BEIS and National Grid

Unserved Energy Model

Contents

Background

Background

UEM

- Standalone Unserved Energy Model (UEM) was developed in 2012 for DECC.
- Provided results consistent to those generated by National Grid & Ofgem in their annual Capacity Assessment modelling, in a computationally efficient way.
- Models uncertainty in wind, demand and plant outages.
- The main outputs of the model are estimates of EEU (Expected Energy Unserved) and LOLE (Loss of Load Expectation), and:
  - can be run in time-collapsed or sequential mode
  - sequential model enables the uncertainty in the outputs to be quantified
- In 2013, the time-collapsed version of the calculation was integrated into the core of DECC's Dynamic Dispatch Model (DDM), to calculate the Capacity Market (CM) auction capacity requirement (based on a LOLE target) and the outturn LOLE/EEU in each year.
- Since 2014, the DDM has been used by National Grid to produce the analysis for its annual Electricity Capacity Report, and provide recommendations on the CM auction capacity requirement.

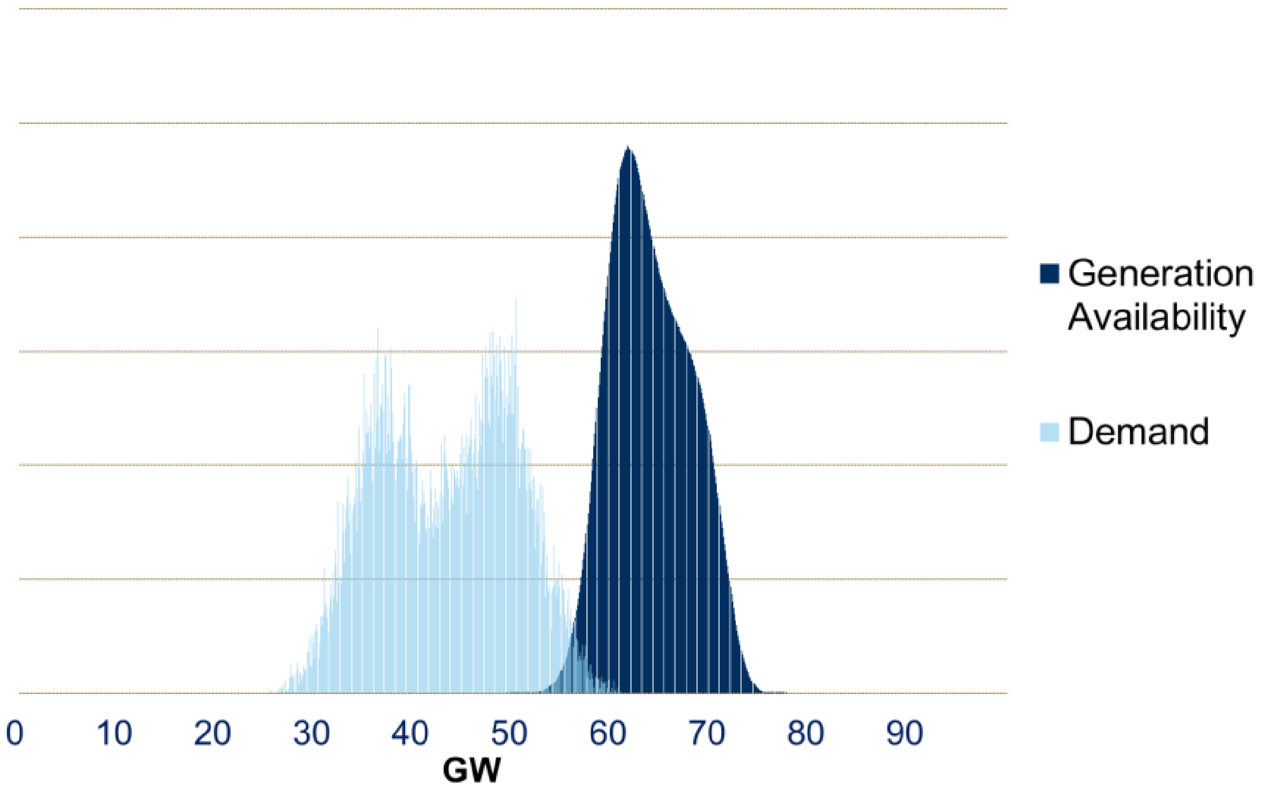
Methodology

Methodology

Time collapsed vs. Sequential

- The standalone UEM can be run in both time-collapsed and sequential modes.

- "Time-collapsed" is a probabilistic calculation that combines the distributions for wind, demand and conventional plant availability to produce single-point estimates for LOLE and EEU.



Methodology

Time collapsed vs. Sequential

Time collapsed	*Sequential*
LOLE and EEU: Single-point estimates	LOLE and EEU: Uncertainty quantified
Fast, single calculation per year	Slower, 10,000+ simulations to converge
Integrated into DDM & standalone UEM	Standalone UEM
No information on the duration & severity of events	Duration & severity metrics available

* Approximately 4 minutes per year for a 10,000 sim run

Methodology

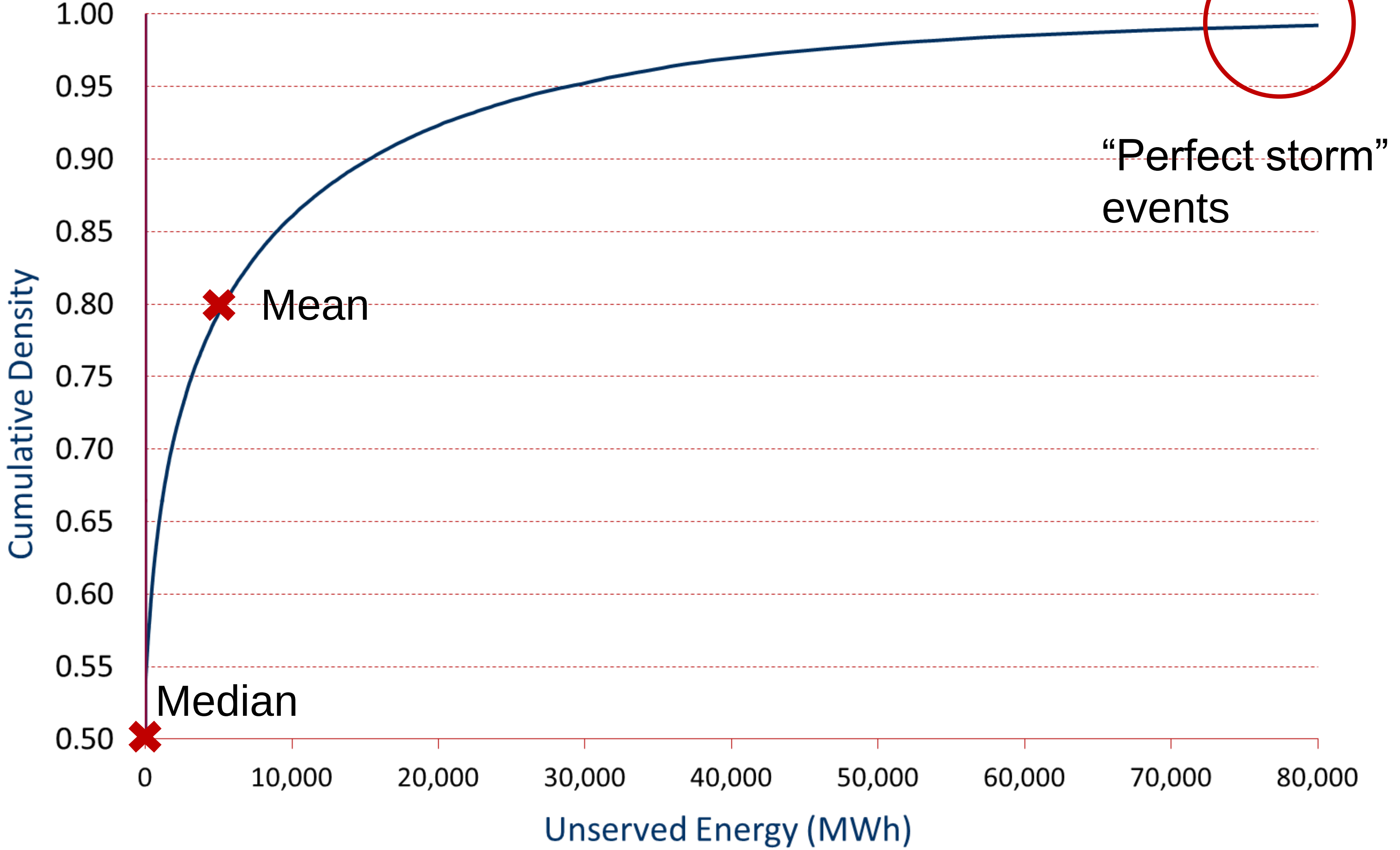
Sequential mode

- In "sequential" mode, the calculation is based on a Monte Carlo (MC) approach.
  - In each MC simulation the year/winter is simulated at half-hourly granularity.
  - Each half-hour is simulated sequentially to capture the hour-to-hour dependencies (length of outages, wind patterns, demand shape).
- Sequential mode enables the uncertainty in the LOLE, EEU outputs to be quantified, including the Loss of Load Probability metric (LOLP). This is important because the distributions can have very long tails.
  - For example, for a LOLE of 3 hours, there may be a 60% probability of 0 hours, but a 5% probability of more than 30 hours.
- Sequential mode also allows the duration and severity of unserved energy events to be quantified.
- Results from the two modes should converge if enough sequential mode simulations are run. This typically requires 10,000+ simulations.

Methodology

Sequential mode

Illustrative example of an EEU distribution.



Methodology

Sequential mode

Wind and demand. Uses the same historic distribution that are used in the DDM's time collapsed calculation:

- Wind: Historic wind speed data from NASA MERRA, available back to 1979. Converted to load factors based on wind plant locations and power curves.
- Demand: Based on National Grid INDO data, available back to 2005.

• Whole weeks of wind and demand are sampled from each season, to capture any patterns that occur across multiple days.

- Option to de-sync wind and demand, which means that wind and demand are sampled independently (consistent with time-collapsed calculation).

Plant Outages. The probability of an outage occurring in any half hour depends on a plant's average availability and the expected duration of its outages.

- The duration of plant outages are simulated using a geometric distribution.
- Plant outages are assumed to be independent between plant.

Conventional Generation Capacity

Sequential mode

- For conventional generating capacity, outages are simulated using a combination of:
  - Expected outage length (in half hours) - $E[o]$
  - Average availability - a

- It is assumed the availability of the plants follow a Markov chain process alternating between the states of available and experiencing an outage.

- Every half hour, when available a plant has probability p_o of experiencing an outage and when out a plant has a probability p_r of recovering.

- This gives the transition matrix of the Markov chain as $\begin{matrix} 1-p_o & p_o \\ p_r & 1-p_r \end{matrix}$

Conventional Generation Capacity

Sequential mode

- When a plant is out its time to recovery follows a geometric distribution with parameter p_r. This gives an expected outage length of $\frac{1}{p_r}$ so that if is $E[o]$ is the expected outage length (in half hours) then $p_r = \frac{1}{E[o]}$.

- The stationary distribution of the Markov chain is $\left(\frac{p_r}{p_r+p_o}, \frac{p_o}{p_r+p_o}\right)$ meaning the average availability of the plant a is $\frac{p_r}{p_r+p_o}$.

- Knowing a and p_r allows the calculation of $p_o = \frac{p_r(1-a)}{a}$.

- Having calculated the parameters, each plant is started from its stationary distribution and a truncated exponential random variable is used to simulate the geometrically distributed transition times.

Demand & wind sampling

Sequential mode

- Historical wind and demand data sampling uses a statistical technique called bootstrapping, whereby the historical data are bucketed and randomly drawn.
- Users can define the bucketing periods in the year and length of period (in days) to draw samples from.
- Default setting is bucketing by season (e.g. winter defined as 01/11-31/03) and drawing weeks at a time.
- Within each simulation, the run period is split into sections equal in length to the draw period.
- The corresponding bucket is determined for each section and a random draw determines which sample from that bucket to use.
- By default, wind and demand are sampled independently of each other.

Additional Sampling Options

Sequential mode

- Users can choose pairwise sampling. In this case, wind and demand are sampled from matching historical periods i.e. if the 3rd week of winter 2005 is randomly drawn for demand, the same week will be drawn for wind.
  - This mode limits the amount of wind and demand data that can be used as exactly the same amount of historical data is required to match periods

- There is also an option to sample whole seasons from historical data as they happened, e.g. simulating winter will draw 01/11-31/03 exactly for both wind and demand for a historical data year
  - In this mode, the number of simulations that will be run is the number specified on the UI multiplied by the number of historical years of data

- To increase the number of possible samples, there is the option to “de-sync” wind and demand, where the wind sample is randomly offset from its initial draw and looped round. This provides results that converge to the time collapsed calculation.

Wind/Demand Correlation

Sequential mode

- The sequential mode also has the option to implement wind/demand correlation functionality.
- After the three series of generation availability, demand and wind have been simulated, for each day peak demand is calculated which is then used to generate the correlation scalar value to multiply wind on that day by.
- This is done for each day in each simulation.

Graphical Illustration

Example

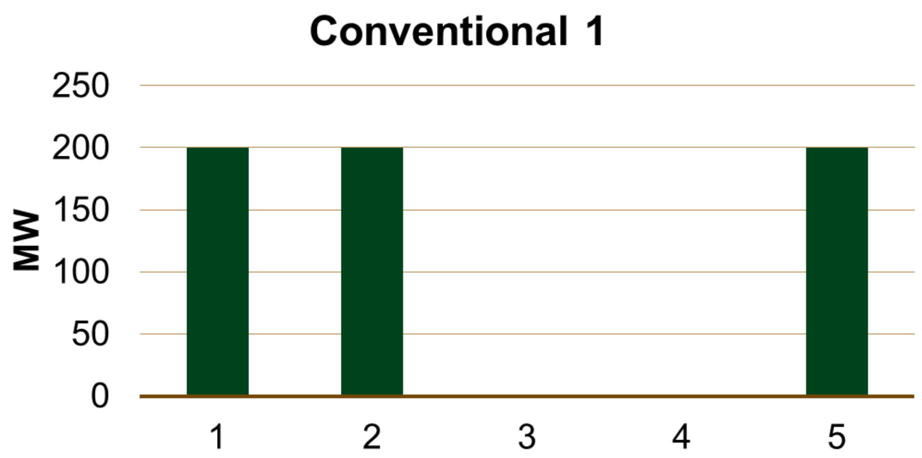
- The following slides will outline a simple example of the sequential mode
- The following assumptions are made in this example:
  - There are 3 conventional plants and 1 wind plant which have the capacities outlined below
  - There are 5 time periods

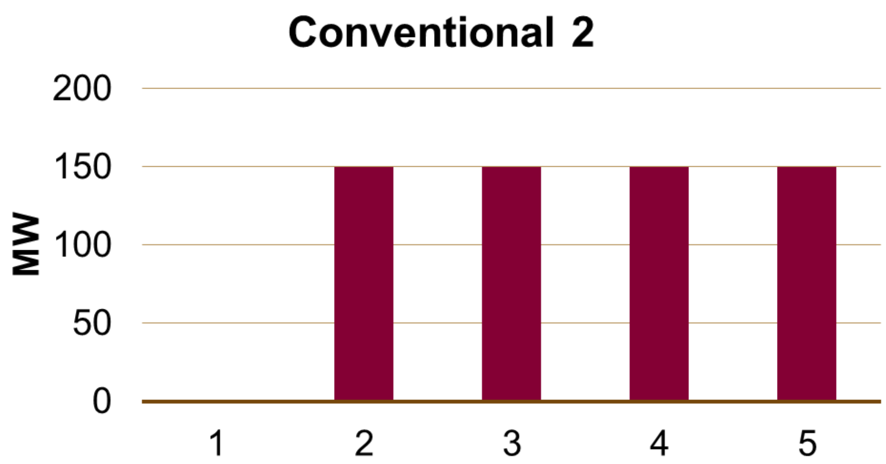
Name	Capacity
Conventional 1	200 MW
Conventional 2	150 MW
Conventional 3	250 MW
Wind	200 MW

Graphical Illustration

Example

- Firstly, outages are simulated for each plant.
- The below graphs indicate the simulated available capacity for each plant in each period





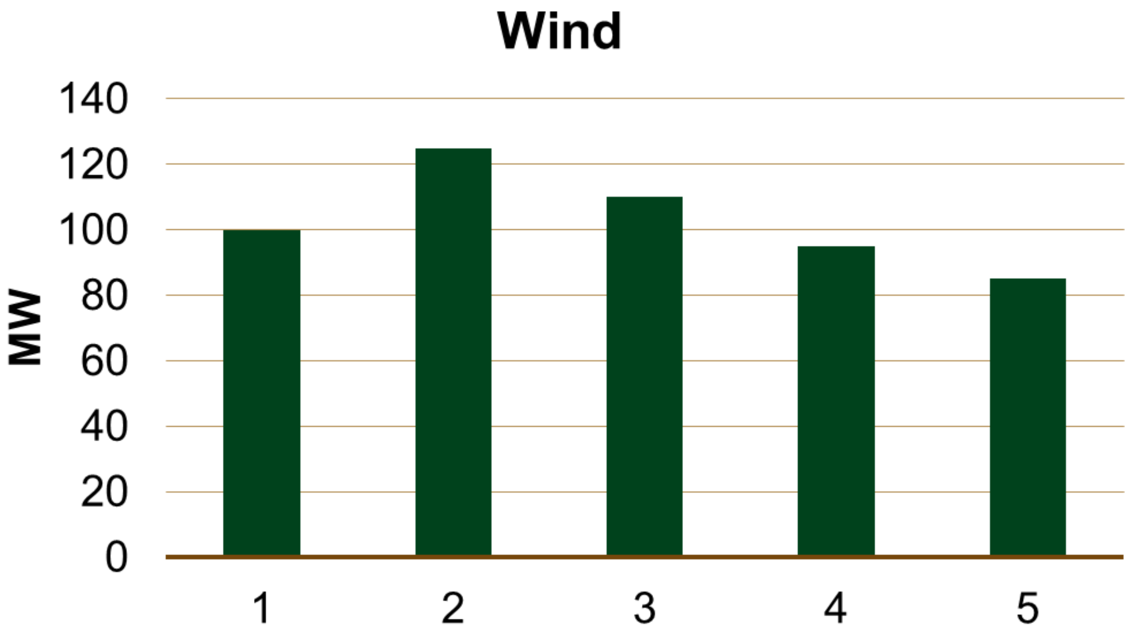
- Conventional 1 has a 2 period outage starting in period 3
- Conventional 2 has a 1 period outage starting in period 1
- Conventional 3 had no outages

NB: plants are not limited to 1 outage ahead of time. This is simply how this simulation turned out.

Graphical Illustration

Example

- Next wind is simulated, drawing load factors randomly from historical data.
- The simulated load factors are then multiplied by the capacity of the wind plant to give the available capacity of wind over the simulated time period.
- In this simulation, this has resulted in wind having the following profile:

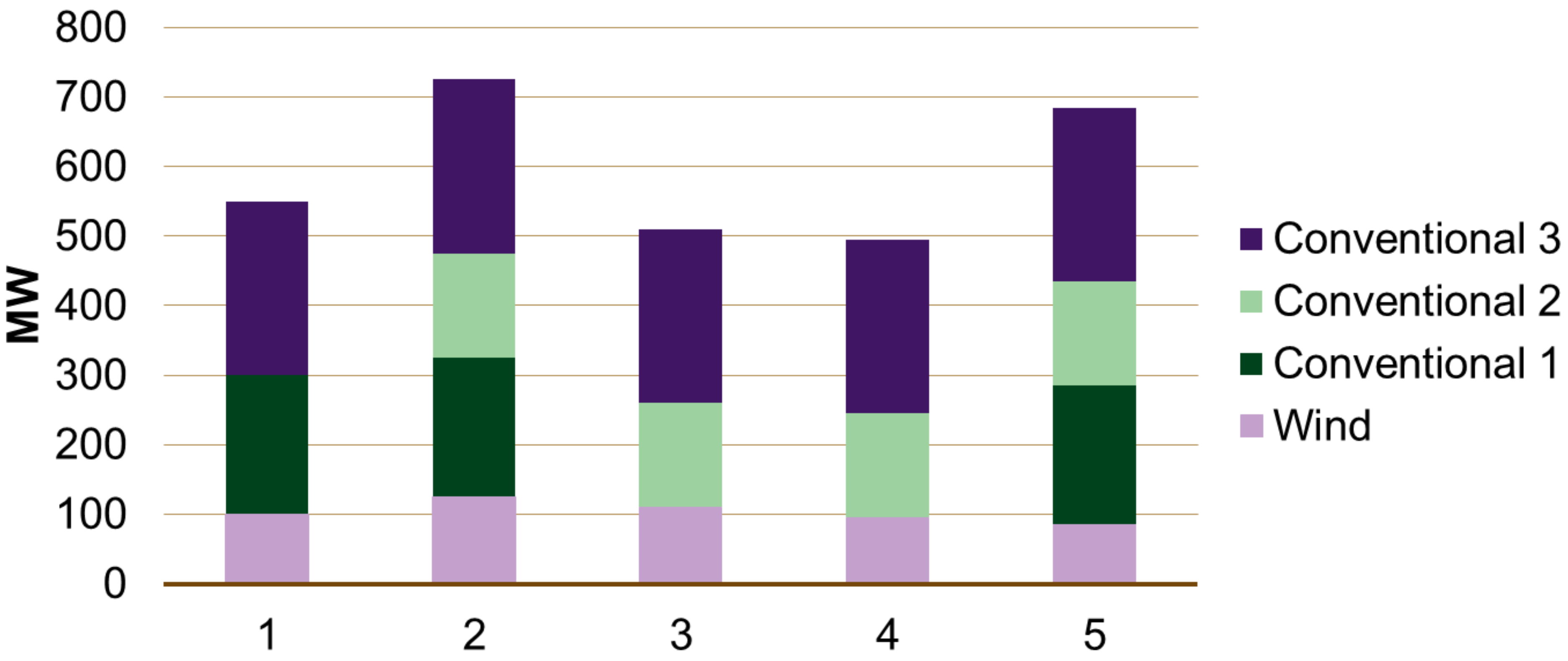


Load factor over the period is between 43-63%

Graphical Illustration

Example

- All available generation is then summed ready to be compared against simulated demand to calculate margin.

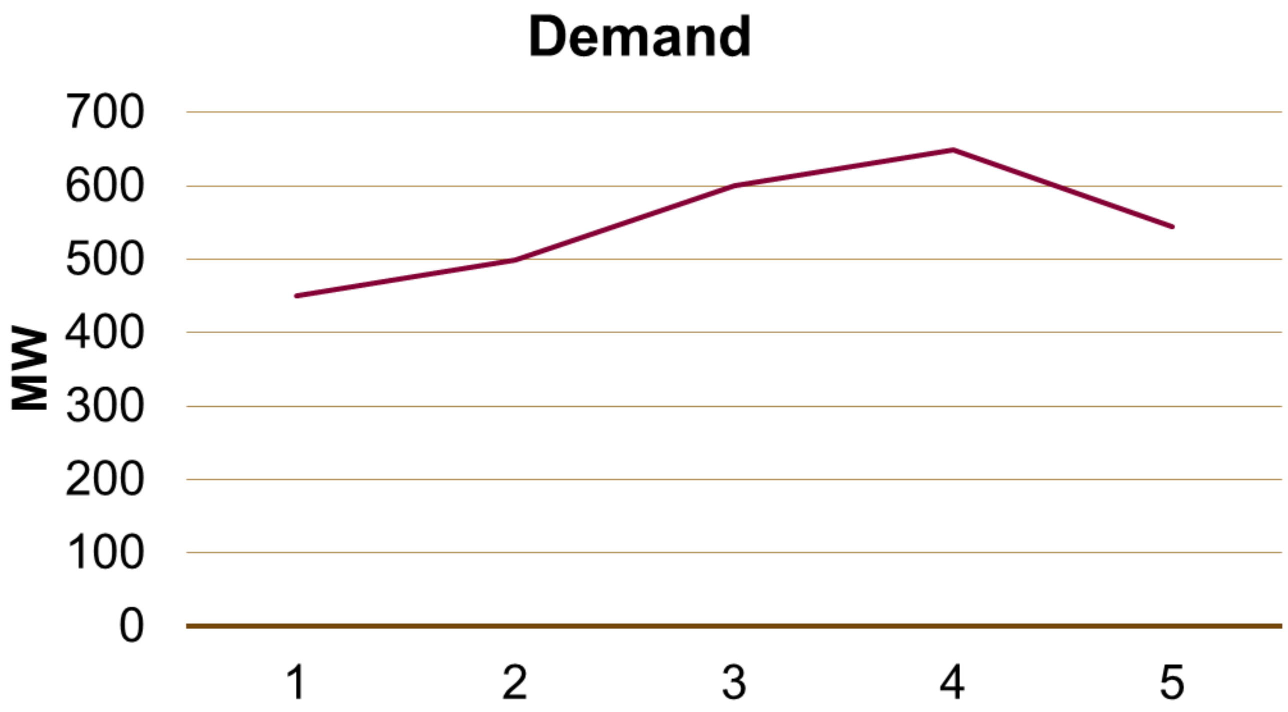


Load factor over the period is between 43-63%

Graphical Illustration

Example

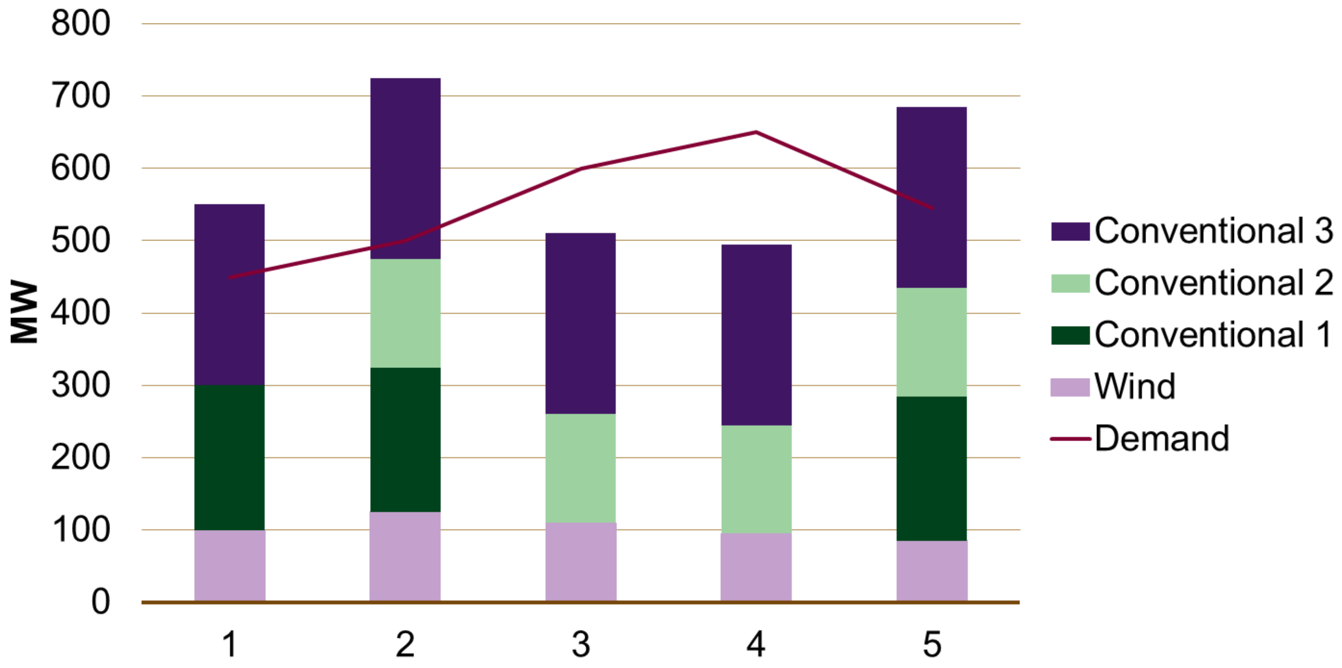
- Demand is simulated in the similar fashion to wind
- However, rather than load factors, it is percentage of ACS peak demand drawn from historical data. These are then multiplied by the ACS peak demand for the simulated year.
- In this simulation, this resulted in demand having the following profile:



Graphical Illustration

Example

- Everything is then pulled together on the supply and demand sides to give the view for margin.



- As available capacity in periods 3 & 4 is less than demand, there has been a 2 period system event calculated.
- This process is repeated 10,000 times with metrics and distributions or lost load calculated

Outputs

Current Outputs

Breakdown

- LOLE/EEU/LOLP by year and scenario
  - For each year run, the loss of load expectation (hours), loss of load probability (percentage, available in sequential mode only) and expected energy unserved (MWh) is given in a table for each user defined capacity shift scenario.

- Severity and duration analysis
  - This gives the probability of a stress event happening given a certain severity and duration, e.g. *the probability of experiencing a shortage of at least 2GW for at least 2 hours would be 0.14%.*
  - This could be used to ‘price’ LOLE depending on the severity of the event, as the first GW of shortage may be much cheaper to satisfy than the fifth GW.

Current Outputs

Breakdown

- Cumulative distribution of unserved energy
  - This gives the probability of a certain amount of unserved energy, plotting the cumulative density of occurrences against unserved energy.
- Time collapsed calculation results
  - Performs the same calculation as the DDM and gives tables comparing LOLE & EEU between the time collapsed and sequential modes.
- A plot of the distributions of demand and generation
  - The overlap of these curves represents loss of load.
  - This chart can be used to understand, for example, how the addition or removal of certain plant affects the shape and mean of the generation availability.

About LCP

LCP's Energy Analytics practice has been at the heart of Electricity Market Reform (EMR) analysis since the first design proposals. We provide analytic and consulting services that support the industry in understanding the impacts of these significant reforms to the GB power market. We also provide some of the key tools in the industry, including the Dynamic Dispatch Model that is used by BEIS and National Grid for analysis such as the final EMR delivery plan and the setting of the capacity requirement for the annual GB capacity auctions. More widely we support our clients to understand how these fundamental changes to the market will affect portfolio profitability and risk over the medium to long term. We provide a range of services including asset valuation, impact analysis and strategic advice.

If you would like any assistance or further information, please contact Tom Porter, tom.porter@lcp.uk.com, who heads up our Energy Analytics practice.

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