Portfolio Optimization for Generators & Discoms

Three-day Residential Course on
"Power Market and Impact of Renewables and Electric Vehicles"

IEX & IIT- Kanpur Initiative @ IITK Campus

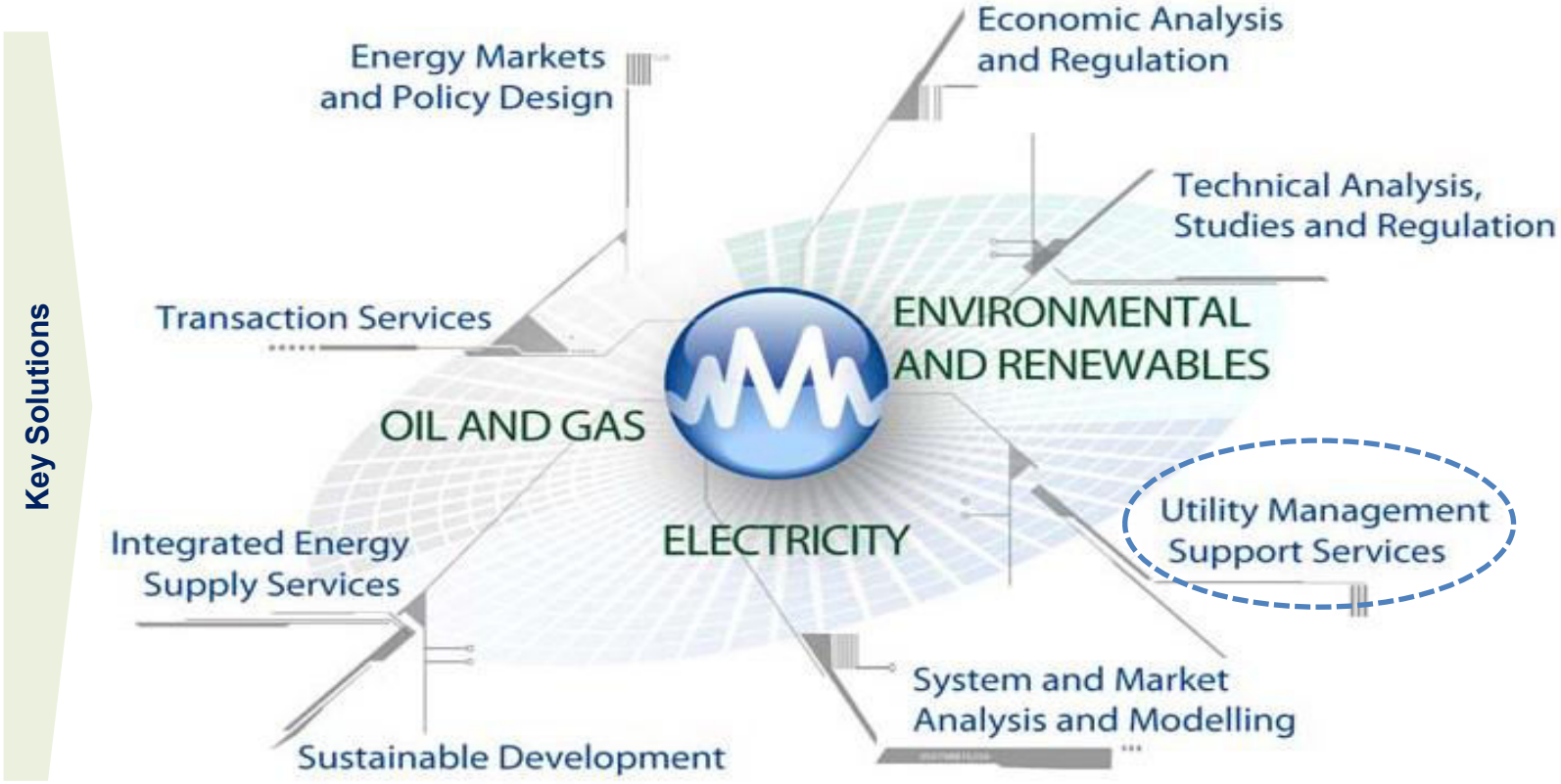
Draft for Discussion

02nd May 2018

Mercados EMI

Who We Are, What We Do

Mercados EMI is exclusively focused on business solutions in the energy and environment domain. Mercados EMI has been working in South Asia since 1999 and is in the forefront of development of analytical energy solutions in the South Asian Region.



Why Portfolio Management

- Nationally, electricity markets are undergoing extraordinarily rapid change in the last one decade
  - Market Participants need to develop ways to protect themselves from price fluctuations found in competitive markets.
  - Utilities need to protect themselves (without undue transfer of risk to consumers) from uncertainties in wholesale markets, transmission congestion costs, environmental compliance costs, credit risks, fuel price risk, and ancillary service costs
- Portfolio Management is a way to deal with the evolving developments, uncertainties, and volatilities in the electricity industry
- Discoms must choose between buying power or building generators and must determine the appropriate amount and types of generation assets for its needs.

"*Everything has changed, and change shows no sign of abating*"

  - New or improved generation technologies dominate markets – markets that did not exist ten years ago.
  - Bilateral power contracts continue to be important, but against a backdrop of shifting standards for rate-making and transmission access.
  - Discoms are often required to obtain new and different power products and a wide range of ancillary services.
  - New power products are traded in new markets, derivatives markets.
  - Transactions with traders and brokers, rather than traditional utilities or independent power producers, are commonplace.

In sum, the same old job still needs doing, but in a different technical, financial and regulatory environment, even for utilities operating under traditional regulation.

Key Elements of Portfolio Management

Load Forecasts

- Load Forecasts that best define future consumer demand needs to be defined
- Load forecasts varying from Intra-day to few years ahead/long-term play central role in Portfolio Planning & Management, each with its own significance based on horizon and specific market windows

Supply Assessment

Next step involves assessing the wide variety of generation-related opportunities, like:

- Building power plants;
- Purchasing from the wholesale Spot market;
- Purchasing Short-Term, Medium-Term and Long-Term Forward/Bilateral contracts;
- Purchasing Derivatives to hedge against risk (not available in India*);
- Developing Distributed Generation options;
- Building or purchasing Renewable resources; and
- Expanding Transmission and Distribution facilities

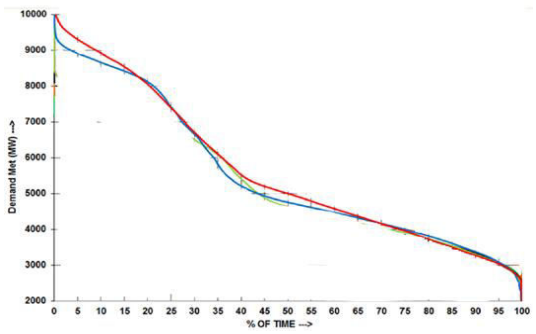
Develop Optimal Mix

- Most challenging step in portfolio management is to develop the optimal mix of these resources that will best achieve various objectives (like least cost, reliability, etc) identified by the utility
- Two prominent methods are used globally in Electricity Markets:
  - ✓ Lagrangian Relaxation (LR) based Optimisation Tools
  - ✓ Mixed Integer Linear Programming (MILP) based Optimisation Tools
- MILP based optimisation engines are widely adopted across developed, owing to their modelling capabilities and better solvers in practical implementation

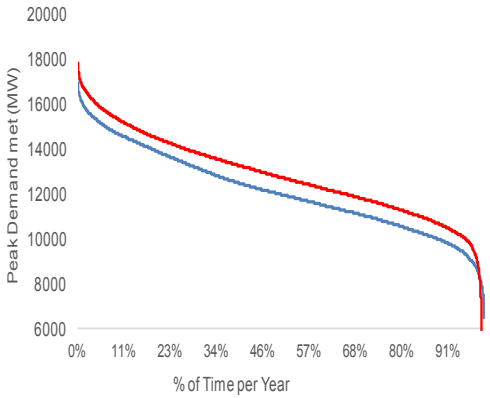
1. Load Forecasts

- Load forecasts play an essential role in electricity portfolio management, as they provide the foundation for making decisions about the need for generation, transmission, and distribution facilities.
- Load forecasts also play a critical role in assessing the potential for energy efficiency resources, because they can reveal the amount and type of electric end uses and their associated efficiency opportunities
- It is important for utilities to forecast both types of demand (Energy-MWh & Peak-MW), because the size of energy and peak demands will have different implications for the types of supply-side and demand-side resources that could be used to meet that demand
- Load Duration Curves (LDC) help in assessing the type supply resources required and consequent planning

Punjab



Uttar Pradesh



Gujarat

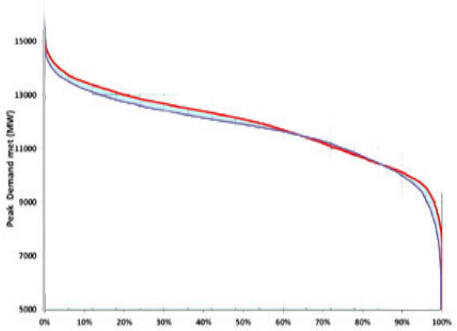


Fig: Load Duration Curves of Select States

Load Forecasts

Load Forecasting Methods:

i. Econometric Forecasting models

- Widely adopted in the electric industry, as the first approach to solve Load Forecasting problem.
- Econometric models correlate electricity demand with relevant economic, demographic and climactic indicators, such as:
  - Electricity prices
  - Population growth,
  - Gross Domestic Product,
  - Temperature/Other Weather Parameters
  - New Electrification
  - Sale of white Goods,
  - Urbanisation
  - Industrialisation, etc
- Econometric models suffer from a lack of detail and an inability to address changes in end-use technologies or changes in the relationships between electricity demand and the factors with which it is assumed to be correlated

ii. End-use Forecasting models

- Help address some of the limitations of econometric forecasting models.
- End-use models use a “bottom- up” approach, which analyzes each contribution to electricity demand, such as lighting measures, appliances, space-heating equipment, refrigeration equipment, motors, etc.
- The model forecasts the number and type of all the end-uses in a Discom’s license area, and multiplies those by estimates of electricity consumed per end-use, to derive the total load forecast.
- The advantage of end- use forecasting is that it allows the user to analyze changes in electric end- use technologies and customer usage patterns, which is necessary for a comprehensive assessment of energy efficiency and load control resources and for integrating the forecasting effort with the demand-side management planning.
- The disadvantage of this approach is that simpler versions do not capture the effect of economic and demographic changes that are likely to affect electricity demand. This limitation can be addressed by using forecasting models that combine both econometric and end- use techniques.

Load Forecasting Methods

Historical Demand Data

- Unrestricted Demand
- Consumer Category-wise load
- Demand Zone wise load

Weather Data

- Temperature
- Humidity
- Rainfall

Time Factors

- Time of the Day
- Day of the Week
- Time of the Year

Special Events

- Festivals
- Public Holidays

Short-term Load Forecasting Model

Univariate Models

- Time series models- ARFIMA, ARIMA-GARCH, SARIMA
- Machine Learning Models – Support Vector Machines

Multivariate Models

- Time Series Models- SARIMAX-GARCH
- Machine Learning Models – AI based model

Combination Model

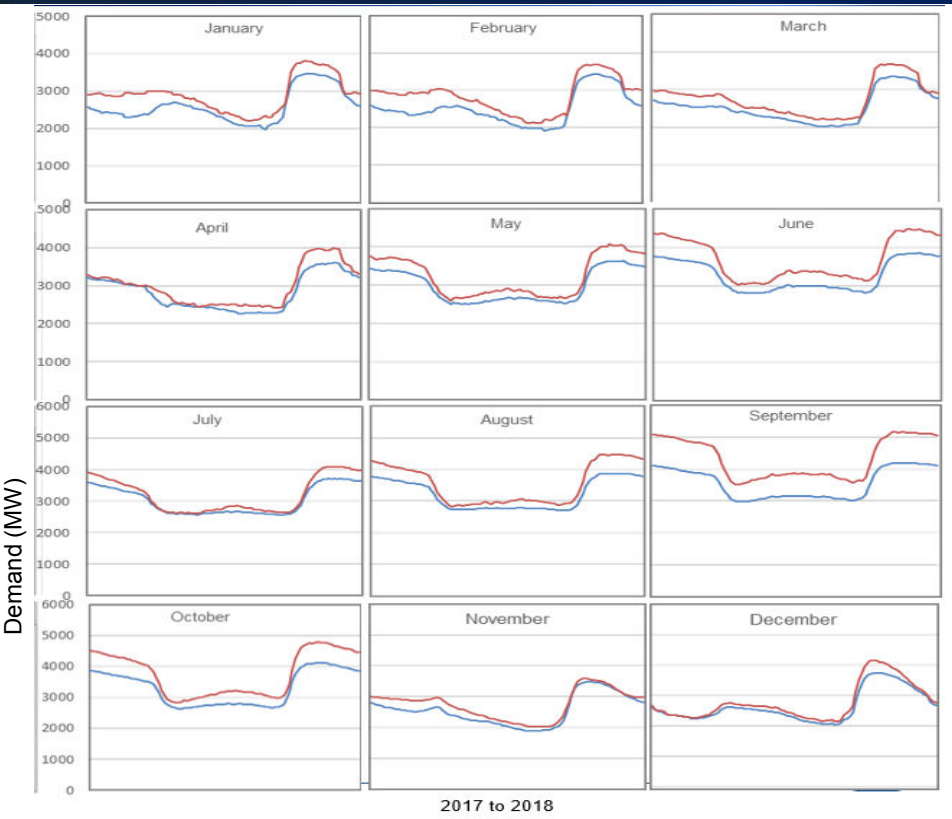
- Model Confidence Sets (MCS)

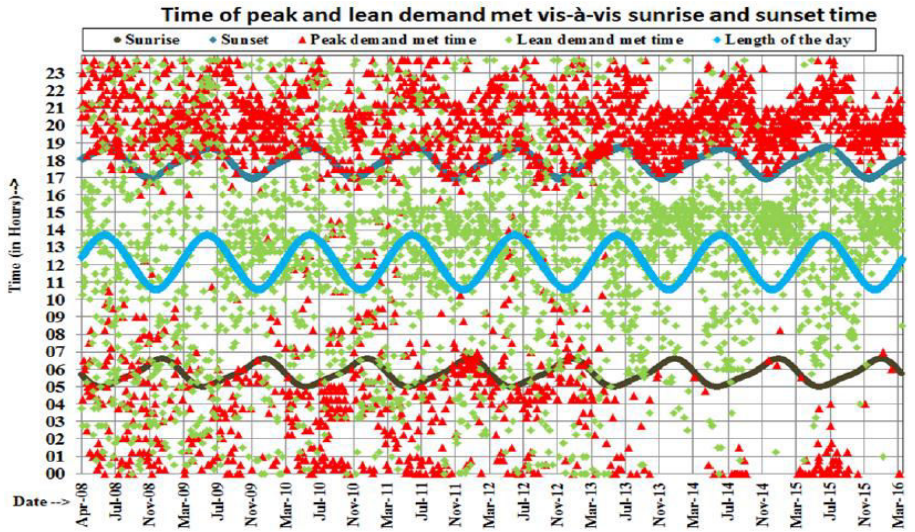
Block-wise Day-ahead Load Forecast

Block-wise Week-ahead Load Forecast

- Uncertainties involved in forecasting future electricity demands: Electricity prices, macro-economic effects, evolution of changing technologies and the rates at which they penetrate the relevant markets, weather, the costs of competing fuels such as natural gas, and other factors can have a substantial effect on customer electricity usage.
- To address the uncertainties utilities should conduct sensitivity analyses, where alternative assumptions are made regarding these key factors, to indicate how the load forecast might change under a different future. Monte Carlo simulations varying multiple factors simultaneously, may be warranted

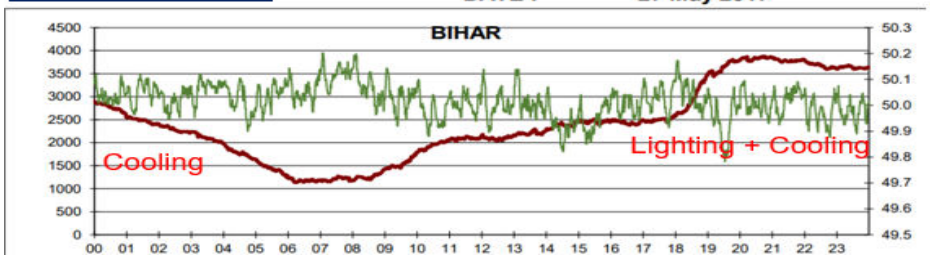
Demand Pattern & Growth
Bihar Case (High Domestic Load)



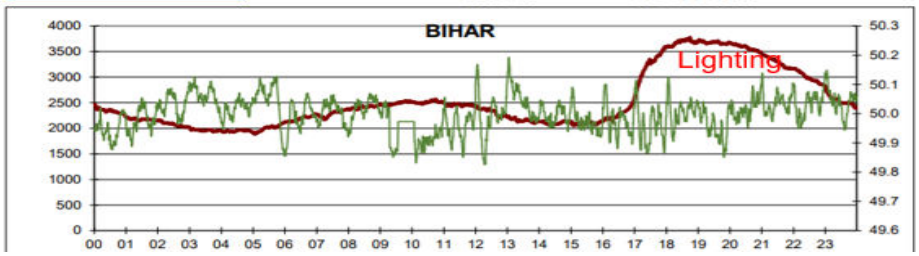


- High incidence of Residential Load in the total demand (over 55%)
- Commercial load is minimal, which results in off-peak during the day hours
- Highly weather demand in short-term, electrification rate defining peaks
- Not suitable for Solar Resource addition

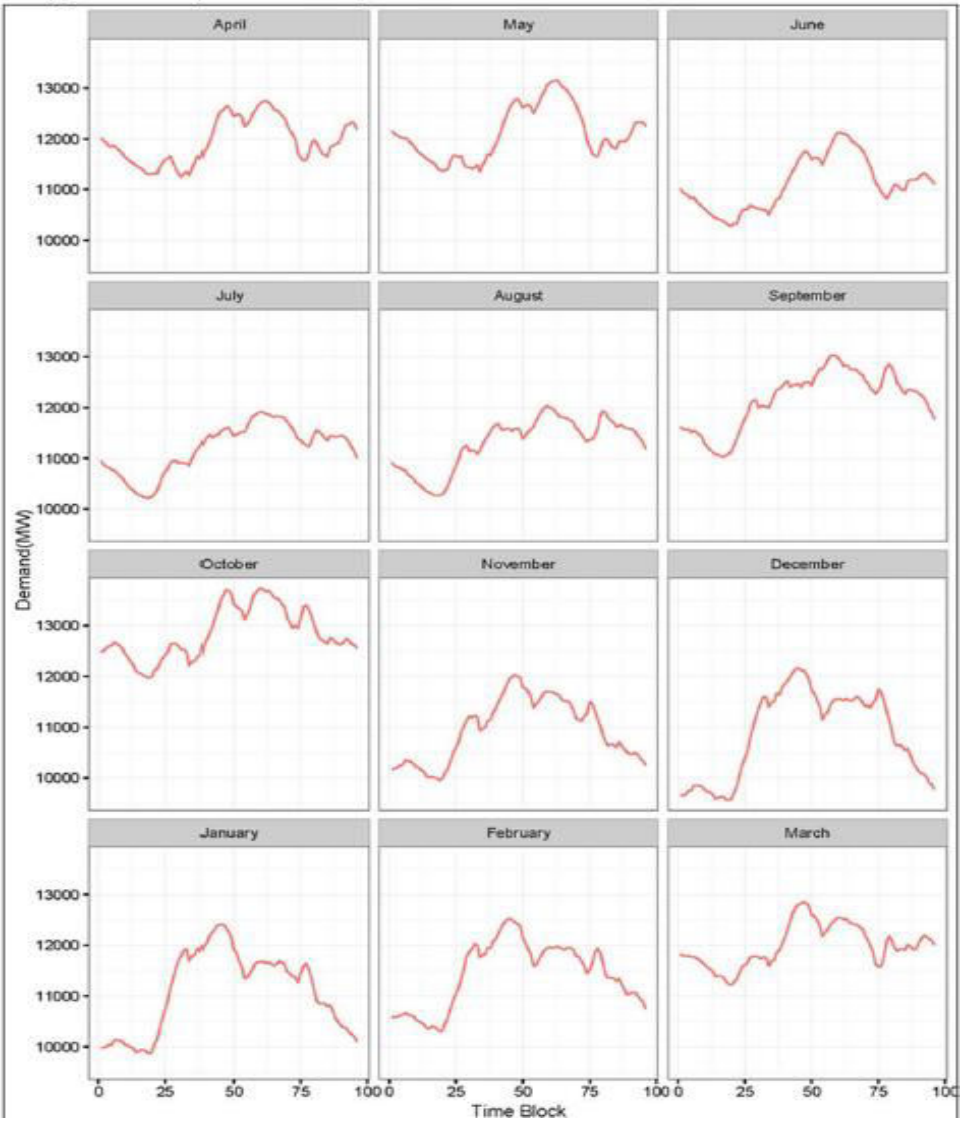
Summer Demand

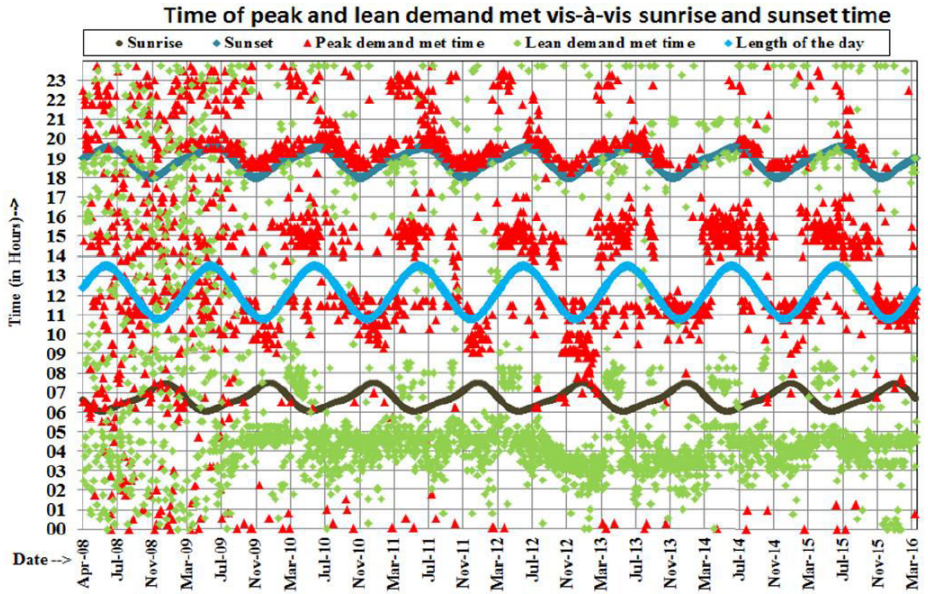


Winter Demand



Demand Pattern & Growth
Gujarat Case (High Commercial & Industrial Load)





- High incidence of Commercial & Industrial Load in the total demand
- Through the years, Commercial Load as taken over Residential in influencing peak demand
- Comparatively less volatile demand profile
- Suitable for Solar capacity addition

2. Supply Assessment & Planning
PM Considerations on supply side

- Sound application of Portfolio Management should lead to diversification of electricity resources, suppliers, and contract types and terms
- It is needed to identify the portfolio management tools most suitable for use under various regulatory regimes and to adapt them to the needs of utilities, default service providers and their customers
- A basic tenet of financial management is the idea that a diverse portfolio is less risky than any single investment
- Reliability benefits should be a factor in valuing portfolio alternatives

Diversification among Smaller Resources	• Diversification can take the form of varied fuels, technologies and a mix of generation, transmission and demand-side resources
Diversification among Technology and Fuel Types	Different types of fuels are subject to different supply risks. • **Coal** is a domestic and abundant fuel, but it has in the past been subject to regional disruption in labour disputes, transportation issues, etc • **Natural gas** is both inherently volatile in price and dependent on a small number of pipelines for delivery, the failure of which can cause supply shortfalls and additional price volatility • A system that relies on **stored fuel supplies** (either storage of fossil fuel near the unit, or stockpile of coal or biomass) or have **short transportation routes** are less subject to fuel disruption. This variation can be properly valued with portfolio management techniques • Certain types of technologies can be subject to industry-wide reliability issues, like **Nuclear** Power Plants • **Solar PV**, which might have not more than 35% capacity factor, but is most available on hot sunny days when loads are highest in most regions, providing significant hedging against peak price fluctuations

Supply Assessment & Planning
PM Considerations on supply side

- variables, such as remaining useful life, licensing risks, vulnerability of fuel delivery and electric transmission routes, maintainability, availability and physical reliability are also important, but should be evaluated for each plant
- Each technology has its own profile of costs and risks. Plant types with high fixed costs or long lead times can become a burden if demand fails to materialize and may not be suitable for peaking requirements. Types with high variable costs can be vulnerable to fuel price fluctuations, but often fit well in moderate quantities as peaking resources

- not all types of fuels and technologies are equally able to enter the markets. Renewable technologies are often more capital intensive than fossil fuel technologies and also face information and capital access barriers that prevent them obtaining financing if their only potential for revenue comes from competing in spot markets or selling under short term contracts. PM can properly value the hedging benefits of such technologies and of energy efficiency, increasing the competitiveness and efficiency of wholesale power markets.

Procurement Options
Pros and Cons

- A well-managed commodity portfolio is usually a combination of many traditional procurement contracts, such as Long-Term, Medium-Term, Short-Term contracts, with optimal usage of Spot markets and Derivatives, if available, for Risk Management. Each of these contract types has its own pluses and minuses, but in combination they can greatly reduce risk.

Spot Market (DAM)	• Paying market price for the day, volume varied as per requirement • Spot market pricing can be quite volatile, but requires no commitments. • Spot market reliance protects against both *falling demand and falling prices*, but exposes the portfolio to risks from *rising demand or prices* • Congestion in transmission corridor may lead to price & volume risk
Forward Contracts Bilateral (ST/MT)	• Trade a specific amount of a commodity at a pre-agreed upon price at a given time or times • Forward/Bilateral contracts avoid exposure to spot market volatility, but accept the risk that market prices may fall, that the counter-party may default, and that demand may fall
Option Contracts (LT PPAs)	• Buyer prepays an Option Fee (Capacity Charge) in return for a commitment from the supplier to reserve a certain quantity of the capacity for the buyer at a pre-negotiated price called the Strike Price (Variable Charge). • Typically, the option is exercised only when the spot price (on the date of need) exceeds the strike price of the option, but in Indian context this is typically not exercised

- Buyers need to find the optimal trade-off between price and flexibility by an appropriate mix of low price, low flexibility , reasonable price but better flexibility, or unknown price and supply but no commitment (the spot market) . Varying durations as well as contract types can help.
- Financial derivatives are another kind of contract that can have definite advantages in risk management as part of a portfolio management

Risks and their Management as Portfolio Management

- Each technology and resource options has its own cost structure and economic drivers.
- Gas generation has moderate capital costs, but significant fuel costs driven by natural gas prices. Wind energy has high capital costs, but is insensitive to fuel prices. By combining them in appropriate proportions, we can get a mix with a lower, more stable cost than by relying on either alone
- Any individual investment or generation alternative has two main sources of risk:
  1. **Unique Risk**: Results from events that are specific to an individual investment or resource. For generation resources, unique risks include a failure at a specific plant and unexpected regulatory costs affecting a technology
  2. **Systematic Risk**: Risks due to macroeconomic factors that threaten all investments or power supplies equally. For generation assets, coal, oil and gas shortages or price spikes are examples; recessions or booms that change the demand-supply balance are also types of systematic or market risks.
- Portfolio Manager should diversify by relying on a variety of different power plants using different fuels and technologies, by using firm power contracts of varying durations and starting dates, and by acquiring a mix of supply and demand side resources.
- Well managed portfolio will draw from both demand and supply side resources, as well as a mix of short-term, medium-term, and long-term contracts to ensure price protection over time. In addition, if there is owned generation in the portfolio, risk protection will be further enhanced by applying the same portfolio management approaches to fuel acquisition, a technique long practiced in that part of the utility industry.

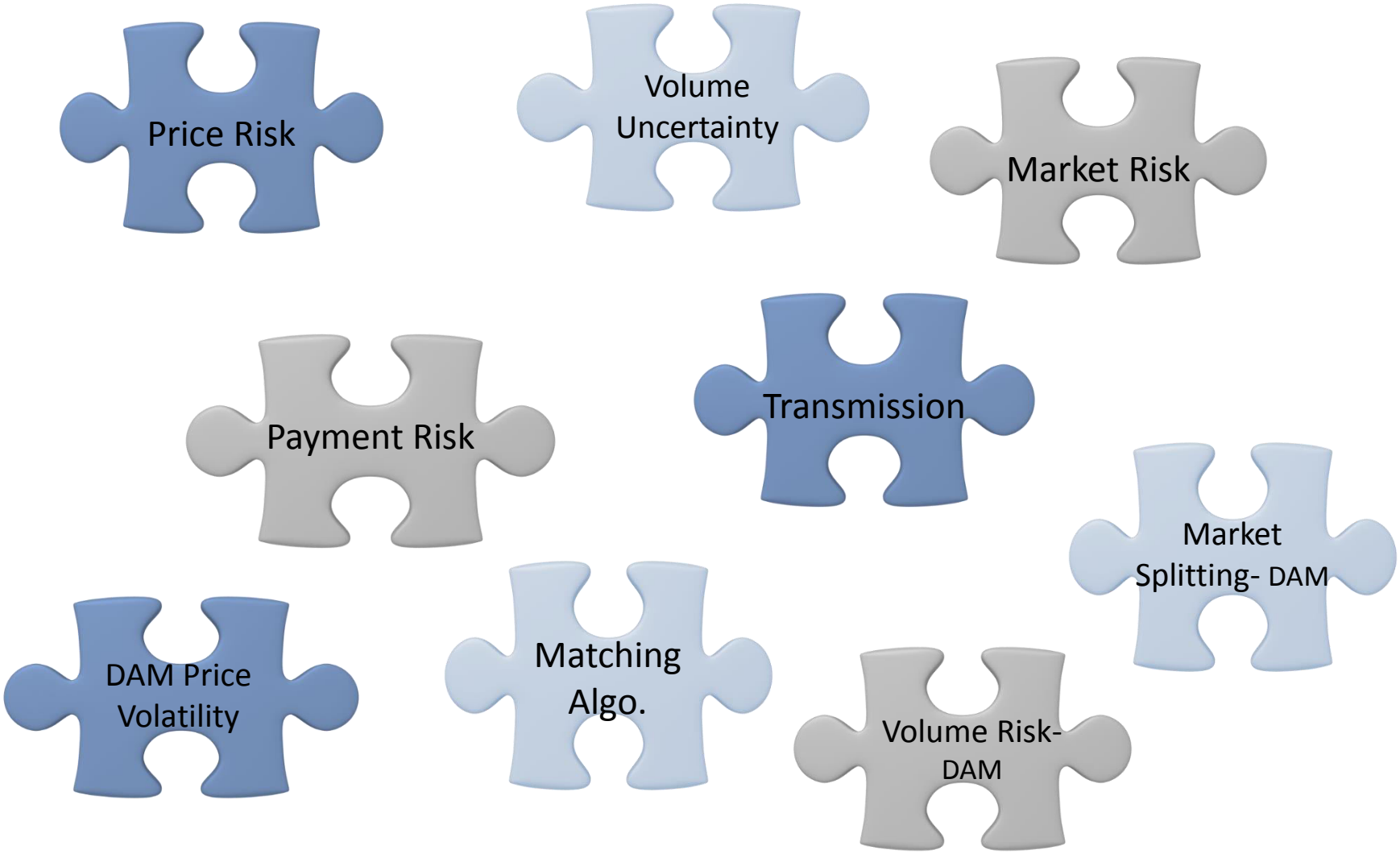
Risks with varying time frames

- Portfolio Manages includes participants to mix short- and long term wholesale power contracts to manage commodity supply and price risk
- Day-to-Day and Month-to-Month volatility of **spot market** prices for fuels and electricity and their impact on cash flows for Discoms/Gencos
- Challenges in addressing very **long term** risks like the viability of a new technology or the future of world oil/gas markets
- In the **medium term**, say three to five years, there are numerous risks affecting specific markets, generating facilities, state and regional economies, and the like
- Care needs to be exercised to not let the focus on risk management be a distraction from the need to minimize total cost of energy service to consumers and society

Key Design Aspects of the Indian Market

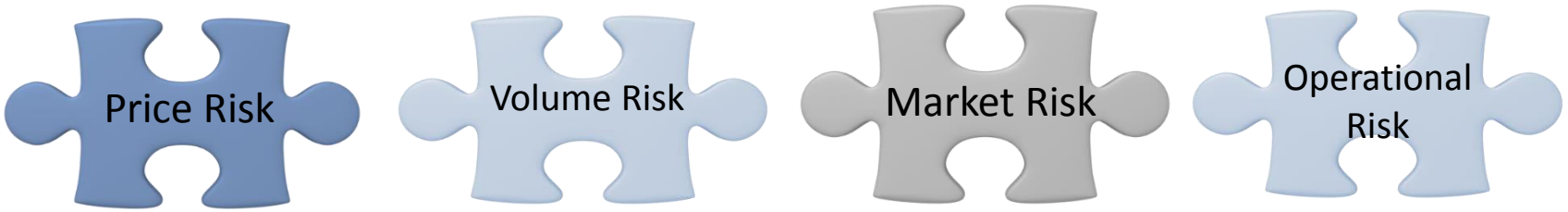
- **Long Term Market** is designed with two part energy pricing with Capacity + Energy (FC+VC)
- **Medium Term** and **Short Term Market** (10% share) comprises of a single energy price component of 'Energy Cost (VC)' only
- Discoms primarily meet their Base Load with Long Term PPAs, i.e. by paying FC & VC (two part)
- Peak Load is primarily served by Discoms in a:
  - Surplus Market either through Short Term Bilateral or Power Exchange's Collective Market (VC).
  - Deficit Market through LT PPA (FC & VC) for the amount of foreseeable Peak Requirements, and unforeseen requirements through Short Term Bilateral or PX's Collective market (VC)
- 'Energy Only' Short Term Market has competitive market segments with varying products and transmission allocation schemes, accounting for high uncertainty in pricing and associated opportunity costs

Risks Involved in Trading in Short Term Market

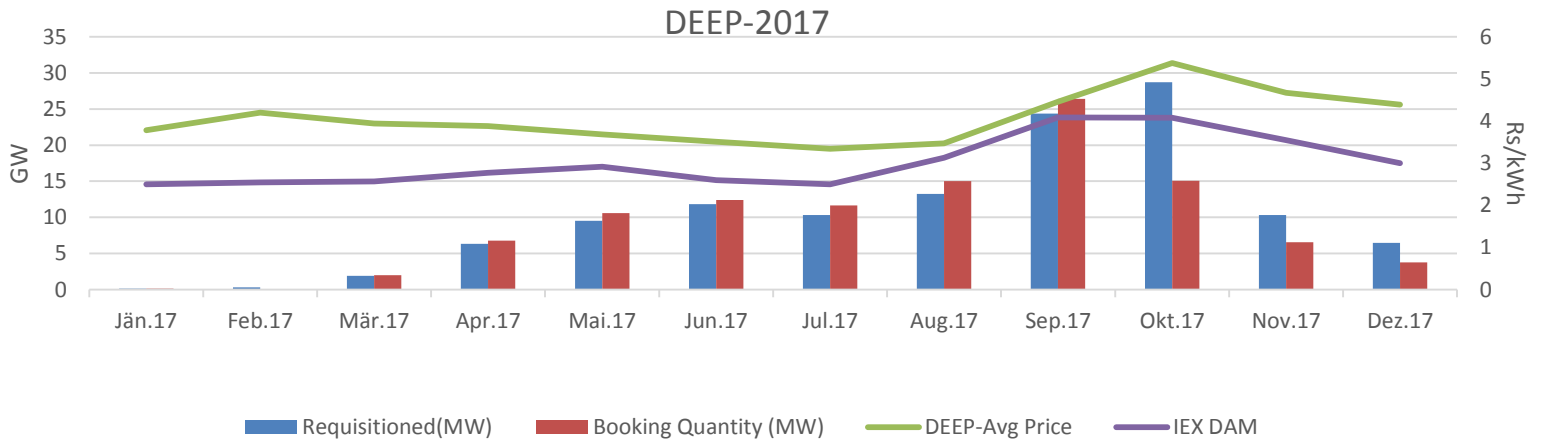


Issues in ST Bilateral Market

- Pricing of Electricity is not supply-demand based
- Intra-day pricing resolution is not present in bilateral contracts
- Liquidity in bilateral auctions is very low, and hence pricing inefficiency
- Uneven risk sharing between participants
- Opportunity cost in Bilateral Contracts w.r.t. prices on Spot DAM Market is not known to buyers and sellers
- With transactions taking place many days ahead of delivery, uncertainty on availability and demand persist



DEEP Vs IEX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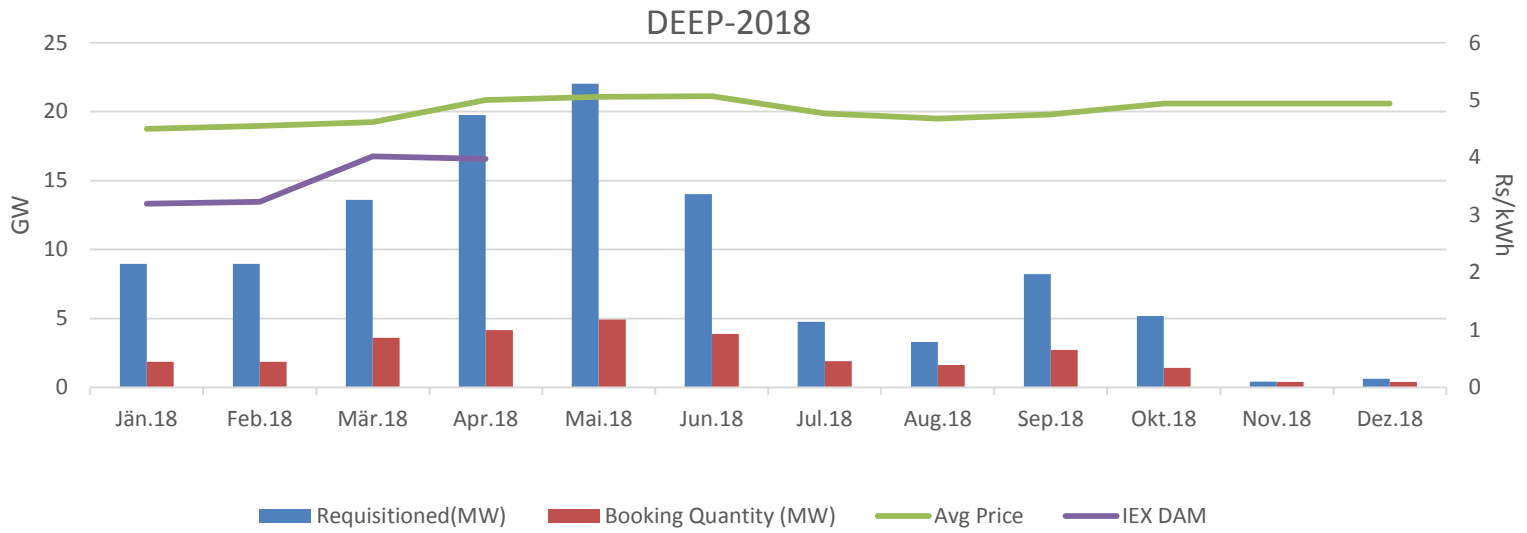
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Requisitioned(MW)
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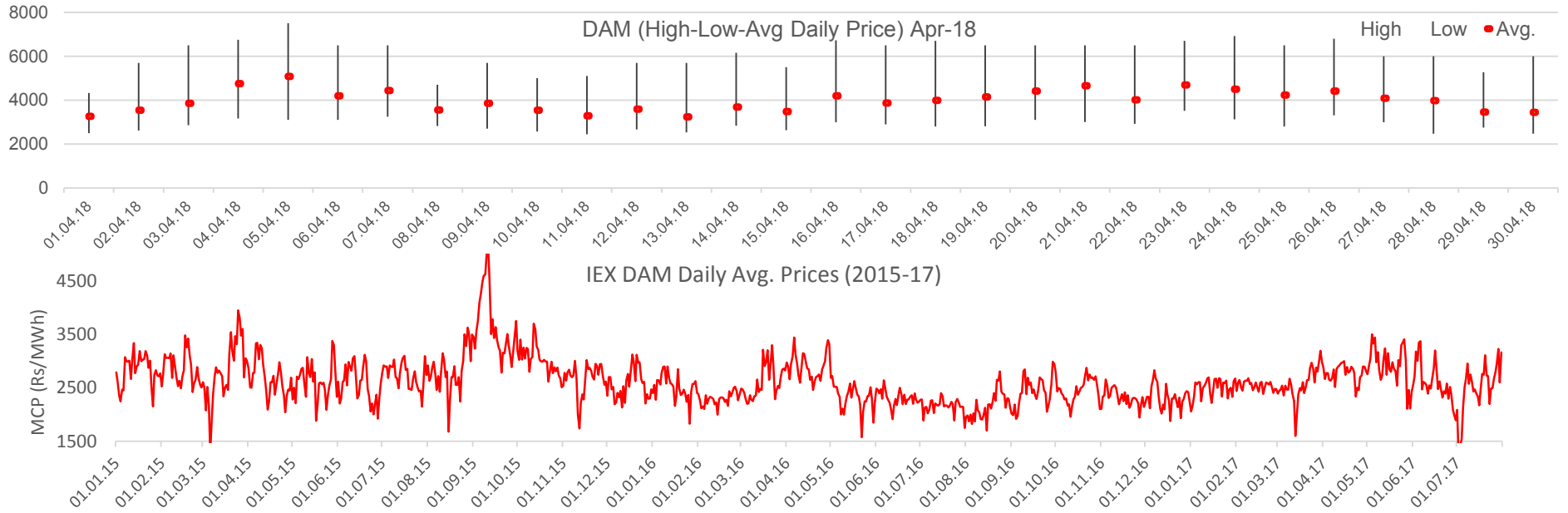
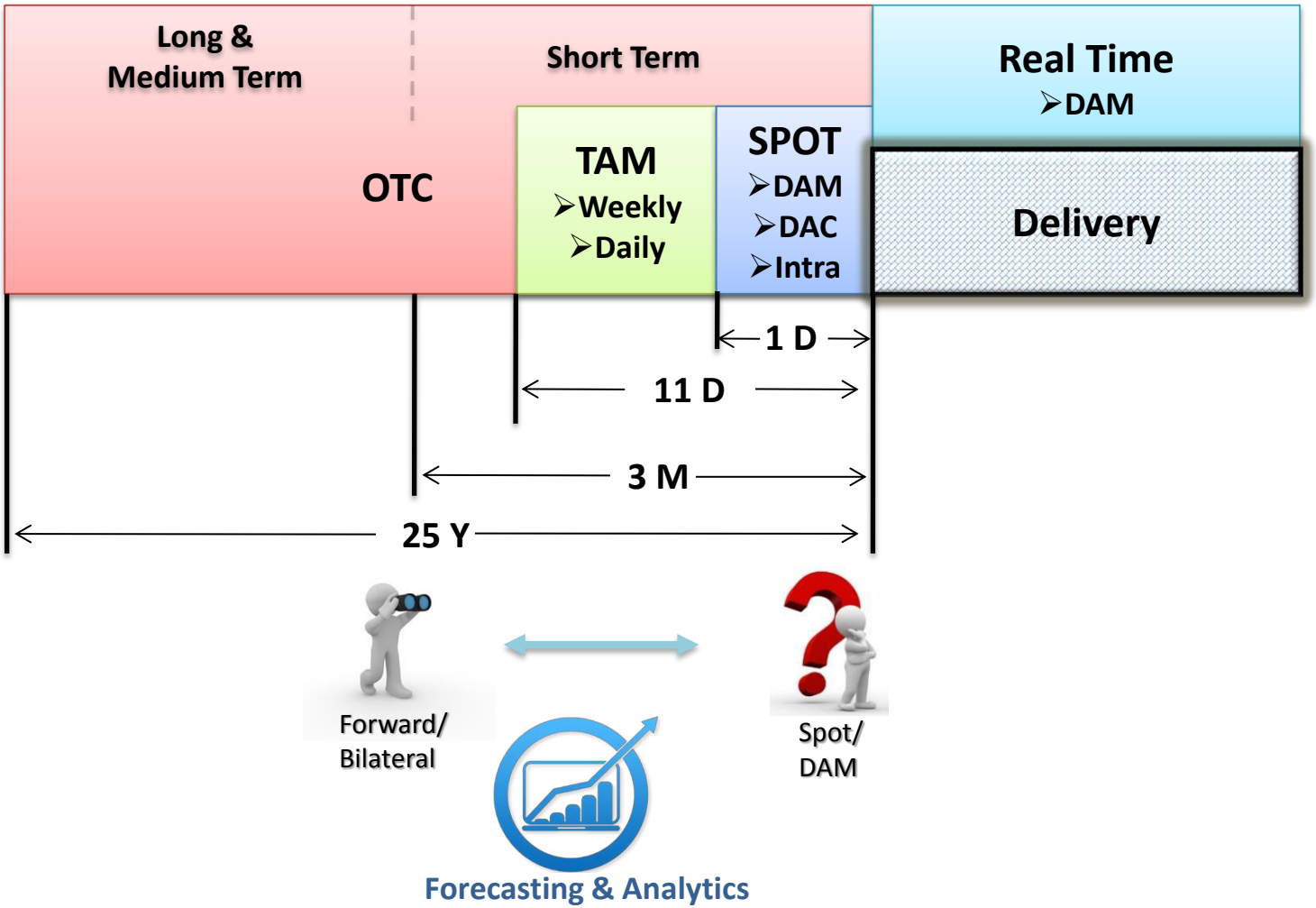
Avg Price
IEX DAM

Spot Markets & Risk Management

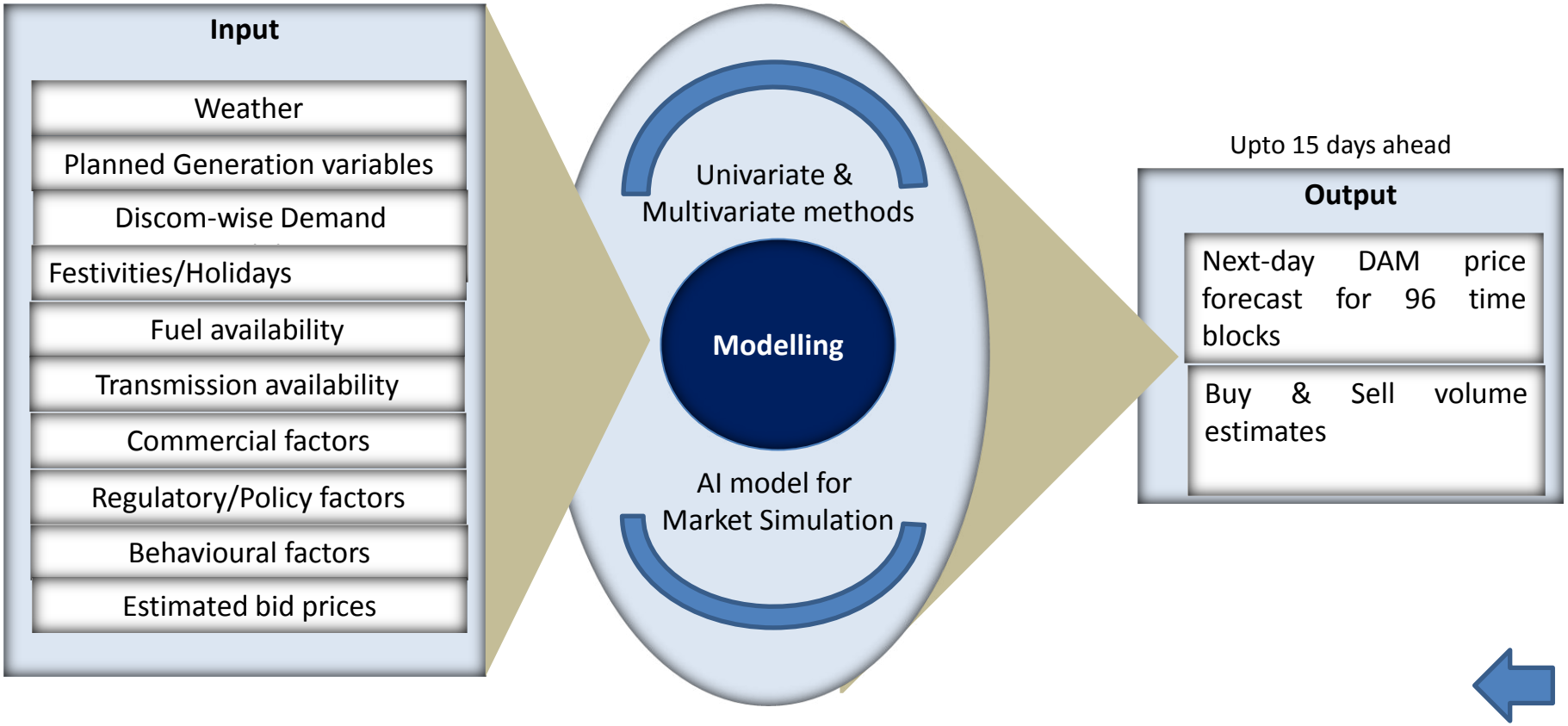
- Electricity spot market (DAM) prices demonstrate extreme volatility compared to other commodities
- This volatility is caused by shifts in supply and demand, volatility in fuel prices, and transmission constraints. Some of these shifts are predictable. However, demand for electricity is also heavily affected by unpredictable and uncontrollable factors like weather and the economy.
- Additional complicating factors include demand surges during summer heat waves, inability to store large quantities of power, the existence of few substitutes, relatively inelastic demand, and market entry barriers, notably high capital costs relative to the marginal production cost & plant lead times.
- Because electricity prices have been regulated for most of the last century, price risk management is relatively new for this market
- Volume & Price Risks to be managed to some extent through Price Forecasts and Bidding Strategies



Uncertainty in Short Term Market?



Price Forecasting
Spot Electricity Price Forecast



Some standard strategies for Portfolio Management

Price Averaging:

- Divide necessary purchases/sale into equal monetary amounts at equally spaced time increments, regardless of price.
- Instead of buying a single bilateral contract for larger duration , a buyer may instead purchase small contracts totalling to the same value.
- While some of the contract prices will be higher or lower, based on the market price for the given period, the math for this technique guarantees that the buyer will acquire more goods when they are inexpensive and less when they are costly.
- Instead of price fluctuations, buyers experience fluctuations in volume of goods purchased. As long as the buyer can bear these changes in volumes, Price Averaging is an excellent technique to manage price fluctuation risk

Laddering:

- Portfolio of power supply contracts can be structured so that a modest fraction of the portfolio turns over each year.
- This laddered approach eliminates both the risk that one will choose a “bad” time to lock in a price for one's entire portfolio and the risk of having to go to market for all of that portfolio in a less than ideal economic environment when a single contract delivery expires

Derivative Use as Portfolio Management

- It is widely agreed that the use of derivatives could help to limit market risk in a deregulated electricity industry, not only for the individual utility, but for the market as a whole

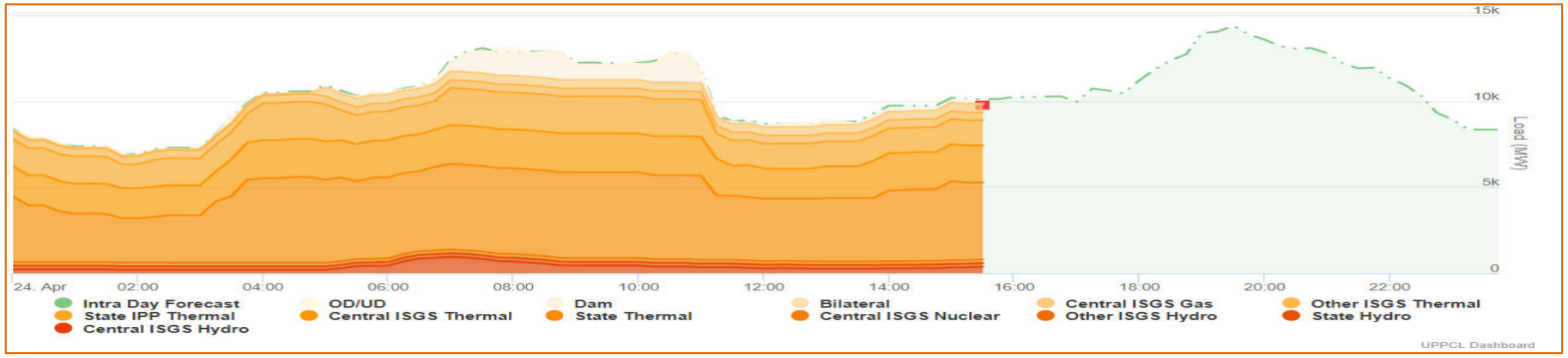
- Derivative instruments are most efficient and successful in commodity markets with large numbers of informed buyers and sellers and in those markets where there is timely, public, and accurate information on prices and quantities traded. And thus, the prospect for an active electricity derivatives market is directly linked to industry restructuring; until electricity spot markets work well, the successful use of electricity derivatives will be limited and hence their adaptability.

- With maturing Spot Market in India, its transparency, liquidity and referencing across the value chain, it is imperative for the market to adopt Derivatives to bring in predictability, stability and reliance to the competitive market.

Portfolio Optimisation

- In order to make decisions and trade-offs between the many different types of electricity resources available, it is necessary to establish clearly-defined objectives
  - Discom → Cost Minimization & Reliability
  - Generator → Revenue Maximisation
- Once Supply-Demand are planned, they are matched through Optimisation considering:
  - ✓ Demand Forecasts,
  - ✓ All Supply Sources, including all the costs & constraints

  Optimal despatch to meet objectives, like Low Total Cost, is modeled and taken for implementation
- Given the growing number of costs and constraints, MILP based Optimisers are widely adopted



Optimisation Model
Overview of ORDENA®

Model Inputs

Demand Side Inputs

- Actual Demand in base year
- Forecasted Demand

Supply Side Inputs

- Existing Generators
- Planned Generators
- Operational Efficiency determining parameters
- Cost Parameters (O&M Charges, Capex, Fuel Costs)
- Transmission Constraints
- Transportation Constraints
- Policy Constraints

Optimiser: ORDENA®

The model uses Mixed Integer Liner Programming (MILP) approach and targets to find the combination of new investment and dispatch to meet the demand at the lowest cost over the year

Model Outputs

- Electricity prices (Month Ahead Upto 1 year)
- Availability of electricity from various sources
- Dispatch of all the generating units (considers transmission networks)
- Optimum Investments to meet the forecasted Load

Model also used at National level to assess prices and electricity availability for medium to long term

Thank you!

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