Technical, economic + commercial opportunities and challenges of a 100% renewably powered Australian National Electricity Market

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Australian All-Energy Conference
Melbourne Convention Centre
11-12th October 2012
We must seize the opportunity for a clean energy future.
Let me be straight: our ongoing failure to realise the full potential of clean energy
technology is alarming. Midway through 2012, energy demand and prices are rising steadily,
energy security concerns are at the forefront of the political agenda, and energy-related
carbon dioxide (CO₂) emissions have reached historic highs. Under current policies, both
energy demand and emissions are likely to double by 2050.

To turn the tide, common energy goals supported by predictable and consistent policies are
needed across the world. But governments cannot do this alone; industry and citizens must
be on board. The public needs to understand the challenges ahead, and give the necessary
support and mandate for policy action and infrastructure development. Only decisive,
effective and efficient policies can create the investment climate that is ultimately needed
to put the world on a sustainable path.

The good news is that technology, together with changed behaviour, offers the prospect
of reaching the international goal of limiting the long-term increase of the global mean
temperature to 2°C. By reducing both energy demand and related greenhouse-gas (GHG)
emissions, strategic application of clean energy technologies would deliver benefits of
enhanced energy security and sustainable economic development, while also reducing
human impact on the environment.

(IEA, Energy Technology Perspectives, 2012)
Growing interest in future 100% renewable electricity

- Many drivers including
  - climate change (and given poor progress of other low carbon options)
  - energy security (most countries see fossil fuel $ as economic liabilities)
  - falling renewable technology costs

- Some key questions
  - Technical feasibility? – can 100% renewables mixes utilizing highly variable and somewhat unpredictable solar and wind reliably meet demand at all times and locations
  - If yes, Economic feasibility? – is 100% renewables economically worth doing given likely costs vs costs of inaction, other options
  - If yes, Commercial feasibility? – can we establish commercial frameworks that drive appropriate deployment at speed and scale required
100% renewables for the NEM?

A significant change from current mix with some hydro, modest wind

Note missing PV, other non-registered renewables

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**Figure 1.2**

Large electricity generators in the National Electricity Market


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**Figure 1.4**

Registered capacity in regions, by fuel source, 2011

(AER, 2012)
Consider only deployed renewable technologies with high Australian potential resource
- On-shore wind, PV, CST, biogas turbines, existing hydro

Hourly simulations of generation dispatch using regional weather observations to meet actual NEM demand over 2010 (8760 hours)

Renewable generation mix and locations chosen by guided exploration
- meet 0.002% Unserved Energy for entire year
- moderate energy ‘spill’
- moderate total biomass energy consumption
- No additional hydro

No consideration of costs, Tx requirements

Implemented in Python – databases, dispatch (Elliston, 2010)
Some new NEM regions to consider

The diversity of Australian climate zones (Source: Bureau of Meteorology)
Supply and Demand for a Typical Week in Summer 2010 – Baseline Simulation

Centre for Energy and Environmental Markets

Cartoon graph showing the supply and demand for electricity in the National Electricity Market (NEM) in 2010, indicating fluctuations throughout the day.
Supply and Demand for a Challenging Week in Winter 2010 – Baseline Simulation

The chart illustrates the supply and demand for the National Electricity Market (2010). The graph shows various energy sources such as unserved, biofuel, hydro, pumped-hydro, and different CSTs (Tibooburra Airport CST, Longreach Aero CST, Roma Airport CST, White Cliffs AWS CST, Nullarbor CST, Woomera Aerodrome CST). The chart highlights the fluctuation in energy supply and demand, indicating that CST does not behave like a fluctuating baseload power station in winter. Much GT energy is used.
Work in progress: Simulation extensions and Search

- **Cost model** – using AETA (BREE, 2012)
  - 2030 projected annualised capital cost ($/kW/yr)
  - Fixed O&M ($/kW/yr) and Variable O&M ($/Mwh)
  - Optionally including ‘high level’ indicative transmission costs

- **Regional model**
  - Each “generator” assigned to a region
  - Dispatch algorithm is now region-aware
  - Tracks hourly energy exchanges between regions

- **Search algorithm**
  - genetic algorithm seeks mix of technologies and locations to minimise overall industry annualised (capital and operating) cost *(including cost of USE)*
A basis for cost comparisons?

Existing plants will eventually require replacement

Climate change requires an effective response

Thermal efficiency versus plant age in the NEM (coal only). Source: Noone (2012)
Possible Replacement scenario

- Replace ageing plants but unchanged fuel types
  - Direct substitute
    - eg. supercritical black coal like-for-like
  - Some upgrading to best available
    - eg. subcritical brown coal to supercritical brown coal
  - Some miscellaneous cases
    - eg. steam turbines fired by natural gas to CCGT

- Calculate cost to meet 2010 demand
  - Re-calculate SRMC for every plant
  - Calculate 2010 operating costs using dispatch data
    - *Exclude plant if not dispatched in 2010*
  - Assume carbon pricing would not alter generator dispatch

*Note: emissions fall 20% from current NEM levels*
Preliminary findings (still under peer review)

A$\text{b/yr}$ for AETA high and low technology cost scenarios

<table>
<thead>
<tr>
<th>Without transmission</th>
<th>With transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low cost</td>
<td>Low cost</td>
</tr>
<tr>
<td>High cost</td>
<td>High cost</td>
</tr>
<tr>
<td>19.6</td>
<td>21.2</td>
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<tr>
<td>22.1</td>
<td>24.4</td>
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</tbody>
</table>

At carbon prices of $50\text{-}100/t\text{CO}_2$ 100% renewables costs can be lower cost than ‘replacement’ scenario
Qualifications, limitations and further work

- Preliminary findings only at this stage
- Simulation and Search limitations
  - 2010 only, hourly resolution and small number of generator sites due to limited data,
  - No modelling of plant or network failures for improved reliability assessments
  - Network model not complete, no constraints
  - Reference scenario not a likely future
- Further work
  - Improve temporal, spatial data resolution
  - Additional scenarios for comparison (eg, CCS, all gas, nuclear)
  - Compare, contrast, learn from and help inform other forthcoming modelling efforts including *AEMO 100% renewables scenario*
### IEA perspective on global clean energy progress, and policy needs towards protecting the climate (max 2 deg.C warming), (Energy Technology Perspectives, 2012)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Status against 2DS objectives</th>
<th>Key policy priorities</th>
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<tbody>
<tr>
<td>HELE coal power</td>
<td>Efficient coal technologies are being deployed, but almost 50% of new plants in 2010 used inefficient technology.</td>
<td>CO₂ emissions, pollution and coal efficiency policies required so that all new plants use best technology and coal demand slows.</td>
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<tr>
<td>Nuclear power</td>
<td>Most countries have not changed their nuclear ambitions. However, 2025 capacity projections are 15% below pre-Fukushima expectations.</td>
<td>Transparent safety protocols and plans; address increasing public opposition to nuclear power.</td>
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<td>Renewable power</td>
<td>More mature renewables are nearing competitiveness in a broader set of circumstances. Progress in hydropower, onshore wind, bioenergy and solar PV are broadly on track with 2DS objectives.</td>
<td>Continued policy support needed to bring down costs to competitive levels and to prompt deployment to more countries with high natural resource potential is required.</td>
</tr>
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<td></td>
<td>Less mature renewables (advanced geothermal, concentrated solar power [CSP], offshore wind) not making necessary progress.</td>
<td>Large-scale RD&amp;D efforts to advance less mature technologies with high potential.</td>
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*CO₂ reduction share by 2020*