (in MU) by adding a loss trajectory
- Peak demand estimation based on the average load factor
- Conduct sensitivity and probabilistic analysis

Resource Planning

- Mapping of all existing, upcoming, and retiring resources
- Critical characteristics and parameters of the generating machines, such as:
  - *Heat rate, auxiliary consumption, ramp-up rate, ramp-down rate, etc., for thermal machines;*
  - *Hydrology and machine characteristics, etc., for hydro machines; and*
  - *Renewable resource forecasts, CUFs, etc. for renewable resource–based power plants*
- Constraints such as:
  - *Penalties for unmet demand, forced outages, spinning reserve requirements, and system emission limits*
- Planning Reserve as specified by the commission or as per suitability
- Identify resource gap for long and medium term
- Conduct sensitivity and probabilistic analysis

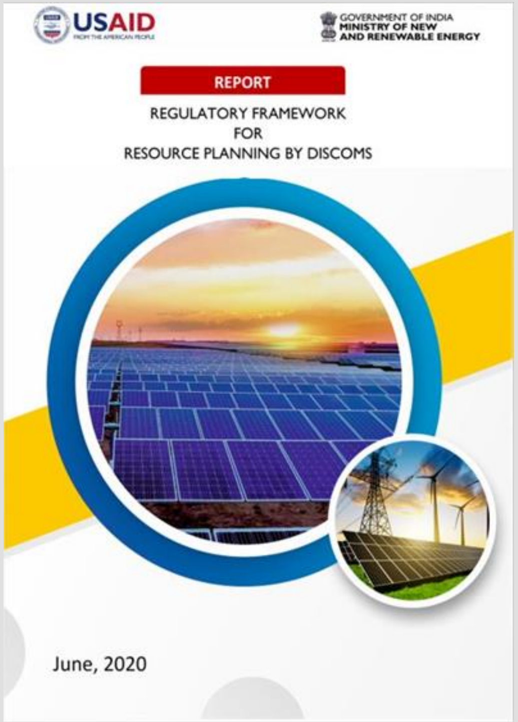
Power Procurement Optimization

- Resource gap: Base and Variable
- Power for base gap through long-term contracts and for variable gap by medium-term contracts considering:
  - *Cost;*
  - *Grid integration cost;*
  - *Power available at power exchanges;*
  - *Demand response and other demand-side measures*
- Power procurement through competitive bidding as per MoP guidelines
- Power through MoU with prior approval of the Commission
- Power from generating sources with prior approval of the Commission
- Short-term power procurement from power exchange through an agreement or through a transparent process of open tendering and competitive bidding.

Model Regulations

The full report on the methodology and analysis and draft model regulations is available at:

https://www.pace-d.com/wp-content/uploads/2020/11/Regulatory-Framework-for-Resource-Planing.pdf



Quiz

USAID
FROM THE AMERICAN PEOPLE

GOVERNMENT OF INDIA
MINISTRY OF NEW
AND RENEWABLE ENERGY

ANNEXURE 1: TUTORIALS

DESIGNING RENEWABLE DOMINATED RESOURCE PLANS FOR FUTURE UTILITIES

Tutorial: Current Practices of Resource Planning and International Best Practices

October 14, 2020; Time: 02:30 – 04:30 pm

USAID PACE-D 2.0 RE Program

Faculty - Dr. Rafael Kelman, Executive Director, PSR Consulting

Dr. Rafael Kelman

- BSc in Civil Engineering, MSc in Water Resources and PhD in Optimization from COPPE/UFRJ.
- Dr. Kelman coordinates studies in power sector, such as the integration of renewable energy, market studies and water-energy nexus. He also participates in the development of models ranging from long-term planning to short-term scheduling of power systems.

Summary

- Integrated Resource Planning
- G&T Expansion Planning Models
- Example: Brazil IRP case
- Distribution System of the future
- Proposed Methodology
- Models
- Study Case
- Next steps

Faculty – IRP Tutorial

Mr. Lucas Okamura

- BSc in Electrical Engineering (Power Systems) from UFRJ with 1 years spent at University of Manchester, UK (2015).
- MSc in Electrical Engineering (Power Systems) from COPPE (2020)
- Joined PSR in 2015

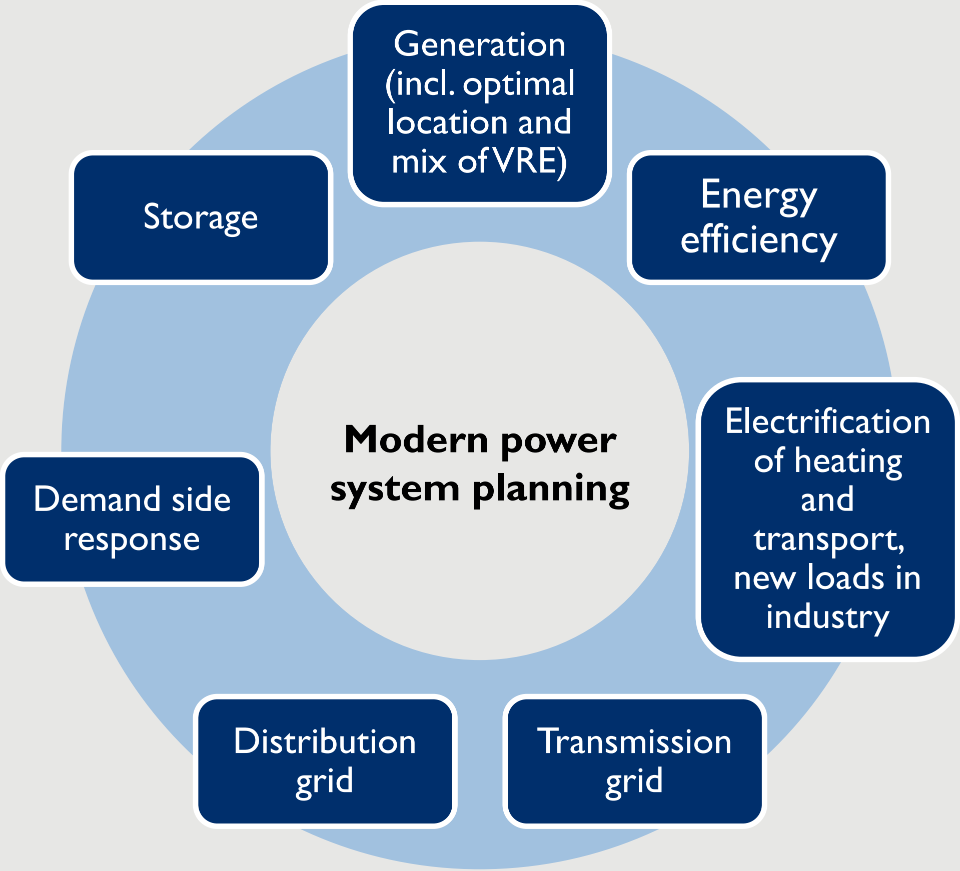
Mr. Alessandro Soares

- BSc in Electrical Engineering and Control Engineering PUC-Rio (2015).
- MSc in Optimization/Operations Research at PUC-RJ (2020).
- Joined PSR in 2017

Ms. Amanda Oliveira

- Electrical engineer (UFRJ, 2019)
- MSc in the Electrical Engineering (Power Systems) at COPPE (2020).
- Joined PSR in 2017

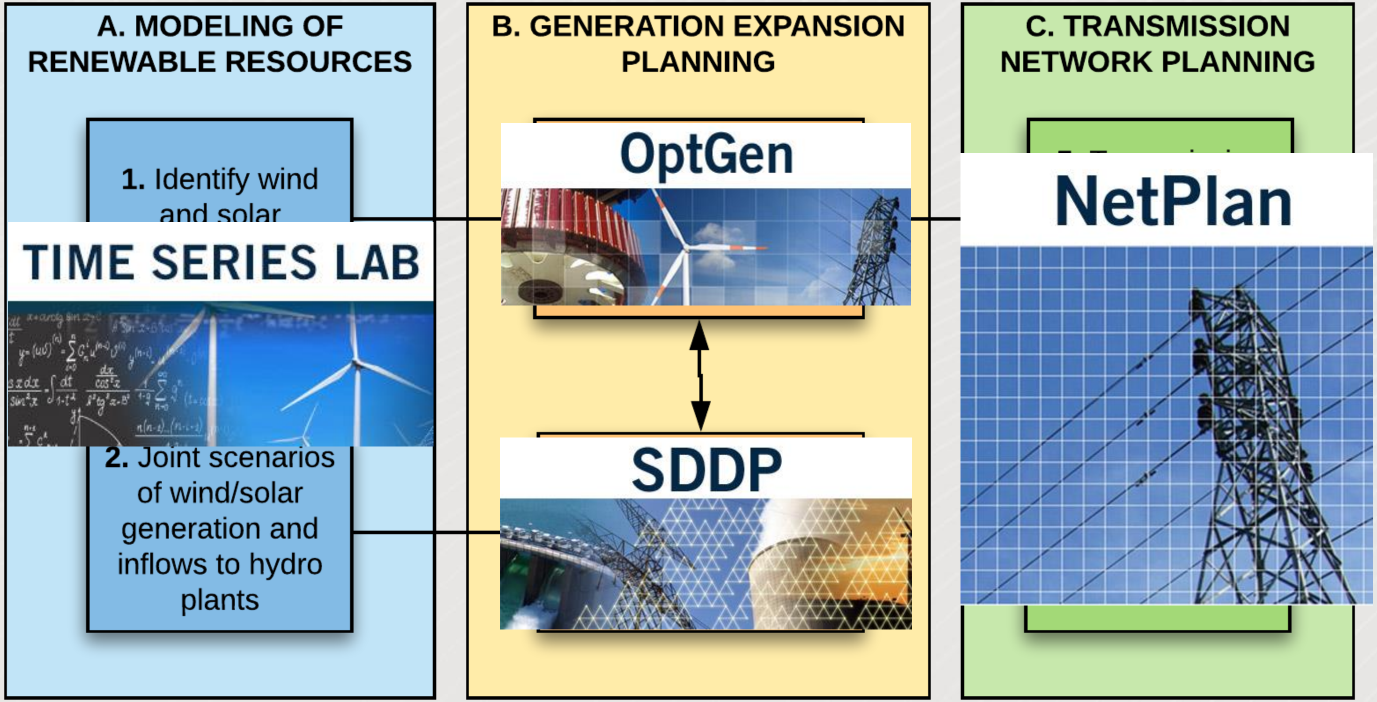
Integrated planning with state-of-the-art tools is crucial



State-of-the-art (probabilistic) modeling tools are indispensible for successful VRE integration

- Need to combine long-term view on expansion with short-term view of operation
  - (sub) Hourly time steps
  - Unit commitment decisions
  - Ramping constraints
  - Hydraulic constraints in river basins
  - Variability of renewables, inflows & demand (uncertainties)
  - Energy, capacity and reserve requirements

G&T Expansion planning: (PSR approach)

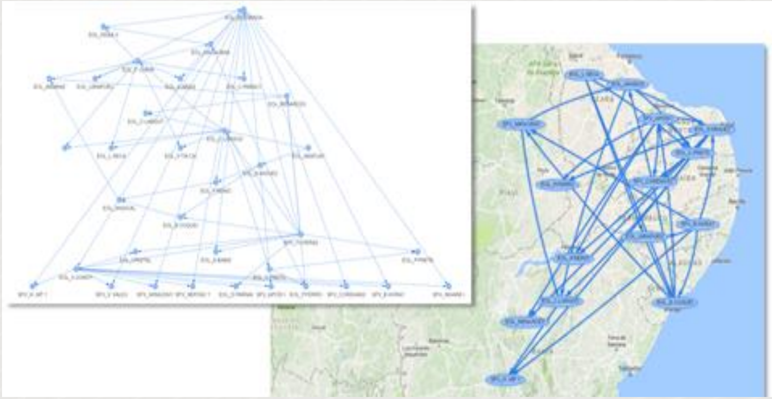


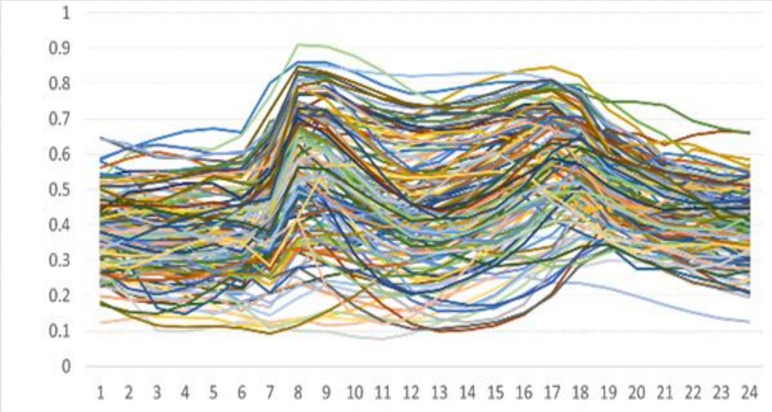
Activity A - Modeling of renewable resources

- Identify candidate projects for wind and solar generation.
  - As with hydropower projects, which require historical inflow records, each renewable candidate requires historic energy production with hourly resolution.
  - This is usually done with global databases, such as MERRA-2, which contain ~40 years of hourly wind speed and solar radiation data for the entire planet.
- Data for each candidate site is refined/calibrated based on the measured wind / solar records (usually 2-3 years) from existing neighboring plants.
- Finally, the calibrated wind speed and the solar records are transformed into 40 years of hourly energy production using the parameters of the candidate project (type of wind turbine, hub height, solar trackers, etc.).

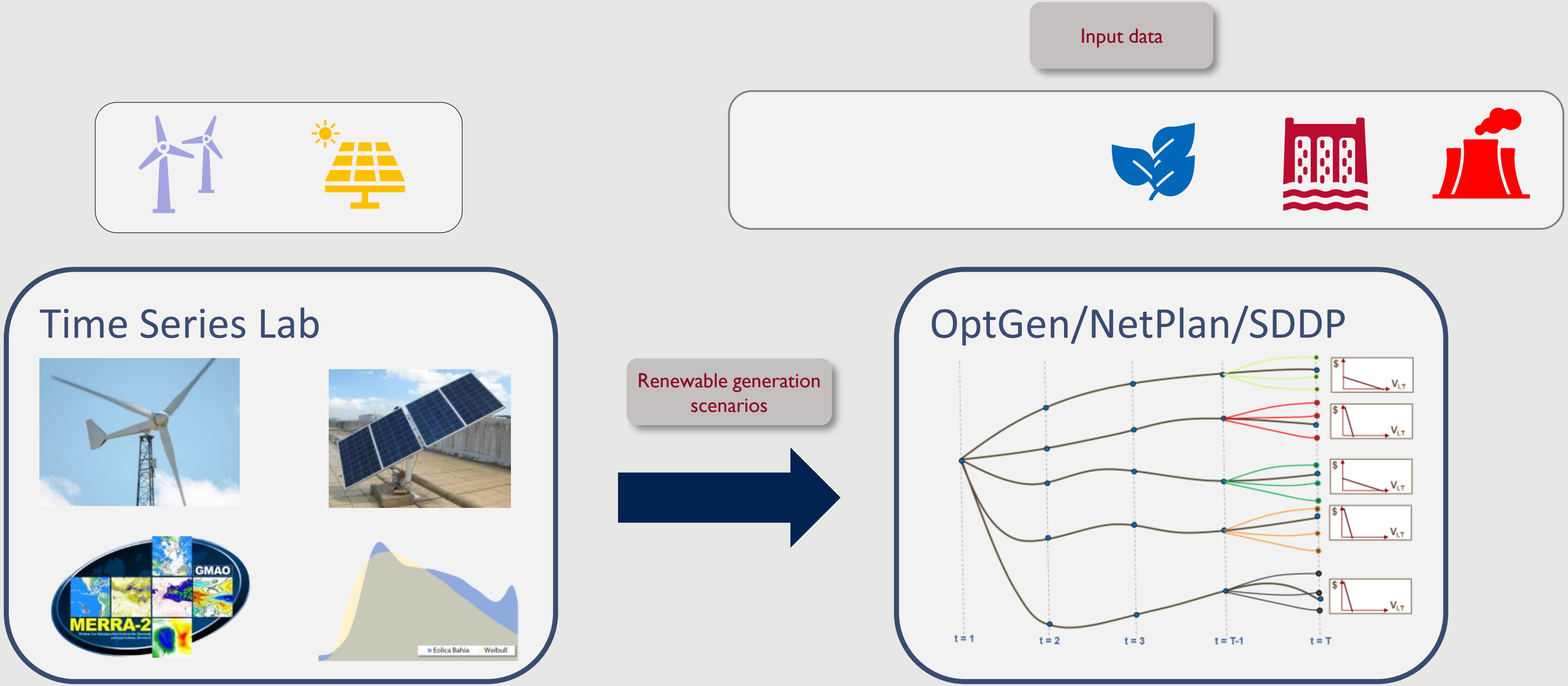
Activity A - Modeling of renewable resources

- Generation scenarios for existing and candidate renewable sources, including hydro.
  The methodological challenges are:
  - Significant spatial correlation between wind energy and inflows in some regions.
  - Generation of scenarios must be integrated (wind, solar, and inflows to hydro plants) and with multiple time scales (hourly for wind & solar, monthly/weekly for inflows).
  - Integrated/multiscale scenarios produced by a Bayesian network, a statistical model with variables and their conditional dependencies represented through a graph

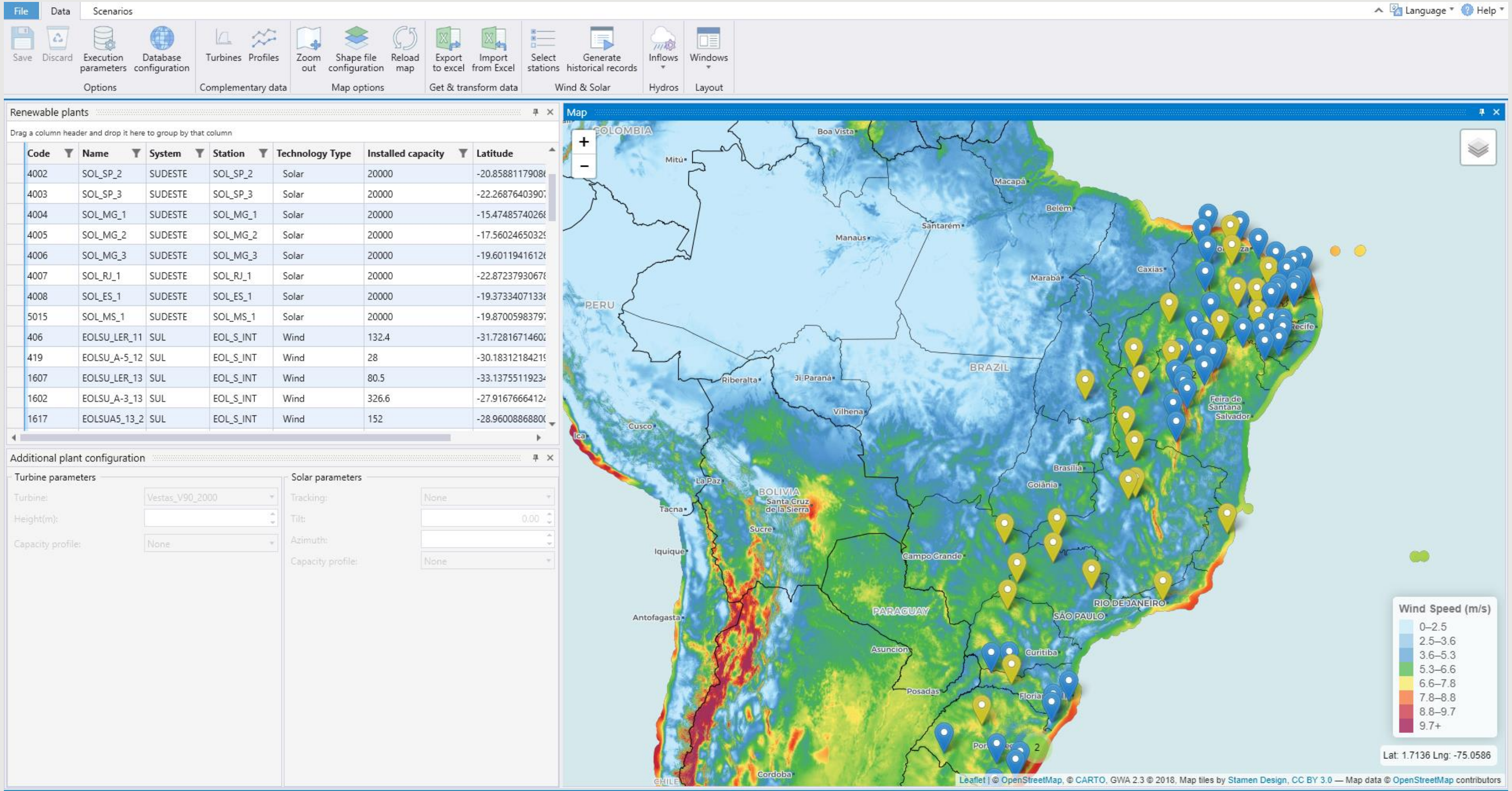




The Time Series Lab Tool in Practice

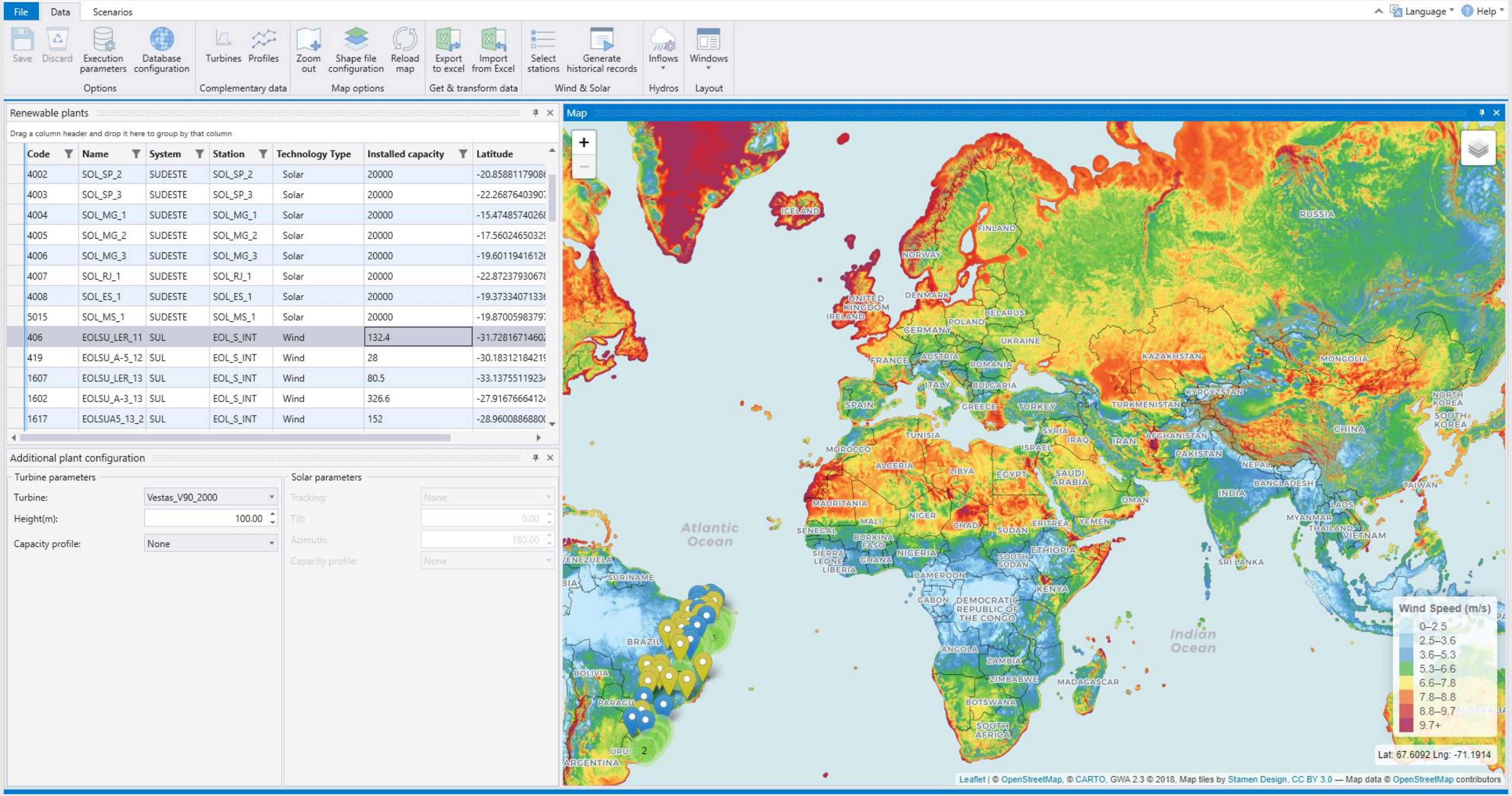


Hotspots for projects

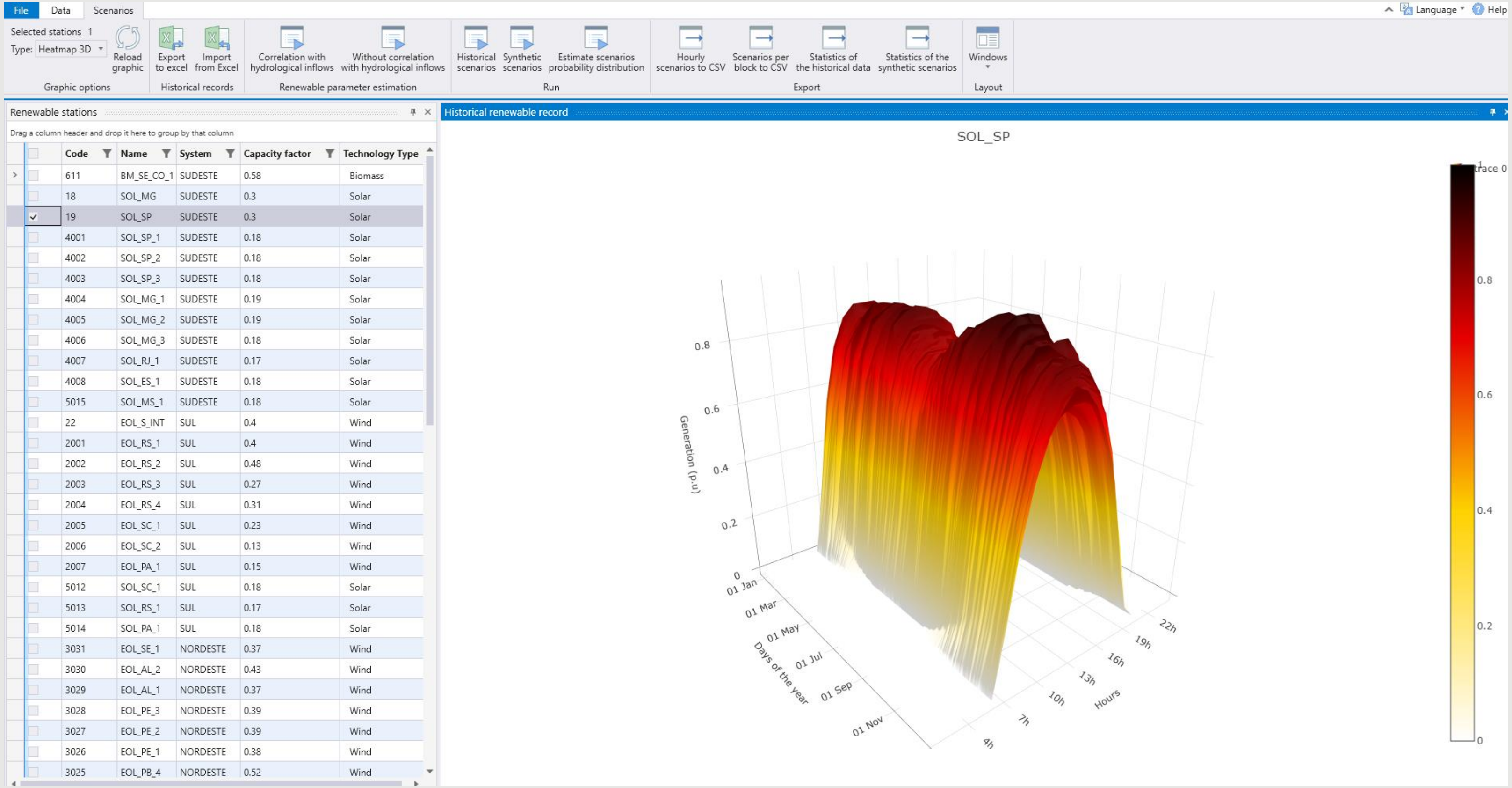


Code	Name	System	Station	Technology Type	Installed capacity	Latitude
4002	SOL_SP_2	SUDESTE	SOL_SP_2	Solar	20000	-20.8588117908
4003	SOL_SP_3	SUDESTE	SOL_SP_3	Solar	20000	-22.2687640390
4004	SOL_MG_1	SUDESTE	SOL_MG_1	Solar	20000	-15.4748574026
4005	SOL_MG_2	SUDESTE	SOL_MG_2	Solar	20000	-17.5602465032
4006	SOL_MG_3	SUDESTE	SOL_MG_3	Solar	20000	-19.6011941612
4007	SOL_RJ_1	SUDESTE	SOL_RJ_1	Solar	20000	-22.8723793067
4008	SOL_ES_1	SUDESTE	SOL_ES_1	Solar	20000	-19.3733407133
5015	SOL_MS_1	SUDESTE	SOL_MS_1	Solar	20000	-19.8700598379
406	EOLSU_LER_11	SUL	EOL_S_INT	Wind	132.4	-31.7281671460
419	EOLSU_A-5_12	SUL	EOL_S_INT	Wind	28	-30.1831218421
1607	EOLSU_LER_13	SUL	EOL_S_INT	Wind	80.5	-33.1375511923
1602	EOLSU_A-3_13	SUL	EOL_S_INT	Wind	326.6	-27.9167666412
1617	EOLSUA5_13_2	SUL	EOL_S_INT	Wind	152	-28.9600886880

Data for the whole world

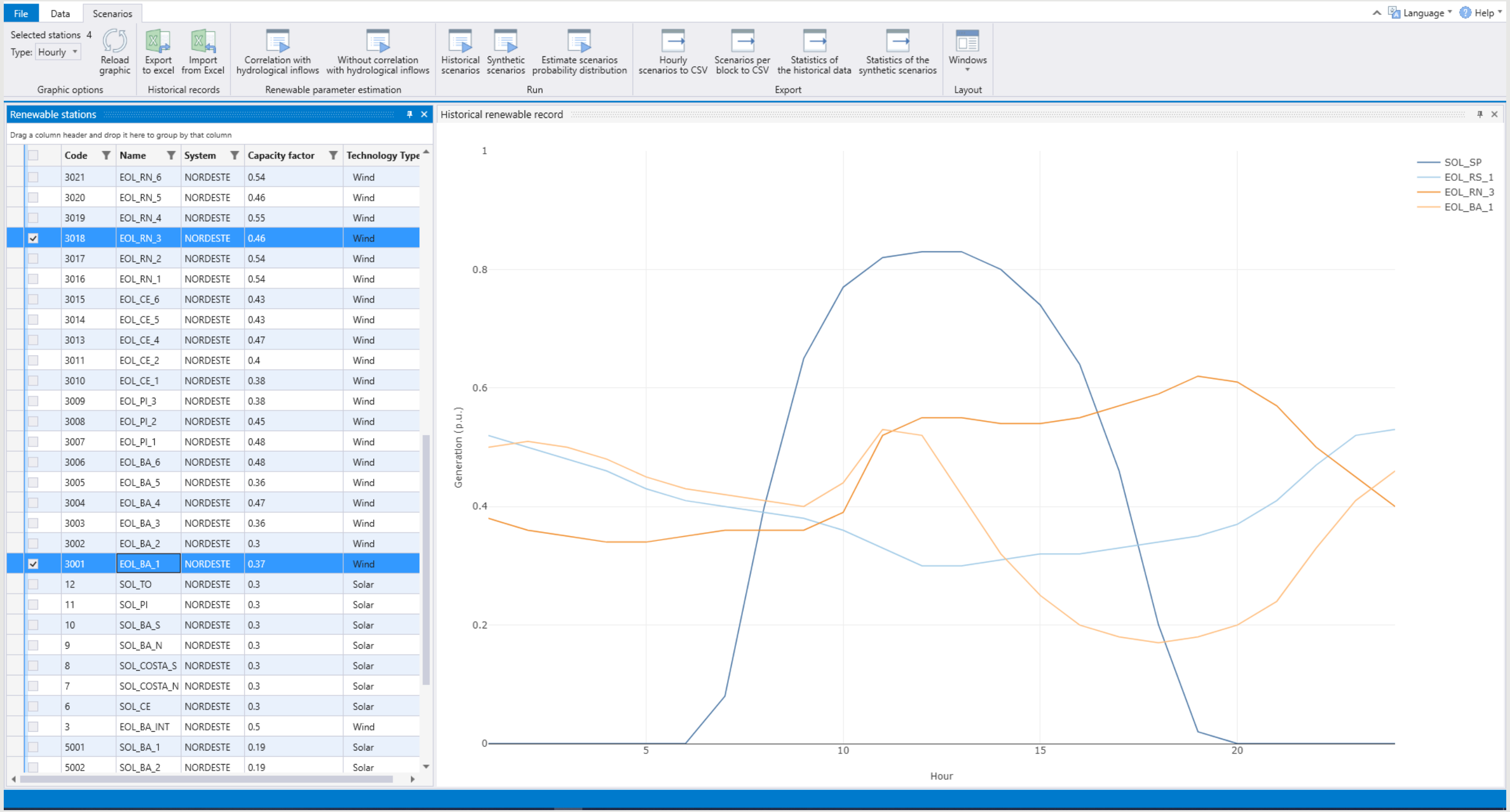


Visualization of historical data



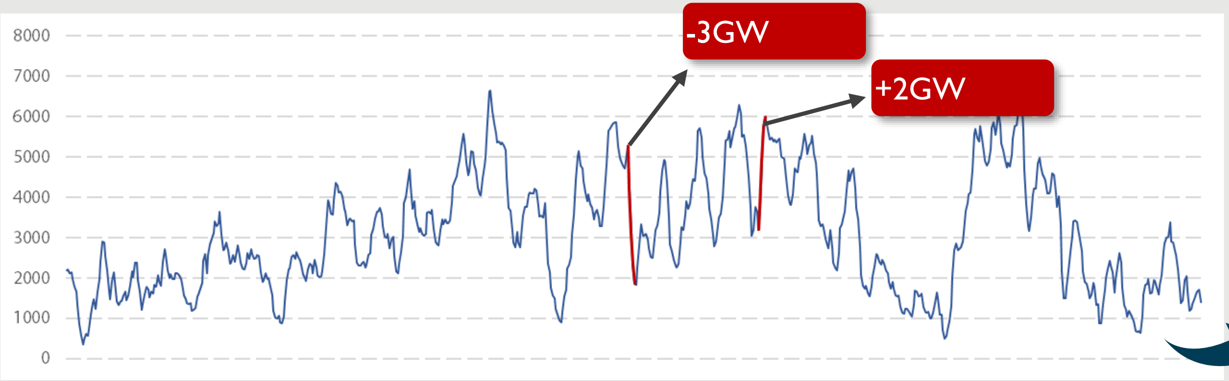
Code	Name	System	Capacity factor	Technology Type
611	BM_SE_CO_1	SUDESTE	0.58	Biomass
18	SOL_MG	SUDESTE	0.3	Solar
19	SOL_SP	SUDESTE	0.3	Solar
4001	SOL_SP_1	SUDESTE	0.18	Solar
4002	SOL_SP_2	SUDESTE	0.18	Solar
4003	SOL_SP_3	SUDESTE	0.18	Solar
4004	SOL_MG_1	SUDESTE	0.19	Solar
4005	SOL_MG_2	SUDESTE	0.19	Solar
4006	SOL_MG_3	SUDESTE	0.18	Solar
4007	SOL_RJ_1	SUDESTE	0.17	Solar
4008	SOL_ES_1	SUDESTE	0.18	Solar
5015	SOL_MS_1	SUDESTE	0.18	Solar
22	EOL_S_INT	SUL	0.4	Wind
2001	EOL_RS_1	SUL	0.4	Wind
2002	EOL_RS_2	SUL	0.48	Wind
2003	EOL_RS_3	SUL	0.27	Wind
2004	EOL_RS_4	SUL	0.31	Wind
2005	EOL_SC_1	SUL	0.23	Wind
2006	EOL_SC_2	SUL	0.13	Wind
2007	EOL_PA_1	SUL	0.15	Wind
5012	SOL_SC_1	SUL	0.18	Solar
5013	SOL_RS_1	SUL	0.17	Solar
5014	SOL_PA_1	SUL	0.18	Solar
3031	EOL_SE_1	NORDESTE	0.37	Wind
3030	EOL_AL_2	NORDESTE	0.43	Wind
3029	EOL_AL_1	NORDESTE	0.37	Wind
3028	EOL_PE_3	NORDESTE	0.39	Wind
3027	EOL_PE_2	NORDESTE	0.39	Wind
3026	EOL_PE_1	NORDESTE	0.38	Wind
3025	EOL_PB_4	NORDESTE	0.52	Wind

Visualization of historical data

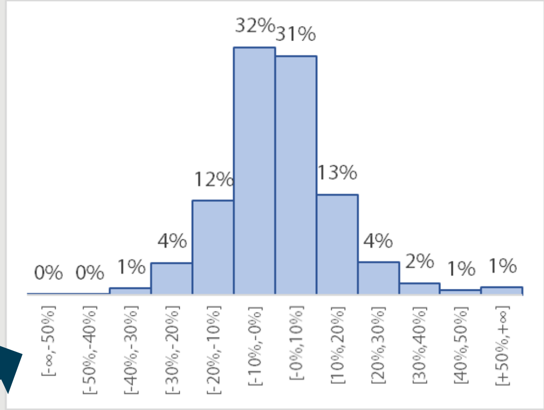


Scenarios (projections) for the future

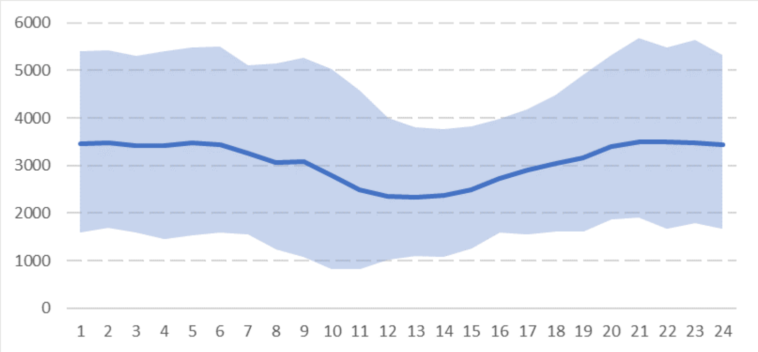
Hourly generation of a wind plant in Brazil



Hourly variation

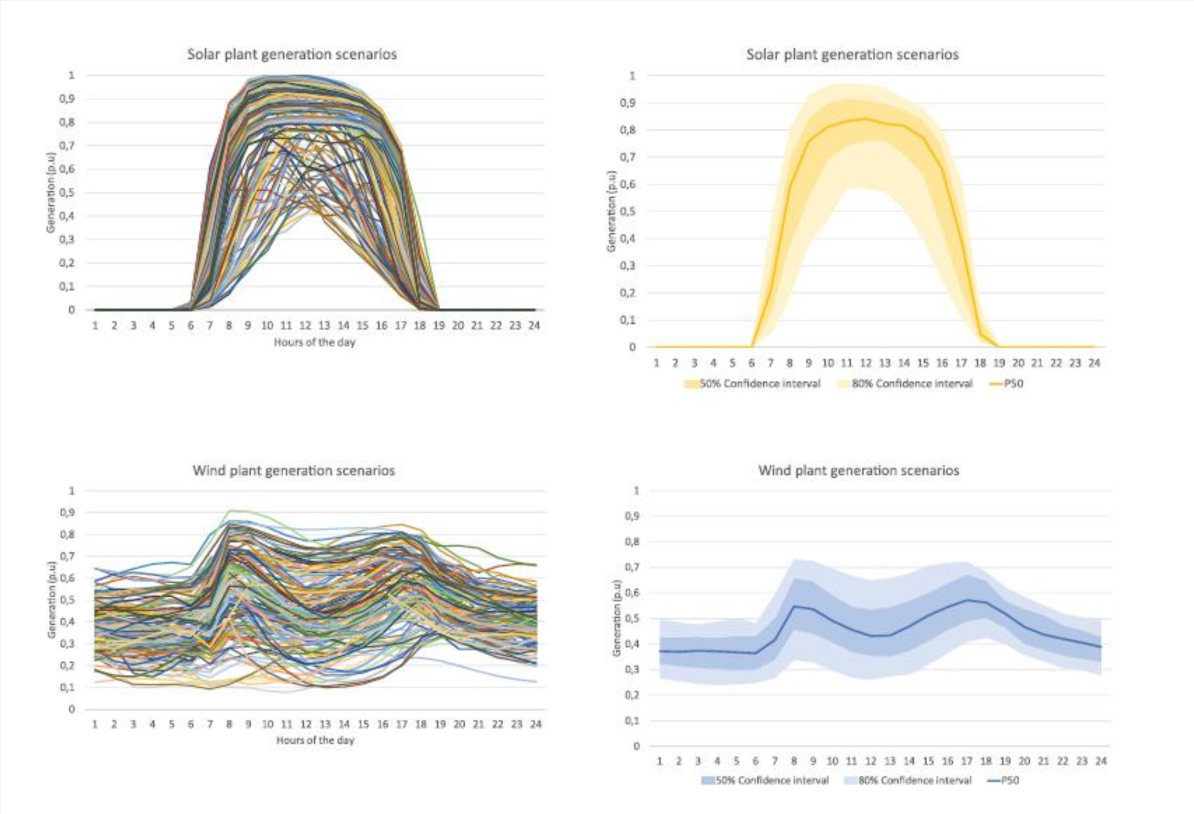


Hourly generation – Daily profile



The Time Series Lab tool is able to generate future synthetic scenarios (or projections) of renewable generations, that are used by SDDP to generate scenarios of energy price, dispatch, and so on.

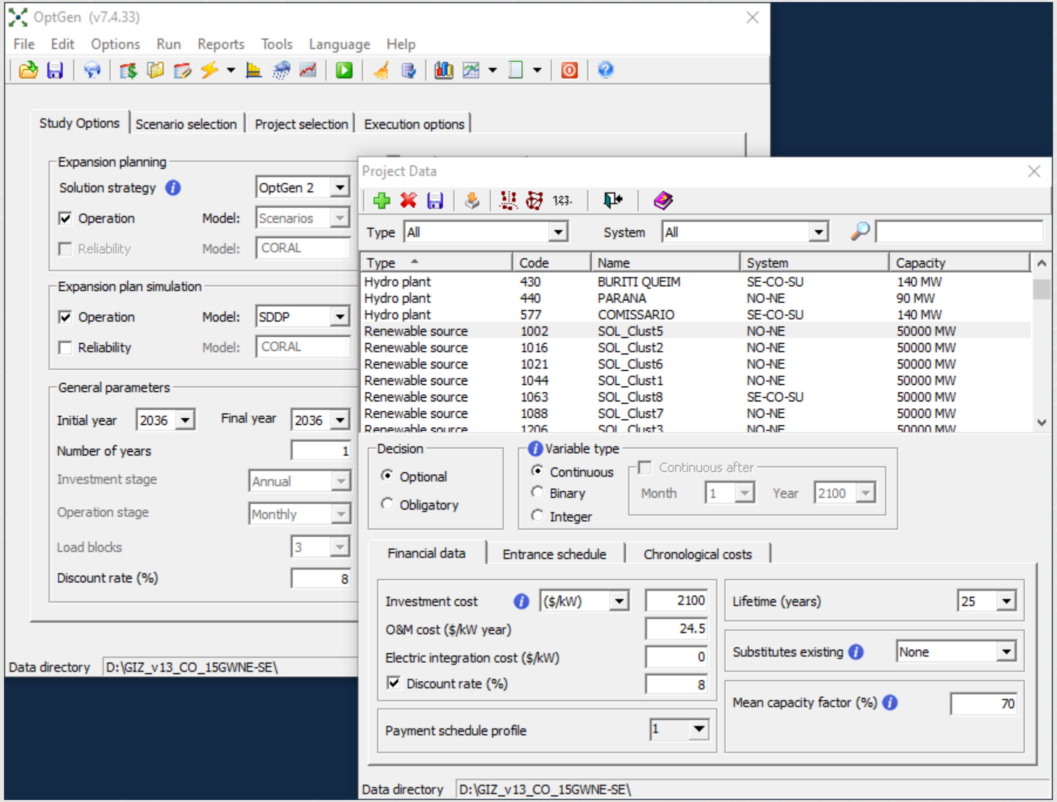
The scenarios are created for Wind, Solar and Hydro inflows



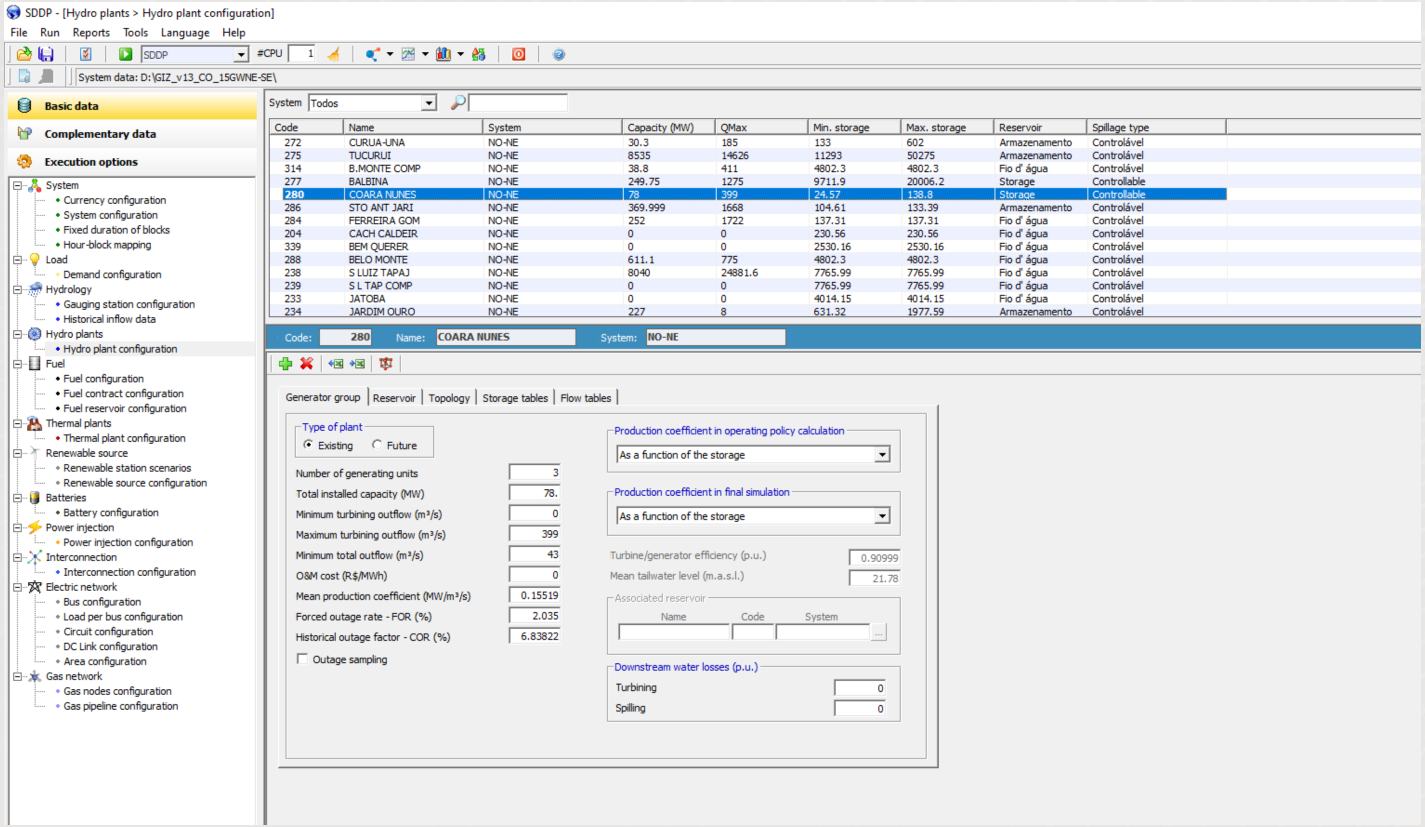
Activity B - Planning the expansion of G&T

- The objective of this activity is to determine the set of generation and regional interconnections reinforcements over the planning period that minimize the present value of the sum of investment costs and expected value of operating costs (fuel costs of thermal plants plus penalties for power supply failure).
- The amount of flexibility resources required to manage the variability of renewable sources decided with a Dynamic Probabilistic Reserve (DPR) (arXiv preprint arXiv:1910.00454).
- The DPR determines for each hour the amount of fast response generation reserves (batteries, hydro, natural gas plants etc.) necessary to compensate for the uncertainty of renewable production in consecutive hours.
- The calculation of probabilistic generation reserves for renewables is a topic of intense research worldwide. The differential of DPR in relation to other methodologies is that the required reserve automatically adjusts to the entrance of new renewable projects

OPTGEN Model



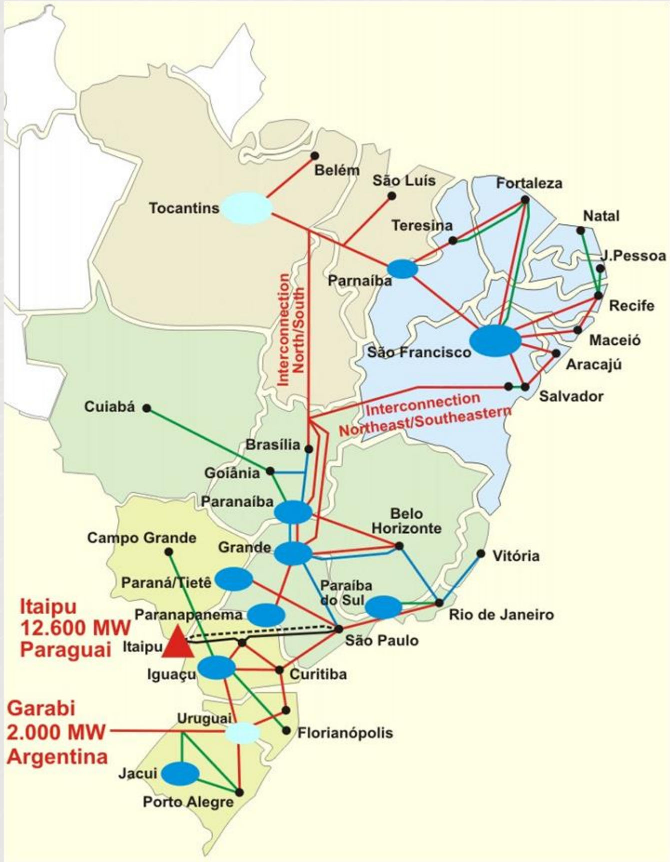
SDDP Model



SDDP - [Hydro plants > Hydro plant configuration]
File Run Reports Tools Language Help
SDDP
#CPU 1
System data: D:\GIZ_v13_CO_15GWNE-SE\
Basic data
Complementary data
Execution options
System
Currency configuration
System configuration
Fixed duration of blocks
Hour-block mapping
Load
Demand configuration
Hydrology
Gauging station configuration
Historical inflow data
Hydro plants
Hydro plant configuration
Fuel
Fuel configuration
Fuel contract configuration
Fuel reservoir configuration
Thermal plants
Thermal plant configuration
Renewable source
Renewable station scenarios
Renewable source configuration
Batteries
Battery configuration
Power injection
Power injection configuration
Interconnection
Interconnection configuration
Electric network
Bus configuration
Load per bus configuration
Circuit configuration
DC Link configuration
Area configuration
Gas network
Gas nodes configuration
Gas pipeline configuration
System Todos
Code | Name | System | Capacity (MW) | QMax | Min. storage | Max. storage | Reservoir | Spillage type
272 | CURUA-UNA | NO-NE | 30.3 | 185 | 133 | 602 | Armazenamento | Controlável
275 | TUCURUI | NO-NE | 8535 | 14626 | 11293 | 50275 | Armazenamento | Controlável
314 | B.MONTE COMP | NO-NE | 38.8 | 411 | 4802.3 | 4802.3 | Fio d' água | Controlável
277 | BALBINA | NO-NE | 249.75 | 1275 | 9711.9 | 20006.2 | Storage | Controllable
280 | COARA NUNES | NO-NE | 78 | 399 | 24.57 | 138.8 | Storage | Controllable
286 | STO ANT JARI | NO-NE | 369.999 | 1668 | 104.61 | 133.39 | Armazenamento | Controlável
284 | FERREIRA GOM | NO-NE | 252 | 1722 | 137.31 | 137.31 | Fio d' água | Controlável
204 | CACH CALDEIR | NO-NE | 0 | 0 | 230.56 | 230.56 | Fio d' água | Controlável
339 | BEM QUERER | NO-NE | 0 | 0 | 2530.16 | 2530.16 | Fio d' água | Controlável
288 | BELO MONTE | NO-NE | 611.1 | 775 | 4802.3 | 4802.3 | Fio d' água | Controlável
238 | S LUIZ TAPAJ | NO-NE | 8040 | 24881.6 | 7765.99 | 7765.99 | Fio d' água | Controlável
239 | S L TAP COMP | NO-NE | 0 | 0 | 7765.99 | 7765.99 | Fio d' água | Controlável
233 | JATOBA | NO-NE | 0 | 0 | 4014.15 | 4014.15 | Fio d' água | Controlável
234 | JARDIM OURO | NO-NE | 227 | 8 | 631.32 | 1977.59 | Armazenamento | Controlável
Code: 280 Name: COARA NUNES System: NO-NE
Generator group | Reservoir | Topology | Storage tables | Flow tables
Type of plant
Existing Future
Number of generating units 3
Total installed capacity (MW) 78.
Minimum turbining outflow (m³/s) 0
Maximum turbining outflow (m³/s) 399
Minimum total outflow (m³/s) 43
O&M cost (R$/MWh) 0
Mean production coefficient (MW/m³/s) 0.15519
Forced outage rate - FOR (%) 2.035
Historical outage factor - COR (%) 6.83822
Outage sampling
Production coefficient in operating policy calculation
As a function of the storage
Production coefficient in final simulation
As a function of the storage
Turbine/generator efficiency (p.u.) 0.90999
Mean tailwater level (m.a.s.l.) 21.78
Associated reservoir
Name Code System
Downstream water losses (p.u.)
Turbining 0
Spilling 0

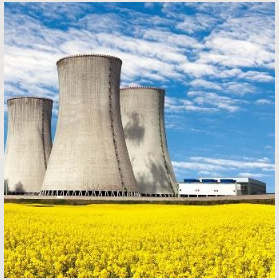
Brazil in numbers (2020)

- 210 million inhabitantes, 8.5 million km2 of area (USA + half Alaska) and GDP of \$3.5 trillion (PPP)
- A **National Interconnected System** with 140,000 km of HV lines (98% of the national load).
- Supply: 160 hydro plants (110 GW), 140 thermal (52 GW) using gas, coal, nuclear & bagasse, wind power (16 GW) and solar PV (3 GW)
- HV transmission network with 5 thousand buses and 7 thousand circuits

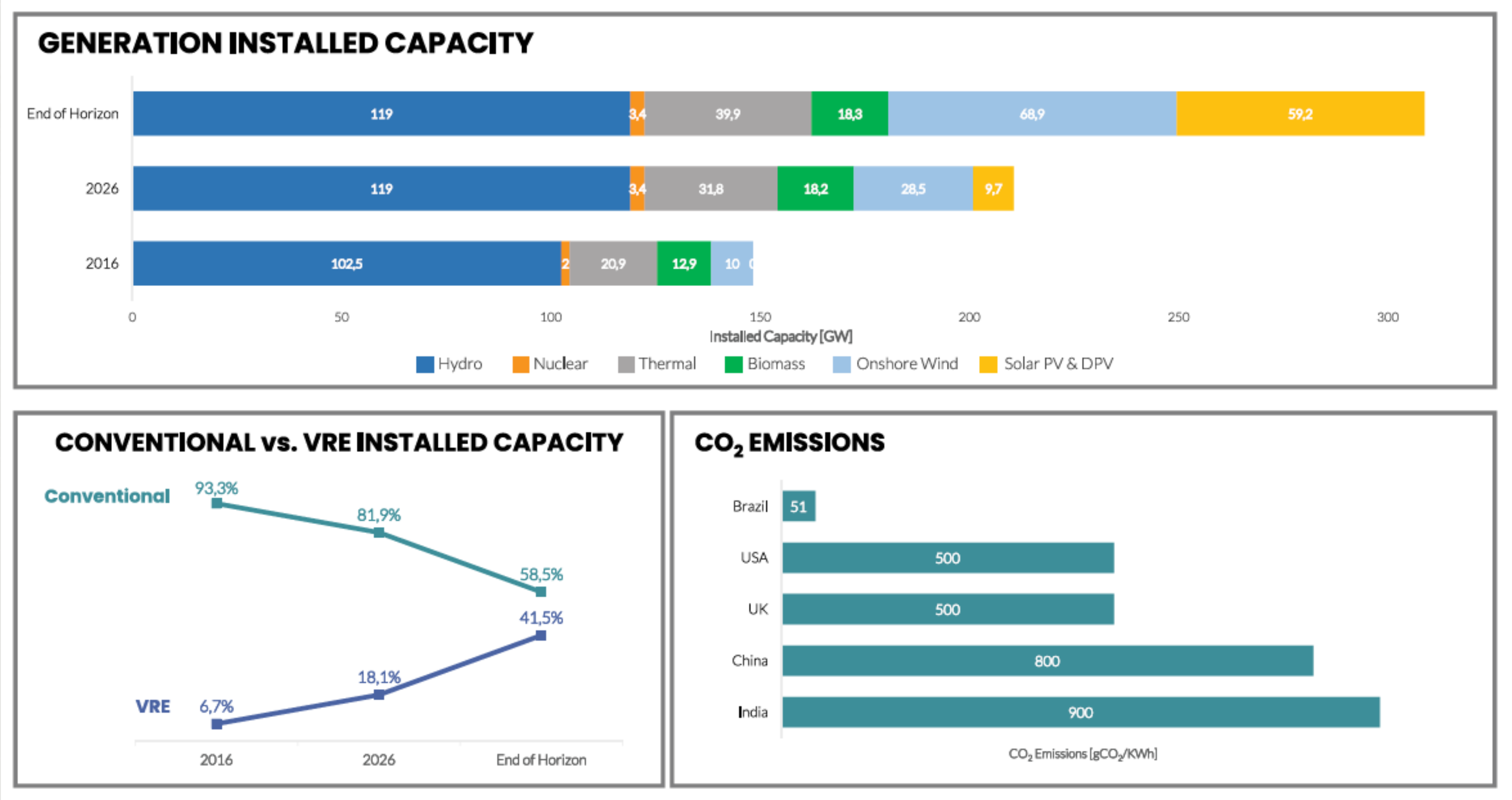


Brazil IRP case: **planning for 2x of load**

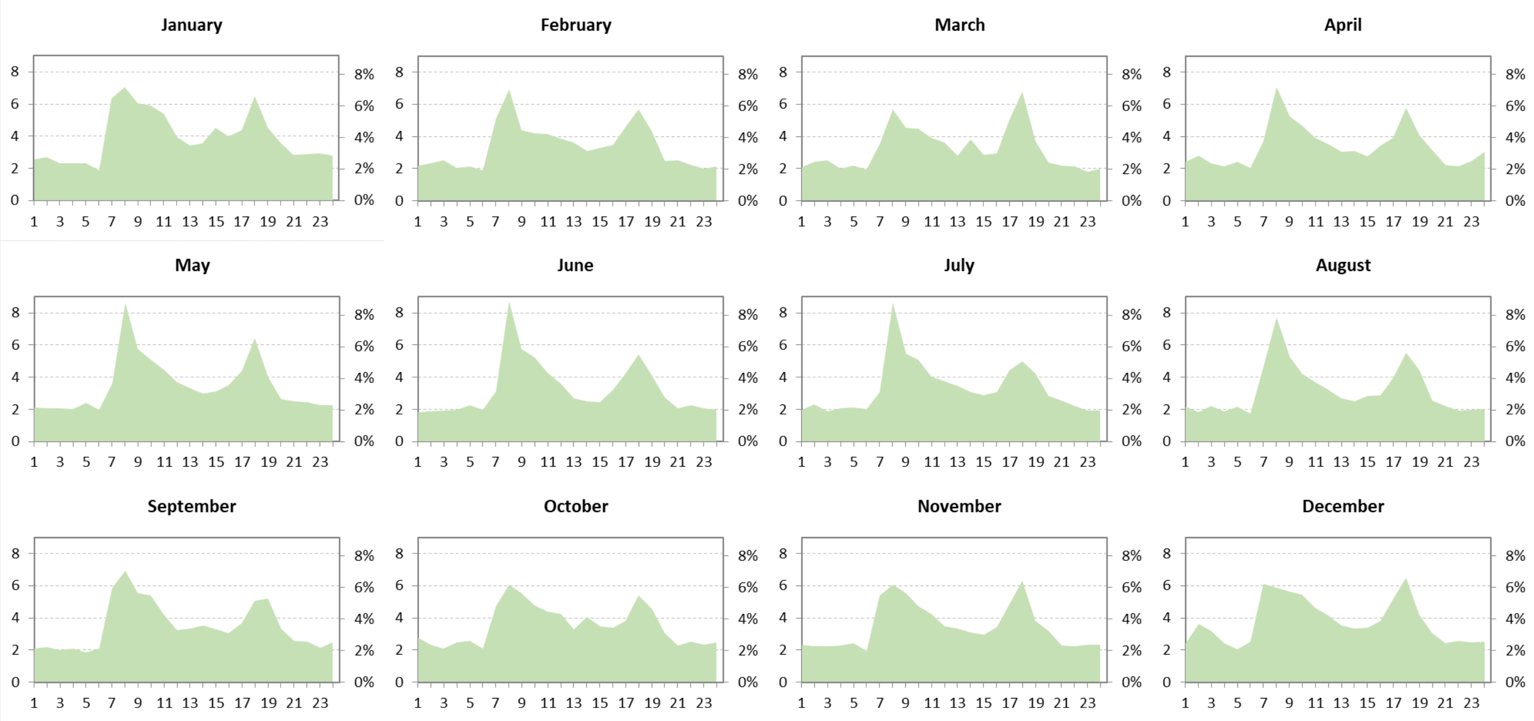
- Candidate project preparation per technology resulted from discussions between Consultants and EPE based on market references (mainly auctions)
- Coal, open cycle and combined cycle natural gas, nuclear, biomass, wind, solar PV, storage devices, interconnections, no hydropower after 2026.
- Technical parameters (such as ramps, startup costs and possible dispatch models)
- Economic parameters, such as CAPEX and OPEX (fixed and variable) and fuel prices
- Expected technological advances considered (e.g. increase in turbine size, decrease of costs for solar, wind and storage)



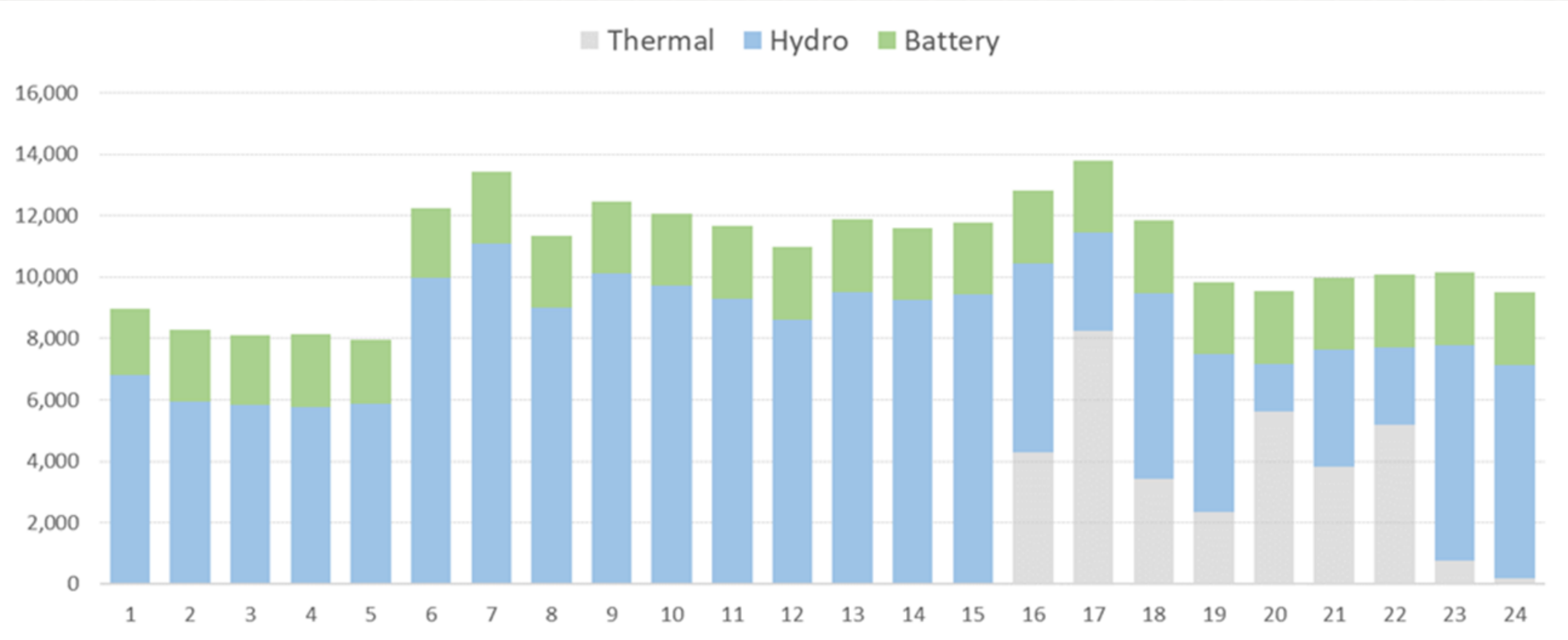
Brazil IRP case: generation expansion plan



Brazil IRP case: dynamic probabilistic reserves (GW, % Renewable installed capacity)

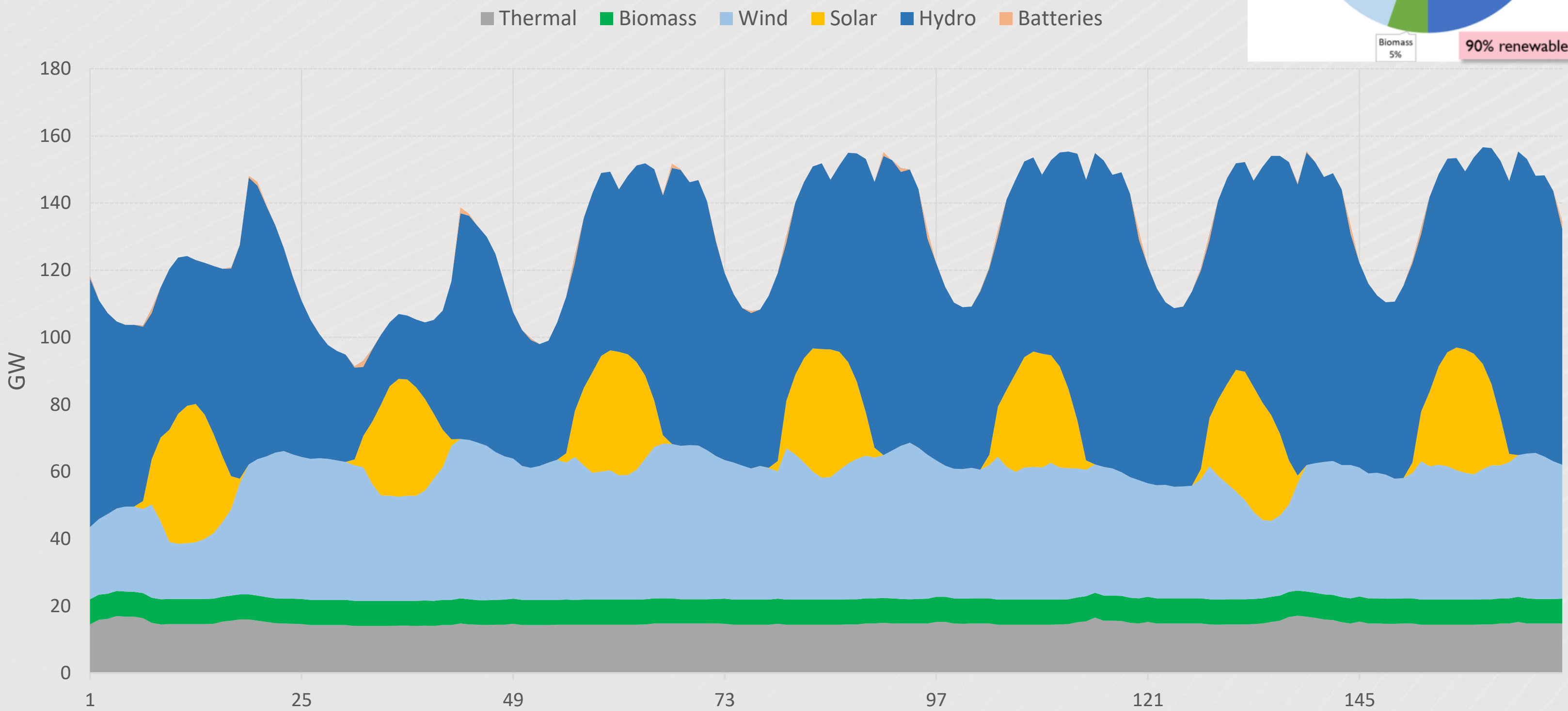


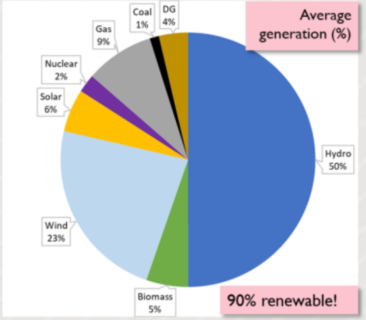
Brazil IRP case: allocated reserve – typical day



Brazil IRP case: Weekly operation at end-of-horizon (August)

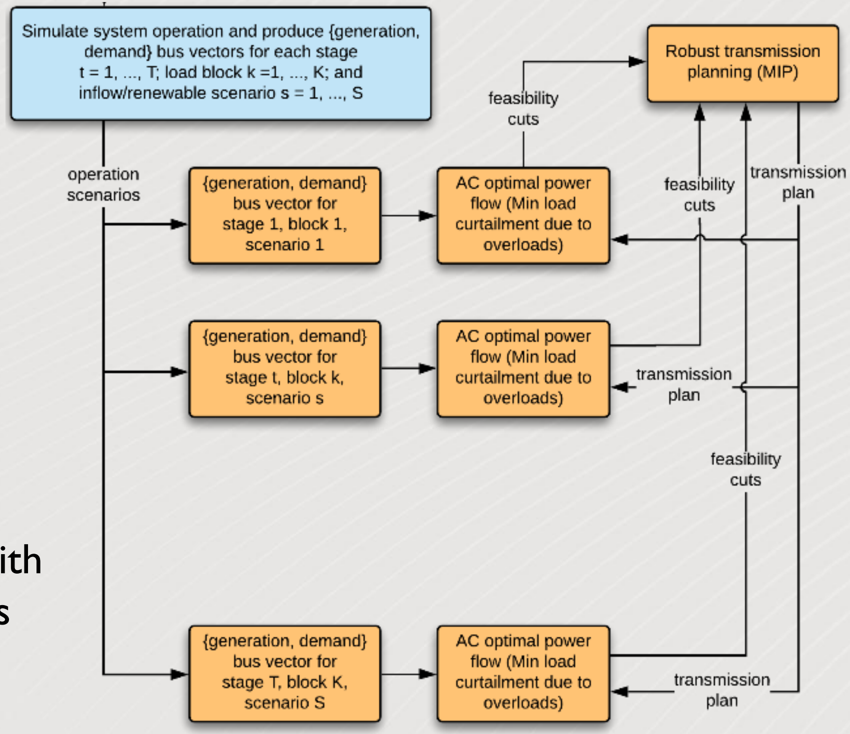
IRP Resulted in large penetration of wind and solar power



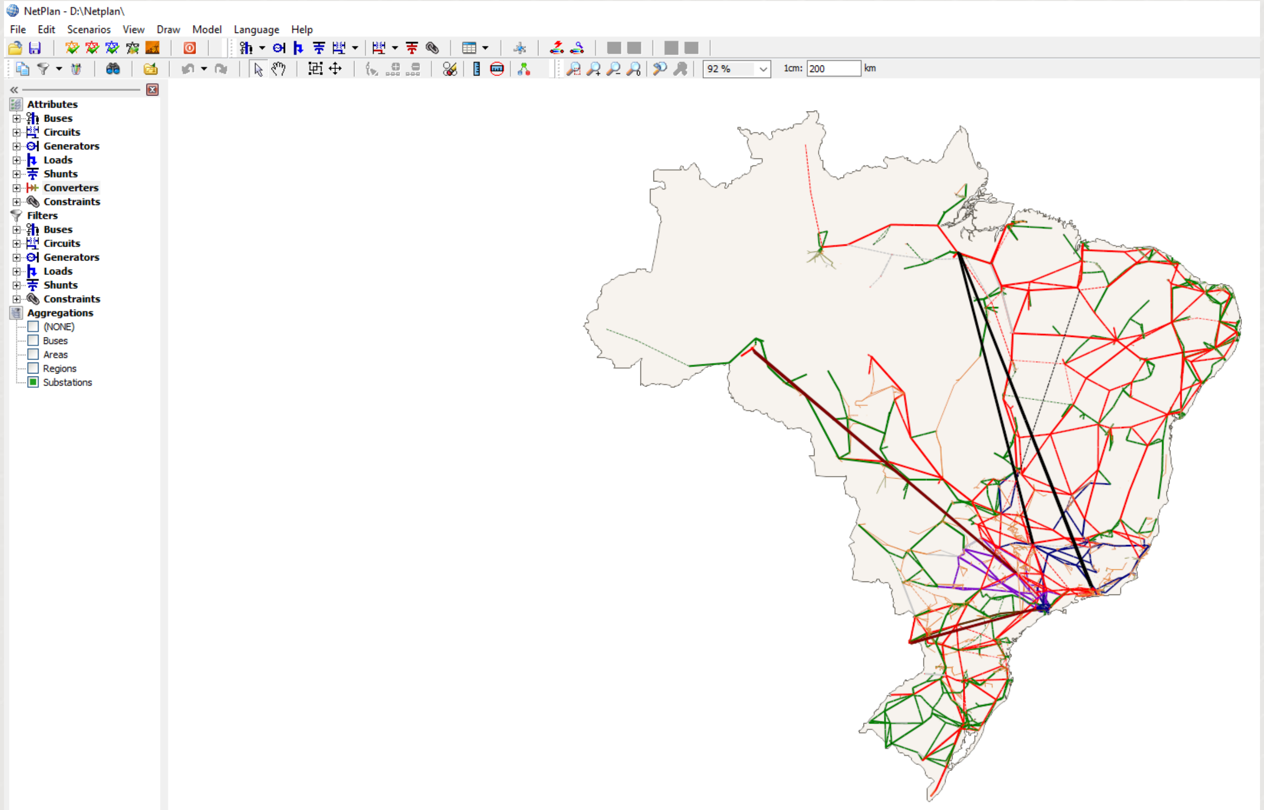


Activity C - Transmission planning under uncertainty

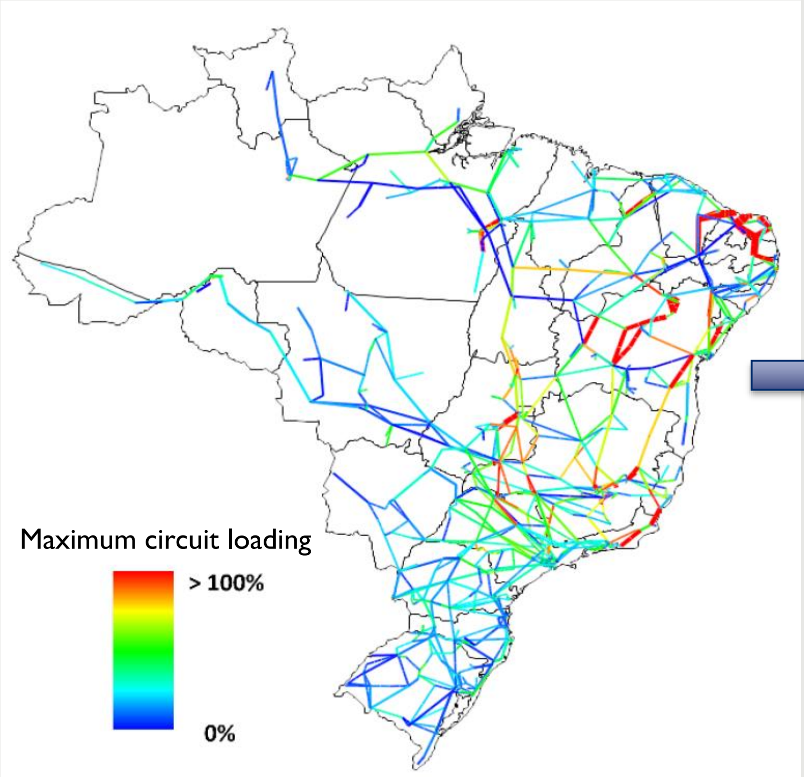
- Variability of hydro, wind and solar power leads to diverse power flow patterns in the grid.
- Renewable sources often built in places with no foreseeable power injections.
- Reinforcement of transmission grid to accommodate multiple generation patterns is required to avoid dispatch of more expensive generators to alleviate overloads or avoid load shedding.
- Robust transmission plan must be feasible (i.e. with no overloads) for each of the multiple conditions that result from the probabilistic operation from the expansion plan of Activity B

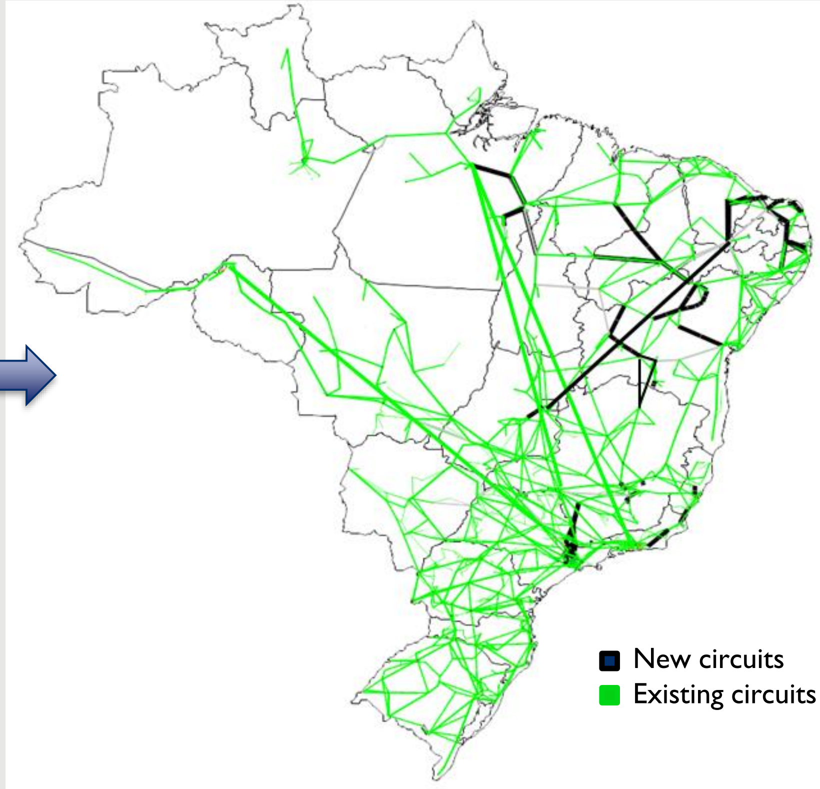


NETPLAN – Graphical Interface



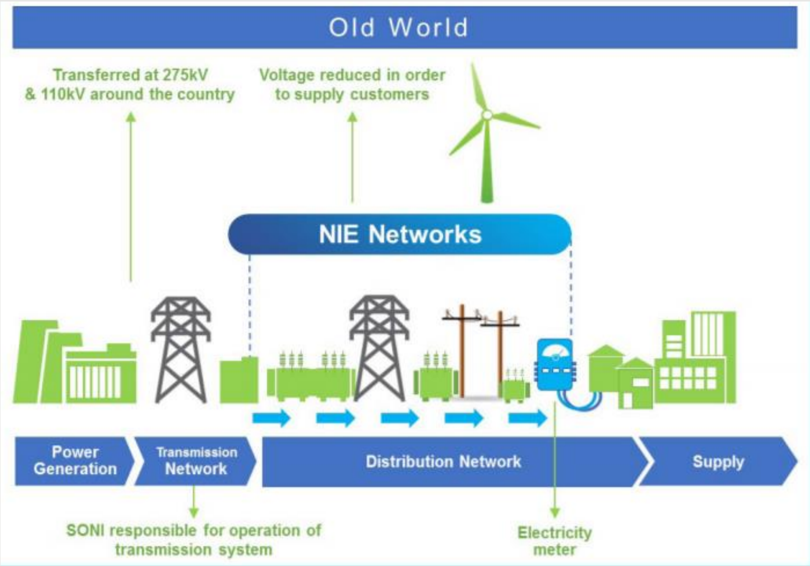
Brazil IRP case: Transmission reinforcements



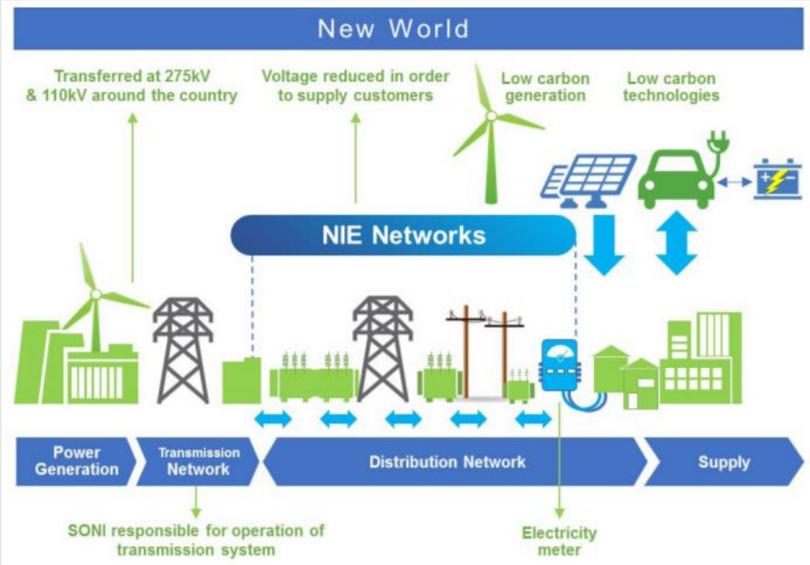


Distribution System of the future

One way flow

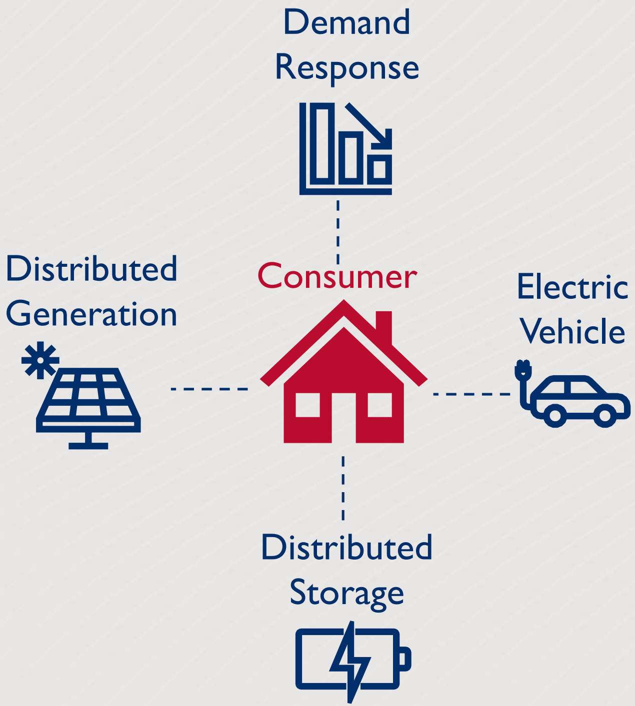


Two way flow



Source: NIE - 2018

Distribution System of the future



- How do the consumers behave?
- What are the impacts (services) of the Distributed Energy Resources?

Proposed methodology

Expansion planning with endogenous representation of DERs

- Hierarchical planning model composed of three levels (L)

L1 – Module corresponding to high voltage systems (Transmission)

It considers every element of the centralized grid, generation and basic grid (BG)

L2 – *n* modules corresponding to high voltage distribution (HVD) network

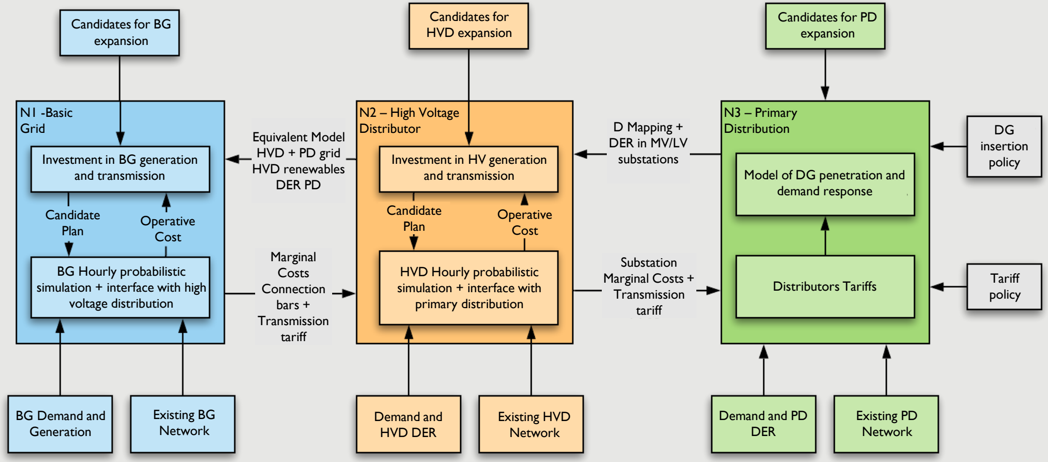
L3 – *n x m* modules of Primary-Secondary Distribution (PSD), corresponding to systems that originate from each distribution substation (MV/LV).

It is not computationally feasible to represent the three levels in a single optimization model

Hierarchical levels

Integrated and iterative process

Main components of the methodology



Models

DERs Optimization

- How the consumers behave given the economic signals

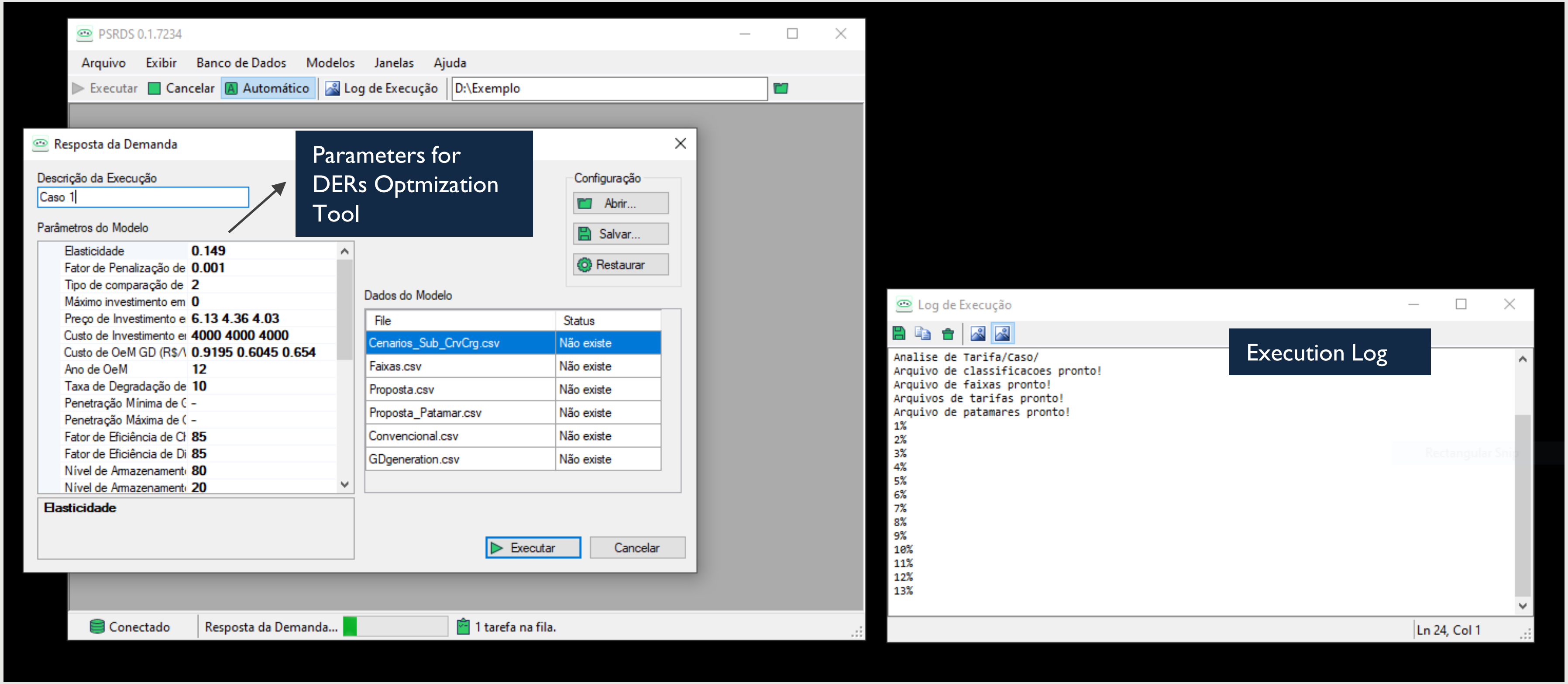
Optimal Power Flow (L2)

- How the DERs impact the high voltage distribution network

Power Flow (L3)

- How the DERs impact the medium-low voltage distribution network

Models



PSRDS 0.1.7234
Arquivo Exibir Banco de Dados Modelos Janelas Ajuda
Executar Cancelar Automático Log de Execução D:\Exemplo
Resposta da Demanda
Parameters for DERs Optmization Tool
Descrição da Execução
Caso 1
Parâmetros do Modelo
Elasticidade 0.149
Fator de Penalização de 0.001
Tipo de comparação de 2
Máximo investimento em 0
Preço de Investimento e 6.13 4.36 4.03
Custo de Investimento e 4000 4000 4000
Custo de OeM GD (R$/ 0.9195 0.6045 0.654
Ano de OeM 12
Taxa de Degradação de 10
Penetração Mínima de -
Penetração Máxima de -
Fator de Eficiência de C 85
Fator de Eficiência de Di 85
Nível de Armazenament 80
Nível de Armazenament 20
Elasticidade
Configuração
Abrir...
Salvar...
Restaurar
Dados do Modelo
File Status
Cenarios_Sub_CrvCrg.csv Não existe
Faixas.csv Não existe
Proposta.csv Não existe
Proposta_Patamar.csv Não existe
Convencional.csv Não existe
GDgeneration.csv Não existe
Executar Cancelar
Conectado Resposta da Demanda... 1 tarefa na fila.
Log de Execução
Execution Log
Analise de Tarifa/Caso/
Arquivo de classificacoes pronto!
Arquivo de faixas pronto!
Arquivos de tarifas pronto!
Arquivo de patamares pronto!
1%
2%
3%
4%
5%
6%
7%
8%
9%
10%
11%
12%
13%
Ln 24, Col 1

Study Case

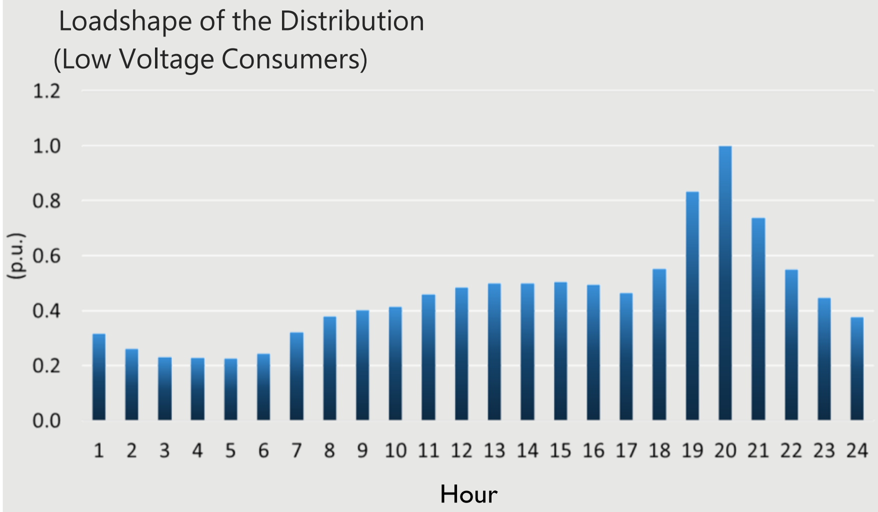
Brazilian Distribution Company

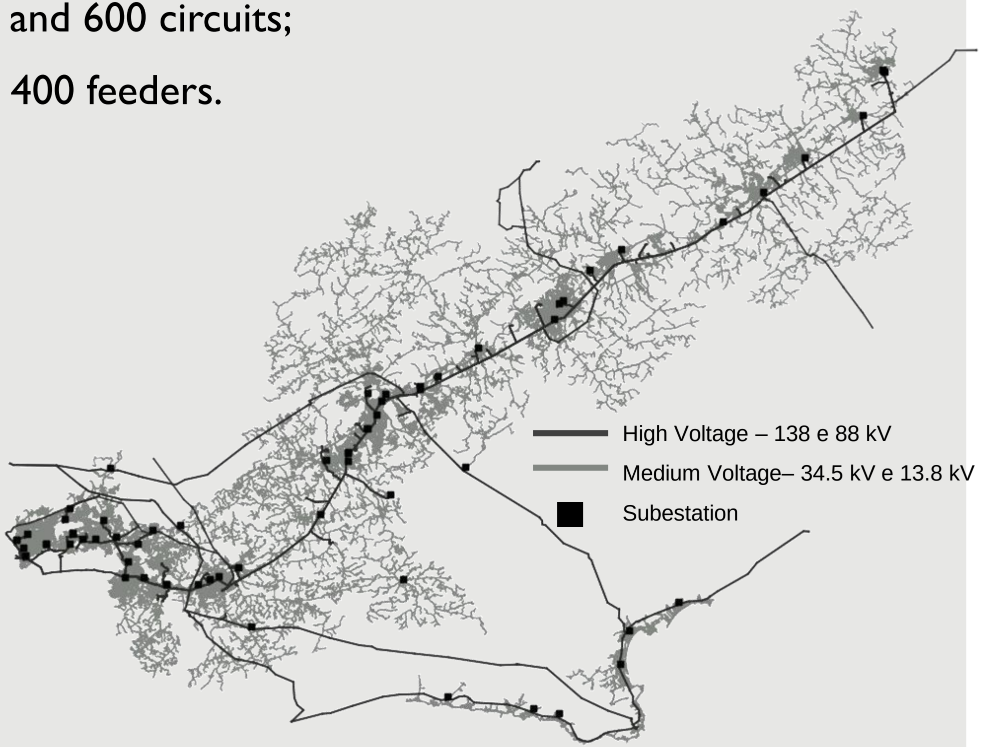
Binomial Tariff for Low Voltage Consumers

Impact of Solar Panels (PV) on the distribution network

Study Case

- > 1.5 million consumers connected to the Low Voltage (above 1 kV);
- High Voltage Distribution Network: 500 buses and 600 circuits;
- Medium-Low Voltage Distribution Network: ~ 400 feeders.





Study Case

DERs Optimization

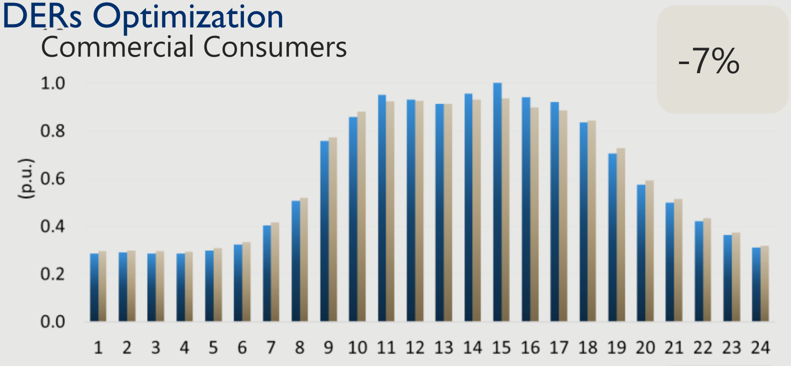
1. *Hourly load shape for every consumer*
2. *Tariff information*
3. *DERs Investment costs (Solar Panels and Batteries)*

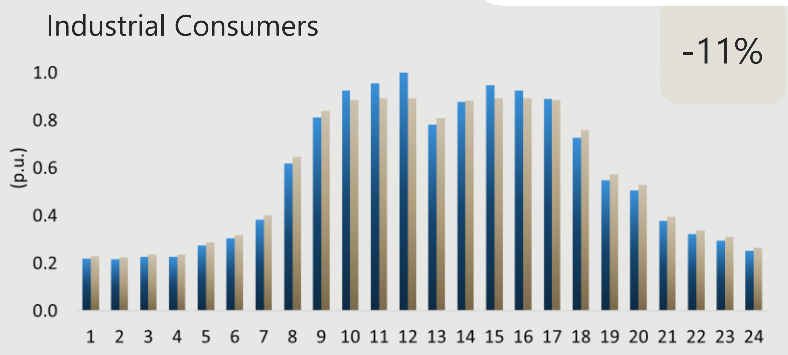
→ **DERs Optimization** →

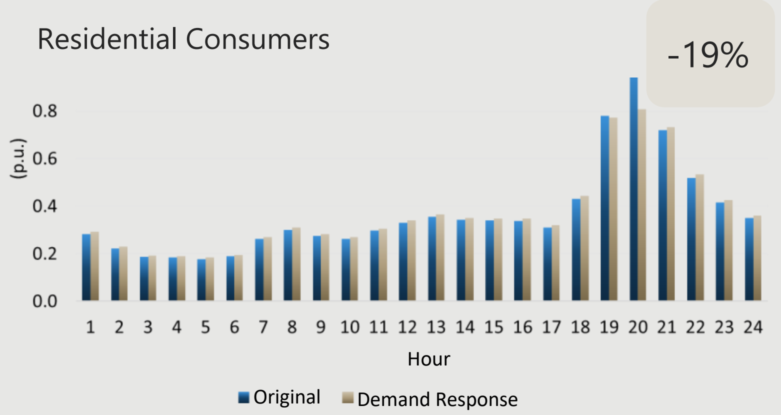
1. *New load shape of every consumer (Demand Response)*
2. *Investment in DERs*

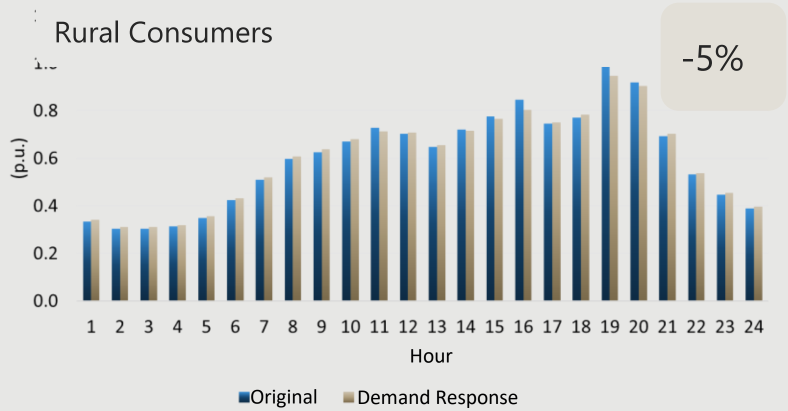
Study Case

DERs Optimization









Residencial Consumers have more “space” to shift their peak load to other hours

Study Case

Optimal Power Flow (L2)

1. *High Voltage Electrical Data*
2. *Marginal Cost at the connection point between Distribution and Transmission System*
3. *Consumers Response (load shape and DERs)*

Optimal Power Flow (L2)

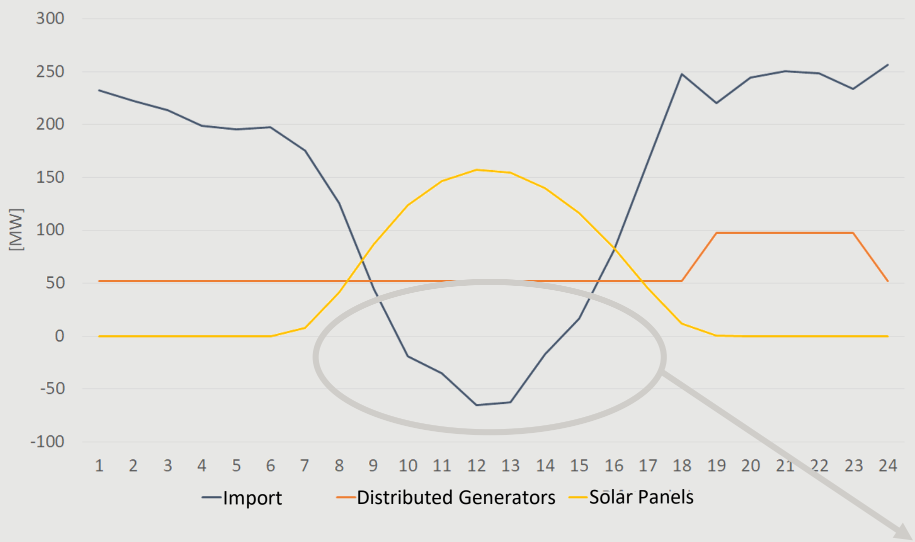
1. *Circuit Losses*
2. *Energy Import from Transmission System*
3. *Circuit Loading*

Study Case

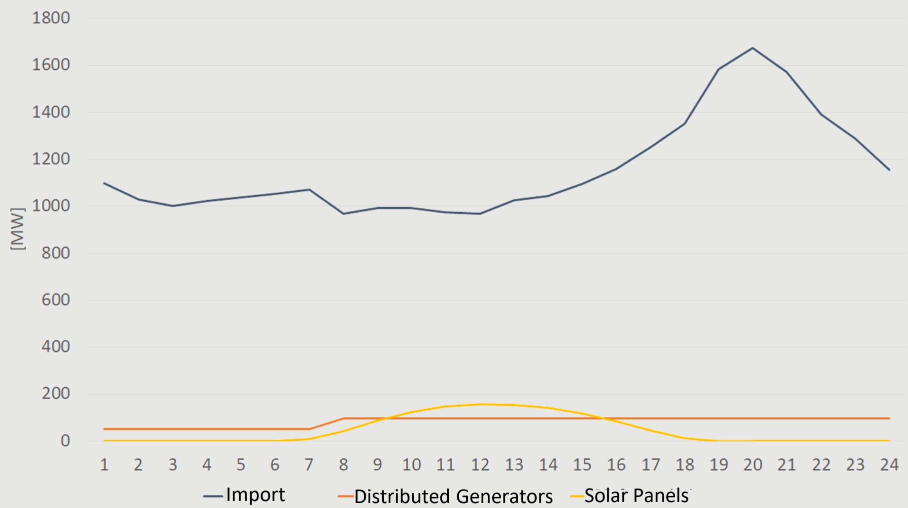
Optimal Power Flow (L2)

- Insertion of Solar Panels equal to 10% of consumption in the Low Voltage
- Solar Panels distributed among the consumers according to the attractive results from DERs Optimization

February - Sunday



February – Working Day



Exporting Energy to the Transmission System

Study Case

Power Flow (L3)

1. *Medium/Low Voltage Electrical Data*
2. *Consumers Response (load shape and DERs)*

→ **Power Flow (L3)** →

1. *Circuit Losses*
2. *Circuit Loading*
3. *Voltage Analysis*

The Power Flow studies carried out in this study were made using the software OpenDSS, publicly available by EPRI.

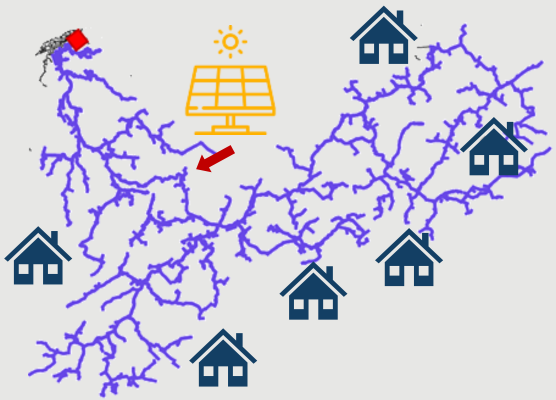
PSR software allows to automate these analyses and to compile the results

Study Case

Power Flow (L3)

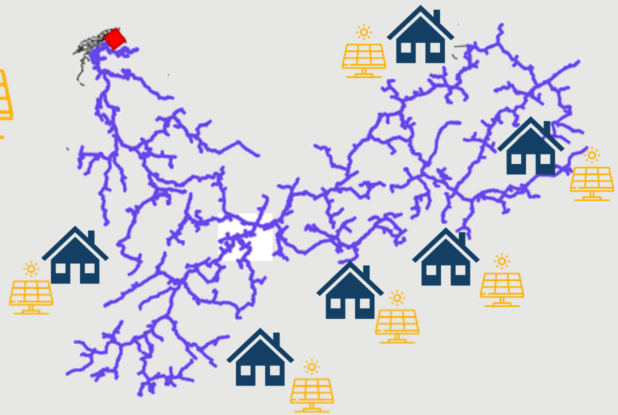
- Insertion of Solar Panels equal to 10% of consumption in the Low Voltage
- Solar Panels (PV) distributed in three different locational

PV at the beginning of the feeder



PV at the end of the feeder

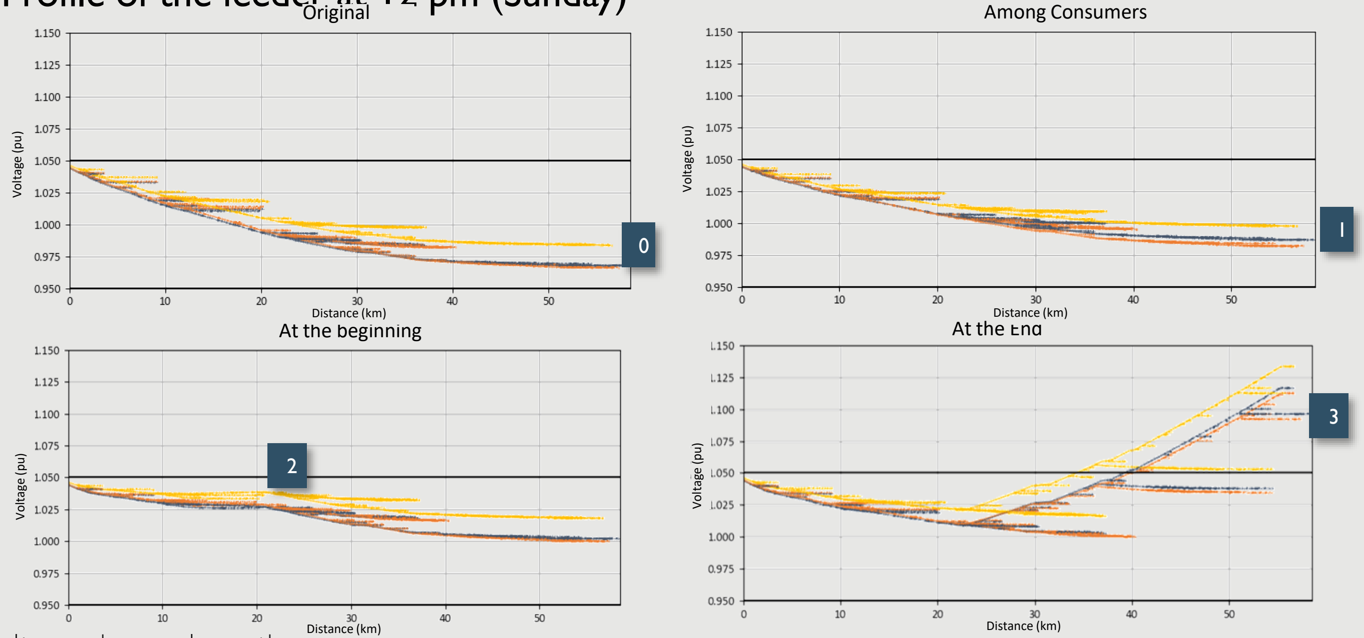
PV distributed among consumers



Study Case

Power Flow (L3)

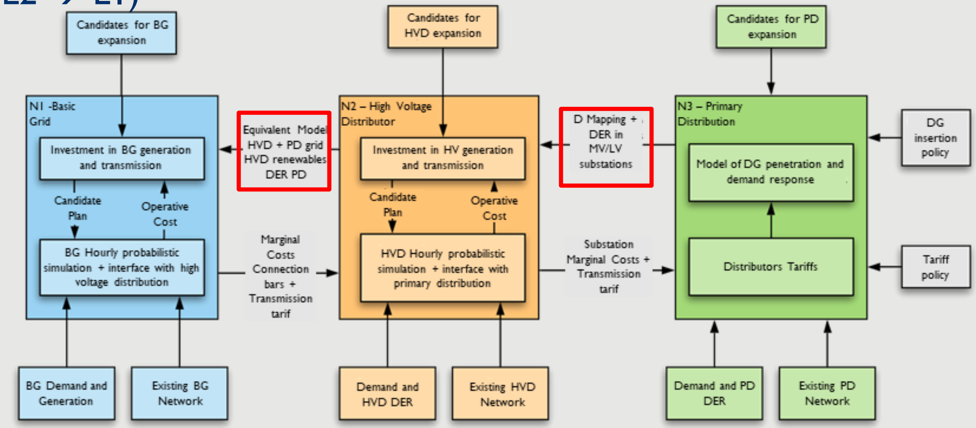
- Voltage Profile of the feeder at 12 pm (Sunday)



0	The voltage drops along the feeder
1	For PV among the consumers, there is an improvement in the voltage level along the feeder
2	For PV at the beginning, the voltage level increases where the PV is located
3	For PV at the end, the voltage level is greater than the limit (need for investments)

Next Steps

Feedback (L3 → L2 and L2 → L1)



Detail of 1st feedback

L3 – Primary distribution

- Output data -

Investment in solar generation, DR, batteries etc.

L2 – "HV" Distribution

- Input data -

New demand and generation injections mapped to the substations

L2 Expansion

- Output data -

New set of generations and reinforcements in L2

L1 – HV network

- Input data -

New network equivalent

L1 Expansion

USAID FROM THE AMERICAN PEOPLE

GOVERNMENT OF INDIA
MINISTRY OF NEW
AND RENEWABLE ENERGY

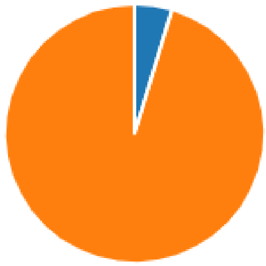
ANNEXURE 2: QUIZ

Module 1:

1. When the demand is higher than supply, the frequency will

More Details

Increase	2
Decrease	41
No impact	0



2. What are the characteristics of good resource plan?

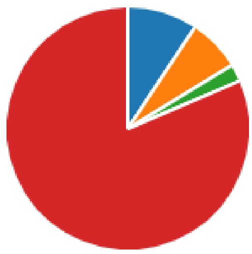
More Details

Reserve margin	14
Low cost	21
Low emission	1
Higher RE	7

3. What is the best way to minimize the system integration cost?

More Details

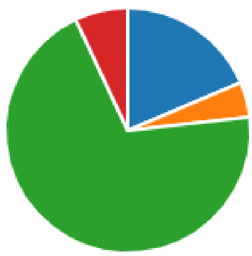
Suitable energy storage	4
Higher spinning reserve	3
Higher operation of governin...	1
Matching the profile of deman...	35



4. What is the most critical aspects of IRP?

More Details

Accurate prediction of demand	8
Accurate prediction of supply ...	2
Reliability and availability of d...	30
Use of high-end software	3



Module II:

Quiz 1:

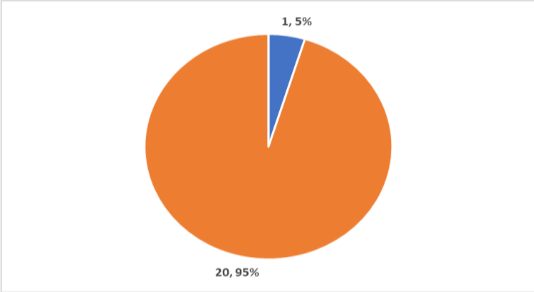
1. To Optimize the supply sources, the objective must be to:

    a. Minimize the operation cost of the existing and committed generating stations (1)

    b. Minimize the CAPEX of new generating stations

    c. Minimize start-up cost and fuel transportation cost

    d. All of the above (20)



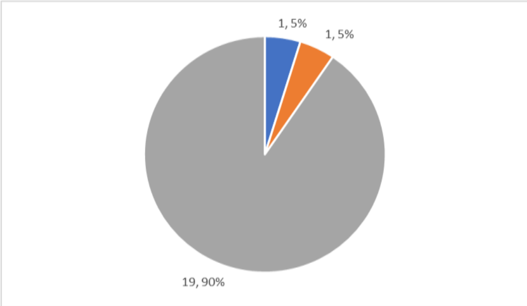
2. The reliability of the power system supply is measured through:

    a. Loss of Load Probability (LOLP) (1)

    b. Energy not Served (ENS) (1)

    c. Cost of Energy not Served

    d. All of the above (19)



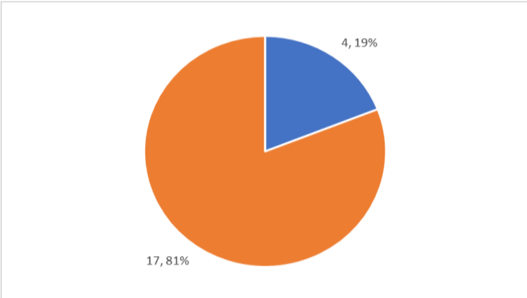
3. Sensitivity studies are done based on the following criteria/criteria's:

    a. Demand Variation (4)

    b. Reduction in VRE Generation

    c. Variation in Capital Cost

    d. All of the above (17)



Quiz 2:

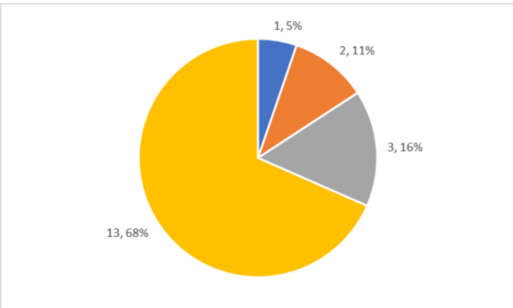
1. Which statement is not true regarding Variable Renewable Energy - VRE sources?

    a. They are more modular than conventional sources (1)

    b. They are non-synchronous forms of generation (2)

    c. They are uncertain (3)

    d. Their OPEX is higher than CAPEX (13)



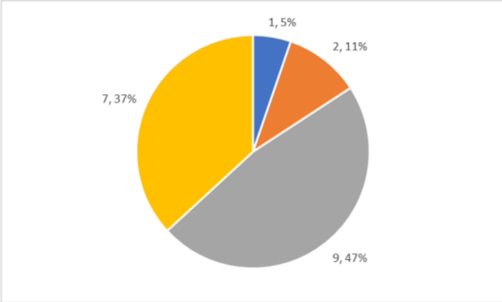
2. Which of these does not help in mitigating variability of wind and solar PV power?

a. Fast response sources of energy (1)

b. Secure energy storage (2)

c. Limiting demand response (9)

d. Strengthening the grid (7)



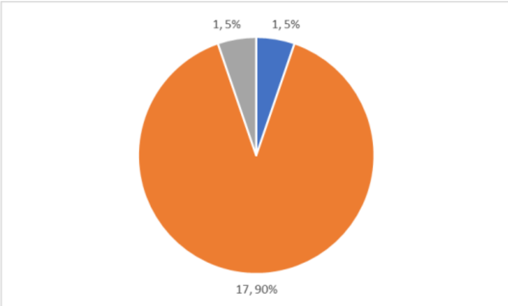
3. The incorporation of VRE uncertainties is important in planning models because

a. Solar PV and wind power have little variability (1)

b. Synergies between sources are small

c. Co-optimization of energy and reserves provides cost savings (17)

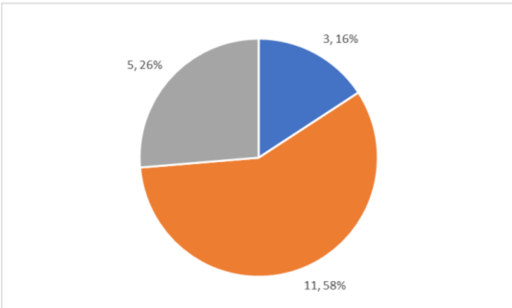
d. Solar power has large potential (1)



4. Regarding International experience what is not true?

a. In the USA utilities are authorized by regulators to procure new resources for the grid based on results of the Integrated Resource Planning activity (3)

b. Supply adequacy is a key concern in planning models



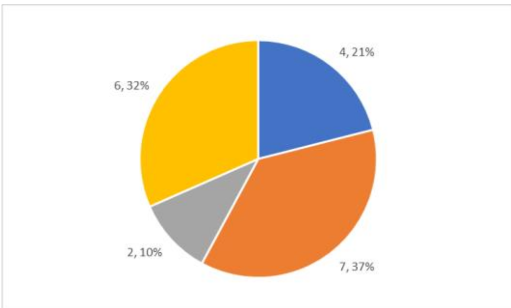
c. Demand forecasting is simplified with the increase of Variable Renewable Energy (11)

d. Variable renewable energy and distributed energy resources increase the complexity of forecasting demand to be supplied by dispatchable utility scale generation (5)

5. What is *not true* regarding distributed energy resources potential benefits?

a. Storage can avoid overload in investments on grid (4)

b. Electric Vehicles can postpone investments on grid depending on recharge (7)



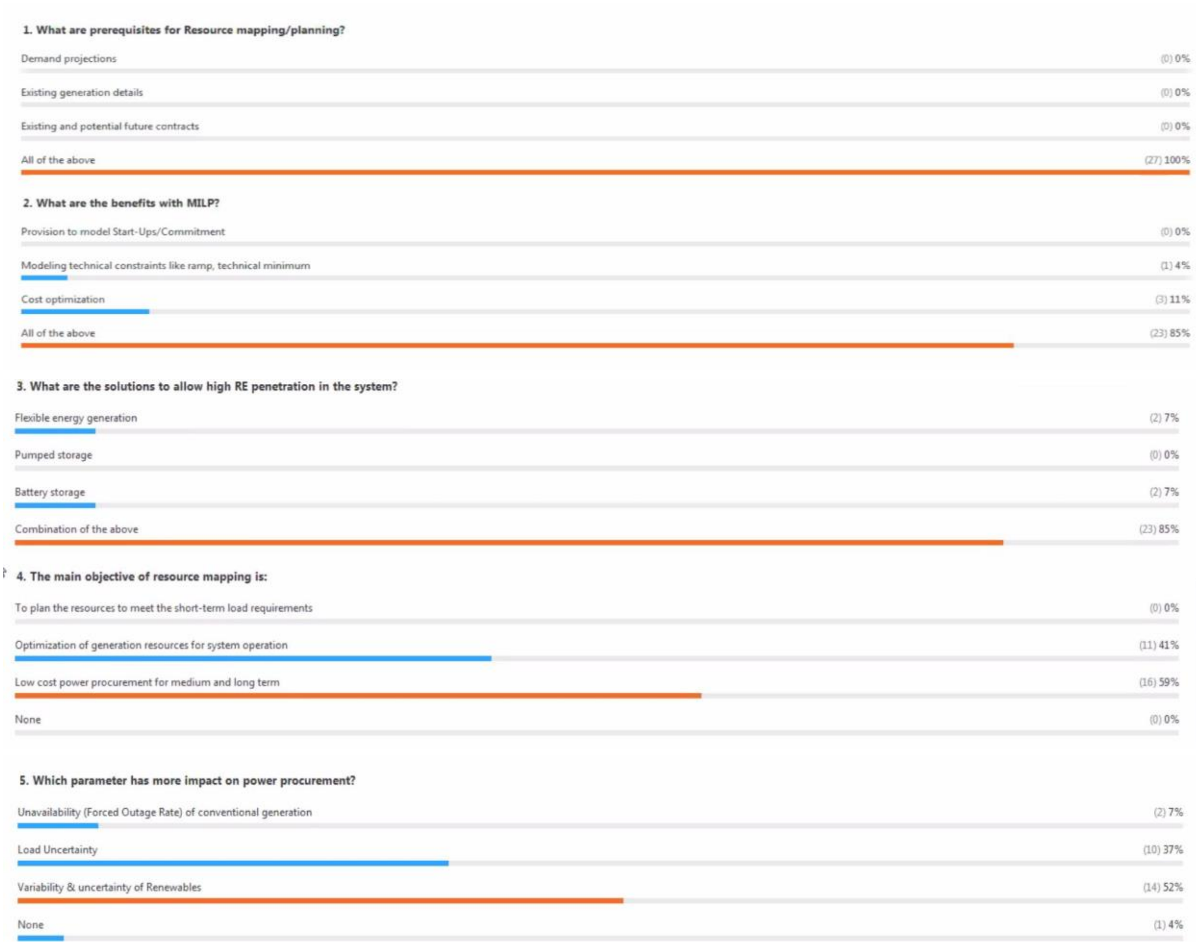
c. Demand Response decreases overloads in grid (2)

d. Distributed Generation provides flexibility, frequency control and reserves (6)

Module III:

1. Which is true regarding over estimation of demand?
    a. Load Shedding
    b. Increased Capital Expenditure (✓)
    c. Low tariff for consumers
    d. All of the Above
2. Which among the following is not an independent variable?
    a. Gross Domestic Product (GDP)
    b. Population
    c. Energy Sales (✓)
    d. Temperature
3. While computing the demand forecast through regression analysis, the best curve is selected based on:
    a. Lowest R^2 and Highest Standard Deviation
    b. Lowest R^2 and Lowest Standard Deviation
    c. Highest R^2 and Highest Standard Deviation
    d. Highest R^2 and Lowest Standard Deviation (✓)
4. Load Research helps to collect:
    a. Data at consumption level (✓)
    b. Energy Sales
    c. Weather data
    d. Econometric Data
5. Which among the following methods are more accurate to compute the medium-term forecasts:
    a. CAGR and Trend
    b. Trend and Econometric
    c. ARIMA and ANN (✓)
6. With renewable energy having higher share in planning, it is better to forecast demand at:
    a. Yearly level
    b. Monthly level
    c. Seasonal level
    d. Hourly level (✓)

Module IV:



Module V:

1. Why Resource Planning Regulation are needed
   a) Resource Planning has high financial impact on DISCOM (✓)
   b) DISCOM business is a regulated business (✓)
   c) To include more RE in power portfolio (✓)
   d) To support power system operation (✓)
2. The model regulations suggest regulatory review of resource plan every
   a) One year
   b) Two year (✓)
   c) Three year
   d) Five year
3. If demand is over estimated, it will result into
   a) More load shedding
   b) Unutilized generation (✓)
   c) Economic loss
   d) Unmet targets for electrifications

ANNEXURE 3: REFERENCE MATERIAL

The reference material developed under different modules is uploaded on the official website of the program. Click on the link below to access the material.

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