Possibilities for 100% renewables in Australia’s electricity sector

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How and when can Australia go 100% renewable?
AIE Sydney Branch Meeting
12 May 2014
Growing interest in future high RE electricity sector

- Many drivers including
  - climate change and other environmental impacts
  - energy security (most countries see fossil fuel $ as economic liabilities)
  - falling costs for some key renewable technologies, deployment success
  - poor progress with some of the ‘alternatives’

- Some key questions
  - Technical feasibility? – can high (even 100%) renewables mixes utilizing highly variable and somewhat unpredictable solar and wind reliably meet demand at all times and locations
  - If yes, is it an ethical course of action and will it facilitate broader sustainability objectives
  - If yes, Economic feasibility? – is 100% renewables economically worth doing given likely costs vs costs of inaction, other options
  - If yes, how might we get there and what is required now
Significant regions of world currently have local energy deficits

Figure TS-5 | Number of people in countries that are dependent on imported oil
Some (but not all) key RE technology costs falling

… or not rising as fast as costs of some other options

(AIE, 2013)
Non-climate enviro impacts also becoming key drivers

“China’s State Council has announced that it is banning the construction of new coal-fired power plants near Beijing, Shanghai and Guangdong. The goal is to cut air pollution in the country’s eastern megalopolises. The hope is that by 2017 Beijing residents will be breathing in 25% less fine particulate matter than in 2012.”

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An elephant in the room – Climate Change

- Currently a lack of domestic and international progress, apparent loss of public and political interest and will in some jurisdictions
- … but even a dead elephant in the room is a problem
Climate protection requires major global… and hence Australian emissions reductions

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With major job ahead for electricity sector

Direct Sectoral CO₂ and Non-CO₂ GHG Emissions in Baseline and Mitigation Scenarios with and without CCS

(IPCC, 2014)
RE one of the few emission reduction successes to date

... although progress may be faltering and still a long way to go

*Other key success is falling demand in some OECD countries*

**1.3 Annual capacity investment**

**(IEA, 2013)**

![Graph showing annual capacity investment](image)

**FIGURE 5. GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY BY SECTOR, 2013, AND GROWTH ON 2012, $BN**

<table>
<thead>
<tr>
<th>Sector</th>
<th>2013</th>
<th>2012</th>
<th>2011</th>
<th>Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>114</td>
<td>80</td>
<td>80</td>
<td>-20%</td>
</tr>
<tr>
<td>Wind</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>-1%</td>
</tr>
<tr>
<td>Biomass &amp; w-t-e</td>
<td>8</td>
<td>5</td>
<td>5</td>
<td>-28%</td>
</tr>
<tr>
<td>Biofuels</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>-26%</td>
</tr>
<tr>
<td>Small hydro</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>-16%</td>
</tr>
<tr>
<td>Geothermal</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>38%</td>
</tr>
<tr>
<td>Marine</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>-41%</td>
</tr>
</tbody>
</table>

**FIGURE 23. RENEWABLE POWER GENERATION AND CAPACITY AS A SHARE OF GLOBAL POWER, 2007-2013, %**

Renewables figure excludes large hydro. Renewable capacity figures based on Bloomberg New Energy Finance global totals.

Source: Bloomberg New Energy Finance

**(BNEF, 2014)**
Taking a longer-term perspective, 100% renewables a question of when.. and how

- Our only technically feasible truly long-term option
- ... although seemingly plenty of fossil fuels, other options

<table>
<thead>
<tr>
<th></th>
<th>Historical production through 2005</th>
<th>Production 2005</th>
<th>Reserves</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[EJ]</td>
<td>[EJ]</td>
<td>[EJ]</td>
<td>[EJ]</td>
</tr>
<tr>
<td>Conventional oil</td>
<td>6069</td>
<td>147.9</td>
<td>4900–7610</td>
<td>4170–6150</td>
</tr>
<tr>
<td>Unconventional oil</td>
<td>513</td>
<td>20.2</td>
<td>3750–5600</td>
<td>11,280–14,800</td>
</tr>
<tr>
<td>Conventional gas</td>
<td>3087</td>
<td>89.8</td>
<td>5000–7100</td>
<td>7200–8900</td>
</tr>
<tr>
<td>Unconventional gas</td>
<td>113</td>
<td>9.6</td>
<td>20,100–67,100</td>
<td>40,200–121,900</td>
</tr>
<tr>
<td>Coal</td>
<td>6712</td>
<td>123.8</td>
<td>17,300–21,000</td>
<td>291,000–435,000</td>
</tr>
<tr>
<td>Conventional uranium</td>
<td>1218</td>
<td>24.7</td>
<td>2400</td>
<td>7400</td>
</tr>
<tr>
<td>Unconventional uranium</td>
<td>34</td>
<td>n.a.</td>
<td></td>
<td>7100</td>
</tr>
</tbody>
</table>

(Global Energy Assessment, 2012)

(Murphy, http://physics.ucsd.edu/do-the-math/, 2012)

[Diagram of energy scale and historical energy production]

(UNSW: THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA)
Growing plans on transition pathways

DK Energy Agreement, March 22 2012

- With the Energy Agreement of March 22, we have succeeded in obtaining broad political commitment to an ambitious green transition for Denmark that focuses on energy savings throughout society and promotes renewable energy in all sectors.
- This agreement implies a 12% reduction of gross energy consumption in 2020 in comparison to 2006; a share of 35% renewable energy in 2020; and 50% wind energy in Danish electricity consumption in 2020.
- The agreement is important for delivering on the political goal that Denmark’s entire energy supply (electricity, heating, industry and transport) is covered by renewable energy in 2050.
Some alternatives struggling at present

**CARBON CAPTURE AND STORAGE**

CCS is another area of technology that could help to curb emissions, if applied to coal- or gas-fired power stations or to carbon-intensive industrial plants such as cement works. Progress with carbon capture has, however, been disappointing in recent years. Five projects at demonstration scale (1MtCO2/yr) have started construction or operations but this is still short of 2005 G8 targets of 20 operational projects by 2020.

In 2013, investment fell to just $1.8 billion, down 59% from 2012’s $4.3 billion. Last year’s total was split between government and corporate R&D spending, steady at $1.6 billion, and asset finance, at just $128 million compared to $2.7 billion the previous year.

*(BNEF, 2014)*

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**Annual Variation in Global Electricity Production since 2000 from Nuclear, Wind and Solar Photovoltaics (in TWh/y)**

*World Nuclear Status Report, 2013*

**1.11 Annual capacity investment**

*(IEA, 2013)*
Technical feasibility: range of proven renewables

A range of renewable technologies more advanced that CCS, or Nuclear Gen IV
Technical feasibility: ‘what exists is possible’ wind a significant contributor in growing number of electricity industries around the world.
High renewables for the NEM?
A significant change from current mix with some hydro, modest wind
Note missing PV, other non-registered renewables

Figure 1.2
Large electricity generators in the National Electricity Market

QLD: Av. load 5600MW
Gen Capacity 12,000MW

NSW: Av. load 8500MW
Gen Capacity 16,000MW

VIC: Av. load 5700MW
Gen Capacity 11,000MW

SA: Av. load 1500MW
Gen Capacity 4000MW

TAS: Av. load 1200MW
Gen Capacity 3000MW

The Australian National Electricity Market

AIE Forum - 100% RE for the Australian electricity sector

(AER, 2012)
Technical feasibility?: Simulations based on hourly estimates of RE availability across the NEM versus demand – eg. a challenging Week in Winter 2010

(Elliston, 2012)
Economic feasibility - 100% RE findings

A$\text{b/yr for AETA} \text{ high and low technology cost scenarios} \quad \text{(Elliston, 2013)}

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

Generation mix

- By capacity
- By energy

Current NEM costs approx. $10b/year. At carbon prices of $50-100/tCO2 100% renewables costs can be lower cost than ‘replacement’ scenario
Additional scenarios for comparison

- **CCGT**: conventional CCGTs plant, existing NEM, OCGT
- **CCGT + CCS**: as above with CCS on CCGTs
- **Coal + CCS**: supercritical pulverised black coal with post-combustion CCS, existing hydro, OCGT

(Elliston, Renewable Energy, 2013)
Scenario 1: Rapid transformation and moderate growth—this scenario assumes strong progress on lowering technology costs, improving demand side participation (DSP), and a conservative average demand growth outlook in the lead up to the year being modelled.

Scenario 2: Moderate transformation and high growth—this scenario assumes current trends in lowering technology costs, moderate DSP, and robust economic growth in the lead up to the year being modelled.
Comparing 100% RE versus other options

- Treasury - No carbon price
- Treasury: 550 ppm
- Treasury: 450 ppm
- CSIRO (Low, Medium, High fuel prices)
- AEMO 100% Renewables Scenarios (original, with trajectory costs)

(Riesz, 2013)
Does high RE add or reduce risk?

(Vithayasrichareon, 2013)
How to get there? Better understand how markets are responding to renewables already present

(AEMO, 2013)

<table>
<thead>
<tr>
<th>Energy source</th>
<th>South Australia registered generation capacity</th>
<th>Electricity generated in 2012–13 by energy source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Megawatts (MW)</td>
<td>Percentage of total</td>
</tr>
<tr>
<td>Gas</td>
<td>2,672</td>
<td>50%</td>
</tr>
<tr>
<td>Wind</td>
<td>1,203</td>
<td>23%</td>
</tr>
<tr>
<td>Coal</td>
<td>770</td>
<td>14%</td>
</tr>
<tr>
<td>Rooftop PV*</td>
<td>400</td>
<td>7%</td>
</tr>
<tr>
<td>Diesel</td>
<td>270</td>
<td>5%</td>
</tr>
<tr>
<td>Landfill methane/landfill gas</td>
<td>16</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Hydro</td>
<td>3</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Total</td>
<td>5,334</td>
<td>100%</td>
</tr>
</tbody>
</table>

(Cludius, 2014)
Questions of future market design for high RE

- Single platform (no day ahead)
- Unit commitment self-managed
- Renewables fully participate in market
- Sophisticated frequency ancillary services market
- Strong price signals for flexibility
- 5 min
- Single balancing area
- Energy-only

(Riesz, 2013)
Some real retail competition with PV


<table>
<thead>
<tr>
<th>State</th>
<th>#systems</th>
<th>Capacity (MW)</th>
<th>Proportion of dwellings with Solar Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>14,000</td>
<td>38</td>
<td>10%</td>
</tr>
<tr>
<td>NSW</td>
<td>252,000</td>
<td>633</td>
<td>10%</td>
</tr>
<tr>
<td>NT</td>
<td>3,000</td>
<td>11</td>
<td>4%</td>
</tr>
<tr>
<td>QLD</td>
<td>360,000</td>
<td>986</td>
<td>22%</td>
</tr>
<tr>
<td>SA</td>
<td>160,000</td>
<td>450</td>
<td>25%</td>
</tr>
<tr>
<td>TAS</td>
<td>18,000</td>
<td>55</td>
<td>9%</td>
</tr>
<tr>
<td>VIC</td>
<td>201,000</td>
<td>532</td>
<td>10%</td>
</tr>
<tr>
<td>WA</td>
<td>149,000</td>
<td>334</td>
<td>18%</td>
</tr>
<tr>
<td>National</td>
<td>1,157,000</td>
<td>3,039</td>
<td>14%</td>
</tr>
</tbody>
</table>

Follow the money

HPVc: Household PV customers
R: Electricity retailers
NSP: Network service providers

G: Generators
Gov: NSW government
All eC: All electricity customers

(Oliva, 2014)
Smart grids and Demand-Side Participation can improve our options for high RE

4.5 Smart grid technologies

Table 15.1 Emissions reductions and investment needs in the 2DS, by technology

<table>
<thead>
<tr>
<th>Sector</th>
<th>CO₂ savings (Gt) 2050</th>
<th>Cumulative CO₂ savings (Gt) 2010 to 2050</th>
<th>Investment needs (USD trillion) 2010 to 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power generation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioenergy for heat and power</td>
<td>1.7</td>
<td>20.4</td>
<td>0.5</td>
</tr>
<tr>
<td>CCS in power generation</td>
<td>3.3</td>
<td>57.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Concentrating solar power</td>
<td>1.7</td>
<td>22.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Geothermal for heat and power</td>
<td>0.5</td>
<td>7.1</td>
<td>1.3</td>
</tr>
<tr>
<td>High efficiency, low emissions coal</td>
<td>n.a.</td>
<td>n.a.</td>
<td>1.9</td>
</tr>
<tr>
<td>Hydropower</td>
<td>0.9</td>
<td>19.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Nuclear</td>
<td>5.2</td>
<td>59.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Smart grids</td>
<td>1.7</td>
<td>36.4</td>
<td>5.0 to 6.0</td>
</tr>
<tr>
<td>Solar photovoltaic (PV)</td>
<td>1.7</td>
<td>27.7</td>
<td>3.9</td>
</tr>
<tr>
<td>Wind</td>
<td>3.0</td>
<td>61.0</td>
<td>5.9</td>
</tr>
</tbody>
</table>

(IEA, 2012)

(IEA, 2013)

(BNEF, 2014)
Potential policy implications

- Renewables will likely play the key role in any effective global and Australian electricity* supply sector response to climate change
- … and offer other potential benefits
- As such, require major, appropriately targeted and robust deployment oriented policy support
- … as do other potential options
- continuing, and expanding now
- … and as renewable penetrations grow we need governance arrangements to ensure appropriate energy market design, regulation and policy frameworks that can manage the challenges that will emerge
Thank you… and questions

Many of our publications are available at:
www.ceem.unsw.edu.au