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Integrating renewable energy into the electricity market:

A case study on wind generation and spot prices in the Australian National Electricity Market

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www.ceem.unsw.edu.au

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Project Background

- In the past few years a significant amount of wind generation has been installed in the Australian State of South Australia (SA)
- Electricity market data for SA, including 5-min wind power generation is publicly available online*
- Research questions:
  - Is fluctuating wind power having an effect on market prices and if so how much?
  - What are the potential implications for installing more wind power generation?
  - What lessons might be learned for other types of renewable electricity generation?

*http://www.aemo.com.au/data/market_data.html

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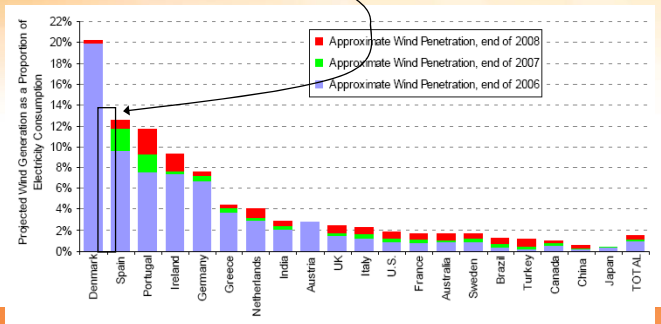
Wind Energy Integration

- Many of the power systems in these countries are interconnected to other countries
- The Australian power system is not even connected east to west!
- Take South Australia on its own… (data source www.aemo.com.au for July 2008 to June 2009)



Source: Berkeley Lab estimates based on data from BTM Consult and elsewhere

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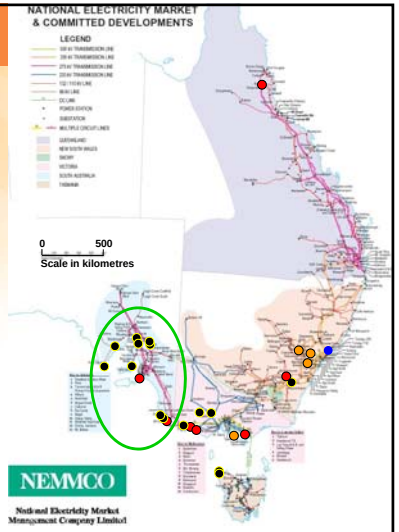
Wind Energy in Australia

- National Electricity Market (NEM) →
- Wind Farms currently installed in the grid →

Legend:
Wind farm size
- 0-1 MW
- 1-10 MW
- 10-50 MW
- > 50 MW



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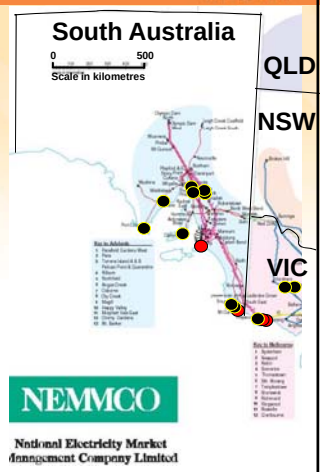
South Australia (SA)

Supply type	Total installed capacity in SA (2008-09)
Wind	868 MW
Coal	770 MW
Gas	2640 MW
Inter-connectors	680 MW

Electricity demand in SA (2008-09)	
Minimum	1200 MW
Maximum	3200 MW
Population (June 2009)	1.6 million



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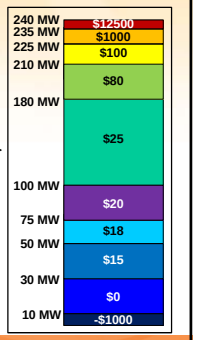
The NEM and South Australia

- The NEM has a hybrid 5-min to 30-min spot electricity market
- All generators put in bids for each 30-min interval in the coming day in 10 supply bins and corresponding prices
- One of these for every 30-minute interval for each generator! →
- Closer to real-time the quantities can be rebidded on a 5-min basis (but not the prices)



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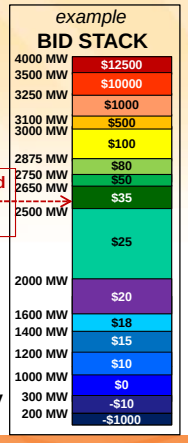
The NEM and South Australia

- The regional 30-min spot price is decided by solving the demand-supply balance subject to dynamic security constraints (eg. line ratings, available ramp rates for generators)
- It is an 'energy-only' market with a high price cap ($10,000/MWh) and no additional payments to generators for capacity or availability



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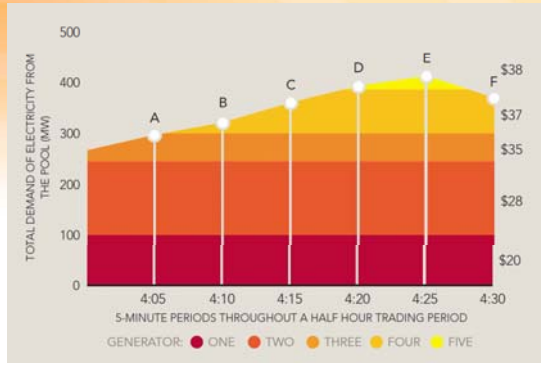
NEM price setting over a 30-min period



Source: "An Introduction to Australia's National Electricity Market." from http://aemo.com.au/corporate/0000-0006.pdf

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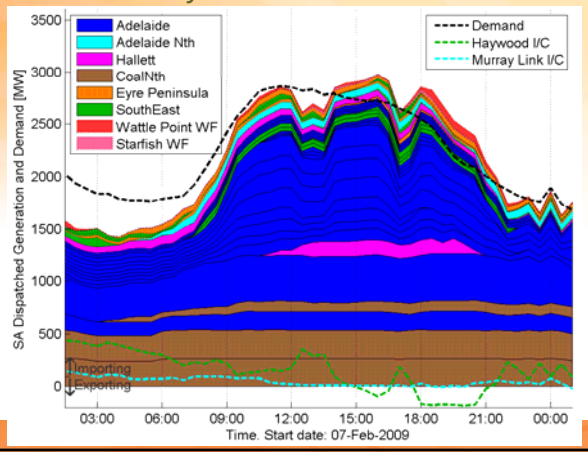
A day in South Australia



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Generator classification in the NEM

- Until recently, there were two types of generator classifications:
  - Scheduled: bid into the market, can be dispatched
  - Non-scheduled: do not bid, considered as negative demand
- A new market generator classification has been introduced for wind farms: semi-scheduled
  - They have to bid into the market and they can be regulated down during specified conditions, but not regulated up
  - Three wind farms out of eleven were semi-scheduled in 2009. All the new wind farms will be semi-scheduled

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The project

- Studied market data for one full year July 2008-June 2009
- Looked at 30-min averages for:
  - Market (spot) price
  - Total and individual wind farm SA wind power generation
  - SA electricity demand

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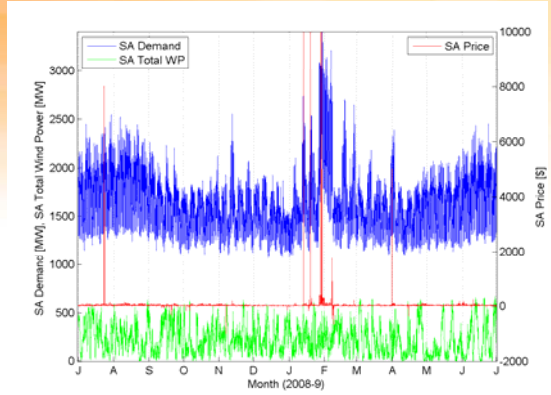
SA demand, wind power and price in 2008-9



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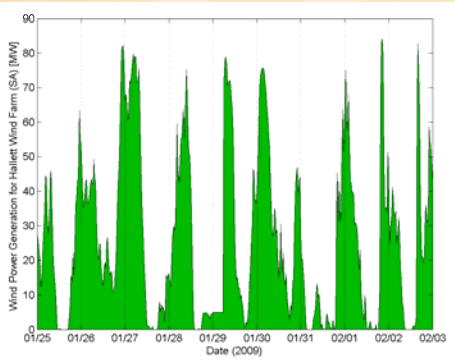
Wind Energy Integration

- The wind power resource:
  - Highly variable

Single wind farm in SA



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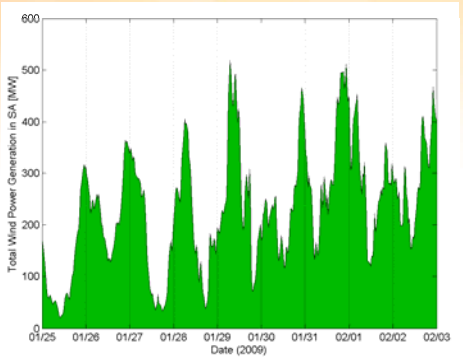
Wind Energy Integration

- The wind power resource:
  - Highly variable
  - But less so with spatial diversity in wind farms

Total of 9 wind farms in SA



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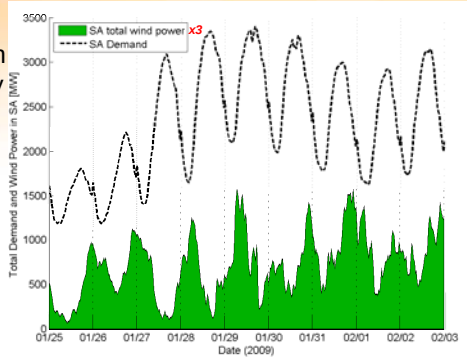
Wind Energy Integration

- The wind power resource:
  - Highly variable
  - But less so with spatial diversity in wind farms
  - Variation can be opposite to demand sometimes

Total wind power plus Demand in SA



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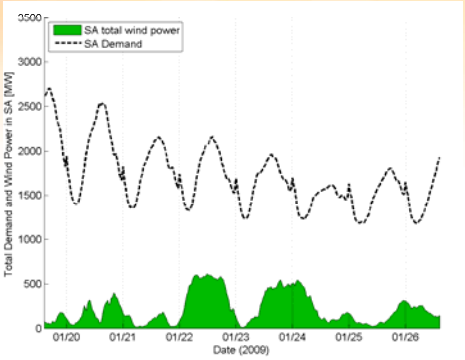
Wind Energy Integration

- The wind power resource:
  - Highly variable
  - But less so with spatial diversity in wind farms
  - Variation can be opposite to demand sometimes and similar to demand at other times



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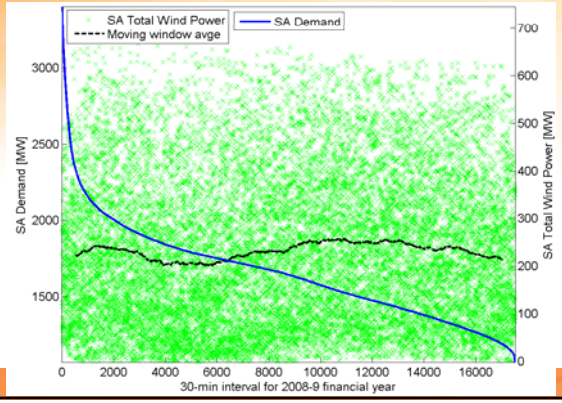
Wind Power and SA Demand

- There is a high variability in both and no clear relationship



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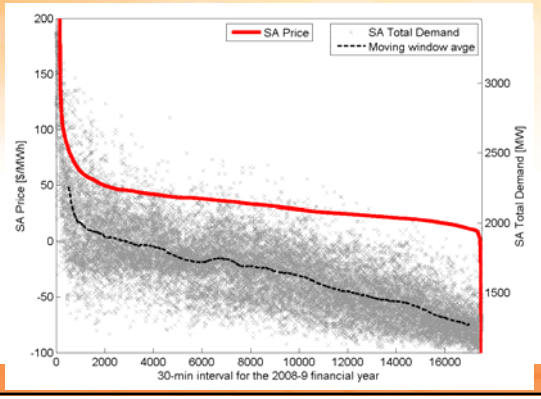
SA Demand and SA Price

- A clear and comparatively tight relationship



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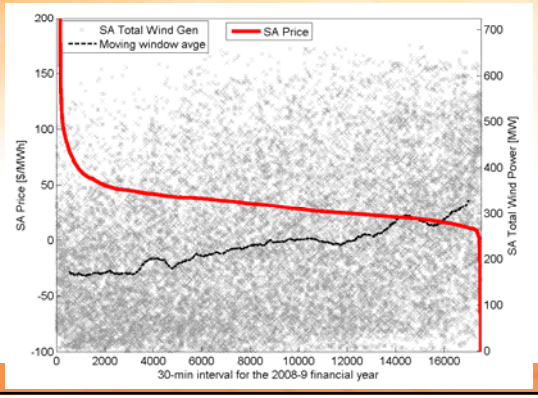
SA Wind Power and SA Price

- Wind is highly variable yet there is an underlying relationship



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Hypotheses

- Is the market price influenced by the amount of wind generation at a given time?

OR

- Does the wind tend to blow more at times of low prices due to other reasons?

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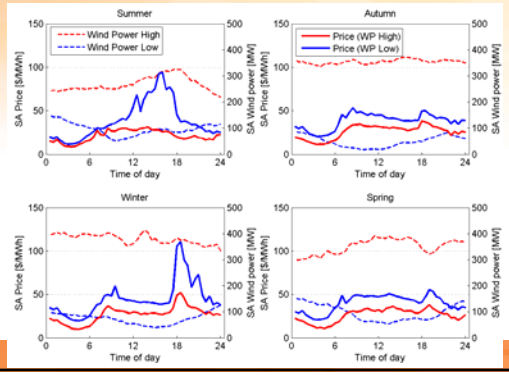
Daily profiles of price during high and low wind

Average daily profiles of price in South Australia for 2008-9 during "high wind" (highest 25% of wind power cases over all working days) and during "low wind" (lowest 25%) days (after truncating price between $0 and $415/MWh)



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Possible reasons for an apparent inverse relationship between wind and price (1)

- The cost of operating a wind farm is very low (fuel source is free and they receive green energy certificates), hence when the wind blows the marginal generator is likely to be lower cost
- Wind arises from resolving temperature differences, hence when the wind blows the temperature is less likely to be extreme and hence the demand is also unlikely to be very high (although this effect seems to be very small)
- Market participants are used to forecasting electricity demand but are not yet used to forecasting wind power generation. Thus wind power can act as unforeseen reduced demand.

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The value of wind power

- Previous slides show the 'spot energy value'
  - The marginal cost of energy in the grid in real-time
  - Doesn't strictly account for the environmental costs of different generation types (although wind may appear cheaper due to additional green energy credits)
  - The results show that in 2008-9, when the wind blew, the prices were lower and were less likely to peak
- The variation in wind is readily accounted for by gas rather than coal generators (since coal is more inflexible in that they cannot start-up quickly). Hence for wind to replace coal generation need good wind forecasts out to at least 6 hours ahead

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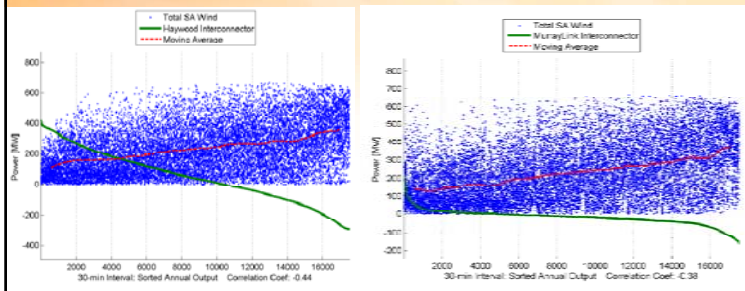
Flow on interconnectors and wind power

The interconnected NEM region Victoria appears to be contributing to managing wind generation in South Australia



Source: Larsen T., undergraduate thesis, University of New South Wales, 2009

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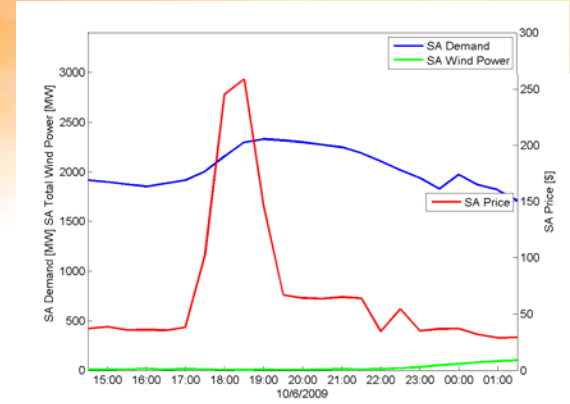
Winter price spike pattern



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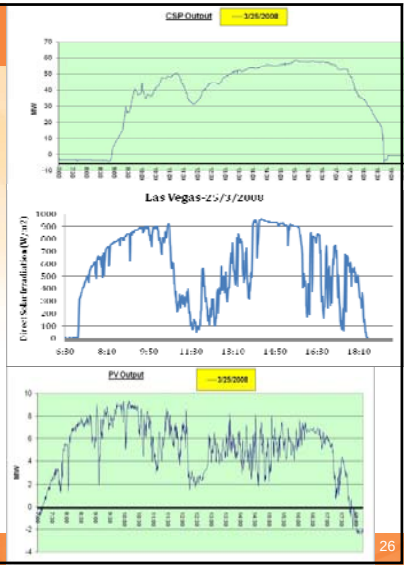
Variability of large-scale PV and CSP plants

- Growing international experience
  - PV systems on MW scale can experience variations in output of 50% on 30-90 second time frame and 70% on 5-10 minute time frame … phenomenon can occur many times in a single day during certain weather events (NERC, 2009).

Source: Boerema N., undergraduate thesis, University of New South Wales, 2010



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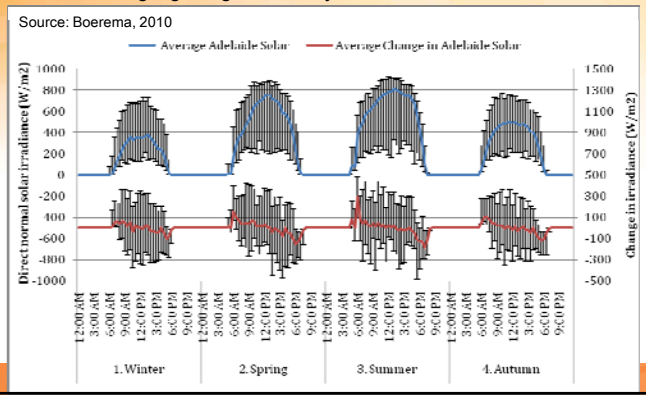
Solar irradiance in Adelaide, South Australia

- Average and 95% CI daily direct solar irradiance and ½ hour changes for each season highlight high variability

Source: Boerema, 2010



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Renewable Energy Integration

- Other renewable energy sources like wind with fluctuating, non-storable sources (eg. solar, wave) will also play a part in the electricity market
- Opportunities to facilitate them:
  - Improve renewable energy forecasting
  - More control on electricity demand
    - Control off-peak water heating more as well as other appliances
    - Controlled charging of millions of plug-in electric vehicles
  - Introduce more energy storage in the grid

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Summary

- Wind power generation is highly variable and has no clear relationship with demand in South Australia
- Demand still has dominant effect on price
- There is an apparent inverse relationship between wind power and price, likely to be due to combination of factors including:
  - Wind generation has no fuel cost and thus reduces market prices since the more expensive generators are not required
  - When the wind blows, temperatures are less likely to be extreme and thus demand is not likely to be extreme

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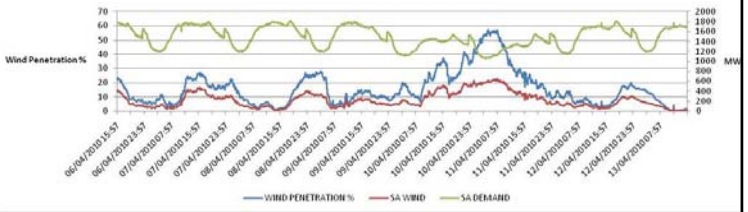
Thank you & Questions

- **Environmental Economics Research Hub**
  http://www.crawford.anu.edu.au/research_units/eerh/
- Renewable Energy Research Conference 2010
- Supervisors: Iain MacGill and Hugh Outhred

RECORD DAY 11 April 2010: **57%** of SA demand was supplied by wind power generation



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