Centre for Energy and Environmental Markets

UNSW

Dispelling energy market myths about wind

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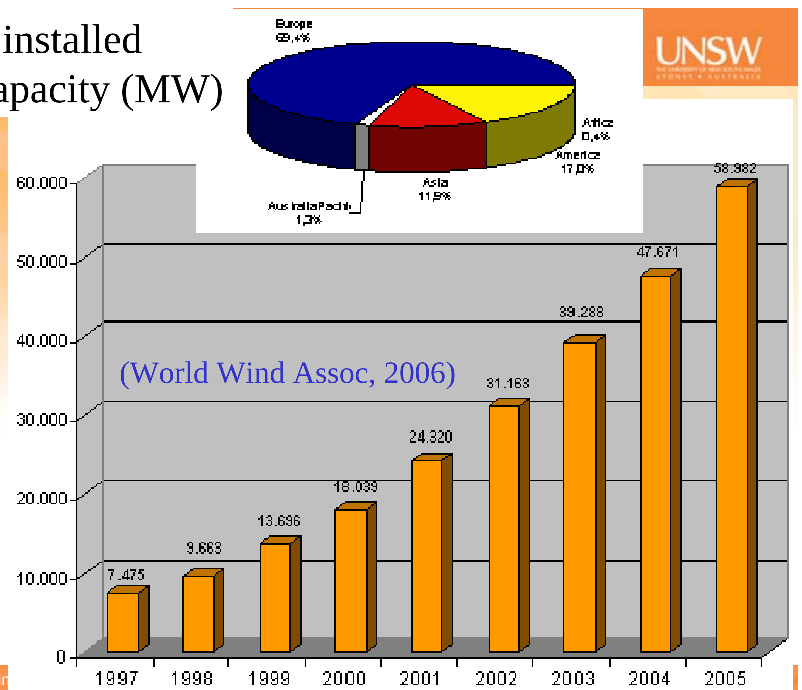
Comparing generation options

(CO2 Coefficients & Costs: Securing Australia's Energy Future (most); Energy payback: Wind:www.windpower.dk; PV: www.eere.energy.gov)

Type	CO2 g/kWh	Egy Payback (yr)	Cost in 2010 ($/MWh)
Coal SC (CCS)	700-1100 (150-200)	<1 (n/a)	30-40 (n/a)
Gas CC (CCS)	450-660 (80-150)	<1 (n/a)	35-45 (n/a)
Solar	100-280	2-5	250-400
Wind	6-29	<1	50-80
Nuclear	9-21	<1	n/a (Aust.)
Hydro	3-11	<1	30-70

Global installed wind capacity (MW)

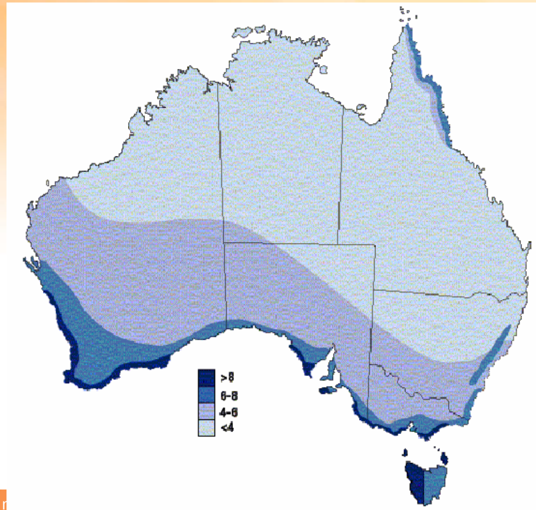


Wind energy characteristics

- Renewable energy fluxes are time-varying:
  - Solar, wind, hydro (tidal), biomass, geothermal, wave
- Wind & solar are non-storable:
  - Can be described as *intermittent energy resources*
  - Geographical aggregation reduces variability
- Electricity generation based on wind & solar energy has been described as intermittent generation
  - Electric power systems don't store electrical energy, hence intermittency reduces value of wind energy
  - Prediction can reduce the loss of value
    - Individual generators usually small, hence aggregation matters

Australian wind resource

(Estimate of background wind (m/s) – AGO)



SA regions with adequate Tx infrastructure

Can accept large wind farms but impacts on network voltage & inter-state flow limits; security concerns

SA regions with limited Tx infrastructure

Good wind resources but network investment required

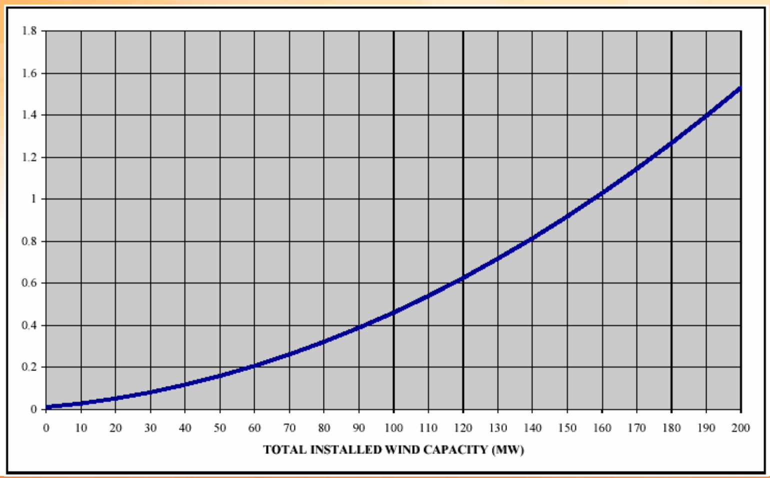
Comparing AusWEA forecast (www.auswea.com.au) & readily acceptable* (RA) wind capacity for Australia

(Outhred, 2004)

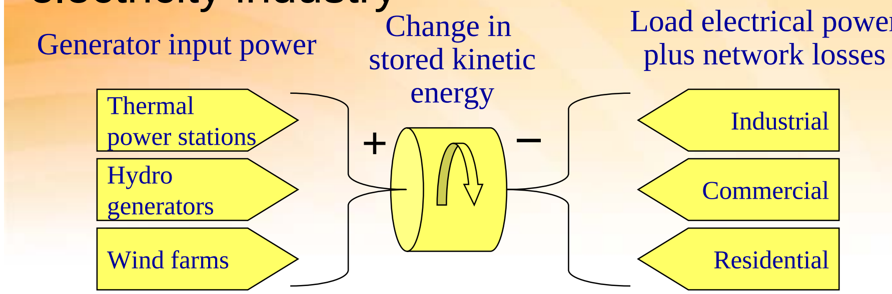
	Qld	NSW	Vic	SA	Tas	WA	Aus
Inst MW	12	17	140	400	65	120	750
App MW	0	154	390	800	215	67	1630
Total MW	*12*	*170*	*530*	*1200*	*280*	*190*	*2380*
RA MW	2100	3100	2200	500	500	500	8900

* subject to Best Practice, geographical diversity, forecasting & staged entry

Western Power's proposed wind penalty charge (c/kWh) (Western Power, 2002)



Managing supply-demand balance in the electricity industry



- Frequency reflects overall supply-demand balance:
  - Always varying due to net imbalance in power flow
- Voltage profile reflects changing pattern of power flow

Intermittent generation (NER)

- National Electricity Rules (NER) definition of intermittent generation:
  - "A generating unit whose output is not readily predictable, including, without limitation, solar generators, wave turbine generators, wind turbine generators and hydro generators without any material storage capability"
  - *Comment: forced outages of all generators are "not readily predictable"*
- Issues identified by NEMMCO:
  - Forecasting; Frequency Control Ancillary Services (FCAS); voltage control; management of network flows

NEMMCO concerns about wind energy

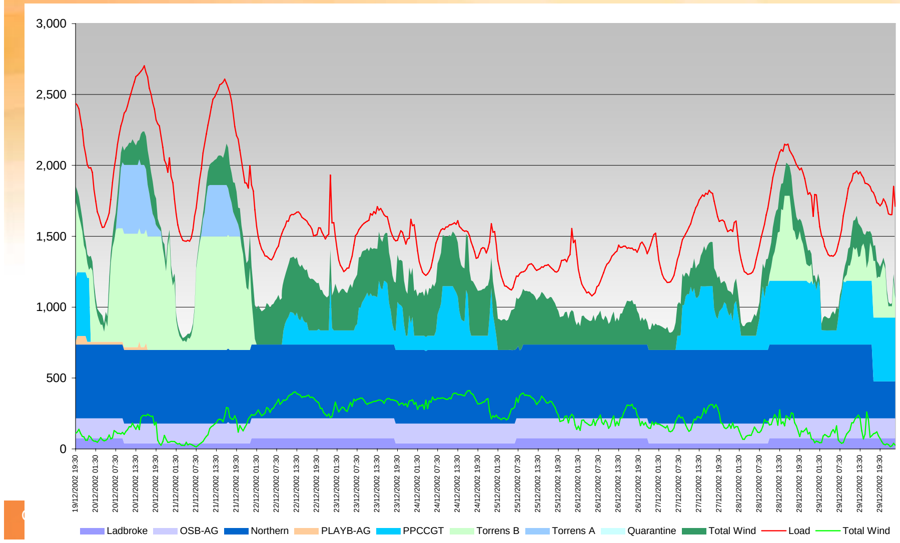
(NEMMCO, 2003)

- Frequency control in normal operation:
  - Frequency regulating service costs ~5 $/MWH
- Security control - largest single contingency
  - Will wind farms ride-through disturbances?
  - Generator technical requirements can be onerous
- Interconnection flow fluctuations:
  - Exceeding flow limit may cause high spot price
- Forecast errors due to wind resource uncertainty:
  - Five minute dispatch forecast (spot price)
  - Pre-dispatch & longer term (PASA & SOO) forecasts

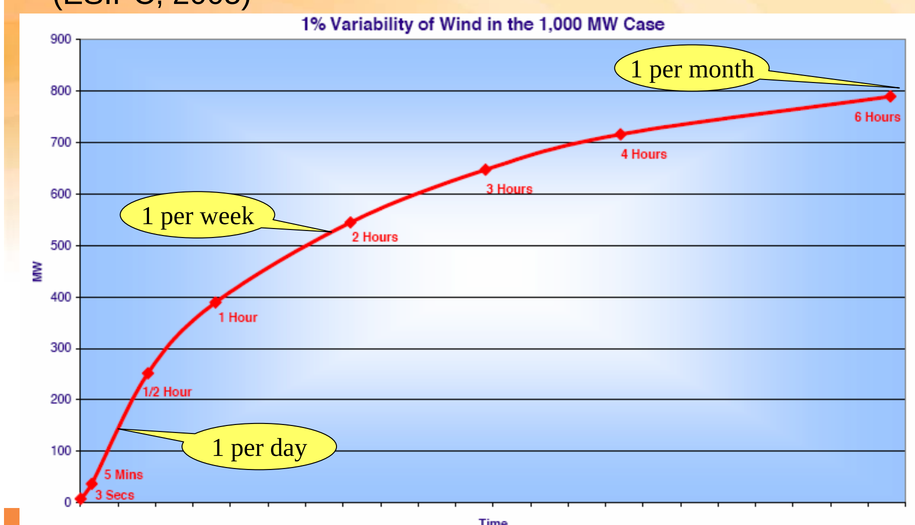
Recommendations from ESIPC advice to ESCOSA on facilitating wind energy in SA

1. Require wind energy forecasting:
   - For local network, regional & system-wide requirements
2. Require wind to fully participate in the NEM:
   - Ancillary service, spot & derivative markets
3. Efficiently allocate market costs (& benefits)
   - Ancillary services, spot energy & derivatives
4. Introduce appropriate technical standards
   - Should be equally applicable to all generators & reflect evolving Best Practice
   - Challenging due to small rating of wind turbines

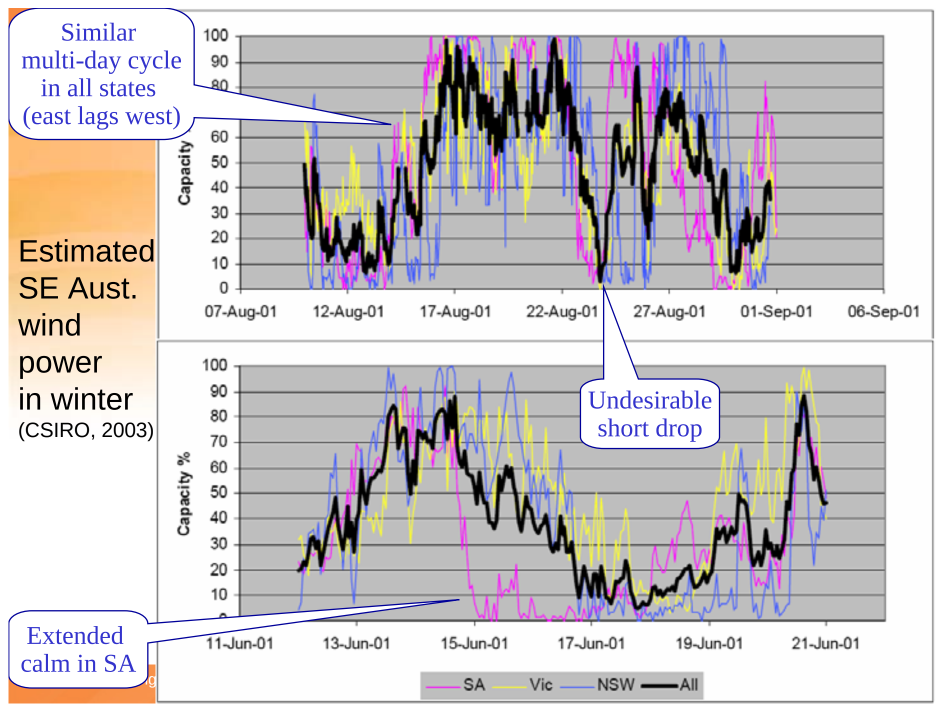
Simulated dispatch with 500MW wind in SA
(Oakeshott, 2005)



1000 MW wind, SA: 1% likelihood variation
(ESIPC, 2005)

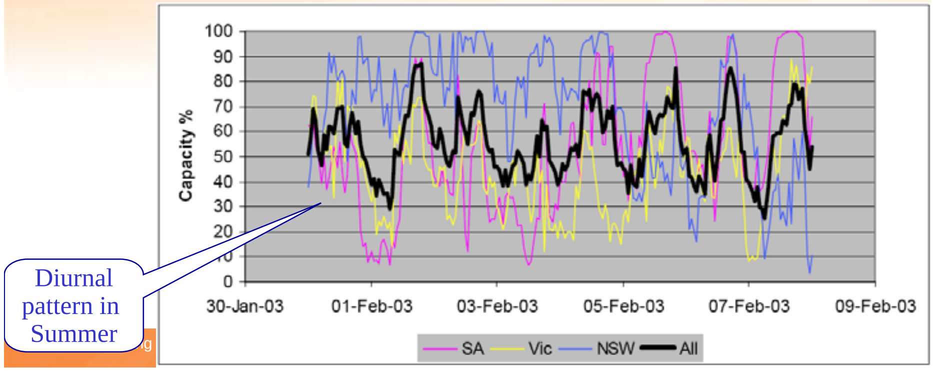


Estimated SE Aust. wind power in winter
(CSIRO, 2003)



Comments on CSIRO SE Aust Wind Study
(CSIRO, 2003)

- Similar multi-day patterns in all states (east lags west)
- Useful smoothing of shorter-term variations (subject to network flow capacity) but some problems remain



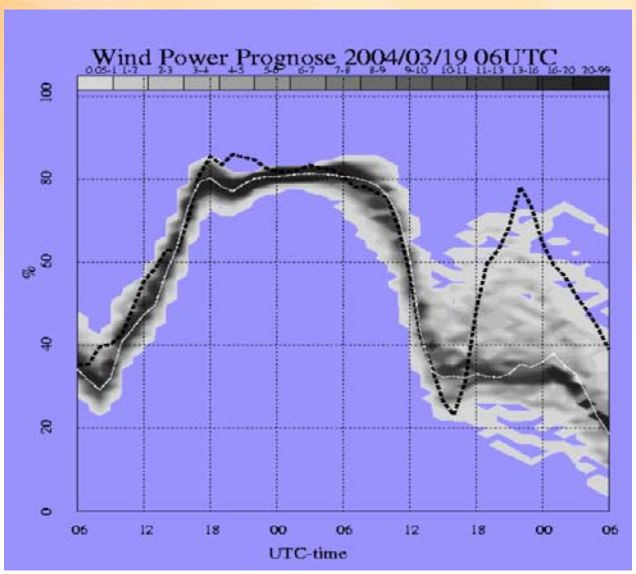
Forecasting the output of wind farms

- 30 minute horizon (FCAS & spot market):
  - Turbulence spectrum - likely to be uncorrelated for turbines spaced > 20 km:
    - Then % power fluctuations ~ $N^{-0.5}$
      - eg for 100 identical wind farms spaced >20 km apart, %fluctuation in total power ~ 0.1x%fluctuation for 1 farm
- 30 minutes to ~3 hours:
  - ARMA model best predictor of future output
- > 3 hours - NWP model best predictor:
  - Key issue: predicting large changes in output of appropriate groups of wind farms

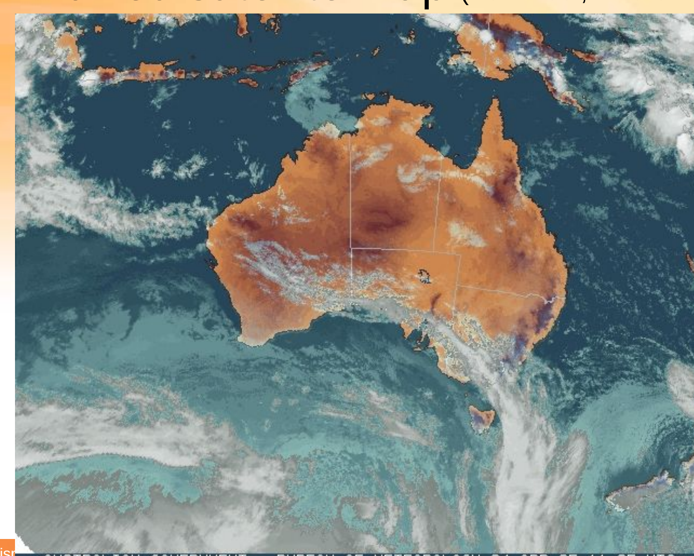
Wind power scenario forecasting
(Jende, 2005)

Actual: ----

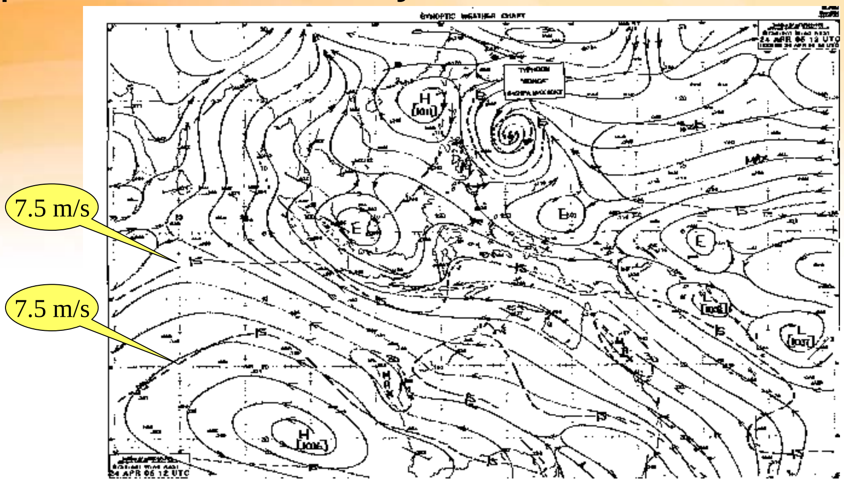
Aust Govt is spending $15m on a wind power forecasting system to facilitate high levels of wind power penetration



S1: Infra-red satellite map (BoM Aust,1125 UTC 24/4/05)



S1: Gradient level (~1km) wind map, produced twice daily (BoM Aust, 12 UTC 24/4/05)



Issues for NEM spot energy market

- Wind farms will operate as “price takers”:
  - Generate whenever wind is blowing
- NEM spot market prices are volatile with a “hockey-stick” price distribution:
  - Prices are usually low, sometimes high
  - Timing of high prices not easily predicted
- Value of wind energy in the spot market:
  - Will depend on how regularly wind farms are producing when spot prices are high

Issues for NEM ancillary services

- Wind farms will be buyers & (if capable) could be sellers in FCAS markets
- Wind farms will be charged for & (if capable) could be providers of network-related ancillary services
- Australian power systems are technically challenging:
  - Wind farm installers should always choose Best Available Technology for both turbines & wind farm control schemes

Issues for NEM derivative markets

- Merchant wind farms may wish to participate in derivative markets:
  - Important to have good forecasts of average production plus seasonal & diurnal patterns
- All market participants will be interested in predicting future wind power at local, regional and system-wide scale:
  - Important to develop high quality forecasting techniques

Conclusions

- Wind energy:
  - Brings new challenges for electricity industry restructuring (technical, market design, regulation)
- Network connection issues:
  - Wind generators small but complex & often in weak parts of network >> *onerous technical requirements*
  - Planning issues - visual & bird impacts:
  - Regional, rather than project specific
- Forecasting & system security issues:
  - Important to develop high-quality forecasting techniques
- Important to choose Best Available Technology