PHES and CSP price sensitivity in 100% renewable electricity scenario

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Overview

• What will the low carbon electricity system of the future look like?
• A number of plans have been presented
  • Some with high penetration of concentrating solar thermal (Wright and Hearps, Jeppesen et al.)
  • Or with PV and pumped hydro energy storage (Blakers et al.)
• Different studies use different input assumptions – sometimes difficult to understand why the results are different
  • Provide a single model to simulate all different scenarios
• Storage is a key factor in a high penetration RE system
Modelling setup

• Find the least cost total system cost for a combination of generation technologies for 100% emission abatement by 2050 (other targets also possible)

• Broad range of technologies considered (technology agnostic)
  • Coal (brown and black coal), Gas (OCGT and CCGT)
  • Hydro, wind, solar
  • Concentrating solar thermal, Carbon capture and storage (CCS), bioenergy, Pumped hydro energy storage (PHES)

• At same time consider transmission constraints and costs of additional transmission capacity

• **Hourly** economic dispatch model, inertia constraints, ramp rates, unit commitment

• We run 8 hours of storage for both PHES and CSP

• Discount rate: 10%

• Electrification of transport
  • 1.4 times demand increase by 2050 cf to 2013
# Technology cost scenarios

Build cost ($/kW) real 2017 dollars (2018-2050) from CSIRO cost projections used in the AEMO’s ISP (integrated System Plan)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CSP ($/kW)</th>
<th>PHES ($/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOW</td>
<td>4434</td>
<td>1860</td>
</tr>
<tr>
<td>NEUTRAL</td>
<td>4434</td>
<td>1386</td>
</tr>
<tr>
<td>RAPID</td>
<td>4434</td>
<td>800</td>
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</tbody>
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- Run various combinations of slow, neutral and rapid for the two technologies.
- CSP is always more expensive, but it’s not just storage, it does generation as well.
Capital cost projections for various technologies ($/kW)

Source: AEMO’s ISP
CSIRO
Value of grid scale storage – based on historical market data

Value of additional hours of storage becomes small after 6-8 hours
This might change in the future with more RE deployment
Pumped hydro storage algorithm

- Blakers et al. study identified thousands of potential PHES sites: we have assumed that each node will have suitable locations
- PHES is dispatched to maximise effectiveness – perfect look-ahead functionality so is charged for the 10 lowest residual demand hours and dispatched for the 8 highest residual demand hours
- The capital costs for PHES will vary significantly from site to site however this has not been considered in this study
**Results for different cost assumptions for PHES and CSP**

- **Neutral CSP, Neutral PHES** – the optimisation builds wind, PV and PHES. (not CSP)
- **Slow PHES** (expensive, upper-bound) and **Rapid CSP** (cheap, lower-bound) – the optimisation build some CSP, but still builds a fairly large amount of PHES
- But total system costs for the two scenarios are similar"
2030 Neutral CSP, Neutral PHES

- SA and TAS would be the first states incorporating off-river PHES
- Black coal would need to do load-following
- Only limited new gas generators to be built to balance the grid
- Transmission augmentation is needed to facilitate inter-regional transfer
- Snowy 2.0 facilitates PV deployment in NSW
• PHES is widely deployed in synergy with PV
• PHES stores a considerable portion of the solar power during the day and dispatches it during the evening while providing inertia in both operations
Strategic placement of renewables is critical, requires integrated system planning for both generation and transmission. Renewables close to the grid/demand centres are good enough.
Impacts on transmission capacity

Lots of new transmission capacity built
Only small difference between CSP and PHES favorable scenarios
Summary

• Modelling study showing the sensitivity of generation mix to costs of CSP and PHES
• Model builds lots of wind and PV
• PHES common to all scenarios
• CSP only built if costs are assumed to drop dramatically
• But only small differences in the present value of the total system cost for the CSP and PHES versions
  • Could go either way