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Integrating renewable energy into the Australian National Electricity Market

Hugh Outhred (*h.outhred@unsw.edu.au)*

Renewable Energy Integration Workshop

UNSW, 17 August 2009

www.ceem.unsw.edu.au

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UNSW-CEEM research team in renewable energy integration

- Academic and/or Research staff:
  - Hugh Outhred, Iain MacGill, Ted Spooner, Muriel Watt, Rob Passey, Merlinde Kaye
  - John Boland (visiting from University of South Australia)
- PhD students:
  - Nick Cutler (degree awarded)
  - Stuart Thorncraft (in examination)

UNSW-CEEM research in renewable energy integration

Year(s)	Project (client)
2003	Wind energy & the Australian NEM with particular reference to South Australia (Australian Greenhouse Office - AGO)
2003	National Wind Power Study – an estimate of readily accepted wind energy in Australian electricity industries (AGO)
2005-2009	Facilitating the Uptake of Stochastic Renewable Energy in the Australian National Electricity Market: Wind Energy (AGO)
2006-2007	Meeting the Challenges of Integrating Renewable Energy into Competitive Electricity Industries (AGO, REEEP & REIL)
2006-2009	Standards for off-grid & grid-connected PV systems (AGO)
2007-2008	Integrating PV into the Western Australian electricity network (WA Office of Energy)
2008-2010	IPCC Special Report on Renewable Energy & Climate Change Mitigation (DRET)
2009-2010 (draft)	Visual decision support tool to forecast large, rapid changes in wind power & manage power system security in the NEM (AEMO)

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Areas covered in UNSW research

- Renewable energy resource forecasting:
  - Mostly wind energy forecasting
- Power system engineering for RE integration:
  - Load flow & stability analyses
  - Design standards & grid-connection requirements
  - Frequency & voltage ancillary services
- Market design & economic value
  - Resource matching with respect to electricity demand
  - Design of electricity markets for high penetration levels
  - Grid extension issues

Evolution of the Australian approach to electricity industry restructuring

- Conceptual foundation (based in Engineering & Economics):
  - Schweppe et al, *Homeostatic Utility Control,* IEEE, 1980
  - Outhred & Schweppe, *Quality of Supply Pricing,* IEEE, 1980
  - Kaye & Outhred, *A Theory of Electricity Tariff Design,* IEEE, 1989
  - Outhred, *Principles of a Market-Based Electricity Industry,* IEE, 1993
  - Outhred & Kaye, Incorporating Network Effects in a Competitive Electricity Industry, in Einhorn & Siddiqui (eds), *Issues in Transmission Pricing & Technology*, Kluwer, 1996
- Practical implementation:
  - COAG brief to NGMC, 1990: *Design an electricity industry that is economically efficient & environmentally sound*
  - Differing & evolving Victorian & NSW internal market designs, 1994-97, including computer simulation of NEM trading rules at UNSW, 1995-6
  - Australian National Electricity Market (NEM) from 1998

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Decision-making framework for a competitive electricity industry

Governance regime	▪ Formal institutions, legislation & policies ▪ *Informal social context including politics*
Security regime	▪ Responsible for core integrity on local or industry-wide basis, with power to override
Technical regime	▪ To allow connected industry components to function as industry-wide machine
Commercial regime	▪ To coordinate decentralised decision-making according to commercial criteria ▪ Includes formally designed markets

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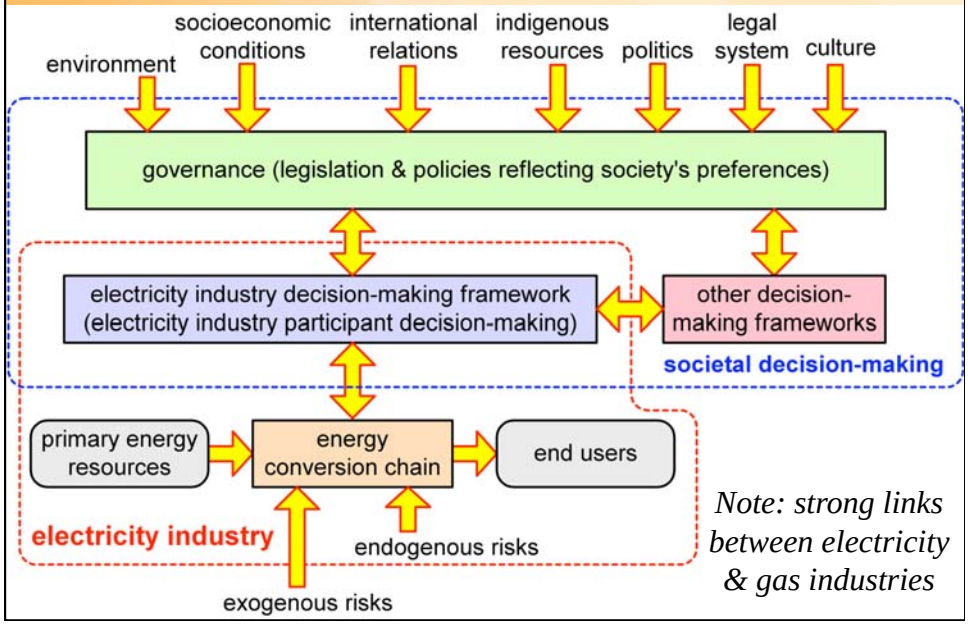
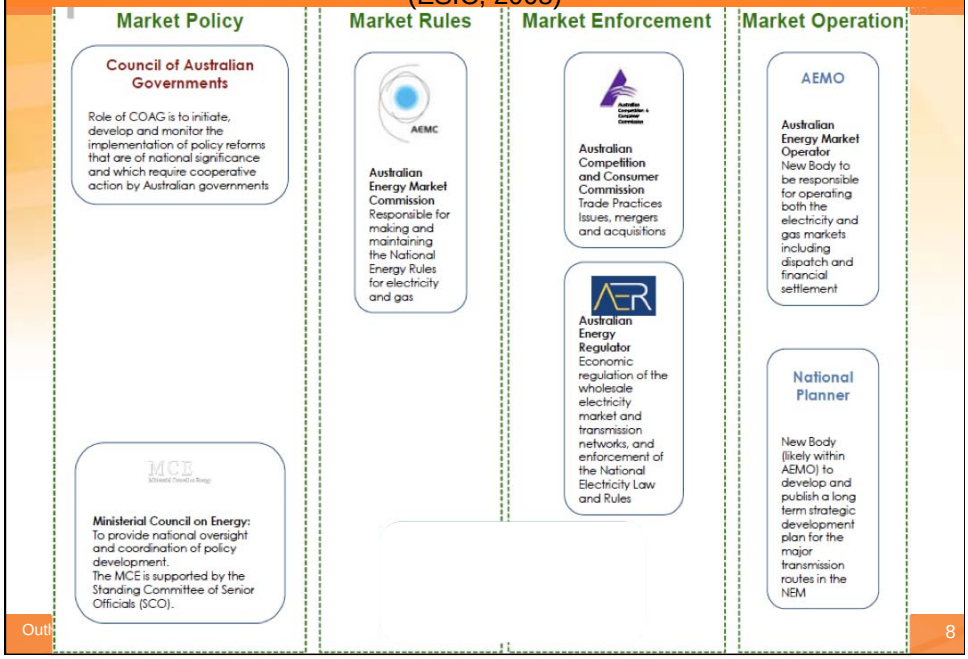
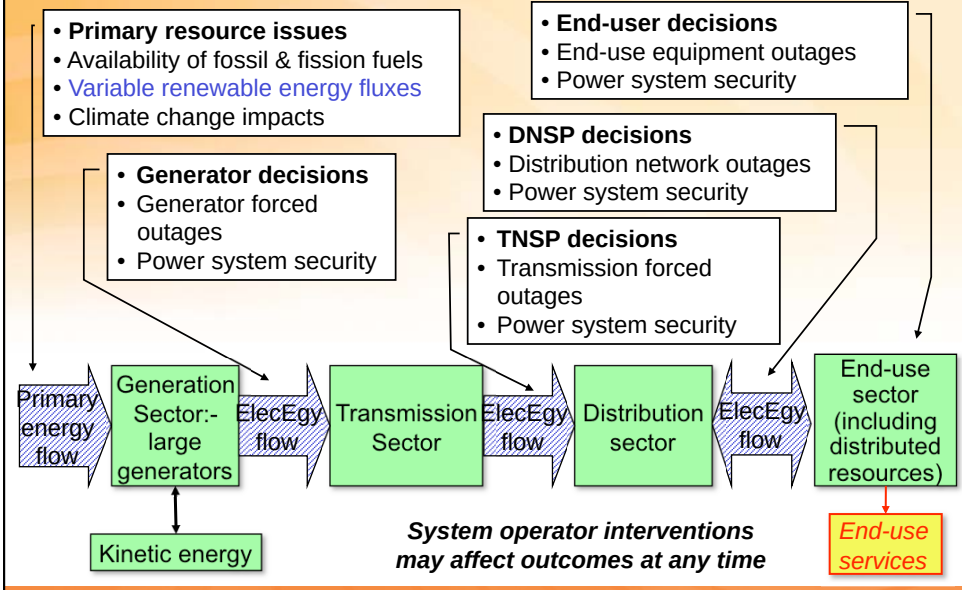
Electricity industry decision-making within the broader societal context (Thorncraft, 2009)



Aust. stationary energy sector governance & security (ESIC, 2008)



Electricity industry energy conversion chain uncertainties & risks to end-use service delivery



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Features of wind & solar energy fluxes

- Non-storable, stochastic primary energy fluxes:
  - Not available when wind or insolation low
- Wind & solar generation type & size:
  - Wind & solar thermal electric: large & free-standing
  - Solar PV: small, building-integrated, electronic interface
- RE generation can possibly contribute to:
  - Local voltage & waveform control
  - System security management
  - *Subject to rating, fault ride-through capability & coordination between multiple generating units*

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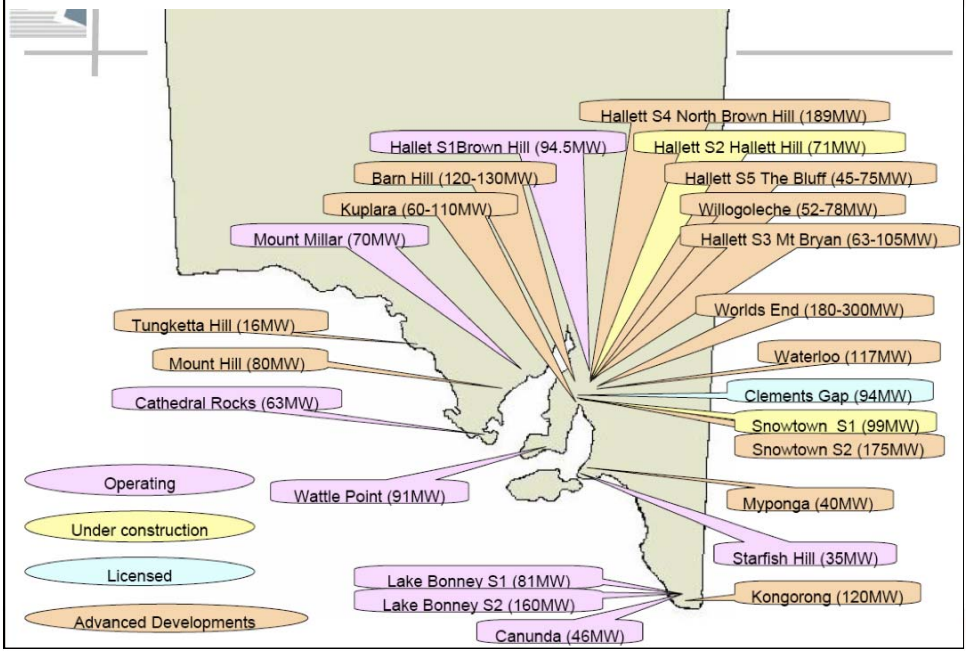
Key issues for wind energy integration

- Physical complexity:
  - Shared, non-storable, time-varying primary energy flow; concerns about robustness to disturbances
- Commercial complexity:
  - Electricity industry infused with short- to long-term risks that are difficult to commercialise (i.e. correctly allocate to industry participants)
- Institutional complexity:
  - Shared issues in wind farm approvals, grid connection & management of power system security

Wind farms in South Australia (ESIPC APR, 2008)



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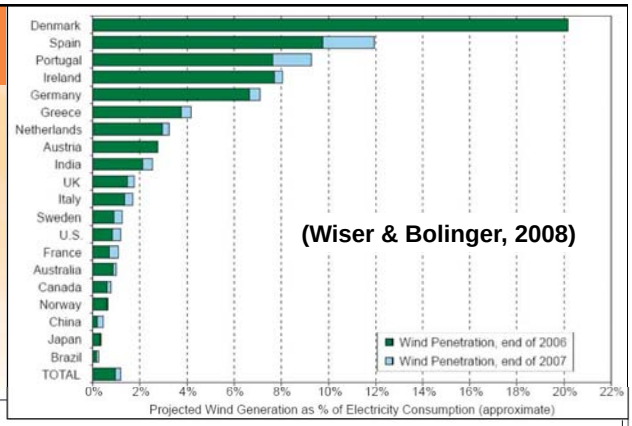
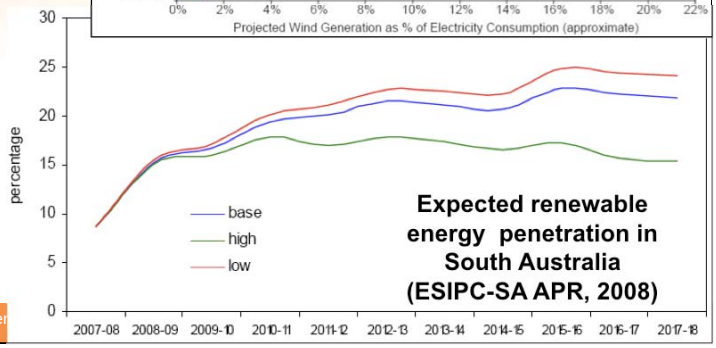
Wind penetration (%energy) globally & for South Australia



(Wiser & Bolinger, 2008)



Expected renewable energy penetration in South Australia (ESIPC-SA APR, 2008)

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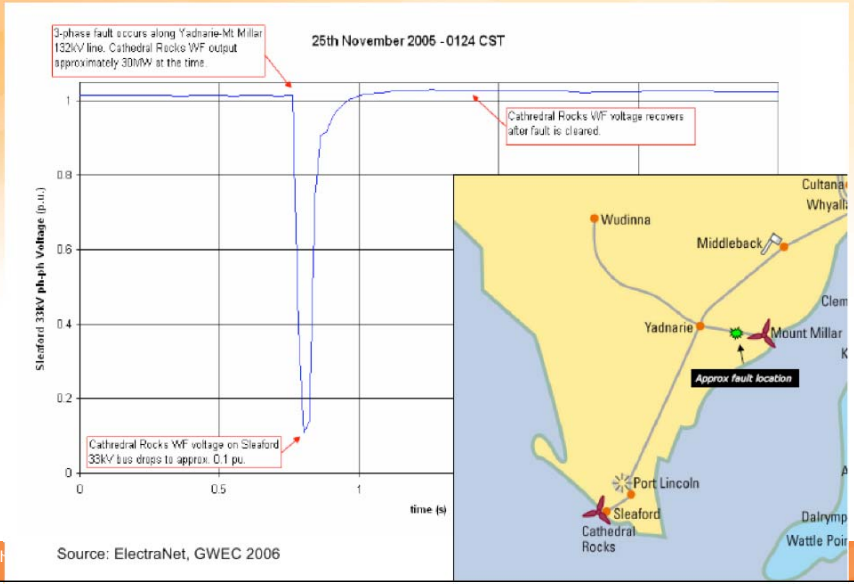
Fault ride through – Example 1



Source: ElectraNet, GWEC 2006

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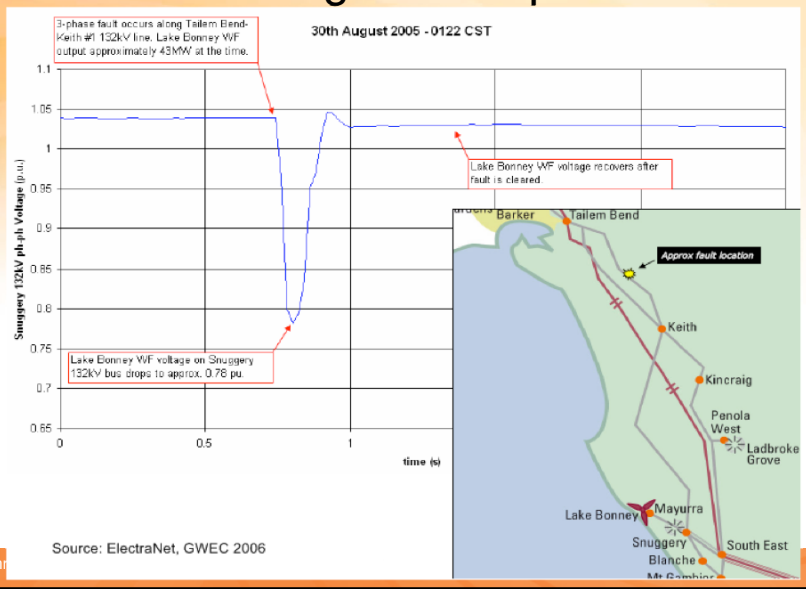
Fault ride through -Example 2



Source: ElectraNet, GWEC 2006

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Scheduled & non-scheduled generators in the NEM

- Scheduled
  - Submission of dispatch offers
  - Compliance with targets
  - Causer-pay for ancillary services
  - Ability to offer ancillary services
  - Publication of individual outputs forecasts, offers and actual output
  - Comply with technical standards
- Non-scheduled
  - Includes “intermittent Generation”
  - Are treated as negative demand
  - Can only be curtailed (by NEMMCO) if system security is at risk

  NEW
  - Publication of grouped outputs, forecasts and actual output
  - New Technical Standards

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Semi-Scheduled now introduced for wind

- **Scheduled**
  - Submission of dispatch offers
  - Compliance with targets
  - Causer-pay for ancillary services
  - Ability to offer ancillary services
  - Publication of individual outputs:- forecast, offered & actual
  - Comply with technical standards
- **Semi-Scheduled**
  - Submission of dispatch offers
  - Causer-pay for ancillary services
  - Ability to offer ancillary services
  - Are treated as positive supply
- If involved in a constraint
  - Compliance with targets if less than forecast
- Publication of data
- **Non-scheduled**
  - Are treated as negative demand
  - Can only be curtailed (by NEMMCO) if system security is at risk

NEW

- Publication of grouped outputs forecast and real
- New Technical Standards

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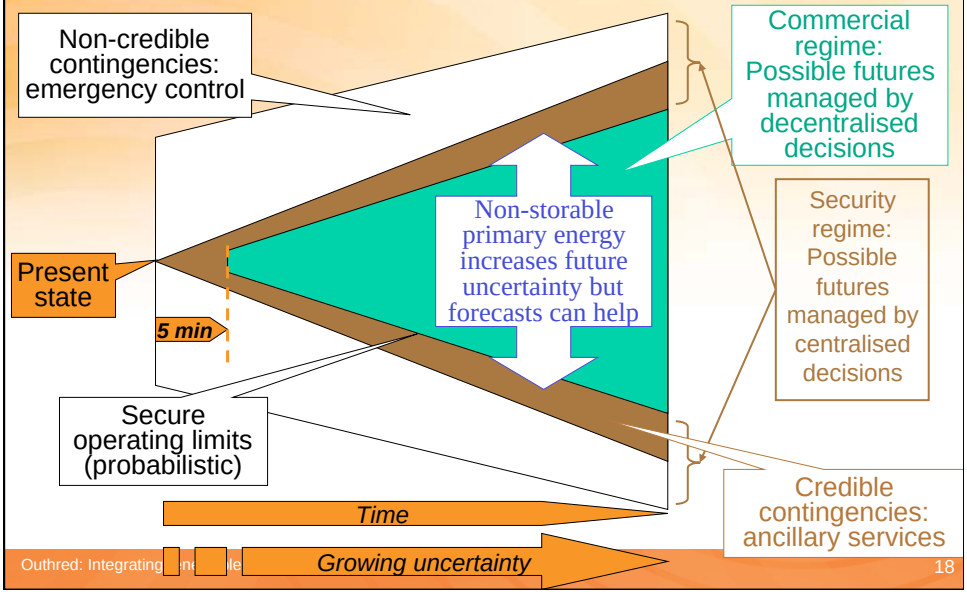
Security & commercial regimes



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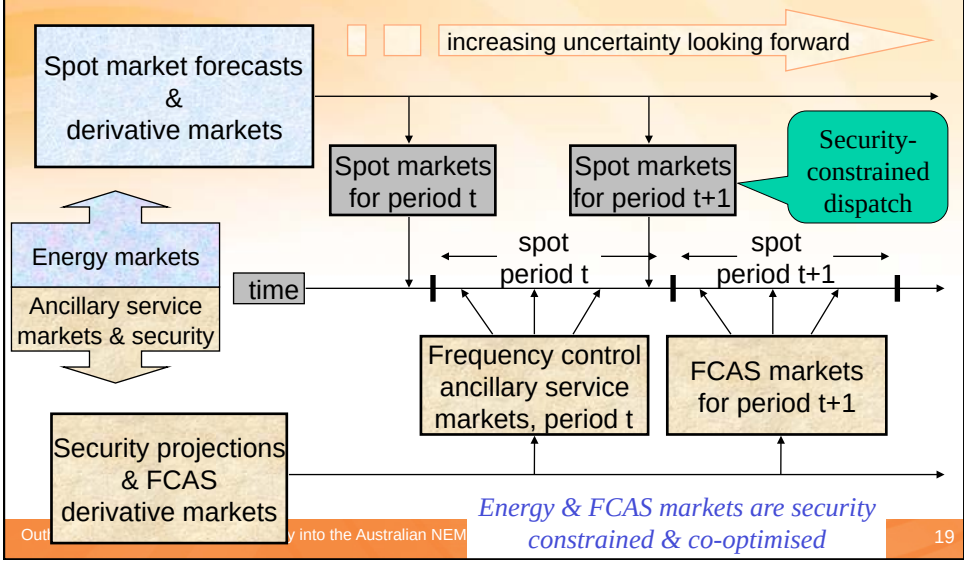
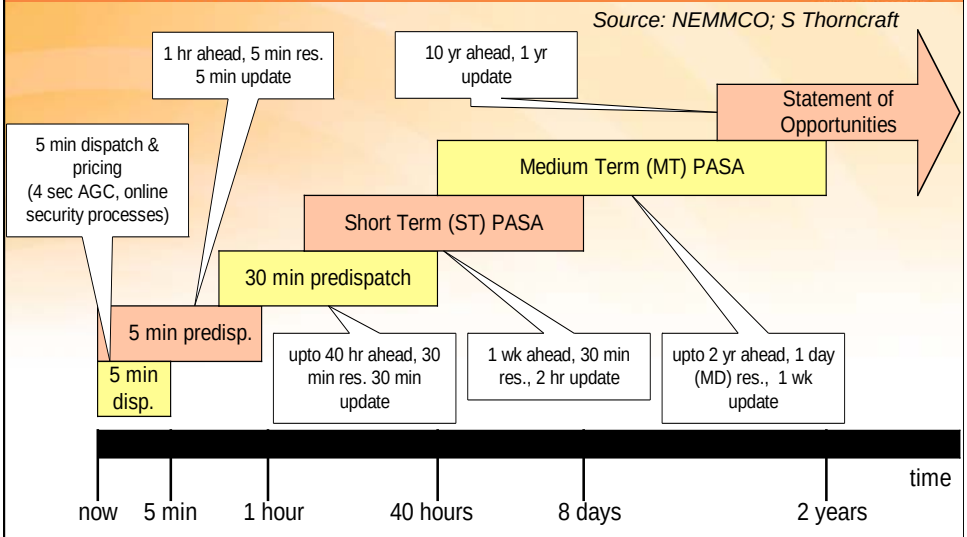
Managing supply-demand balance in NEM



Energy & FCAS markets are security constrained & co-optimised

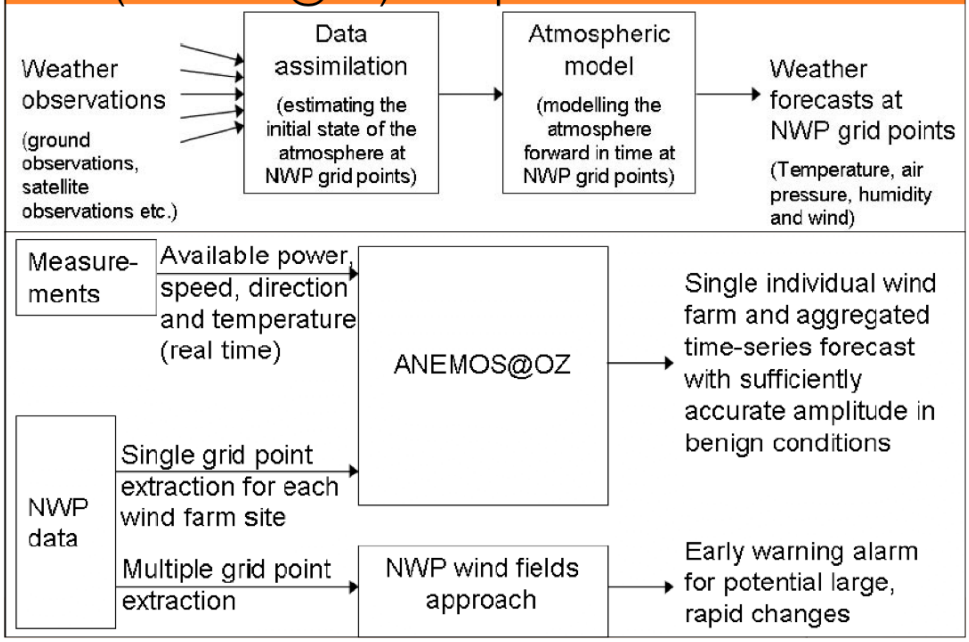
NEM commercial & security processes

Source: NEMMCO; S Thorncraft



(PASA: Projected Assessment of System Adequacy)

Australian Wind Energy Forecasting System (ANEMOS@OZ) & Proposed Enhancements



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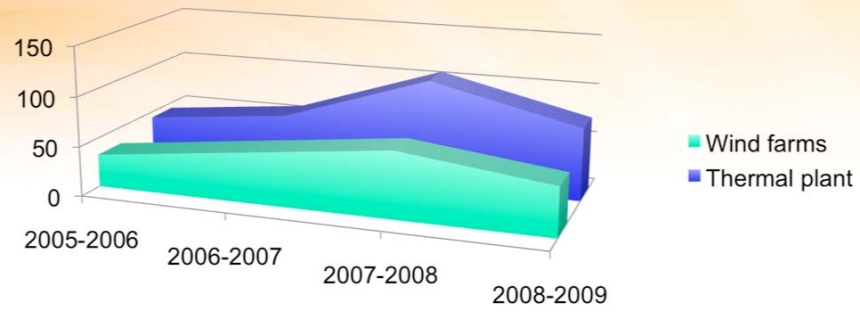
Average spot prices achieved by wind farms & thermal generators in South Australian region of NEM



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Conclusions for renewable energy integration in the Australian NEM

- Issues that have been largely resolved:
  - Connection standards for wind farms & PV systems
  - Integration of AWEFS into NEM security management
  - Inclusion of wind farms into security-constrained dispatch
  - "causer pays" frequency-control ancillary services
  - Design of Renewable Energy Certificate Scheme
- Further research needed:
  - Improved prediction of large changes in wind power
  - Integration of wind forecasting into derivative markets
  - Network augmentation/extension for wind farms
  - Large penetration of solar thermal & solar PV

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Hugh Outhred Bsc, BE (Hons 1), PhD

Hugh Outhred is a Professorial Visiting Fellow at the University of New South Wales (UNSW), an Adjunct Professor at Murdoch University, *Guru Besar Luar Biasa* at STTNAS Jogjakarta, Indonesia and a Director of Ipen Pty Ltd, which provides advisory and educational services on energy, society and the environment.

Hugh retired in 2007 after a 35-year career at UNSW, most recently as Presiding Director, Centre for Energy and Environmental Markets and Head, Electrical Energy Research Group, School of Electrical Engineering and Telecommunications.

During his career, Hugh has been a Fulbright Senior Fellow at the University of California Berkeley, a Board Member of the Australian Cooperative Research Centre for Renewable Energy, an Associate Director of UNSW's Centre for Photovoltaic Devices and Systems, a Member of CSIRO's Energy Flagship Advisory Committee, a Member of the National Electricity Tribunal and a Member of the New South Wales Licence Compliance Advisory Board.

Email: h.outhred@unsw.edu.au