Capacity Expansion Algorithm in Genersys – when to expect the first PCC plants in the NEM

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Presentation outline

• Introduction to Genersys
• Capacity expansion algorithm
• Monte Carlo simulations
• Wind generation case study for South Australia
• Questions
Magnetic termites and self-organisation
Acknowledgments

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Regions in the National Electricity Market

- QLD
- NSW
- VIC
- QLD-NSW
- DIRECTLINK
- VIC-NSW
- MURRAYLINK
- SA-VIC
- BASSLINK
- TAS
- SA
Introduction to Genersys

Main features:
Genersys – National Electricity & Gas Market simulator:
- Integrates gas and electricity
- Employs agent-based simulation
- Generation expansion algorithm
- Monte-Carlo framework
- Links to climate change scenarios.

Modelling challenges:
Agent-based simulation for modelling of companies’ decision process
Modelling of climate dependence of demand and supply
Modelling of investment in new generation and transmission.

Key collaborators:
Core Energy Group and
AGL Energy

Other similar tools:
EMCAS (ANL, USA), Prophet (IES), Plexos™ (Energy Exemplar)
• It enables users to run feasible scenarios of the outlook for the Australian gas and electricity sectors over a short-, mid- and long-term time horizons.

• Proper sophistication of simulation models and components linking technical, commercial and environmental aspects;

• Object-oriented and modular software architecture based on Java;

• Agent-based framework to model decision making and adaptation of companies;

• Rich user interface – easy to use, Scalable Vector Graphics (SVG) mapping, full Scenario Editor and a comprehensive Report Viewer;

• Climate-based approach linking electricity & gas demand as well as hydro and wind performance to weather parameters and climate projections;

• Functionality to account for Policy changes, MRETs and Emissions Trading.

• Flexible data import from third party (AEMO) market systems (actual vs. projection tracking) and export to Excel;
A simulation platform for electricity and gas

- Scenario Editor
- SVG Map
- Report Viewer
- Scenario XML File Format
- Simulation Engine
- History Store
- Simulation Objects
  - Electricity
  - Gas
  - Renewables
  - Policy
Gas model

Has a gas supply agreement with one or more

Gas Pipeline
- Has a reservation with one or more
- Has one or more

Gas Wholesaler
- Has a gas delivery contract with a

Gas Delivery Point
- Connects to

Gas Node
- Connects to

Gas Retailer
- Create demand at

Gas Field
- Connects to
Inter-regional coupling between climate and electricity demand

Daily climate
- NSW
- VIC
- QLD
- SA
- TAS

ELECTRICITY DEMAND MODEL
- NSW
- VIC
- QLD
- SA
- TAS

24 hr demand (30 min steps)

GLOBAL CLIMATE MODEL (DOWN-SCALLED)

Credit: Dr. Marcus Thatcher (CMAR)
Bidding models

Offer price vector

Offer quantities matrix

- Global bid selector
- Lookup bid generator
- Simple big generator
- Select bid generator
- Cost-based bidding – SRMC and LRMC
- File bid generator
- Dynamic bidding
- Energy targeting bidding
- Historical bidding
Half-hour solar output from a simulated solar generator
• Integrated algorithm
• Regional based
• Scheduled and non-scheduled (wind and solar)
• Unserved energy, price premium
• Peak, intermediate, baseload generation technologies
• Modular expansion
Price duration curve premium

- Baseload cap

- Intermediate load capacity factor

- Peaking load capacity factor
Flow chart of the capacity expansion algorithm

1. Start
2. Select region
3. Investment check required?
   - yes
   - Select technology
4. Does potential revenue exceed costs?
   - yes
   - Add technology to list of investment possibilities
5. More technologies for region?
   - yes
   - Select region
   - no
6. Any investment possibilities for region?
   - yes
   - Create new generating unit using most profitable technology
   - no
7. Any more regions?
   - yes
   - Select region
   - no
8. Finish
Capital cost of generation technologies - continued
Carbon price scenarios

![Graph showing carbon price scenarios](image)
Capacity expansion in Queensland – Scenario 1

Capacity expansion in Queensland - no carbon price

- WIND
- OCGT
- GEOTHERMAL_HSA_NSA
- GEOTHERMAL_EGS_NSA
- CCGT_CCS
- CCGT
Capacity expansion in Queensland – Scenario 2

Capacity expansion in Queensland - Core Scenario

- **WIND**
- **OCGT**
- **GEOTHERMAL_HSA_NSA**
- **GEOTHERMAL_EGS_NSA**
- **CCGT_CCS**
- **CCGT**
Capacity expansion in Queensland – Scenario 3

Capacity Expansion in Queensland – High Carbon Price

Capacity [MW]

Year: 2016 to 2040

Legend:
- WIND
- OCGT
- GEOTHERMAL_HSA_NSA
- GEOTHERMAL_EGS_NSA
- CCGT_CCS
- CCGT
Capacity expansion in NSW – Scenario 1

Capacity expansion in NSW - no carbon price

- WIND
- OCGT
- GEOTHERMAL_HSA_NSA
- GEOTHERMAL_EGS_NSA
- CCGT_CCS
- CCGT

Capacity [MW]

Year
Capacity expansion in NSW – Scenario 2

Capacity expansion in NSW - Core Scenario

- **WIND**
- **OCGT**
- **GEOThermal_HSA_NSA**
- **GEOThermal_EGS_NSA**
- **CCGT_CCS**
- **CCGT**
Capacity expansion in NSW – Scenario 3

Capacity expansion in NSW - high carbon price

Year

Capacity [MW]

- WIND
- OCGT
- GEOTHERMAL_HSA_NSA
- GEOTHERMAL_EGS_NSA
- CCGT_CCS
- CCGT
Capacity expansion in Victoria – Scenario 1

Capacity expansion in Victoria - no carbon price

Capacity [MW]

- WIND
- OCGT
- GEOTHERMAL_HSA_NSA
- GEOTHERMAL_EGS_NSA
- CCGT_CCS
- CCGT
Capacity expansion in Victoria – Scenario 3

Capacity expansion in Victoria - High Carbon Price

- WIND
- OCGT
- GEOTHERMAL_HSA_NSA
- GEOTHERMAL_EGS_NSA
- CCGT_CCS
- CCGT

Year: 2013 to 2040
Capacity [MW]: 0 to 1600
Capacity expansion in South Australia – Scenario 1

Capacity expansion in South Australia - no carbon price

- WIND
- OCGT
- GEOTHERMAL_HSA_NSA
- GEOTHERMAL_EGS_NSA
- CCGT_CCS
- CCGT
Capacity expansion in Tasmania – Scenario 1

Capacity expansion in Tasmania - no carbon price

- WIND
- OCGT
- GEOTHERMAL_HSA_NSA
- GEOTHERMAL_EGS_NSA
- CCGT_CCS
- CCGT
Monte Carlo simulations on a computer cluster

IBM eServer Cluster 1350 system, having 123 nodes with Intel Xeon processors HS20 and 2GB / 4GB or 8GB of memory

1. Prepare a scenario
2. Send the Scenario XML file + Data
6. Get Simulated Results

4. Create and execute parallel jobs
5. Aggregate simulated results from the parallel jobs

7. View and analyse simulation results

20 Simulations x 5 years -> 112 GB
804 final reports - 5 GB (4020 attributes)
~1.5 h for a single run
Analysing simulation results using Report Viewer
Example of simulation results

Generation Technology - Hydro dispatch
Example of simulation results

Interconnector Flow – QNI (Queensland to NSW)
Case study for wind generation in South Australia (SA)

- Existing wind generation simulated for one month – March 2010
- Proposed wind farms – ESAA “Electricity Gas 2009”
- Existing + proposed wind generation simulated for one month – March 2020
- The total wind generation is compared with the system demand
- All wind farms as non-scheduled generators
- Partial synchronisation of the output of wind farms in a region.
Wind farms in South Australia (SA)

Lake Bonney Stage 2 Wind Farm
## Existing wind generation capacity in SA - 2010

<table>
<thead>
<tr>
<th>Company</th>
<th>Generator Plant</th>
<th>ID</th>
<th>Maximum Capacity [MW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGL</td>
<td>Wattle Point Wind Farm</td>
<td>WPWF</td>
<td>90.75</td>
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<tr>
<td>AGL</td>
<td>Hallet Wind Farm</td>
<td>HALLWF1</td>
<td>94.50</td>
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<tr>
<td>AGL</td>
<td>Hallet Wind Farm 2</td>
<td>HALLWF2</td>
<td>71.00</td>
</tr>
<tr>
<td>Pacific Hydro Clements Gap Pty Ltd</td>
<td>Clements Gap Wind Farm</td>
<td>CLEMGPWF</td>
<td>57.00</td>
</tr>
<tr>
<td>Babcock and Brown Wind Partners</td>
<td>Lake Bonney Wind Farm</td>
<td>LKBONNY1</td>
<td>80.50</td>
</tr>
<tr>
<td>Babcock and Brown Wind Partners</td>
<td>Lake Bonney Stage 2</td>
<td>LKBONNY2</td>
<td>160.00</td>
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<td>Hydro Tasmania</td>
<td>Cathedral Rocks Wind Farm</td>
<td>CATHROCK</td>
<td>66.00</td>
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<tr>
<td>Tarong Energy</td>
<td>Mount Millar Wind Farm</td>
<td>MTMILLAR</td>
<td>70.00</td>
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<tr>
<td>Tarong Energy</td>
<td>Starfish Hill Wind Farm</td>
<td>STARFISH</td>
<td>34.50</td>
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<tr>
<td>Canunda Power Pty Ltd</td>
<td>Canunda Wind Farm</td>
<td>CANUNDA</td>
<td>46.00</td>
</tr>
<tr>
<td>Snowtown Wind Farm</td>
<td>Snowtown Wind Farm</td>
<td>SNOWTWN1</td>
<td>99.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>EXISTING WIND CAPACITY</strong></td>
<td></td>
<td><strong>869.25</strong></td>
</tr>
</tbody>
</table>
## Proposed wind farms in SA

<table>
<thead>
<tr>
<th>No.</th>
<th>Power Station Name</th>
<th>Company</th>
<th>Capacity (MW)</th>
<th>Plant type</th>
<th>Location</th>
<th>Status</th>
<th>Proposed Commissioning Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Allendale/Laslett</td>
<td>Acciona Energy</td>
<td>150</td>
<td>Wind turbine</td>
<td>Allendale/Laslett</td>
<td>Proposed</td>
<td>1/01/2015</td>
</tr>
<tr>
<td>2</td>
<td>Barn Hill (Red Hill)</td>
<td>Transfield Services</td>
<td>130.2</td>
<td>Wind turbine</td>
<td>Barn Hill</td>
<td>Proposed</td>
<td>2011</td>
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<tr>
<td>3</td>
<td>Barunga</td>
<td>Wind Prospect</td>
<td>170</td>
<td>Wind turbine</td>
<td>Barunga Ranges, Port Pirie</td>
<td>Proposed</td>
<td>1/07/2014</td>
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<tr>
<td>4</td>
<td>Carmody's Hill</td>
<td>Pacific Hydro</td>
<td>175</td>
<td>Wind turbine</td>
<td>East of Georgetown</td>
<td>Proposed</td>
<td>1/07/2015</td>
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<td>5</td>
<td>Elliston Stage I</td>
<td>Ausker Energies</td>
<td>55</td>
<td>Wind turbine</td>
<td>Tungketta Hill</td>
<td>Proposed</td>
<td>1/07/2015</td>
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<tr>
<td>6</td>
<td>Elliston Stage II</td>
<td>Ausker Energies</td>
<td>65</td>
<td>Wind turbine</td>
<td>Tungketta Hill</td>
<td>Proposed</td>
<td>1/07/2016</td>
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<td>7</td>
<td>Green Point</td>
<td>Wind Prospect</td>
<td>54</td>
<td>Wind turbine</td>
<td>Green Point</td>
<td>Proposed</td>
<td>1/01/2016</td>
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<td>8</td>
<td>Hallett 3 (Mt Bryan)</td>
<td>AGL Energy</td>
<td>90</td>
<td>Wind turbine</td>
<td>Near Hallett</td>
<td>Proposed</td>
<td>2011</td>
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<td>9</td>
<td>Hallett 4 (North Brown Hill)</td>
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<td>Wind turbine</td>
<td>Near Hallett</td>
<td>Proposed</td>
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<td>Kongorong</td>
<td>Transfield Services</td>
<td>120</td>
<td>Wind turbine</td>
<td>Kongorong</td>
<td>Proposed</td>
<td>1/07/2016</td>
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<tr>
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<td>Kulpara</td>
<td>Transfield Services</td>
<td>60-110</td>
<td>Wind turbine</td>
<td>Kulpara</td>
<td>Proposed</td>
<td>1/07/2017</td>
</tr>
<tr>
<td>12</td>
<td>Lincoln Gap</td>
<td>Wind Energy Solutions</td>
<td>118</td>
<td>Wind turbine</td>
<td>Lincoln Gap</td>
<td>Proposed</td>
<td>1/12/2016</td>
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<tr>
<td>13</td>
<td>Mount Hill</td>
<td>Transfield Services</td>
<td>80</td>
<td>Wind turbine</td>
<td>Mount Hill</td>
<td>Proposed</td>
<td>1/07/2017</td>
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<tr>
<td>14</td>
<td>Snowtown Stage II</td>
<td>TrustPower</td>
<td>174</td>
<td>Wind turbine</td>
<td>Snowtown</td>
<td>Advanced planning</td>
<td>1/12/2017</td>
</tr>
<tr>
<td>15</td>
<td>Myponga/Sellicks Hill</td>
<td>TrustPower</td>
<td>41</td>
<td>Wind turbine</td>
<td>Myponga</td>
<td>Advanced</td>
<td>2010</td>
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<td>16</td>
<td>Vincent North</td>
<td>Pacific Hydro</td>
<td>59.4</td>
<td>Wind turbine</td>
<td>Yorke Peninsula</td>
<td>Proposed</td>
<td>1/07/2018</td>
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<td>17</td>
<td>Waterloo</td>
<td>Roaring 40s</td>
<td>117</td>
<td>Wind turbine</td>
<td>Near the Clare Valley</td>
<td>Proposed</td>
<td>2010-11</td>
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<td>18</td>
<td>Willogoleche</td>
<td>International Power Australia</td>
<td>52-78</td>
<td>Wind turbine</td>
<td>Near Hallett</td>
<td>Proposed</td>
<td>1/07/2018</td>
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<tr>
<td>19</td>
<td>Worlds End</td>
<td>AGL Energy</td>
<td>180</td>
<td>Wind turbine</td>
<td>Burra</td>
<td>Proposed</td>
<td>1/07/2018</td>
</tr>
</tbody>
</table>
Total capacity of wind generation in SA

Proposed new wind capacity: 2155.60 MW

869.25 MW - 2010

3024.85 MW – 2020
Aggregated wind generation

Wind Generation in SA - March 2010

MW

No of half-hour intervals

0 100 200 300 400 500 600

1 83 165 247 329 411 493 575 657 739 821 903 985 1067 1149 1231 1313 1395
Wind generation and system demand in SA

SA: Wind generation and System Demand
March 2010

MW

No. of half-hour time intervals
Total Wind Generation and System Demand in SA - March 2020
• Genersys - an integrated gas-electricity simulation model has been presented
• A capacity expansion algorithm is available in Genersys
• Some example outputs from Monte Carlo simulations have been presented
• A case study for wind generation in South Australia created and analysed
• As an integrated simulation platform, Genersys could be used by industry, academics and regulators to assess different energy futures and emerging market features.
Thank you