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Workshop Session 3: Energy & frequency issues in the NEM

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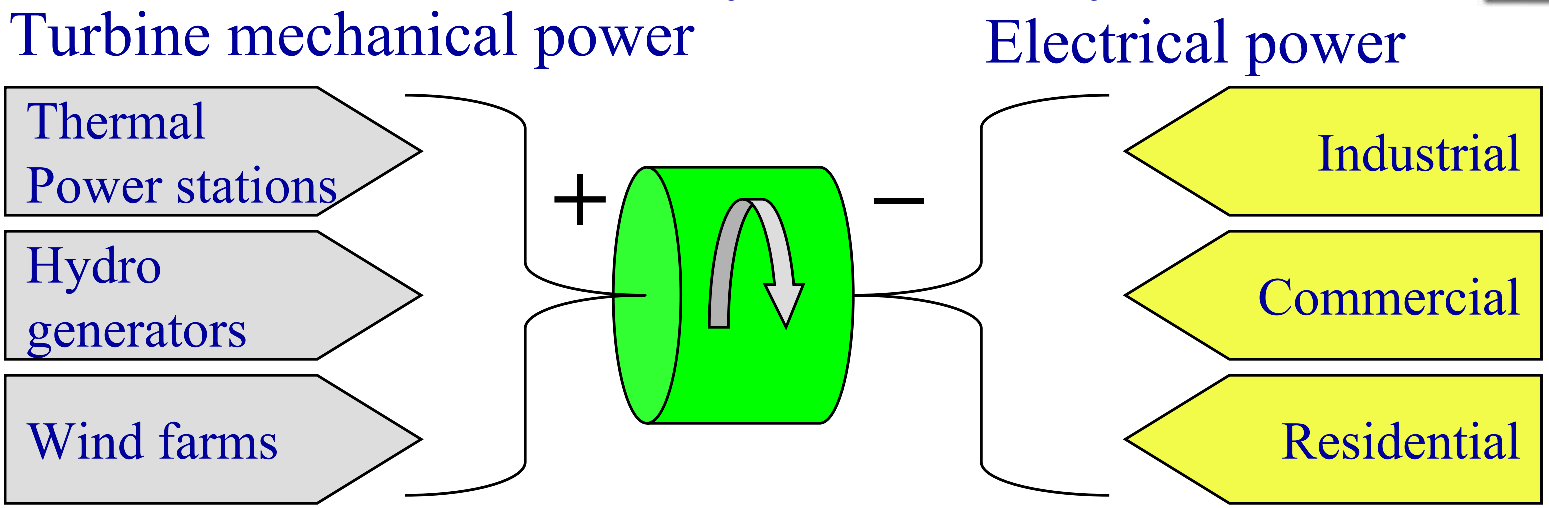
Outline

- Supply-demand balance in the electricity industry
- Timeline of mechanisms for managing supply-demand balance
- Power system operators concerns about wind energy
- Frequency-related ancillary services
- Electricity spot & derivative markets

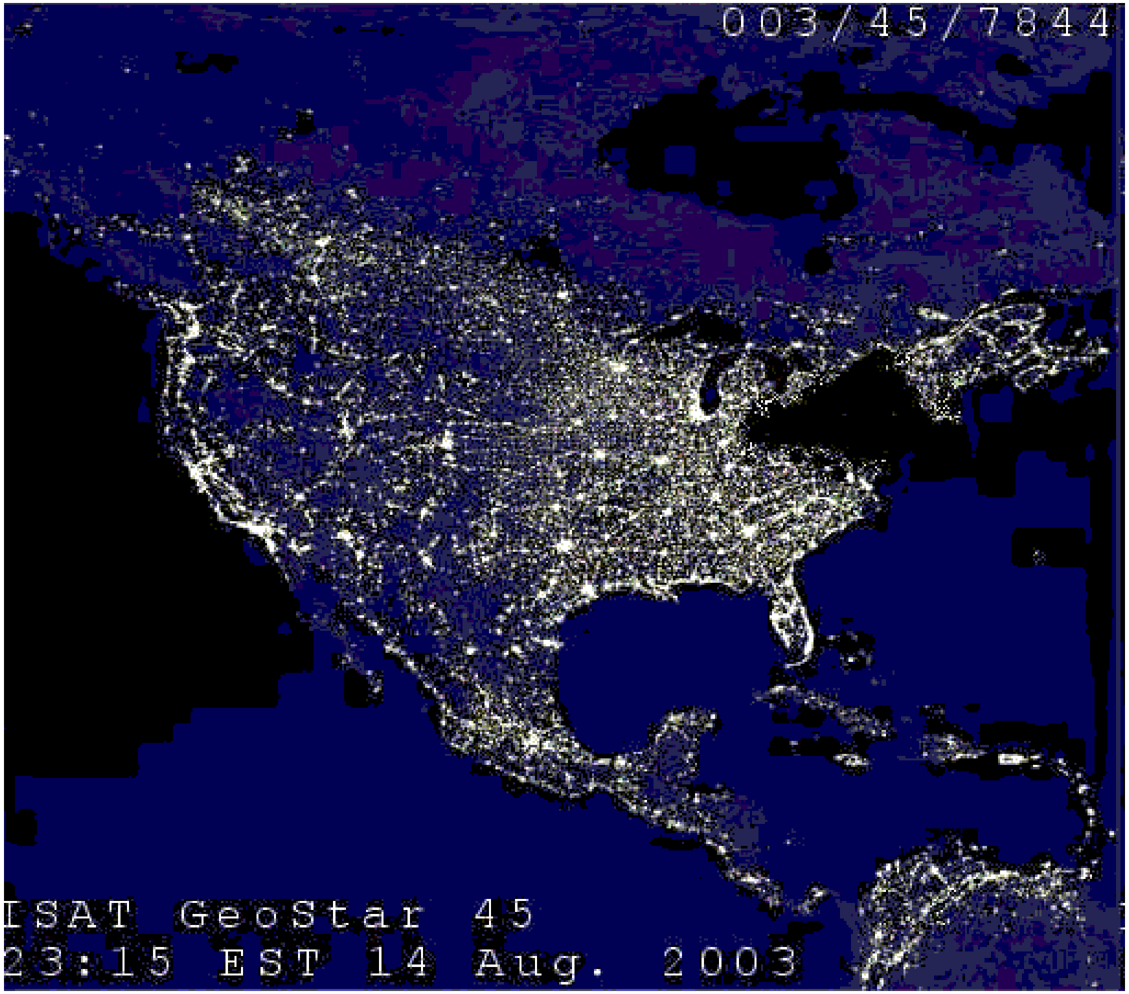
Supply-demand balance in the electricity industry



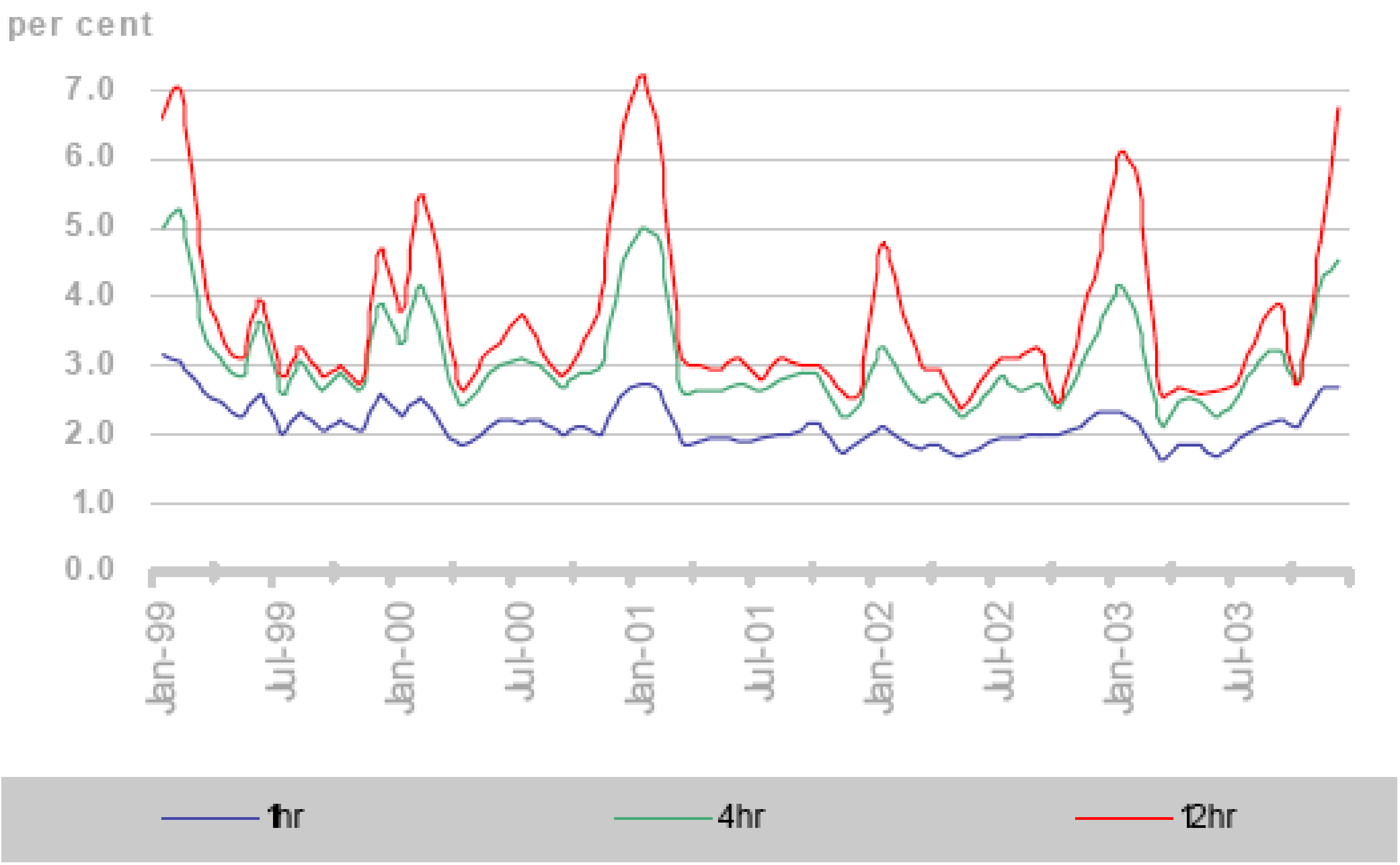
Kinetic energy in rotors of turbine-generators & motor-loads connected via the network
For variations in frequency of bandwidth less than about 0.1Hz, KE $\propto$ (frequency)^2

- Frequency is a measure of supply-demand balance:
  - Rate of change of KE = turbine mechanical power - electrical power
- Power flows & network availability are stochastic processes:
  - Hence frequency is always varying
- Wind farms will make frequency more variable:
  - Does this matter & if so, who should pay for additional control action?

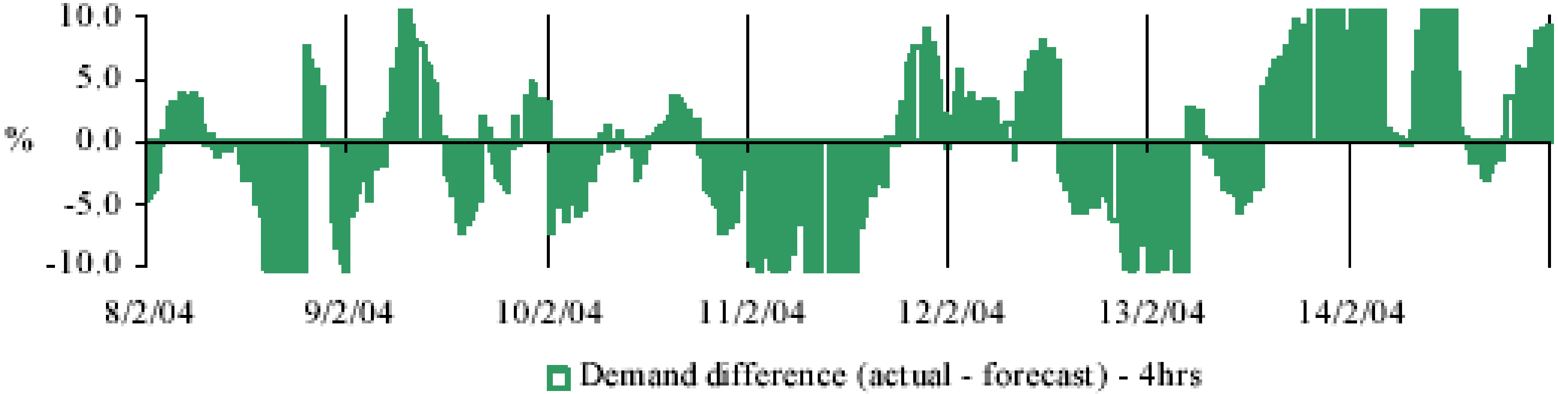
Supply/demand balance matters

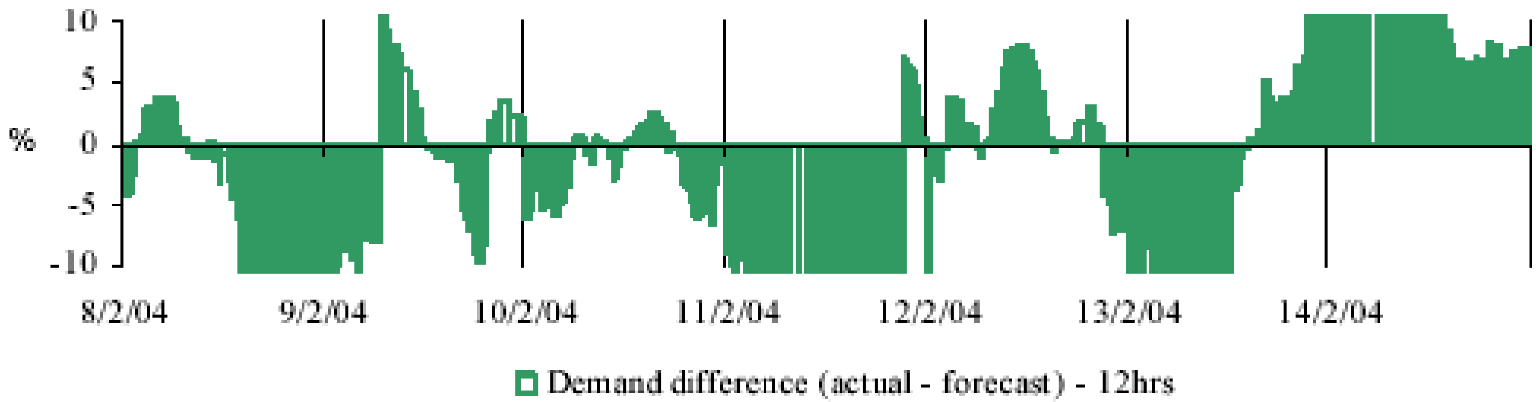


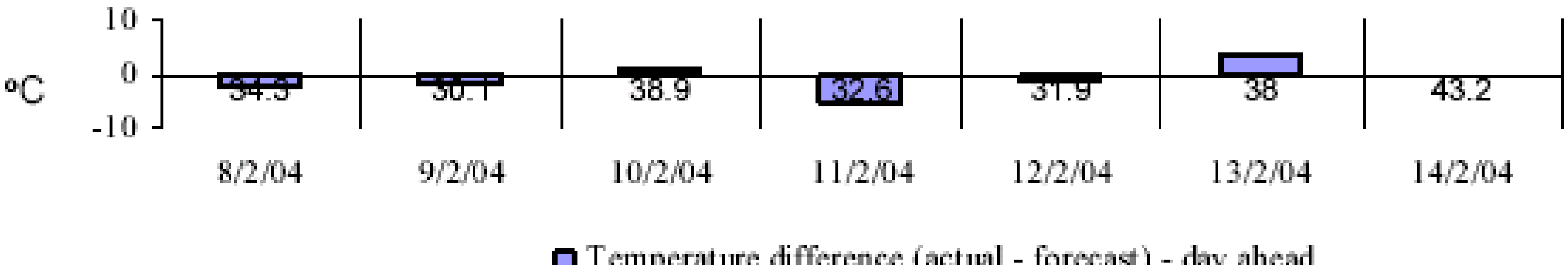
Demand forecast errors SA region to 03Q4 (NECA, 03Q4 Stats, 2004)



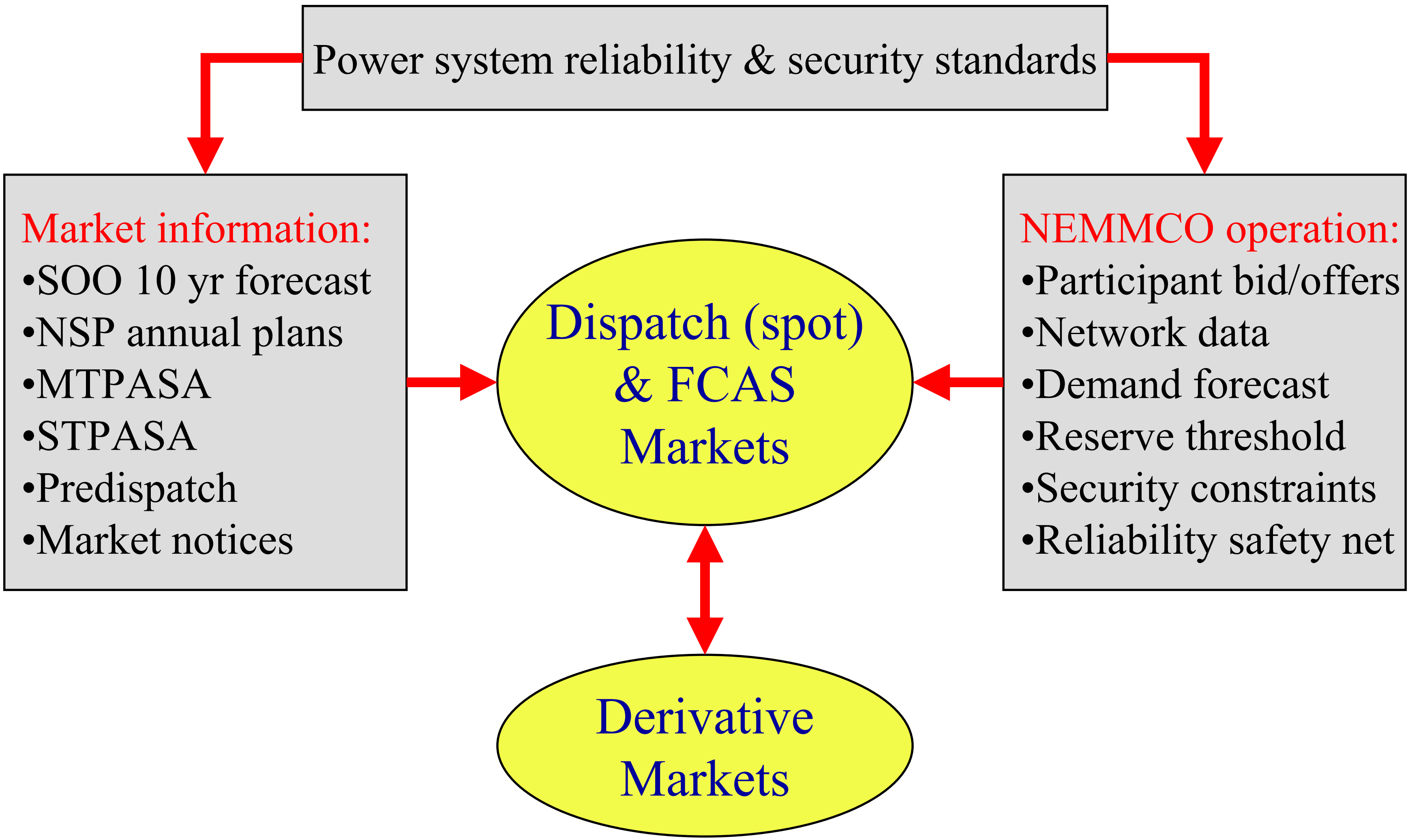
SA demand forecast errors (NECA, 8-14 Feb. 04)



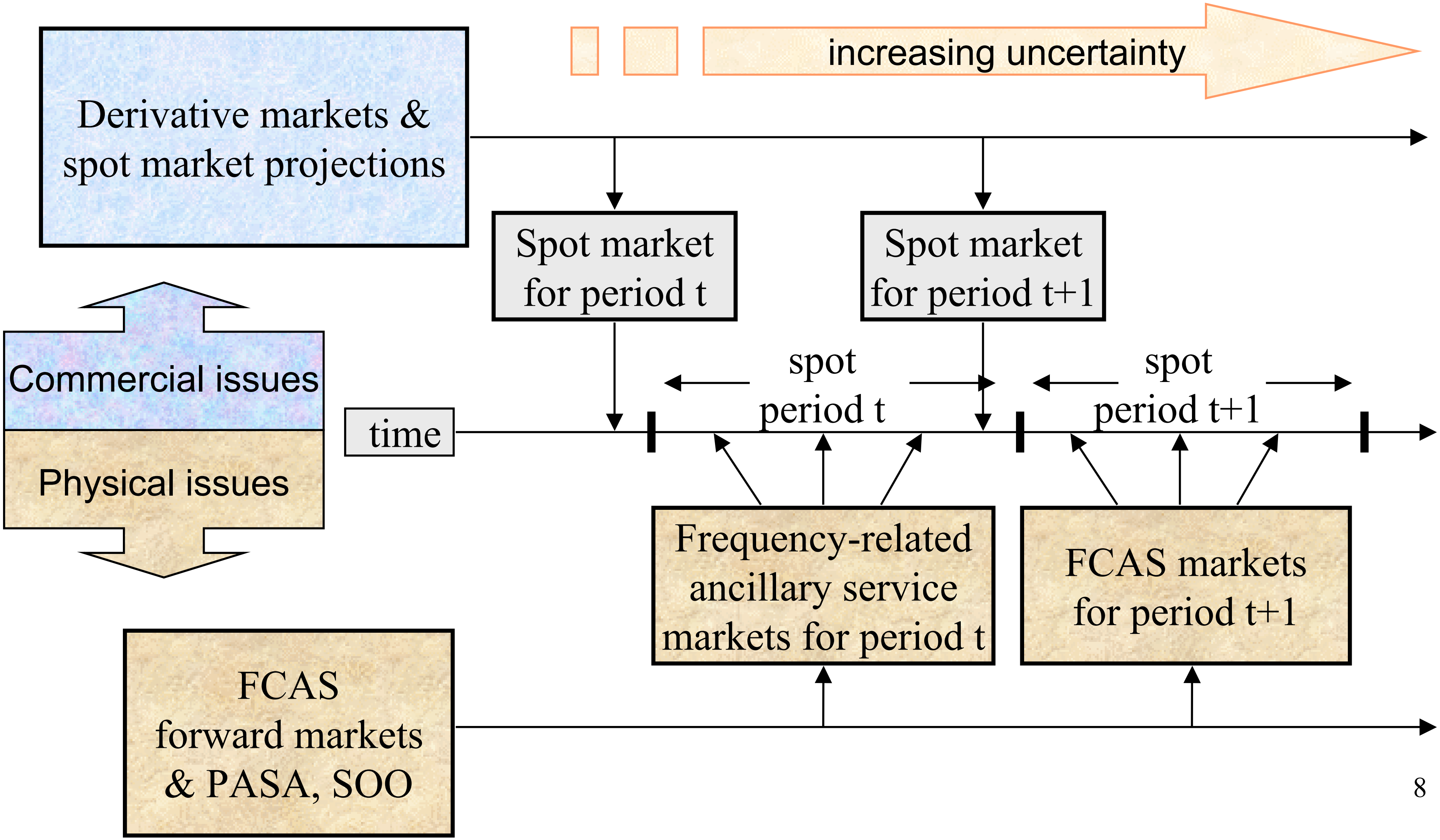




NEM processes for managing supply-demand balance



Managing supply-demand balance in NEM



Concerns of power system operators (Arnott, 2002)

- Frequency control in normal operation:
  - Frequency regulating service costs ~5 $/MWH
- Security control - largest single contingency
  - Will wind farms ride-through disturbances?
- 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 & PASA forecasts:
    - Daily; Weekly updated daily; Biannual updated weekly

NEMMCO

- "Intermittent Generation in the NEM" 'issues'
  - Forecasting
    - Increased errors in price + reserve forecasts

    => Have just released proposal on how to deal with this
  - Frequency control ancillary services
    - increase in usage + cost of these

    => proponents need to know that 'causer pays' – stay 'tuned'
  - Network management
    - impacts on V regulation, sub 5min flows on network may cause power quality + stability issues

    => Proponents should be aware of conditions for permission to connect to network Currently under review - changes could impact on plant design

Western Power

- "Technical + Commercial Issues for Access of Renewable Generation to the WP SWIS"
  - Wind can impact on security services – frequency control, V control + standby generation reserves
    - 10-15% wind (150MW) might require base load steam units to be taken out of service overnight => + costs
      => Can charge, or have curtailment arrangements for wind
  - Network issues – limits in regions depend on particular performance characteristics of machines + siting

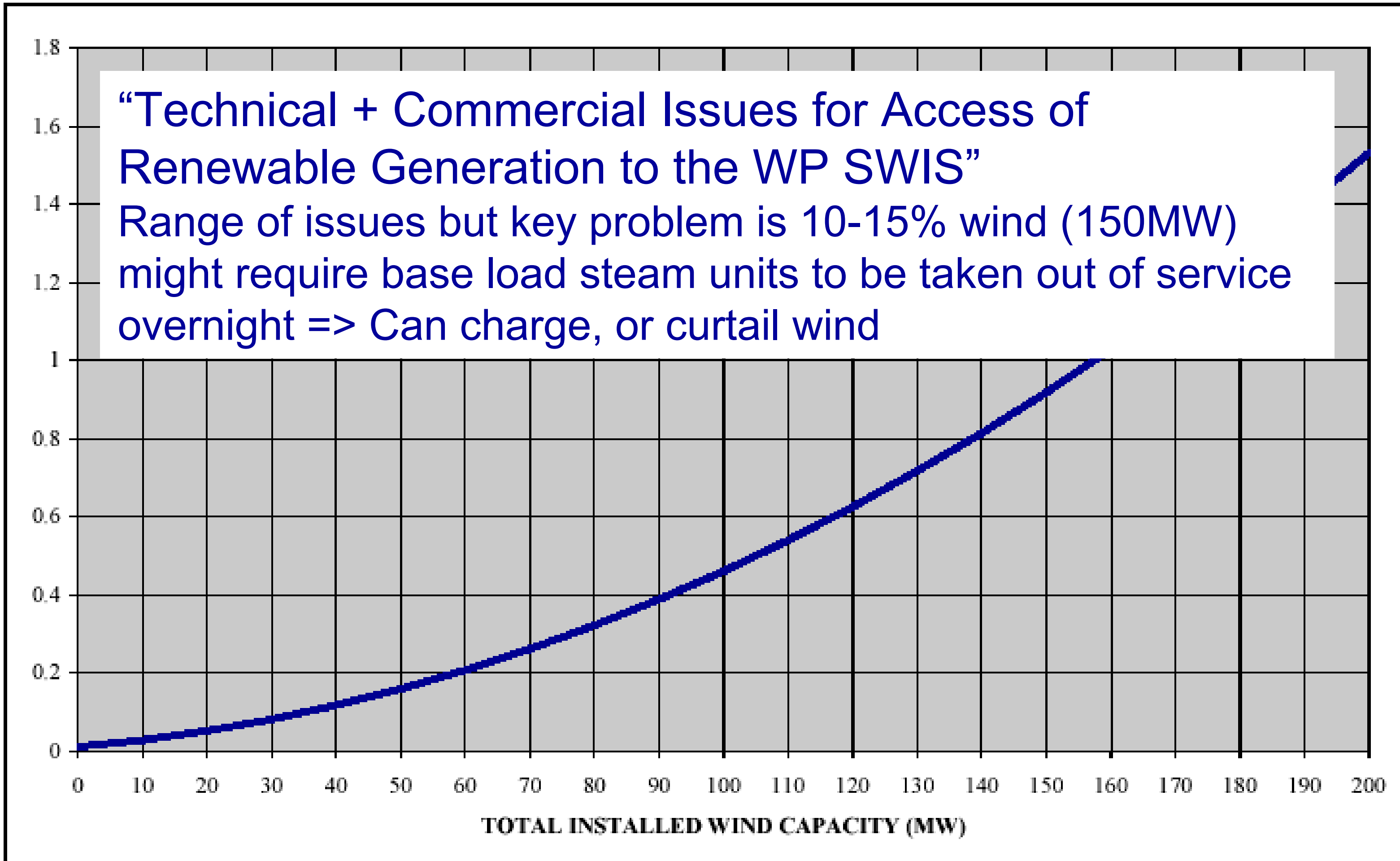
⇒ The way forward

⇒ commercial arrangements should reflect efficient pricing of security services,

⇒ judicious siting can reduce costs

⇒ appropriate generator technology can also help

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



SA ESIPC

- "South Australian Wind Power Study"
  - – Firm capacity is 8% of installed capacity
  - – No specific correlation b/n wind + temp
  - – Reduced interconnector imports
  - – Reduced interconnector constaint hours
  - – Reduced gen by SA incumbents
  - – Load factor not imporved
  - – Practical limits to wind gen not determined

Albany wind farm, WA

(source: Western Power)

Storm front can cause correlated "micro-gust" to 40 m/s for all turbines

Hampton Wind Farm, NSW

(2x660 kW Vestas, connected to different 11 kV feeders)

Turbulence probably fairly high at this site

Induction generators may not ride through voltage dips well.

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

Forecasts for Lake Benton wind farm, USA

138 turbines, 103.5MW, hourly data (Hirst, 2001)

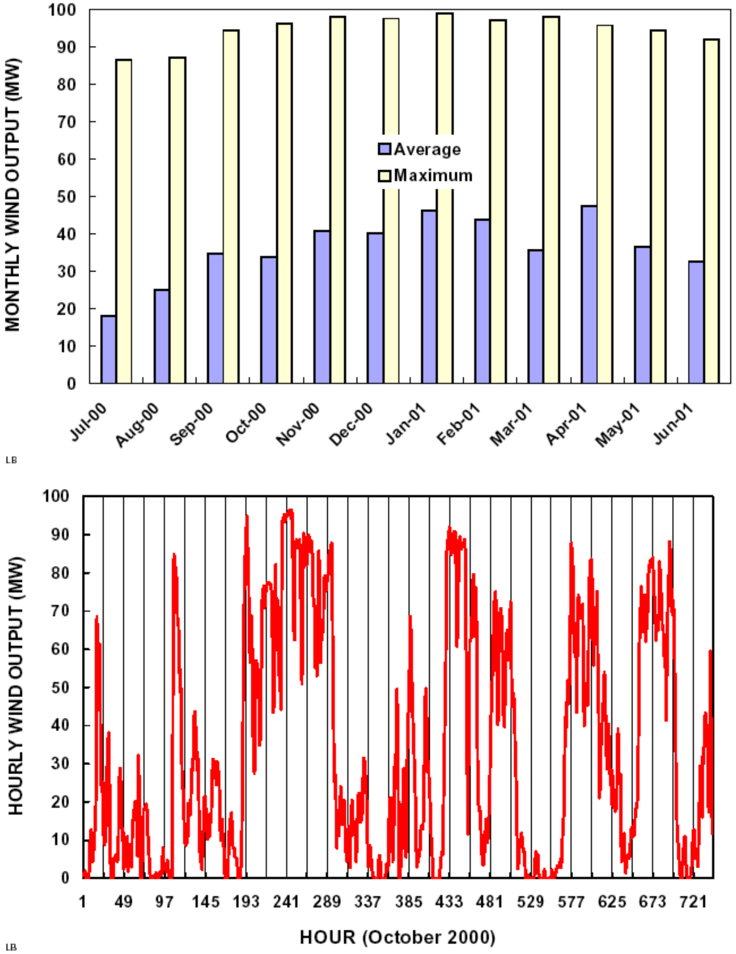


Fig. 3. Summary of hourly data on wind output (MW) by month (top) and hour-by-hour for October 2000 (bottom).

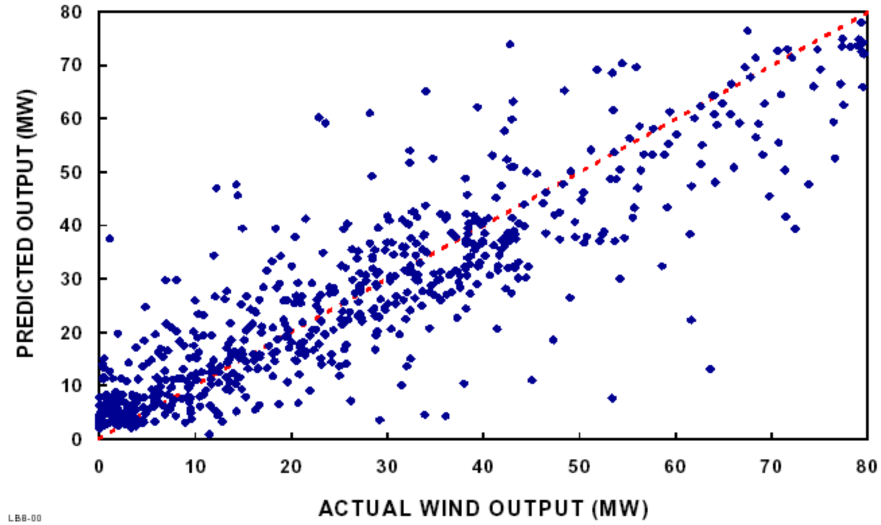


Fig. 7. Hourly predicted vs actual wind output for August 2000. The predicted and actual values are equal along the dotted line.

Two-hour ahead prediction of wind power:

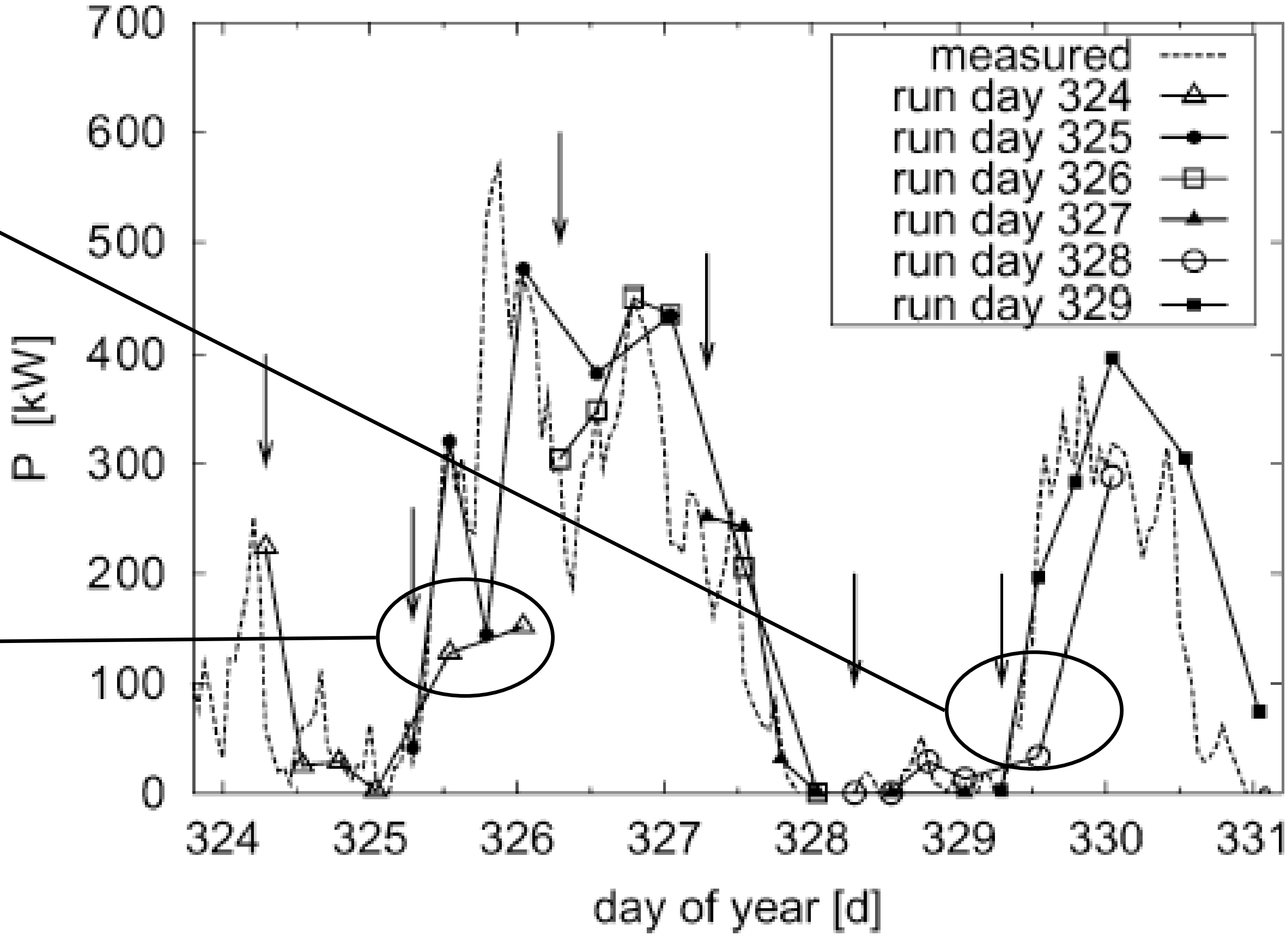
$$MW_{Pred}(T+2) = 2.7 + 0.9xMW(T) + [MW(T) - MW(T-1)]$$

Predicting the output of a wind turbine 6, 12, 18, 24, 36 & 48 hours ahead

(Focken et al, 2002)

48 & 36 hr predictions: Front timing later than actual

48 & 36 hr predictions: Front timing ok but not magnitude



‘Readily acceptable’ wind penetrations

- Readily accepted – technical solutions to any associated problems that are not prohibitively expensive

- NEM might be able to readily accept up to 8000MW ***if***
  - Wind installed in progressive manner
  - Wind farms widely + envely dispersed within NEM
  - Wind farms used advanced turbine technology + control systems with remote monitoring + control
  - Advanced wind forecasting techniques developed for regional projections up to 2 days ahead

(Outhred, 2004)

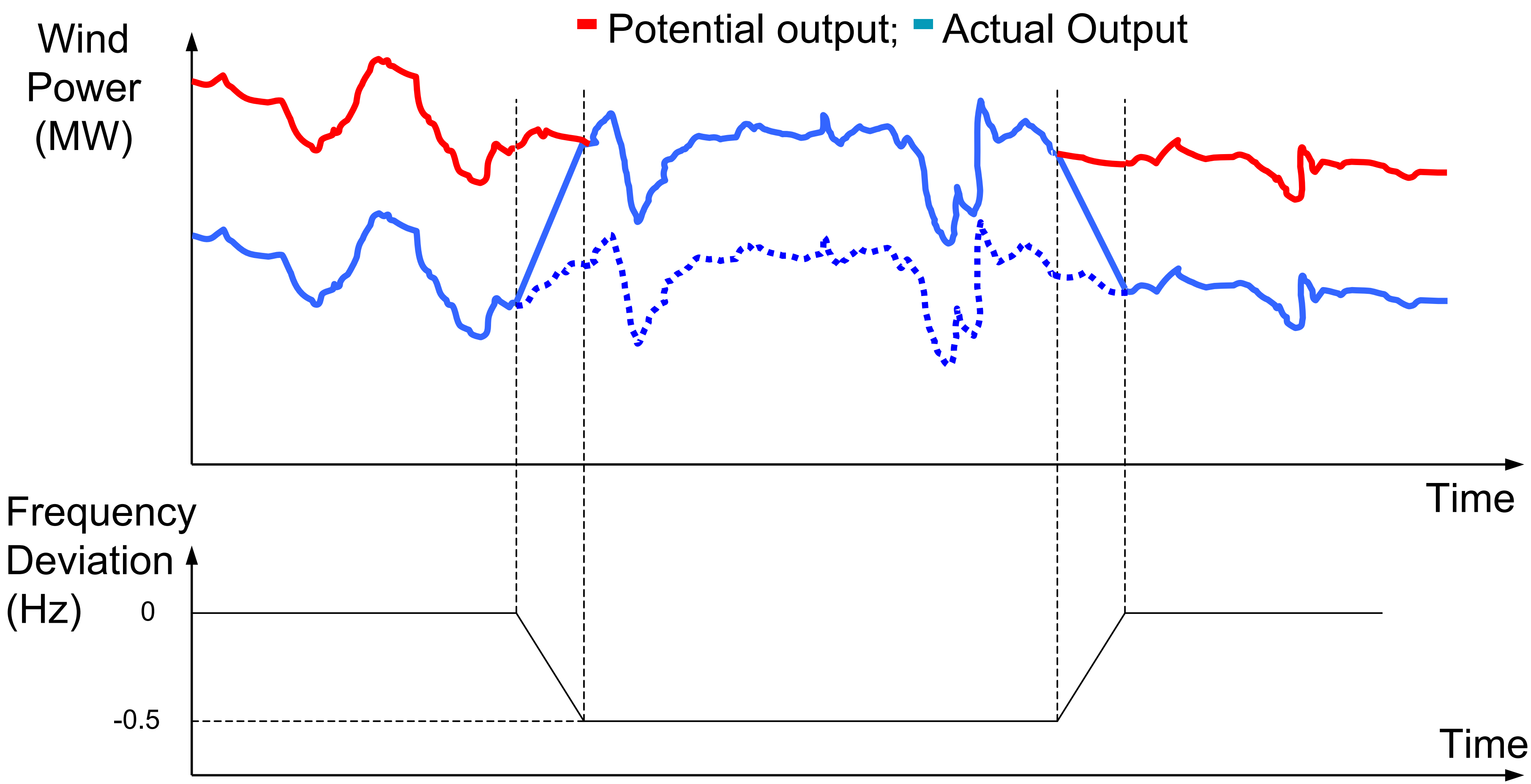
Comparing AusWEA forecast (www.auswea.com.au) & readily acceptable (RA) wind capacity

	Qld	NSW	Vic	SA	Tas	WA	Aus
Inst MW	13	17	92	35	11	28	196
Prop MW	40	115	437	1190	570	347	2699
Total MW	53	132	529	1225	581	375	2895
RA MW	2100	3100	2200	500	500	500	8900

Wind farms and FCAS in NEM

- 8 FCAS markets with 5 minute prices:
  - Frequency regulation (continuous) raise & lower
    - 50±0.15 Hz normal (<100 MW error in 20,000 MW)
    - 50 ±0.25 Hz occasional
  - Contingency FCAS (6 second) raise & lower
  - Contingency FCAS (60 second) raise & lower
  - Contingency FCAS (5 minute) raise & lower
    - ~600 MW contingency support required
- Wind farms could provide FCAS raise&lower
  - By spilling energy regularly or occasionally

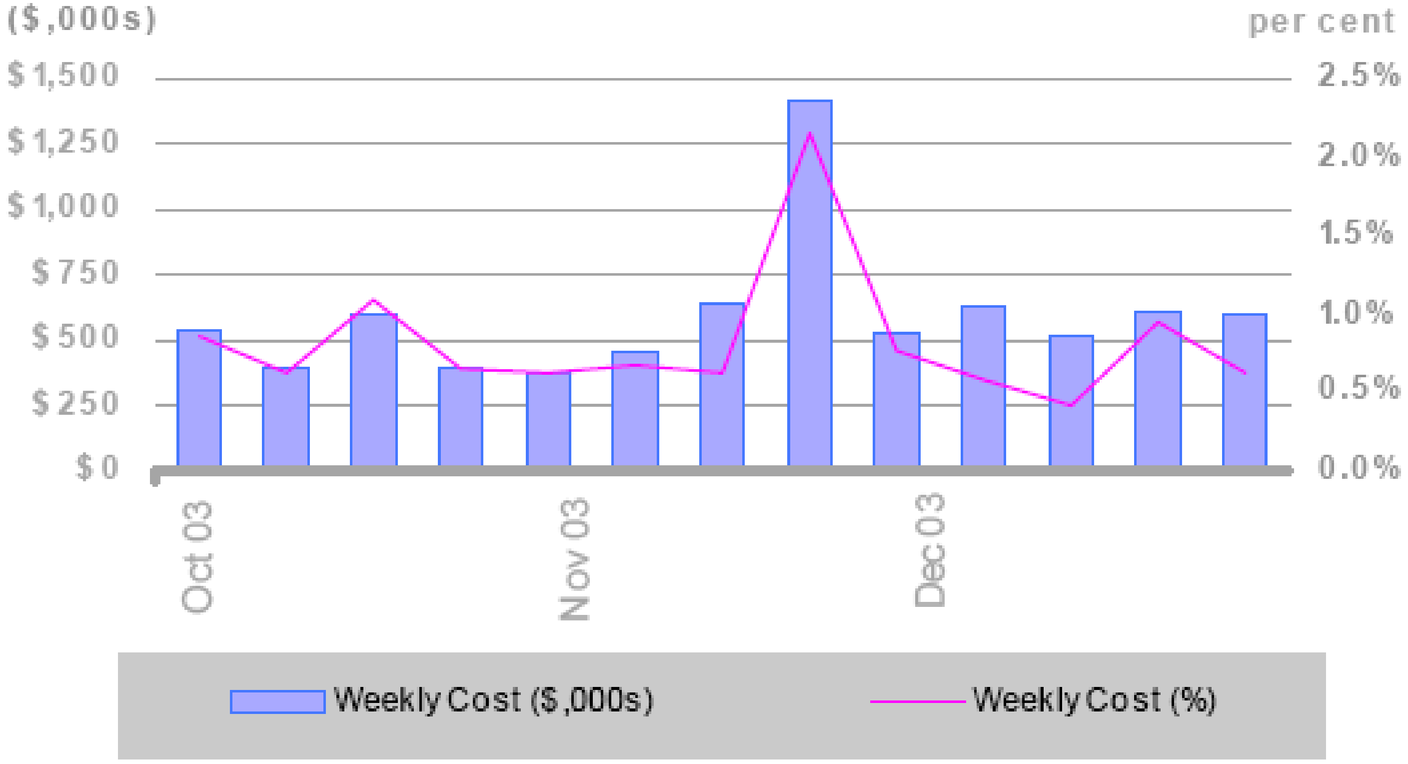
Spilling wind energy continually to provide FCAS raise



(Johnson, 2003, http://local.iee.org/ireland/Senior/Wind%20Event.htm)

FCAS prices 2003 Q4 ($K/week)

(NECA, 03Q4 Stats, 2004)

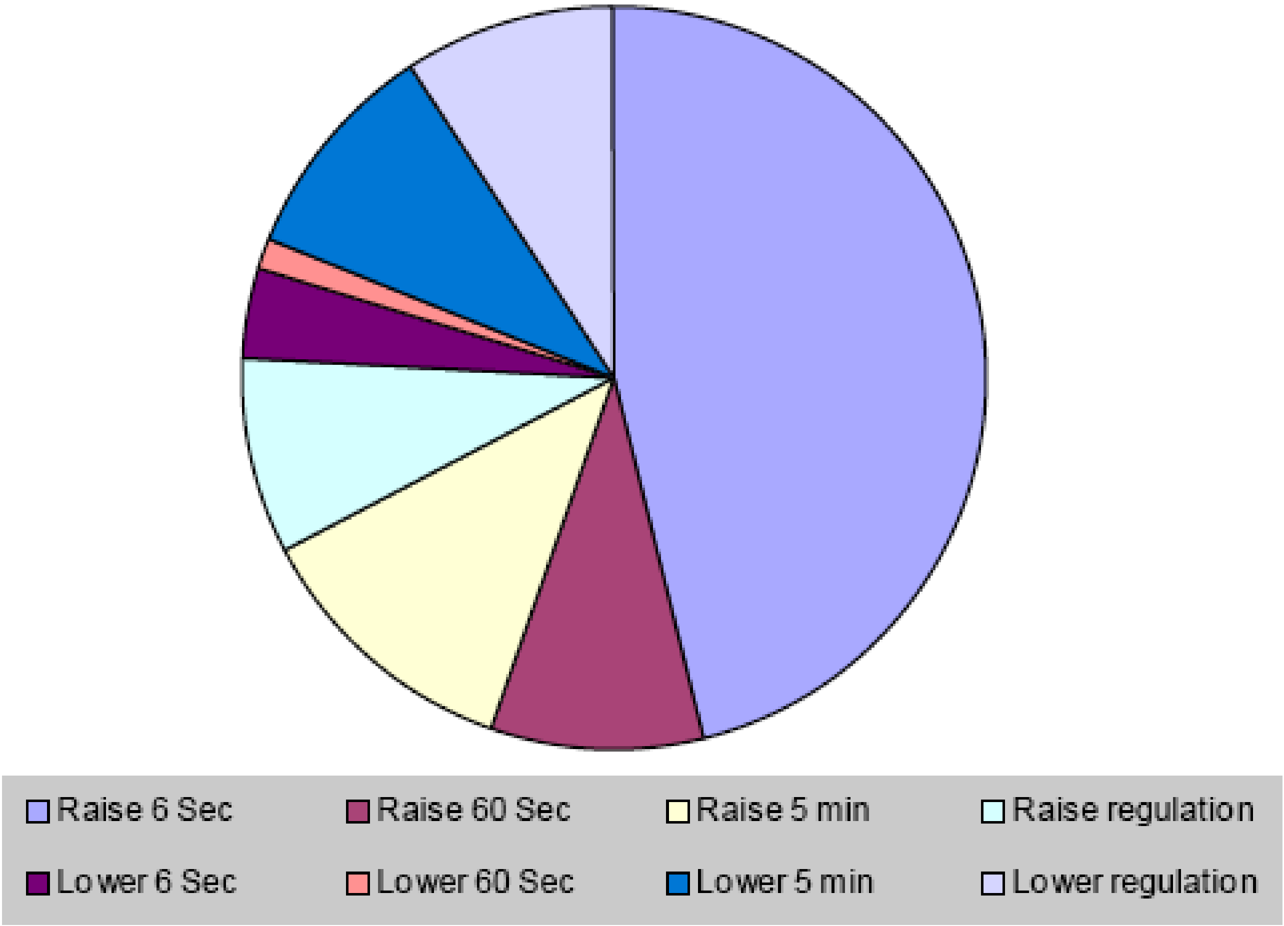


Average FCAS prices ($/MW) 2003 Q4 (NECA, 03Q4 Stats, 2004)

	Raise 6 Sec	Raise 60 Sec	Raise 5 min	Raise reg	Lower 6 Sec	Lower 60 Sec	Lower 5 min	Lower reg	Total Cost
VWA price	$5.23	$1.02	$1.25	$1.61	$1.98	$0.60	$3.44	$1.67	-
VWA price (previous quarter)	$4.80	$0.66	$1.06	$1.74	$0.26	$0.33	$0.41	$1.93	-
Market Cost ($1,000 s)	$3,609	$707	$921	$689	$293	$108	$766	$714	$7,807
% of energy market	0.4%	0.1%	0.1%	0.1%	0.0%	0.0%	0.1%	0.1%	0.8%
% of AS market	46.2%	9.1%	11.8%	8.8%	3.8%	1.4%	9.8%	9.1%	
Market Cost due to local req ($1,000 s)	$0	$0	$0	$0	$249	$5	$351	$0	$605
% due to local requirement	0%	0%	0%	0%	85%	4%	46%	0%	8%

FCAS cost distribution 2003 Q4

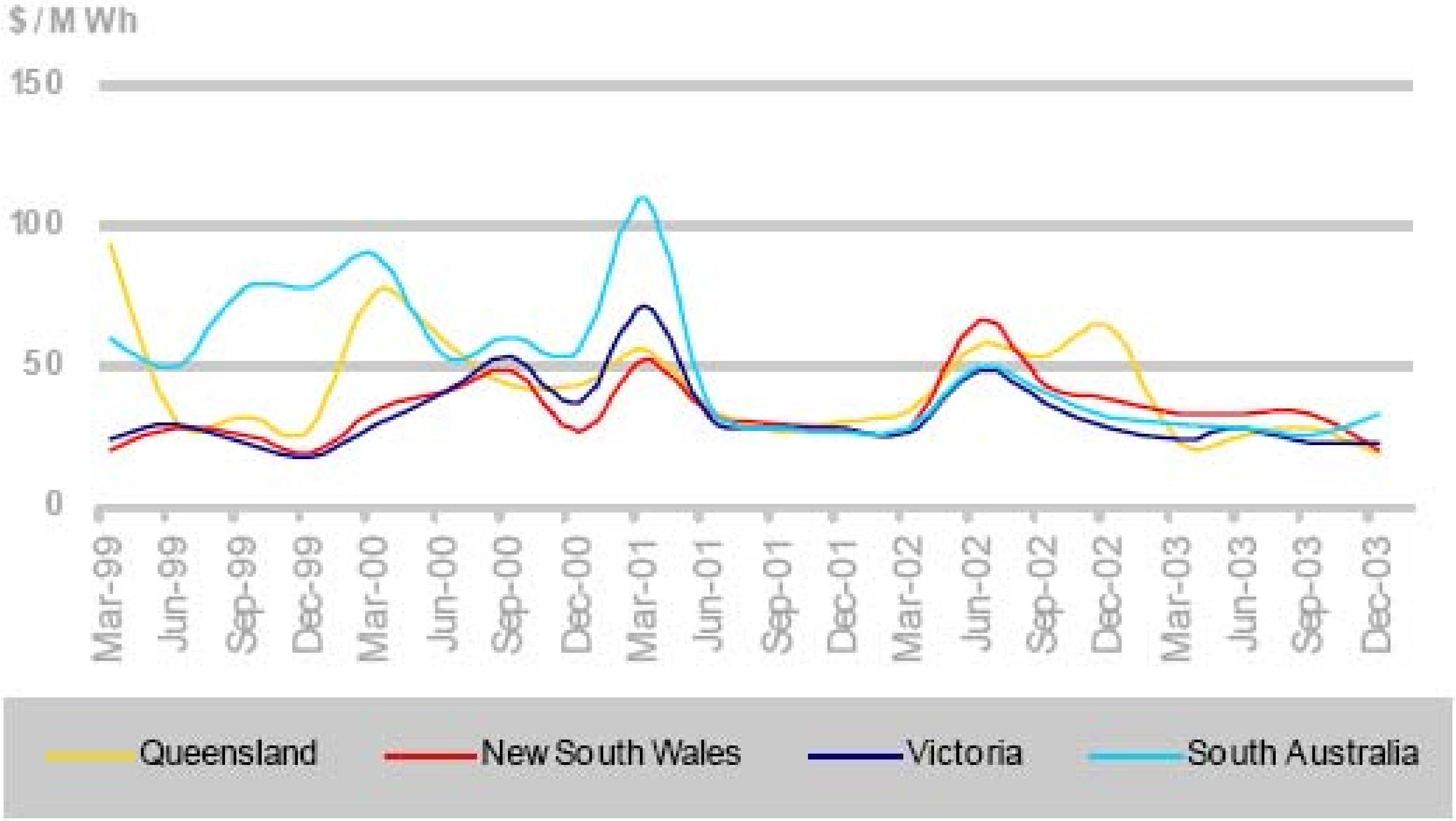
(NECA, 03Q4 Stats, 2004)



Issues for NEM spot market

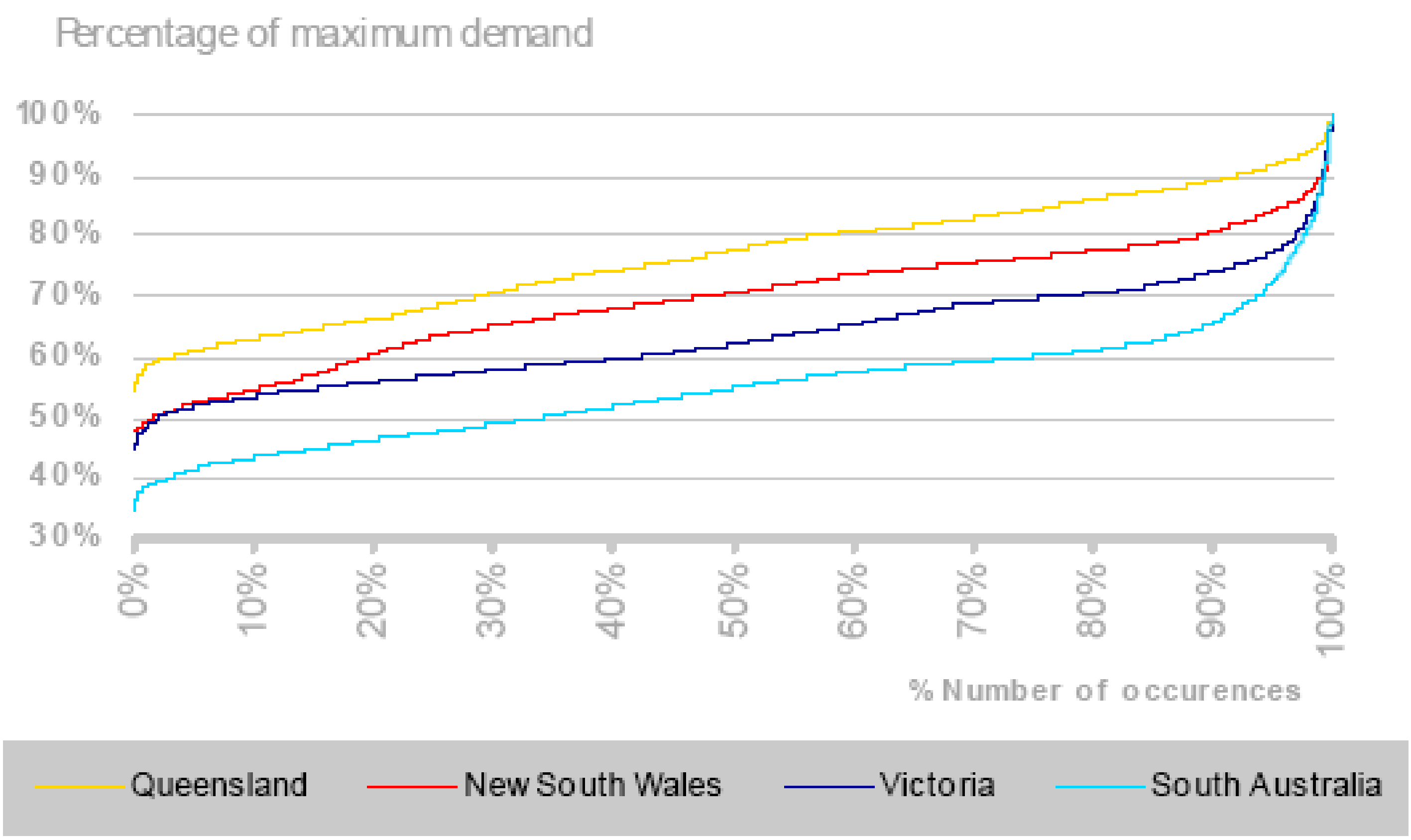
- Wind farms will operate as “price takers”:
  - Generate whenever wind is blowing
- NEM spot market prices are volatile with a “rectangular” price distribution:
  - Prices are usually low, sometimes high
  - Timing of high prices not easily predicted
- Value of wind energy in the spot market:
  - Will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

Weekly average NEM spot prices since market inception (NECA, 03Q4 Stats, 2004)



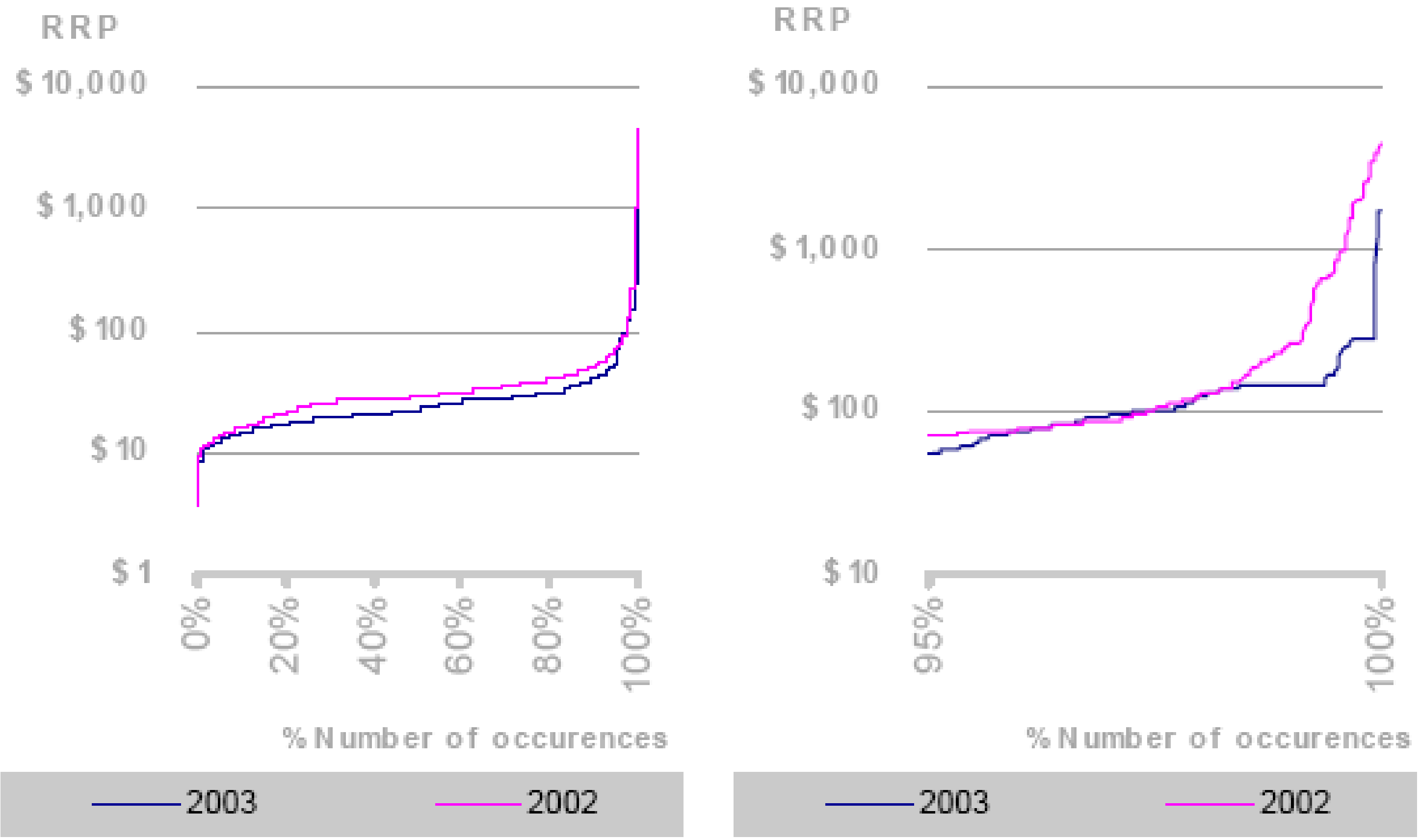
Demand duration curves 2003 Q4

(NECA, 03Q4 Stats, 2003)

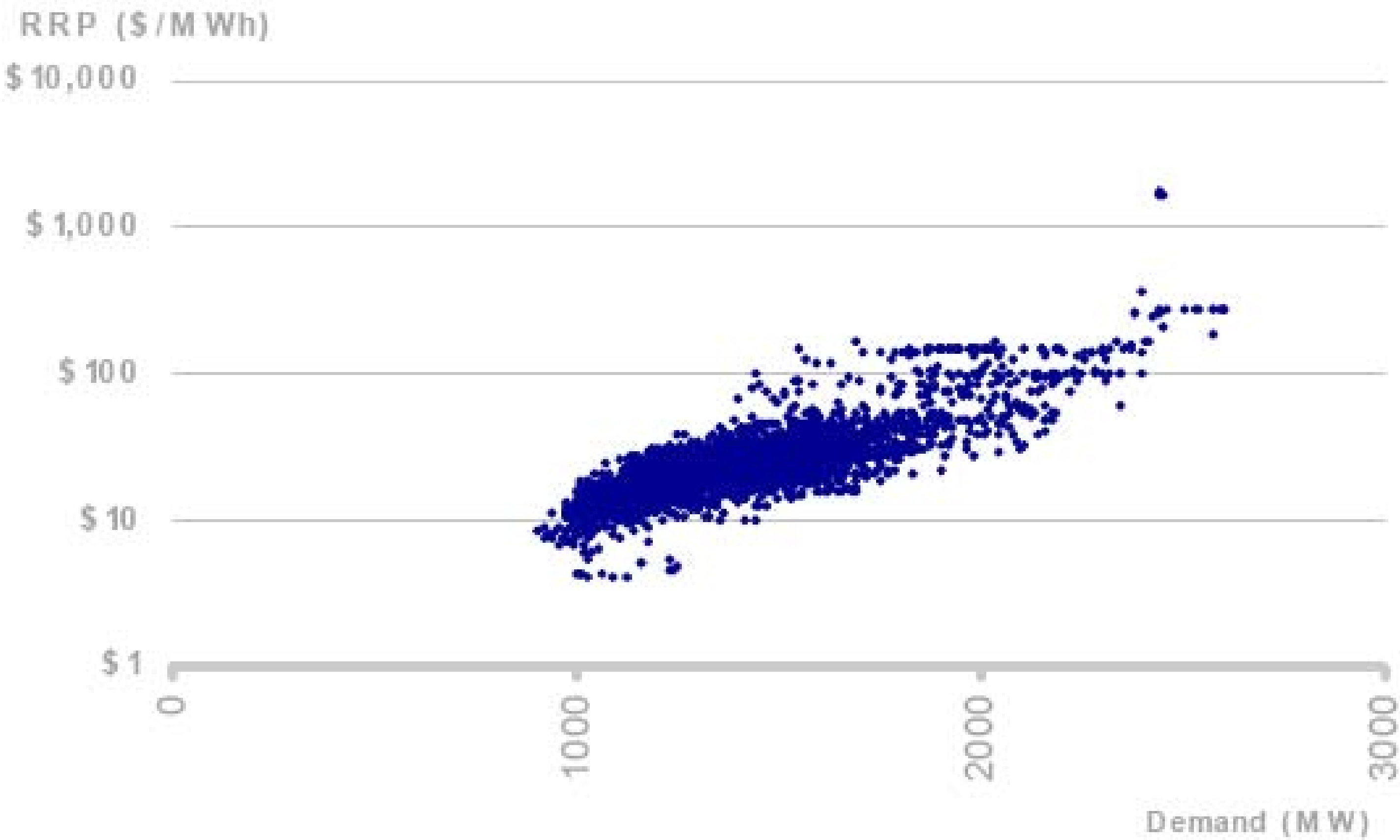


Q4 Spot price duration curve, SA

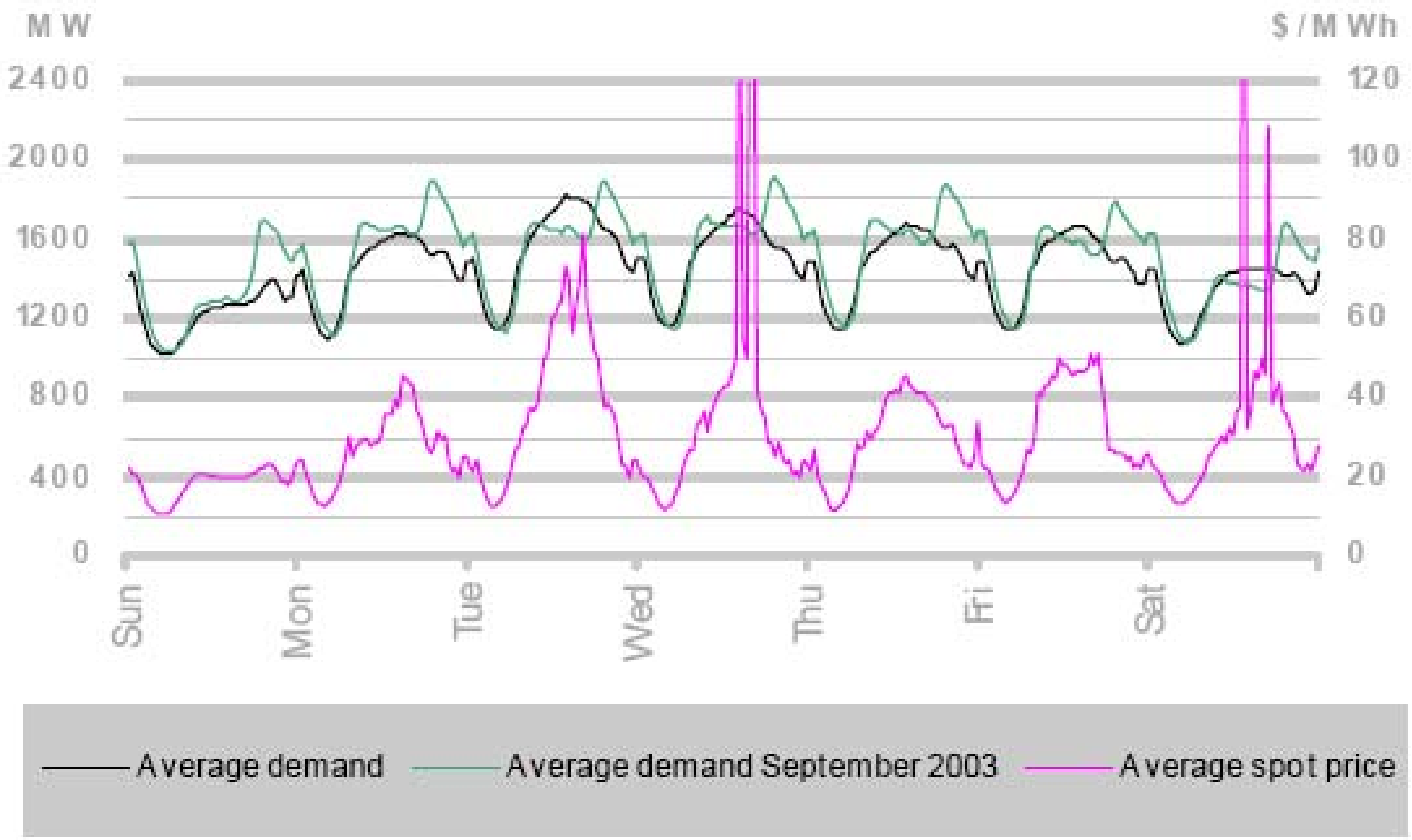
(NECA, 03Q4 Stats, 2004; half-hour spot prices)



Spot price as a function of demand SA,03 Q4 (NECA, 03Q4 Stats, 2004)



Average weekly price & demand, South Aust,03 Q4 (NECA, 03Q4 Stats, 2004)

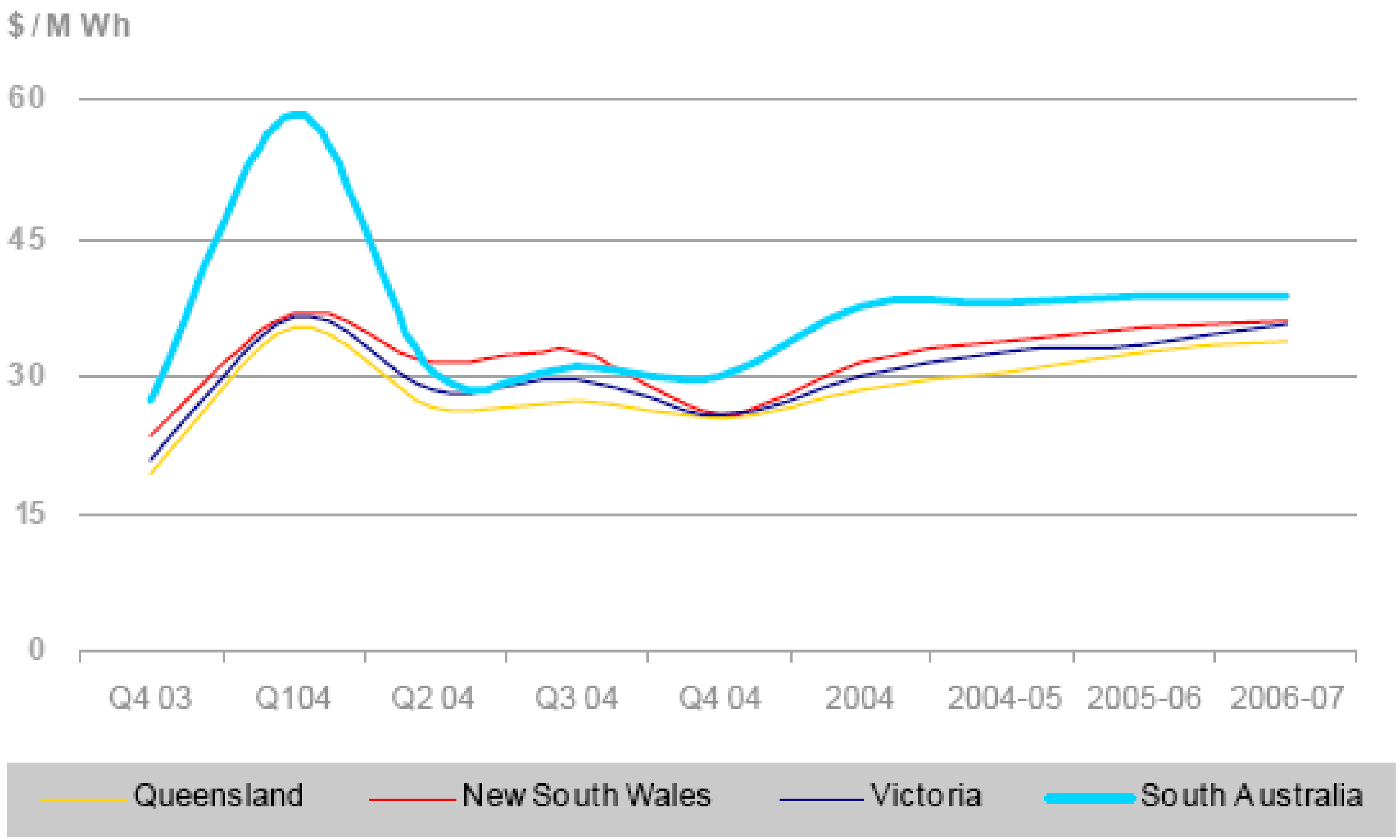


Issues for derivative markets

- Derivative markets include:
  - Forward contract markets (futures)
    - trade expected spot price for a defined load shape & period (eg flat annual demand)
  - Call options (price caps):
    - provide insurance against prices higher than a nominated "strike price"
- Wind farms likely to sell forward contracts:
  - Often as a PPA with a retailer to avoid selling to the NEM (hampered by volume uncertainty)

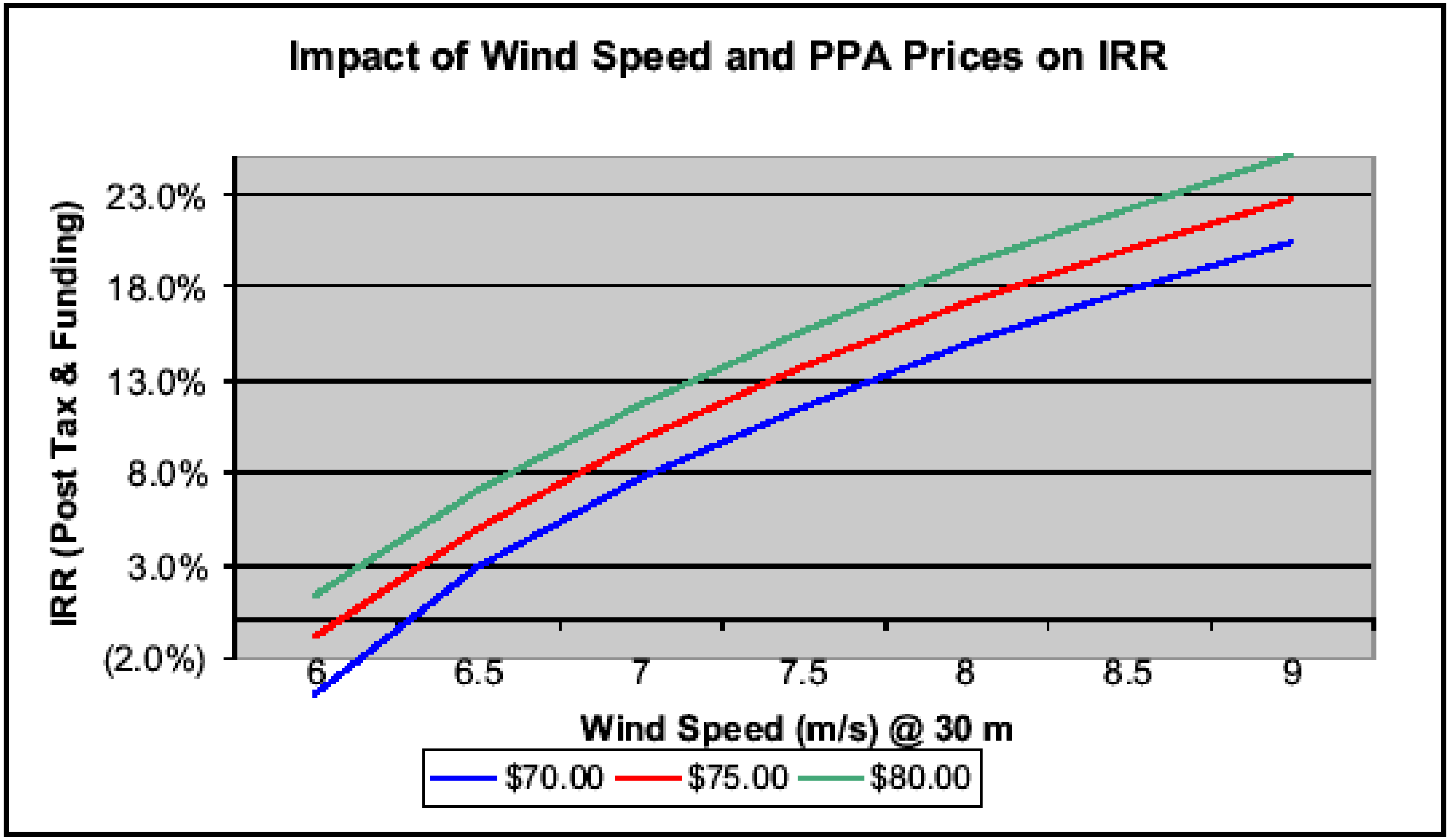
Flat contract prices, Q4 2003

(NECA, 03Q4 Statistics, 2004)

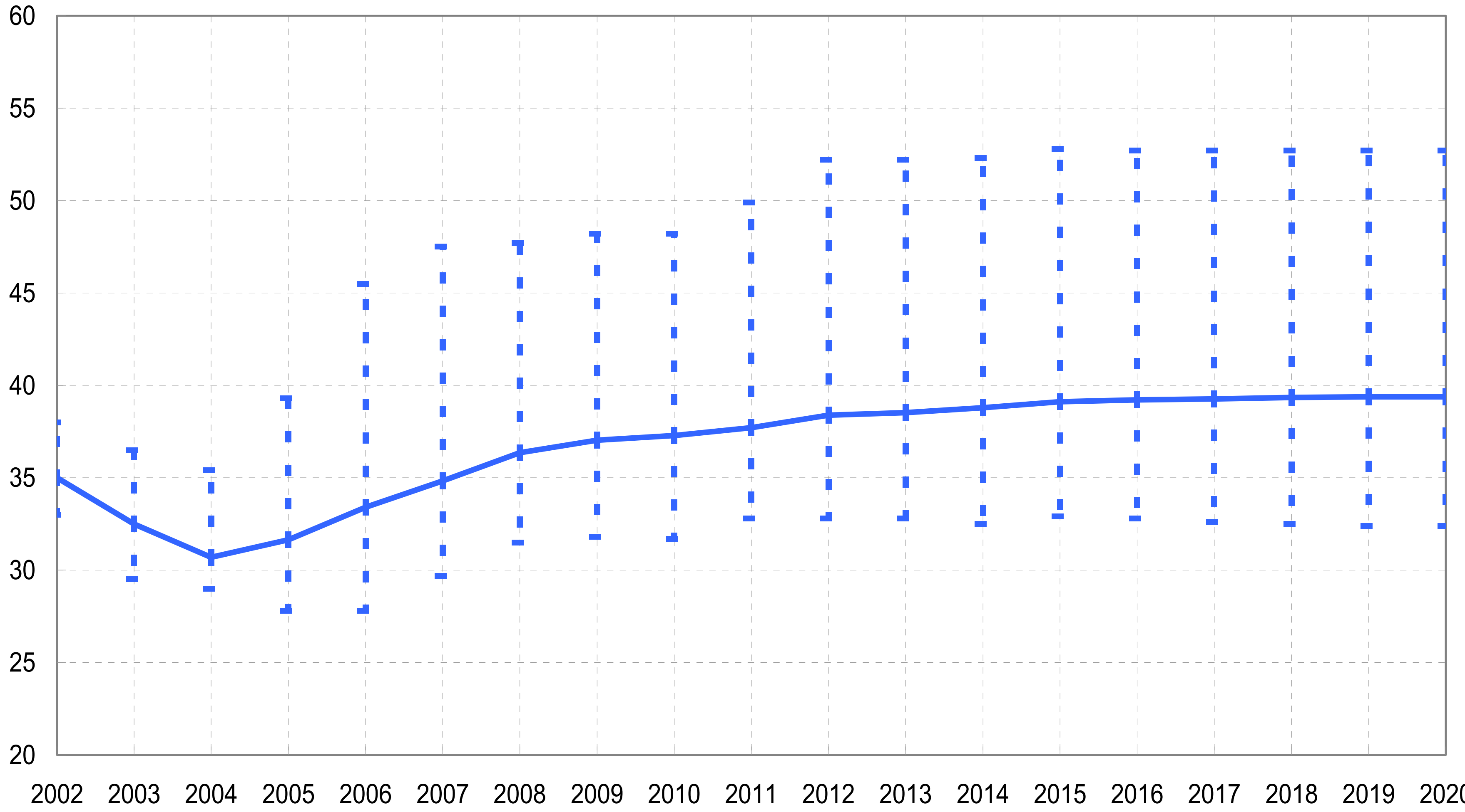


Wind farms marginal at $70/MWH

(PWC, 2002)



Renewable Energy Certificate Prices (A$/MWH)



Forward prices for wind energy

- Wind farms may have to accept a lower price than “flat contract” due to uncertainty in production:
  - Daily
  - Seasonal,
  - Annual

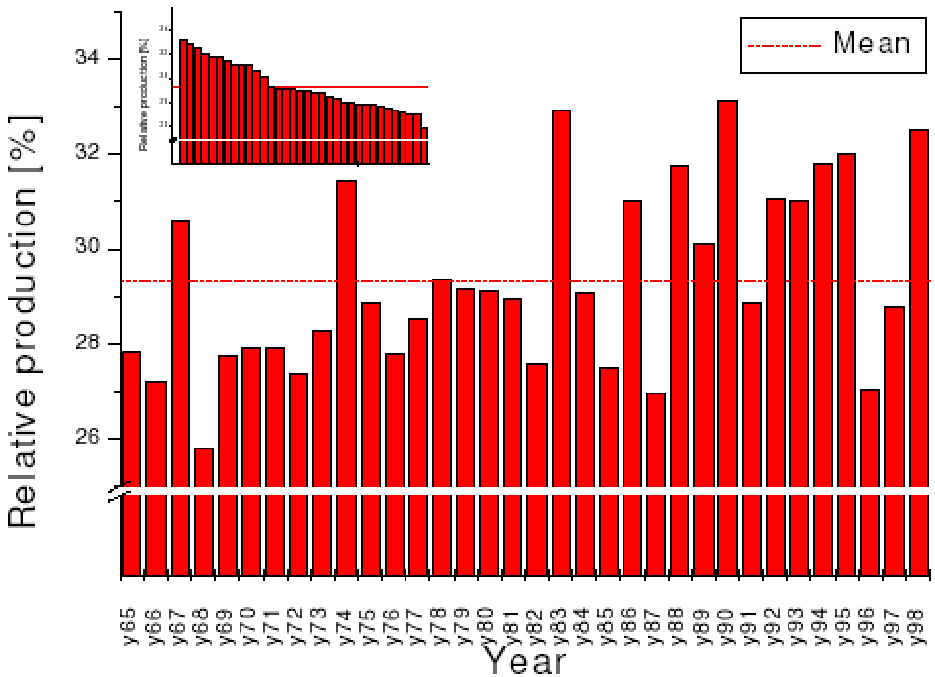


Figure 2: Mean wind power production in Northern Europe for 34 years as a percentage of installed capacity. In the inset: the same graph, ordered by size.

(Giebel (2000) Riso National Lab, Denmark)

Possible responses for energy and frequency issues

- Improve management of short-term uncertainty, e.g:
  - – Wind farm power forecasts - short & long term
  - – Demand-side provision of ancillary services
- Improve management of system security:
  - – Test ride-through capability of wind farms
  - – Enhance demand-side participation
- Revisit broader NEM design philosophy:
  - – FCAS, pre-dispatch, PASA