Aurora’s power modelling methodology
March 2020
Aurora’s power modelling methodology

Our forecasts use Aurora’s proprietary European power market model

**Plant aggregation**

- Aurora’s EU model currently covers 15 regions
  - 10 regions are modelled at the level of individual plants
  - 5 regions aggregate plants into technology classes
- Even in aggregated regions, a single technology class may contain several discrete technologies (e.g. high/mid/low merits CCGT)
- Bi-directional interconnector flows are determined by power price differentials between countries accounting for ramping restrictions, imperfect market integration and flow rate change costs

*Note: sizes and lengths of interconnectors are for visual representation only, illustrative and are not to scale*

Source: Aurora Energy Research
Aurora's power modelling methodology

The model iterates between dispatch and investment decision to find an equilibrium set of prices and capacities

1. Input
   - Technology assumptions (plant parameters)
   - Policy assumptions (e.g. renewables subsidies, CO₂ prices)
   - Demand assumptions (based on in-house analysis on the effect of EVs)
   - Commodity price assumptions (based on in-house AER-GLO model)

2. Dispatch module (on an hourly basis)
   - Wholesale market
     - Dynamic dispatch of plant, considering ramping costs and rate restrictions, and availability of plants and individual generators to form the supply stack
     - Endogenous interconnector flows according to estimated gradient between domestic and foreign electricity spot prices
     - Iterative modelling between wholesale and balancing markets
   - Balancing Mechanism/Ancillary Services

3. Iterations across modules to
   - reach equilibrium solution
   - ensure internal modelling consistency

4. Output
   - Capacity mix (New build entry and exit decisions)
   - Generation mix (at technology/plant level)
   - Wholesale & imbalance prices (half-hourly granularity)
   - Capacity Market prices
   - Profit & loss and NPV for modelled technologies

Time horizon: 2020 - 2050

1. See Appendix 1 for further details of the modelling methodology
Aurora's power modelling methodology

Input assumptions include technology, policy, demand and commodity prices

<table>
<thead>
<tr>
<th>Input assumptions</th>
<th>Dispatch module</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology assumptions</td>
<td>Investment decision module</td>
<td></td>
</tr>
<tr>
<td>• Plant efficiencies (incl. efficiency improvement over time)</td>
<td>• Ramping costs and speeds</td>
<td></td>
</tr>
<tr>
<td>• Plant availabilities</td>
<td>• Subsidised/un-subsidised mode of dispatch</td>
<td></td>
</tr>
<tr>
<td>• Plant costs: fixed &amp; variable O&amp;M costs, capex, refurbishment cost, mothballing cost</td>
<td>• Discount rate by revenue stream (for NPV calculation)</td>
<td></td>
</tr>
<tr>
<td>• Carbon cost regime (e.g. Carbon Price Support in GB)</td>
<td>• (other technical parameters)</td>
<td></td>
</tr>
<tr>
<td>• Mandated plant closure (e.g. coal)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Annual demand time series, which is processed into half hourly data including noise as a proxy for stochastic availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Number of EVs and heat pumps, also processed to half hourly profile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Coal price forecast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Gas price forecast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• EU-ETS price forecast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Commodity prices are typically derived from separate Aurora CGE modelling, though can also be user-defined</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Aurora Energy Research
Based on user-defined inputs, the dispatch model optimizes plant behaviour to minimize costs

- Regional dispatch is optimized to minimize costs while accounting for:
  - Gross production and demand, including losses
  - Interconnector imports and exports
  - Ramping constraints
  - Loss of load
  - Spilled power
  - Plant availability and outages
  - Any additional user-defined constraints (e.g. emissions)

- Costs include
  - Capex, fixed and variable
  - Ramping
  - Spill and loss of load
  - Mothballing and refurbishment
Aurora’s power modelling methodology

Capacity investment decisions are based on plant economics

- In regions like GB which have a Capacity Market:
  - Annual procurement targets are set by the user
  - The model finds the cheapest plants to meet the target de-rated capacity and outputs a Capacity Market price
  - Already existing plants receive 1-year contracts
  - New building plants can receive multi-year contracts
  - Each technology has a specific de-rating factor (i.e. how much can 1MW of each tech count towards the target)
  - The model iterates between the dispatch and investment decision modules until it reaches a consistent, equilibrium set of prices and capacities such that each asset is just able to make its required level of return
Aurora's power modelling methodology

Input assumptions include technology, policy, demand and commodity prices

Source: Aurora Energy Research
Disclaimer

General Disclaimer
This document is provided “as is” for your information only and no representation or warranty, express or implied, is given by Aurora Energy Research Limited (“Aurora”), its directors, employees, agents or affiliates (together its “Associates”) as to its accuracy, reliability or completeness. Aurora and its Associates assume no responsibility, and accept no liability for, any loss arising out of your use of this document. This document is not to be relied upon for any purpose or used in substitution for your own independent investigations and sound judgment. The information contained in this document reflects our beliefs, assumptions, intentions and expectations as of the date of this document and is subject to change. Aurora assumes no obligation, and does not intend, to update this information.

Forward looking statements
This document contains forward-looking statements and information, which reflect Aurora’s current view with respect to future events and financial performance. When used in this document, the words "believes", "expects", "plans", "may", "will", "would", "could", "should", "anticipates", "estimates", "project", "intend" or "outlook" or other variations of these words or other similar expressions are intended to identify forward-looking statements and information. Actual results may differ materially from the expectations expressed or implied in the forward-looking statements as a result of known and unknown risks and uncertainties. Known risks and uncertainties include but are not limited to: risks associated with political events in Europe and elsewhere, contractual risks, creditworthiness of customers, performance of suppliers and management of plant and personnel; risk associated with financial factors such as volatility in exchange rates, increases in interest rates, restrictions on access to capital, and swings in global financial markets; risks associated with domestic and foreign government regulation, including export controls and economic sanctions; and other risks, including litigation. The foregoing list of important factors is not exhaustive.

Copyright
This document and its content (including, but not limited to, the text, images, graphics and illustrations) is the copyright material of Aurora[, unless otherwise stated]. No part of this document may be copied, reproduced, distributed or in any way used for commercial purposes without the prior written consent of Aurora.