Achieving Resource Adequacy in the Australian National Electricity Market

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Outline

- Resource adequacy: managing risks to the continuity of end-use energy service delivery
- Decision-making framework & regimes for achieving resource adequacy
- Managing boundaries between decision-making regimes
- Australian experience to date & future prospects
- Conclusions
Key definitions for this presentation

- What are the key electricity industry objectives?
  - **Technical:** Maintaining the flow of end-use energy services by maintaining near-continuity of energy flow through the electricity industry conversion chain
  - **Economic:** Achieving the above in an economically efficient manner, from short-term to long-term future
  - **Social & environmental:** Achieving the above in a socially & environmentally acceptable manner

- What is (short- & long-term) resource adequacy?
  - Acceptably low risks to the flow of end-use energy services for individual end users (*reliability of supply*) & to the electricity industry overall (*energy conversion chain security*)

Key challenges to resource adequacy

- **Year by year (operation):**
  - Managing increasingly volatile energy flows through a complex conversion chain while minimising cost & risk
  - Growing environmental risks - heatwave, drought, fire

- **Years to decades (investment):**
  - Urgent reductions in climate change emissions:
    1. End-use efficiency, frugality & responsive demand
    2. Near-term supply options: gas; wind; biomass; solar
    3. Long-term supply options: gas & coal with CCS; nuclear; geothermal
  - Network investment to accommodate the above
Key policies for NEM & stationary energy sector more broadly

- Continue EI restructuring to logical conclusion:
  - Direct end-user participation in NEM (rethink retailing):
    - Ancillary service, spot energy & derivative markets
    - AMI: Interval metering of energy, availability & voltage quality with information held in single NEM-wide database
  - Refined NEM ancillary service & energy spot markets
  - Single set of NEM-wide, auction-style derivative markets
- Continue gas industry restructuring to maximise compatibility with NEM
- Introduce efficient emission permit trading or taxes:
  - If permits, all should be auctioned

National Electricity Law: Overall objective for the National Electricity Market (NEM)

- NEL Section 7:
  - The national electricity market objective is to promote efficient investment in, and efficient use of, electricity services for the long term interests of consumers of electricity with respect to price, quality, reliability and security of supply of electricity and the reliability, safety and security of the national electricity system
- Issues with this objective as stated:
  - Ambiguity of the wording with respect to interpretation of terms & trade-offs between sub-objectives
  - Scope of application & potential boundary issues
NEM transmission level reliability target, spot market mechanisms & intervention to meet it (AEMC Reliability Review, 2006)

NEM forecast & actual low reserve conditions (hours/year) (AEMC Comprehensive Reliability Review, 2006)

<table>
<thead>
<tr>
<th>Year</th>
<th>Qld</th>
<th>NSW</th>
<th>Vic</th>
<th>SA</th>
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<tbody>
<tr>
<td>2004 – 2005</td>
<td>17.5</td>
<td>0</td>
<td>0</td>
<td>6</td>
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<tr>
<td>2003 – 2004</td>
<td>11.5</td>
<td>4.5</td>
<td>17.5</td>
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<td>2002 – 2003</td>
<td>2.5</td>
<td>3.5</td>
<td>7</td>
<td>115.5</td>
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<td>2001 – 2002</td>
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<td>0</td>
<td>0</td>
<td>45.5</td>
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<td>2000 – 2001</td>
<td>188</td>
<td>8</td>
<td>67</td>
<td>716</td>
</tr>
<tr>
<td>1999 – 2000</td>
<td>43</td>
<td>33</td>
<td>145</td>
<td>699</td>
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</table>

Forecast duration below the threshold (hours)

<table>
<thead>
<tr>
<th>Year</th>
<th>Qld</th>
<th>NSW</th>
<th>Vic</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 – 2005</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2003 – 2004</td>
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<td>1</td>
<td>4</td>
<td>6</td>
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<td>1</td>
<td>0</td>
<td>0</td>
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<td>2001 – 2002</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2000 – 2001</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>1999 – 2000</td>
<td>5</td>
<td>4</td>
<td>36</td>
<td>88</td>
</tr>
</tbody>
</table>

Actual duration below the threshold (hours)
Contributions to unavailability of supply for small end-users (USA data, AEMC, 2006)

<table>
<thead>
<tr>
<th>Contributor</th>
<th>Average unavailability per customer year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(minutes)</td>
</tr>
<tr>
<td>Generation/transmission</td>
<td>0.5</td>
</tr>
<tr>
<td>132 kV</td>
<td>2.3</td>
</tr>
<tr>
<td>66kV and 33kV</td>
<td>8.0</td>
</tr>
<tr>
<td>11kV and 6.6 kV</td>
<td>58.8</td>
</tr>
<tr>
<td>Low voltage</td>
<td>11.5</td>
</tr>
<tr>
<td>Average shutdowns</td>
<td>15.7</td>
</tr>
<tr>
<td>Total</td>
<td>96.8 minutes</td>
</tr>
</tbody>
</table>

5-year average reliability in EnergyAustralia regions (EnergyAustralia Electricity Network Standards, 2004)
Energy conversion chain uncertainties & risks

End-users will have to play a greater role in managing future uncertainty

- Availability of fossil & nuclear fuels
- Variable renewable energy fluxes
- Climate change impacts
- Conversion chain security

- Generator decisions
- Generator forced outages
- Conversion chain security

- TNSP decisions
- Transmission forced outages
- Conversion chain security

- DNSP decisions
- Distribution network outages
- Conversion chain security

- End-user decisions
- End-use equipment outages
- Reliability of supply

Generation Sector: large generators
Transmission Sector
Distribution sector
End-use sector (including distributed resources)

Primary energy flow
Electricity flow
Electricity flow
Electricity flow

Energy conversion chain uncertainties & risks (geographically local issues in blue)

End-users will have to play a greater role in managing future uncertainty

- Availability of fossil & nuclear fuels
- Variable renewable energy fluxes
- Climate change impacts
- Conversion chain security

- Generator decisions
- Generator forced outages
- Conversion chain security

- TNSP decisions
- Transmission forced outages
- Conversion chain security

- DNSP decisions
- Distribution network outages
- Conversion chain security

- End-user decisions
- End-use equipment outages
- Reliability of supply

Physics & Markets in a Restructured Industry

A restructured electricity industry must understand & efficiently manage, by centralised & decentralised decision-making, the location-dependent risks to the flow of end-use energy services

Primary energy markets
Wholesale Market region
Transmission network
Distribution network
Retail Market 1
Retail Market 2
Retail Market 3
Large end-users

- Small end-user, embedded generators & storage should be supported by energy service advisers

- Wholesale & retail designs should be compatible, with spot & derivative markets that model flow constraints

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Centre for Energy and Environmental Markets
Decision-making framework for a restructured electricity industry

- Governance decision-makers
- Regulators
- System & market operator(s)
- Regulated industry participants
- Competitive industry participants

Underlying societal decision-making

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<table>
<thead>
<tr>
<th>Governance regime</th>
<th>Formal institutions, legislation &amp; policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security regime</td>
<td>Responsible for core integrity on local or</td>
</tr>
<tr>
<td></td>
<td>industry-wide basis, with power to override</td>
</tr>
<tr>
<td>Technical regime</td>
<td>To allow connected industry components to</td>
</tr>
<tr>
<td></td>
<td>function as industry-wide machine</td>
</tr>
<tr>
<td>Commercial regime</td>
<td>To coordinate decentralised decision-</td>
</tr>
<tr>
<td></td>
<td>making according to commercial criteria</td>
</tr>
<tr>
<td></td>
<td>Includes formally designed markets</td>
</tr>
</tbody>
</table>

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Shared responsibility for risks to energy service flow (security & commercial regimes)

Security regime:
- SCADA & AMI
- On-line security assessment
- Central control
- Reliability policy

End-use & distributed resources:
- Energy management systems (security)
- Nodal markets & network access

DNSPs, for radial distribution:
- Distribution system automation (security)
- Network access regime

TNSPs, for meshed transmission:
- Managed by ISO (security)
- Arbitrage in nodal markets

Large generators:
- Operation when directed by ISO (security)
- Nodal markets & network access

Commercial regime:
- Ancillary services, spot energy & derivatives
- Network access

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NEM regions
(NEMMCO SOO, 2006)

State owned Gen & Tx (also Dx & Retail) (ERIG DPs 0611)

1. Generation and transmission cross-ownership

- 5,244 MW govt owned + 2,672 MW under contract + 1,263 MW public/private + 100% of intra-regional transmission
- 11,908 MW govt owned + 100% of intra-regional transmission
- 3,676 MW owned by NSW, Cwth and Vic Govts 100% of intra-regional transmission Govt owned
- 2,246 MW govt owned + 100% of intra-regional transmission
but what kind of forecasts?

A simple typology of uncertainty
(IPCC guidance notes for AR4, 7/05)

<table>
<thead>
<tr>
<th>Type of uncertainty</th>
<th>Indicative example</th>
<th>Typical approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpredictability</td>
<td>Political behaviour</td>
<td>Diverse scenarios</td>
</tr>
<tr>
<td></td>
<td>Chaotic complexity</td>
<td>Ranges from many model runs</td>
</tr>
<tr>
<td>Structural uncertainty</td>
<td>Model inadequacy: incomplete, errors…</td>
<td>Specify assumptions &amp; investigate their validity</td>
</tr>
<tr>
<td>Value uncertainty</td>
<td>Data missing, wrong, inappropriate, poorly understood, varying</td>
<td>Validate by whatever means are available</td>
</tr>
</tbody>
</table>
The art of forecasting

- “Prediction is difficult, especially about the future” (attributed to Niels Bohr)
- Why is this?
  - Science is based on disprovable hypotheses:
    - A currently accepted hypothesis has yet to be proved wrong
    - The most valuable hypotheses are easily disprovable: \( 2 + 2 = 4 \)
  - Facts are required to test a hypothesis
  - A fact is what has happened, not what may happen:
    - There are no facts about the future, only predictions
- Thus, forecasting is Art (opinion-based) not Science

Forecasting approaches #1

- Trend projections of the forecast variable:
  - e.g. assumption of constant exponential growth
  - \textit{Ok if past is a good predictor but not otherwise}
- Econometric projections:
  - Trend projections of assumed causal variables, eg. GDP, population, etc.
  - \textit{Transfers the trend projection problem to the assumed causal variables, hence ok if past is a good predictor but not otherwise}
Forecasting approaches #2

- End-use analysis
  - Engineering, building-block approach
  - Can capture detail better than econometric models but may not correctly anticipate technological change

- System dynamics:
  - Similar to end-use analysis but based on differential equations to incorporate resource constraints
  - A valuable reminder of resource constraints but unlikely to accurately predict when constraints bind

- Scenario analysis (stories about possible futures):
  - Can help assess the potential impact of major change

US experience with energy forecasting #1

(Craig et al, What can history teach us? LBNL-50498, May 2002)

The forecast as extrapolation of past behaviour

Forecasts of US energy use from 1970’s illustrates the limitations of extrapolation from the past

Lovins “Soft energy paths”
US experience with energy forecasting #2
(Craig et al, What can history teach us? LBNL-50498, may 2002)

The forecast as sales pitch #A

Project independence, 1973
“Self sufficiency by 1980 through conservation & expanded production”

actual imports higher in 1980 than in 1973

US experience with energy forecasting #3
(Craig et al, What can history teach us? LBNL-50498, may 2002)

The forecast as sales pitch #B


In practice there were no new orders from 1980 due in part to the 1970’s oil shocks & the Three Mile Island accident.
US experience with energy forecasting #4
(Craig et al, What can history teach us? LBNL-50498, may 2002)

Limitations of econometric forecasting

The historical relationship between US GNP & energy changed in the 1970’s & the rate of GNP growth slowed.

US experience with energy forecasting #5
(Craig et al, What can history teach us? LBNL-50498, may 2002)

Limitations of end-use analysis

Failure to predict the end of a rising trend in the fraction of total primary energy used to generate electricity.
US experience with energy forecasting #6
(Craig et al, What can history teach us? LBNL-50498, may 2002)

Experts are not objective: traditionalist vs reformist opinion of forecasts

<table>
<thead>
<tr>
<th>Study</th>
<th>Quality*</th>
<th>Attention*</th>
<th>Influence*</th>
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<tr>
<td>Ford Energy Policy Project</td>
<td>D</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Project Independence Report</td>
<td>C</td>
<td>E</td>
<td>B</td>
</tr>
<tr>
<td>ERDA-48 and ERDA ’76-1</td>
<td>D</td>
<td>E</td>
<td>D</td>
</tr>
<tr>
<td>MOPPS</td>
<td>C</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Ford-MITRE Study</td>
<td>B</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Lovins “soft paths”</td>
<td>E</td>
<td>A</td>
<td>A</td>
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<tr>
<td>WAES Study</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>CIA assessment of int’l energy</td>
<td>C</td>
<td>B</td>
<td>B</td>
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<tr>
<td>CONAES</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Stobart and Yerges</td>
<td>D</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>RFF-Mello Study</td>
<td>A</td>
<td>B</td>
<td>D</td>
</tr>
<tr>
<td>Ford-RFF Study</td>
<td>A</td>
<td>A</td>
<td>D</td>
</tr>
</tbody>
</table>

*Participants assigned letter grades to each study, from A (highest) to E (lowest).

Trad., traditionalist group; Refor., reformist group (see text for details); ERDA, Energy Research and Development Administration; MOPPS, Market Oriented Program Planning Study; MITRE Corporation; WAES, Workshop on Alternative Energy Strategies; CONAES, National Academy of Sciences Committee on Nuclear and Alternative Energy Strategies; RFF, Resources for the Future.

US experience with energy forecasting #7
(Craig et al, What can history teach us? LBNL-50498, may 2002)

Recommendations

- Document [all identified] assumptions
- Choose an approach that fits the purpose
- Beware of obsession with technical sophistication
- Watch out for discontinuities & irreversibility
- Do not assume fixed laws of human behaviour
- Use [a set of] scenarios
- Use combined approaches
- Expect the unexpected & design for uncertainty
- Communicate effectively
- Be modest [forecasters tend to be prisoners of their own world view]
Temperature-sensitive load (Victoria) size & variability (Energy Efficient Strategies, 2004)

Air conditioner ownership (no. per house) (Energy Efficient Strategies, 2006)
Air conditioner market shares by type
(Energy Efficient Strategies, 2006)

Figure 5 – National Share of Air Conditioner Type

Each non-A/C residential owner subsidises each residential A/C owner over $70 pa
(H Colebourn, EA, 2006)

<table>
<thead>
<tr>
<th></th>
<th>Non A/C</th>
<th>A/C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual energy MWh</td>
<td>5.1</td>
<td>7.0</td>
<td>13.2</td>
</tr>
<tr>
<td>No. Customers, Millions</td>
<td>0.57</td>
<td>0.75</td>
<td>1.32</td>
</tr>
<tr>
<td>Annual Energy</td>
<td>35%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Proportion of revenue thru tariffs</td>
<td>37%</td>
<td>63%</td>
<td></td>
</tr>
<tr>
<td>Revenue FY06 $M</td>
<td>157</td>
<td>273</td>
<td>430</td>
</tr>
<tr>
<td>Demand on network kW</td>
<td>1.8</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>Proportion of demand</td>
<td>25%</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>Marginal cost of supply (90%) $M</td>
<td>97</td>
<td>290</td>
<td>387</td>
</tr>
<tr>
<td>Balance reallocated $M</td>
<td>16</td>
<td>27</td>
<td>43</td>
</tr>
<tr>
<td>Total cost reflective $M</td>
<td>113</td>
<td>317</td>
<td>430</td>
</tr>
<tr>
<td>&quot;Cross subsidy&quot; $M</td>
<td>44</td>
<td>-44</td>
<td></td>
</tr>
<tr>
<td>Annual customer charge</td>
<td>$277</td>
<td>$362</td>
<td>326</td>
</tr>
<tr>
<td>... subsidy per customer</td>
<td>$78</td>
<td>-$59</td>
<td></td>
</tr>
<tr>
<td>... proportion of cost reflective</td>
<td>139%</td>
<td>84%</td>
<td></td>
</tr>
</tbody>
</table>

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Notes:
1. Also ~700 MW demand actively responding to spot price
2. Climate change implications of new coal

Figure 2.9 ANTS Verification Studies, Unaugmented Market Simulation Case, Generation Expansion by Region  (NEMMCO SOO, 2006)

Figure 2.10 ANTS Verification Studies, Unaugmented Market Simulation Case, Generation Expansion by Technology  (NEMMCO SOO, 2006)
NEM commercial & security processes

- Short Term (ST) PASA
  - Upto 40 hr ahead, 30 min res. 30 min update
  - 1 hr ahead, 5 min res. 5 min update
  - 10 yr ahead, 1 yr update

- Medium Term (MT) PASA
  - Upto 2 yr ahead, 1 day (MD) res., 1 wk update
  - 1 wk ahead, 30 min res., 2 hr update
  - Upto 40 hr ahead, 30 min res., 30 min update

- 5 min dispatch & pricing
  (4 sec AGC, online security processes)
  - 5 min predisp.
  - 5 min disp.

- 30 min predisp.

Source: NEMMCO

Resource Adequacy in the Australian National Electricity Market

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Transgrid CT failure @ 2142 13/8/04 led to 3100 MW gen trip. Frequency fell to 48.9Hz, ~2100 MW load shed in NSW, Qld, Vic & SA

~600MW

~900MW
NEM energy revenue, 13/8/04 (IES)

NEM FCAS revenue 13/8/04 (IES)
16 Jan 2007: Blackout in Victoria
(Assistance from NEM Watch & Stuart Thorncraft)

Contributing factors:
- Record demand due to high temperature
- 3 tx lines tripped due to bushfires

Outcomes:
- System separation
- 2600MW load shed & restored
14:50 – 15:00

- 14:50 Lack of reserve conditions declared by NEMMCO
- 14:50 Market notified
- 15:00 Imports into Vic ~ 2700MW

(S Thorncraft)
15:02
- Multiple contingency event occurs
- NEM splits into 2 islands
- LOR3 declared
- Initial load shedding of ~1700MW in VIC
- AGC reconfigured to manage islands

(S Thorncraft)

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15:03-15:25
- Loss of another ~900MW in VIC
- AGC reconfigured

(S Thorncraft)

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15:27-15:40
- Work to align VIC & SA for synchronisation

**Directioned plant to provide freq. control**
NSP directed to manually manage frequency for resynchronisation

**Certain generators directed to provide freq. control**

**Certain generators directed to provide available capacity**

(S Thornycraft)

15:42
- Reconnected SA & VIC
- AGC reconfigured

(S Thornycraft)
15:49-16:12
- Load restoration (potlines & some customer load)
- System declared secure
- ...but insufficient reserves to restore all load

(S Thorncraft)

16:20-16:54
- Load shedding to assist frequency control
- Offline generator brought online
- VOLL override conditions in place

(S Thorncraft)
17:25-17:55

- System stabilised
- Load restoration process
- VoLL override still in place

(S Thorncraft)

17:57-18:15

- System reconnected
- Load restoration
- LOR3 withdrawn

(S Thorncraft)
16 January 2007 Outcomes

- Victoria cabinet met to consider power rationing
- Load shedding estimated to cost Melbourne ~$10m
- Spot market revenues earned by participants:
  - very high in Victoria due to VoLL override
  - negative revenue in Tasmania due to negative price – why?
- Very high ancillary service prices due to local sourcing of ancillary service providers
- ...But market proceeded and core system returned to normal in around 3 hours
- Market incentives seem to be aligned with what was needed physically

Energy Reform Implementation Group Review: initial thinking (www.erig.gov.au)

- Proposed overarching goal:
  - Economic efficiency (productive, allocative, dynamic)
- Proposed government role:
  - Adopt a nationally consistent approach
  - Set supply standards, including reliability
  - Design governance regime to deliver overarching goal
  - Eliminate barriers to entry in competitive industry sectors
  - Emulate competitive market outcomes in regulation
  - End direct government participation in the industry
Energy Reform Implementation Group Review: initial thinking continued

- **Market structure:**
  - Prefer private ownership; not concerned about vertical re-integration; retain energy-only market
  - Fully remove retail price caps & expose end-users to volatile spot prices

- **Transmission:**
  - Don’t over-invest to remove all flow constraints
  - Introduce a formal national network development plan
  - Integrate reliability & economic investment tests

- **Energy financial market concerns:**
  - Retail price caps; govt. ownership; lack of carbon price

**Transmission planning options**

(ERIG discussion papers)

- Weak information co-ordination
- Decentralised decision-making

- National planning
- Information co-ordination
- Decentralised decision-making

**Current NEM arrangements fall here**

**Note:**
These options may not overcome the high level of uncertainty inherent in network planning
Enhanced NEM structure with active end-user participation

Resource Adequacy in the Australian National Electricity Market

Key policies for NEM & stationary energy sector more broadly

- Continue EI restructuring to logical conclusion:
  - Direct end-user participation in NEM (rethink retailing):
    - Ancillary service, spot energy & derivative markets
    - AMI: Interval metering of energy, availability & voltage quality with information held in single NEM-wide database
  - Refined NEM energy & ancillary service markets
  - Single NEM-wide, auction-style derivative market
- Continue gas industry restructuring to maximise compatibility with NEM
- Introduce efficient emission permit trading:
  - All permits should be auctioned
Conclusions

- Broad approach needed to achieve a coherent approach to resource adequacy:
  - Governance, security, technical & commercial regimes

- Strengths of the Australian NEM approach:
  - Consistent & effective security, technical & commercial regimes (governance not bad)

- Weaknesses of the Australian NEM approach:
  - Government-owned businesses remain contentious
  - Retail price caps still in place for some small end-users
  - Network investment remains contentious
  - Incoherent & ineffective climate change policy

- Weaknesses can be reduced or eliminated

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