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Issues for Effective Management of Intermittent Generation in the NEM

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Outline

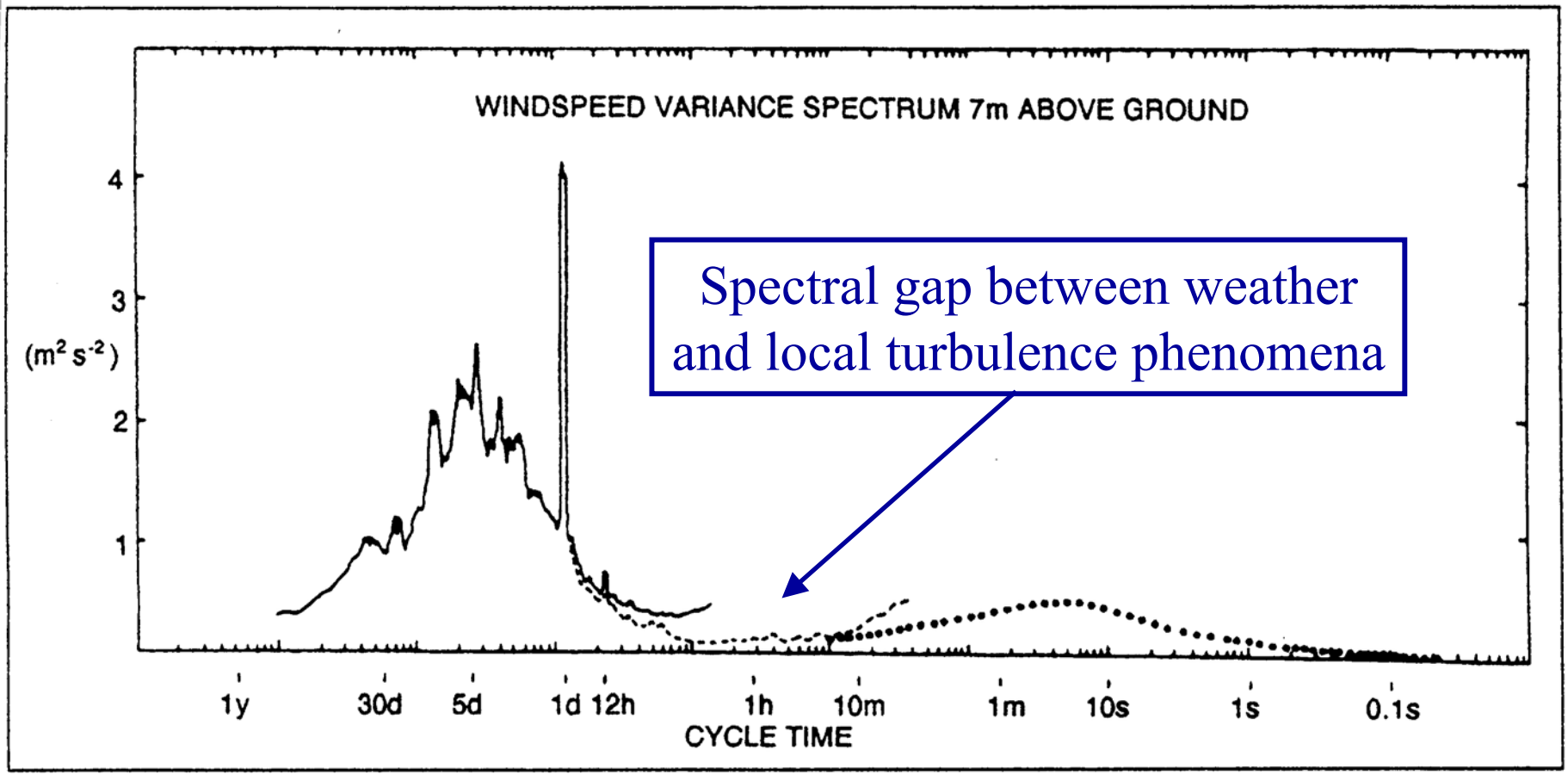
- Issues associated with intermittent generation
  - Wind farms as a case study
- Concerns of NEMMCO & Western Power
- Implications for spot & derivative markets
- Conclusions

Issues associated with intermittent generation

- Starting & stopping transients
- Fluctuations in power output while running
- Ability to contribute to voltage & frequency control
- Ability to forecast output of individual generators & groups of generators
- *Wind farms are an important practical case that will be used to illustrate the issues*

Spectral analysis of Danish long-term wind data (17 years of data)

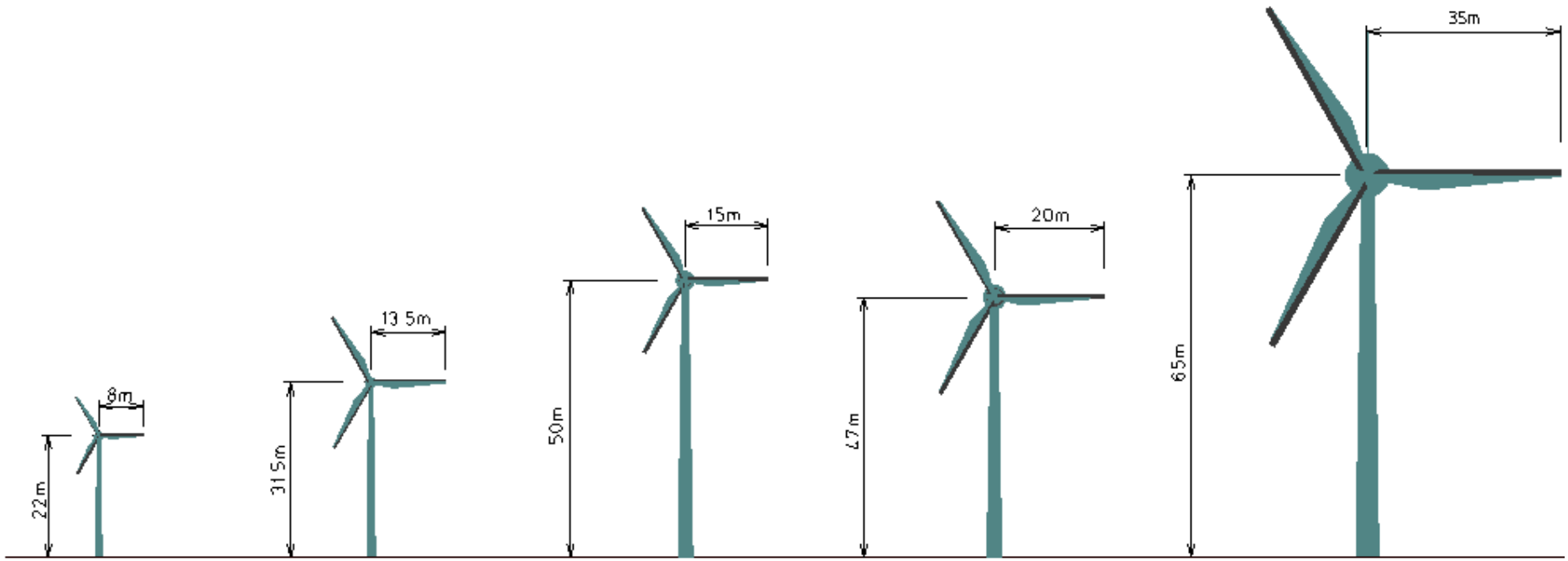
(Sorensen, 2001, Fig 2.110, p194)



NEM:	SOO, PASA & Derivative market	Spot	FCAS

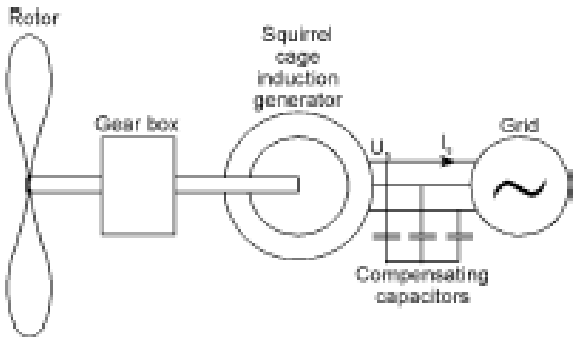
Size of wind turbines used by Western Power (www.wpc.com.au)

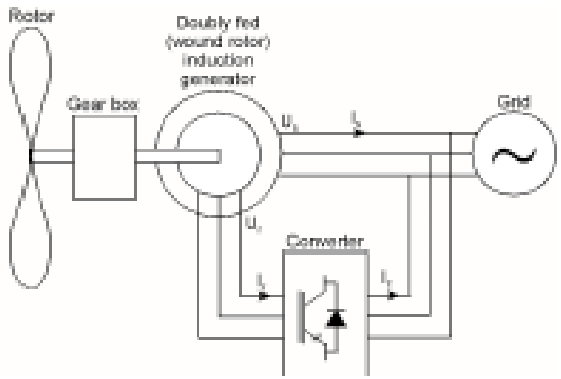
Larger turbines have smoother output due to greater size & height

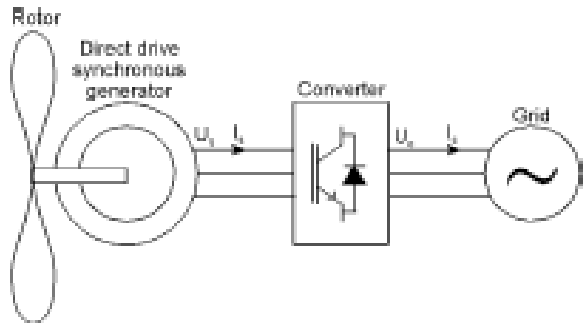


Wind turbine type comparison

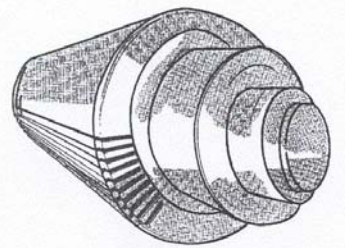
(Slootweg & Kling, TU Delft, 2003,
http://local.iee.org/ireland/Senior/Wind%20Event.htm)





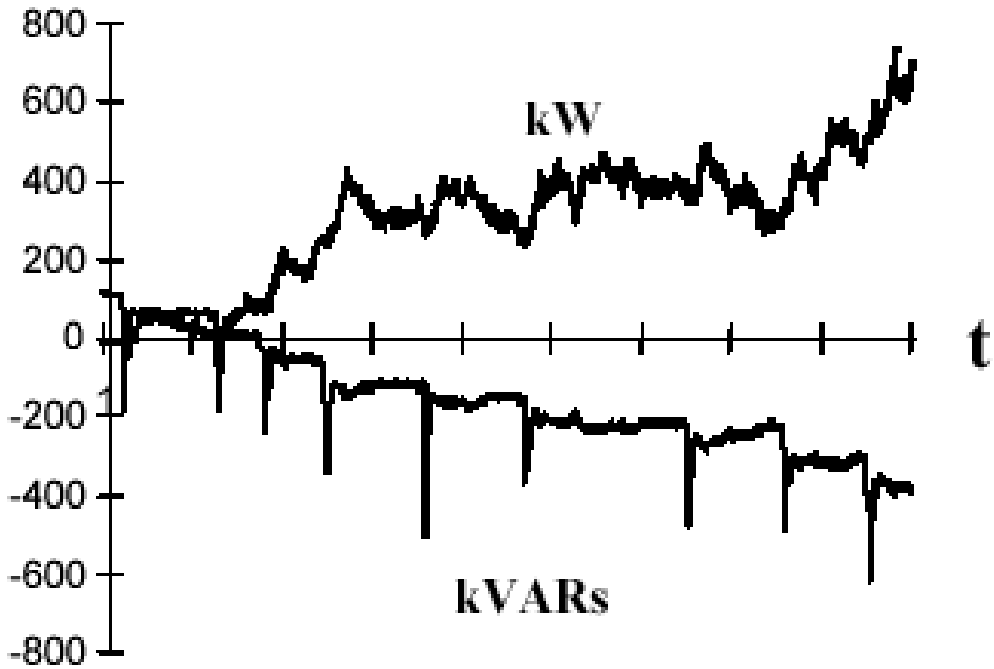


	Constant speed	Doubly fed	Direct drive
Strengths	Robust	Mechanical stress	Mechanical stress
	Cheap	Noise	Noise
	Electrical efficiency	Aerodynamic efficiency	Aerodynamic efficiency
	Standard generator	Standard generator	No gearbox
		Converter rating	
Weaknesses	Aerodynamic efficiency	Electrical efficiency	Electrical efficiency
	Mechanical stress	Gearbox	Converter rating
	Gearbox	Expensive	Very expensive
	Noise		Generator weight and dimensions
	V & F control		Generator complexity



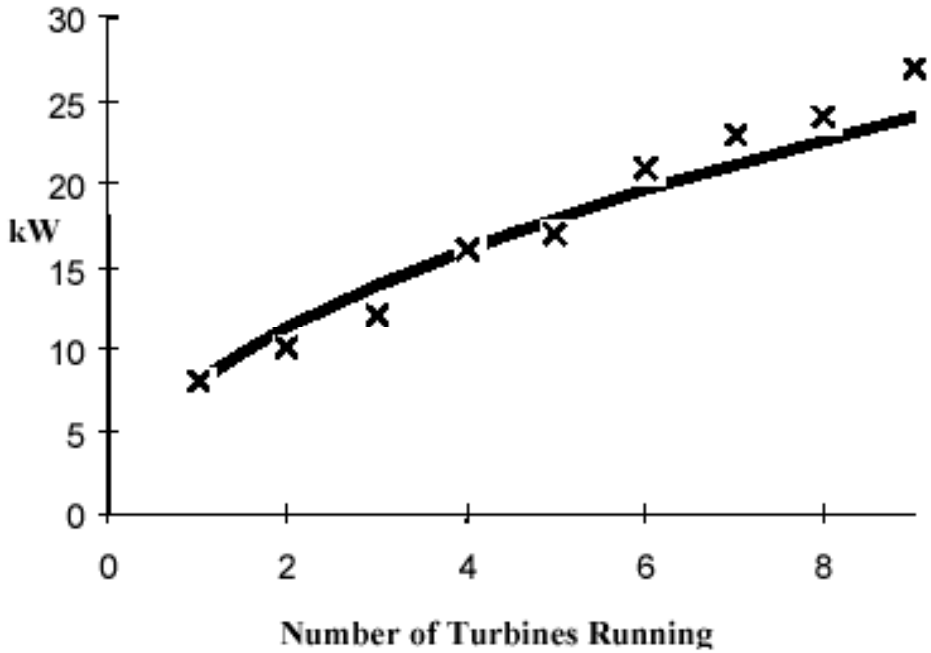
Starting transients for Esperance 2 MW wind farm (Rosser, 1995)

- 9 x 225 kW turbines with squirrel cage IG
- Magnetisation inrush current may cause a voltage dip:- starts should be spaced out



One-second power fluctuations at Esperance 2MW wind farm (Rosser, 1995)

- 9 x 225 kW turbines
- Solid line is proportional to $N^{-0.5}$
  - Implies 1-second fluctuations are uncorrelated

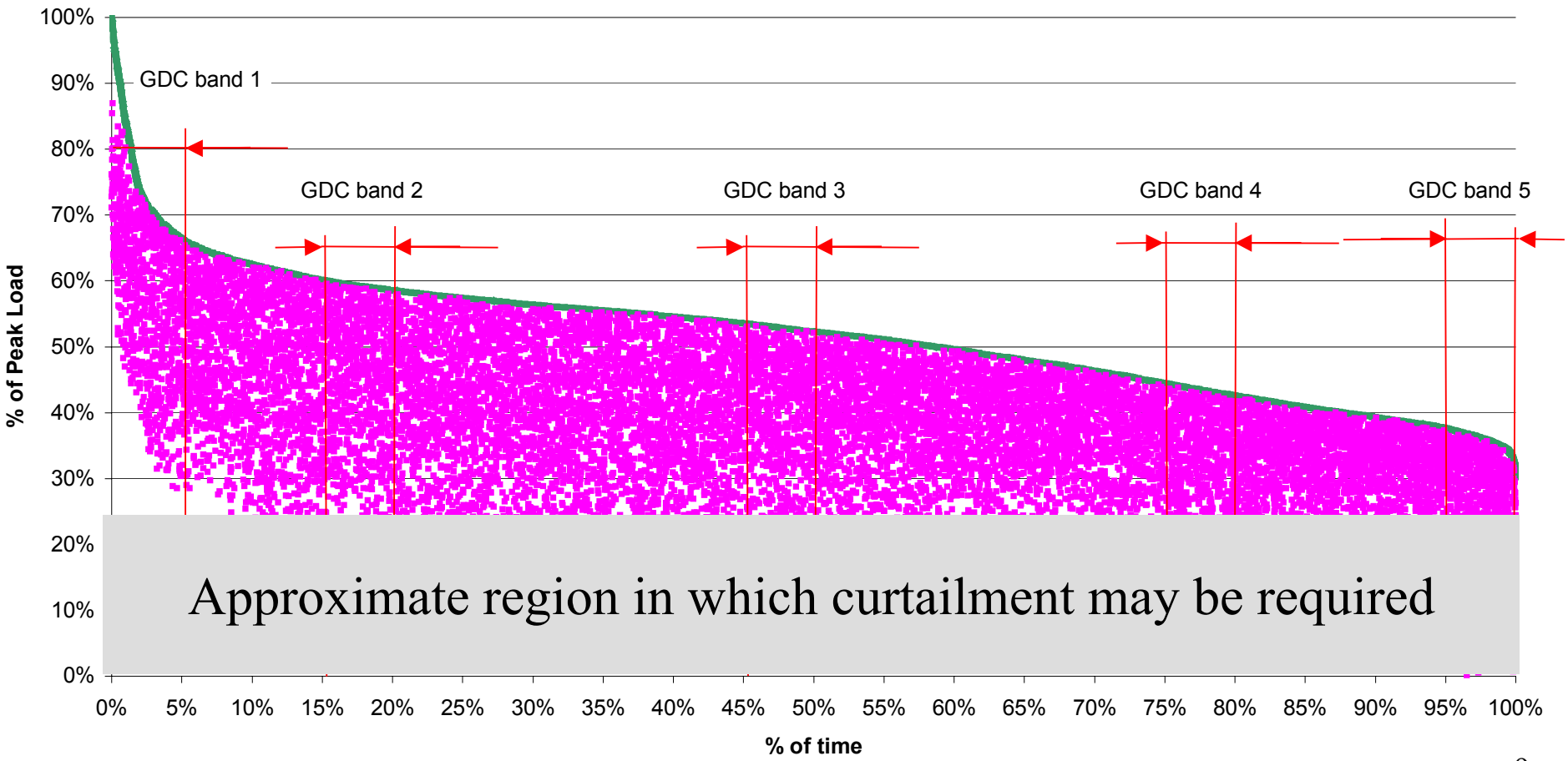


1GW wind contribution to meeting SA Load

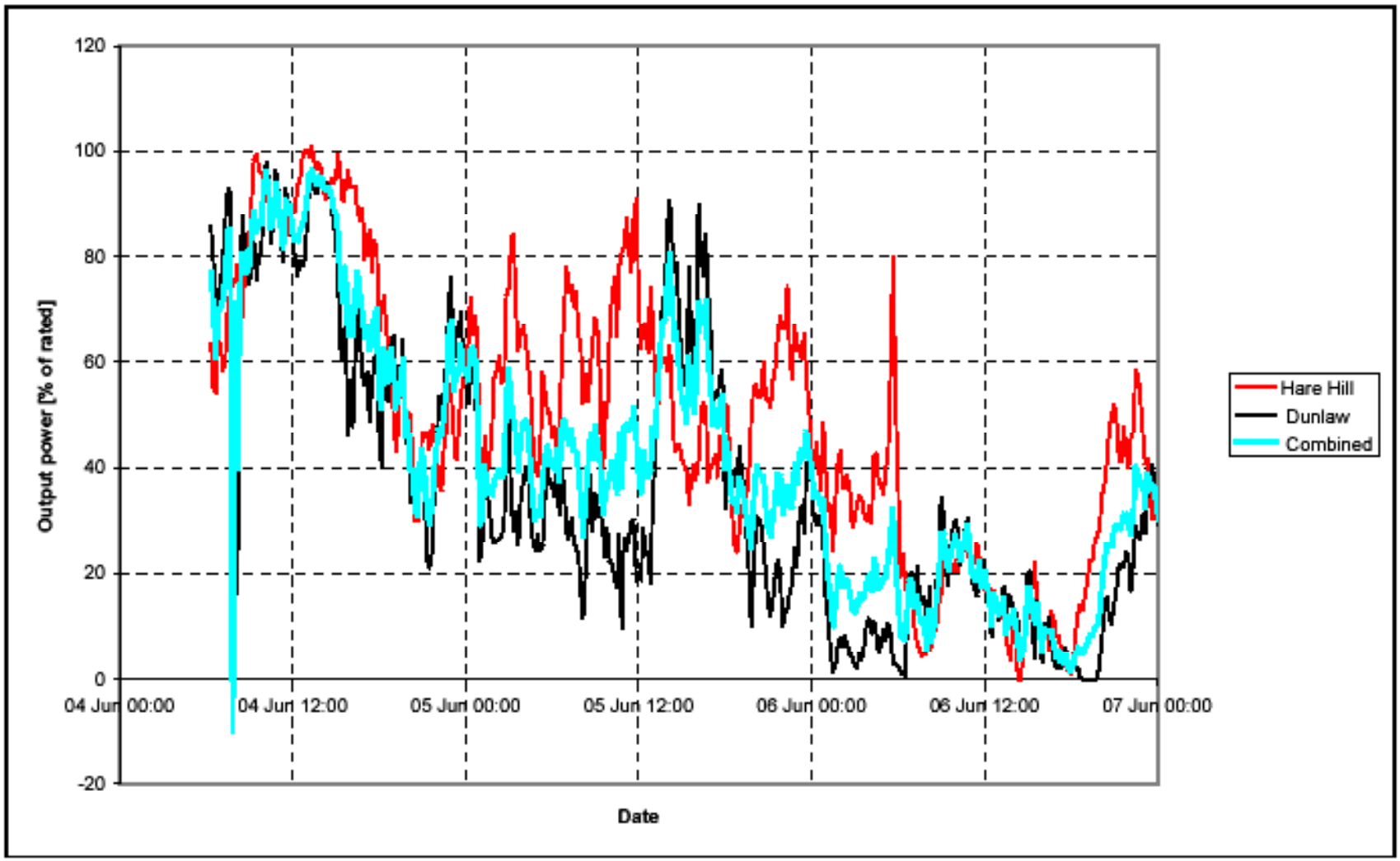
(Simulation study, ESIPC, 2003)

1997-98 Financial Year

SA load duration curve and the reduction from the high wind penetration case

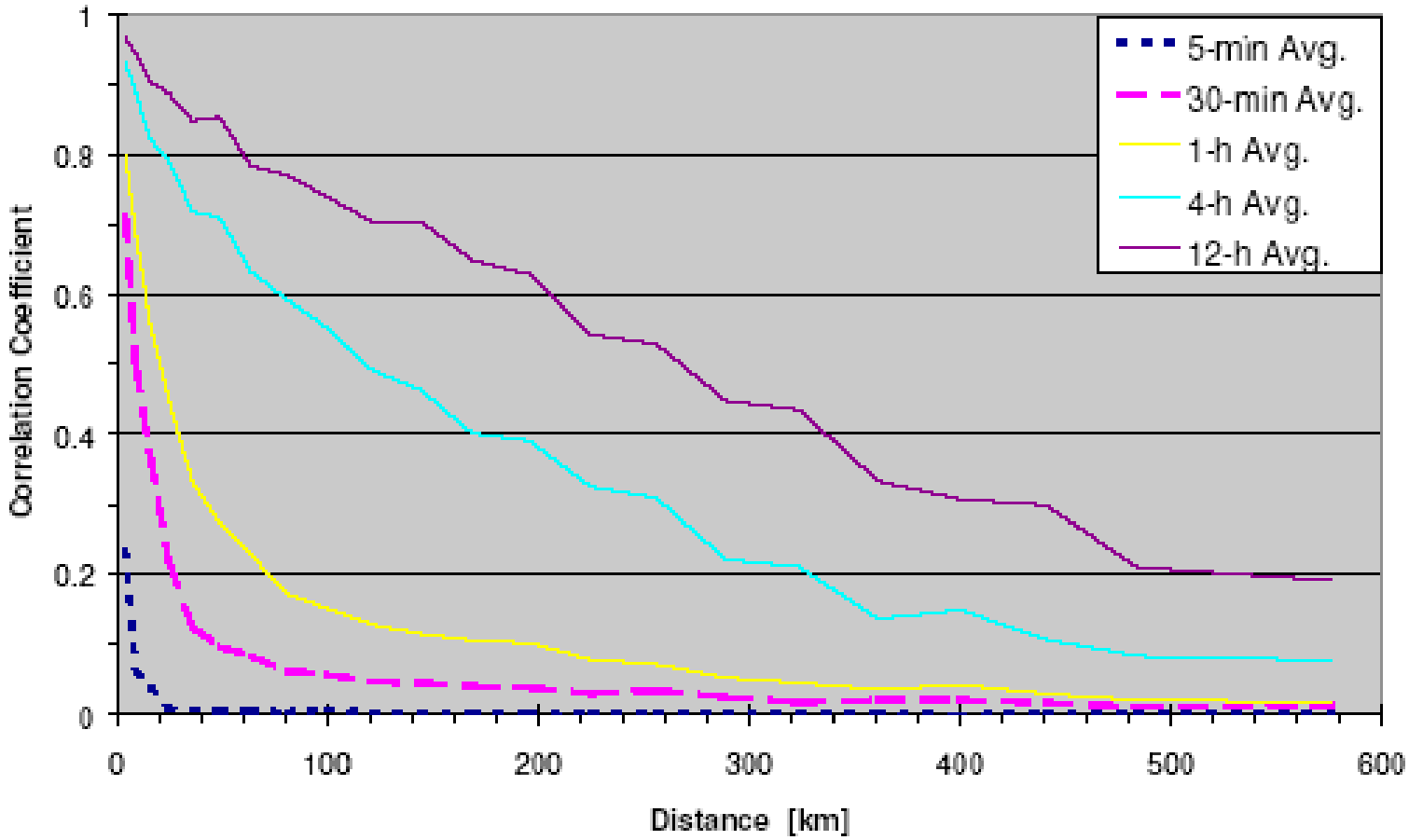


Combined output of 2 wind farms 80 km apart (Gardner et al, 2003)



Cross-correlations between measured power outputs of German wind farms

(Giebel (2000) Riso National Lab, Denmark)



Prediction of wind smoothing effects for Northern Europe

(Giebel (2000) Riso National Lab, Denmark)

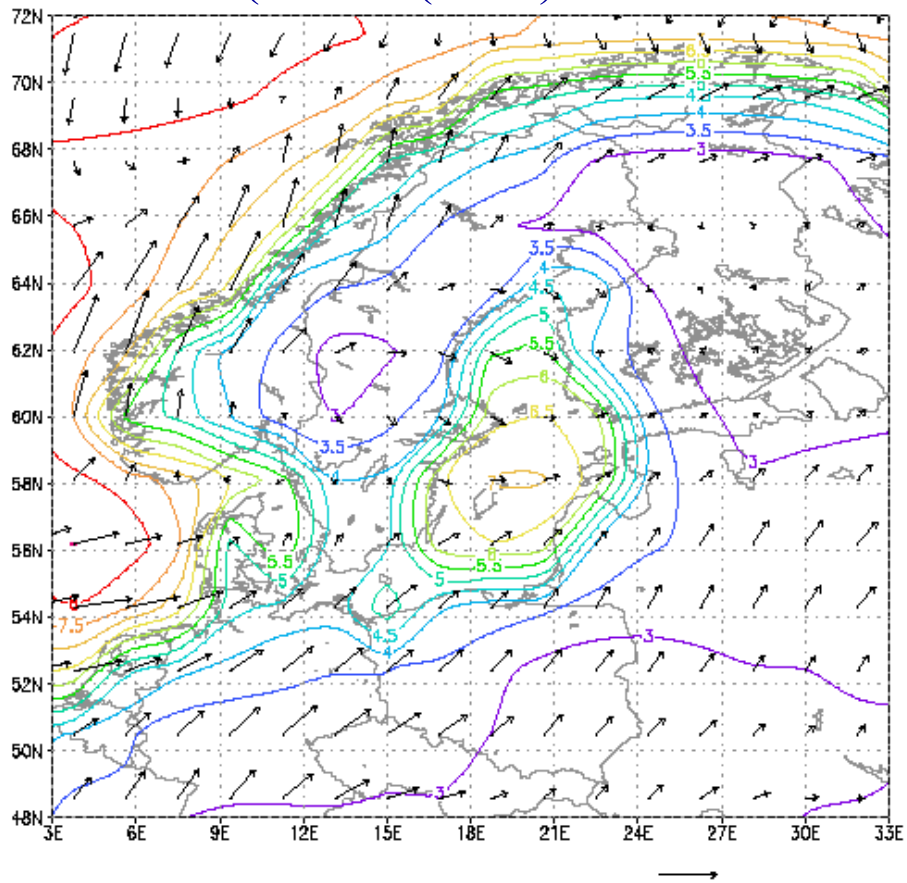
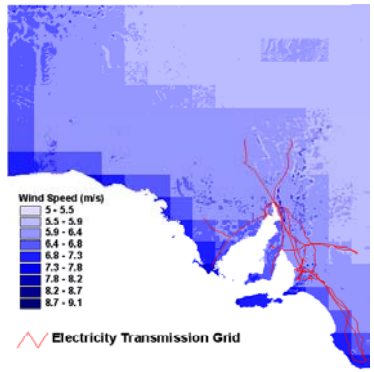


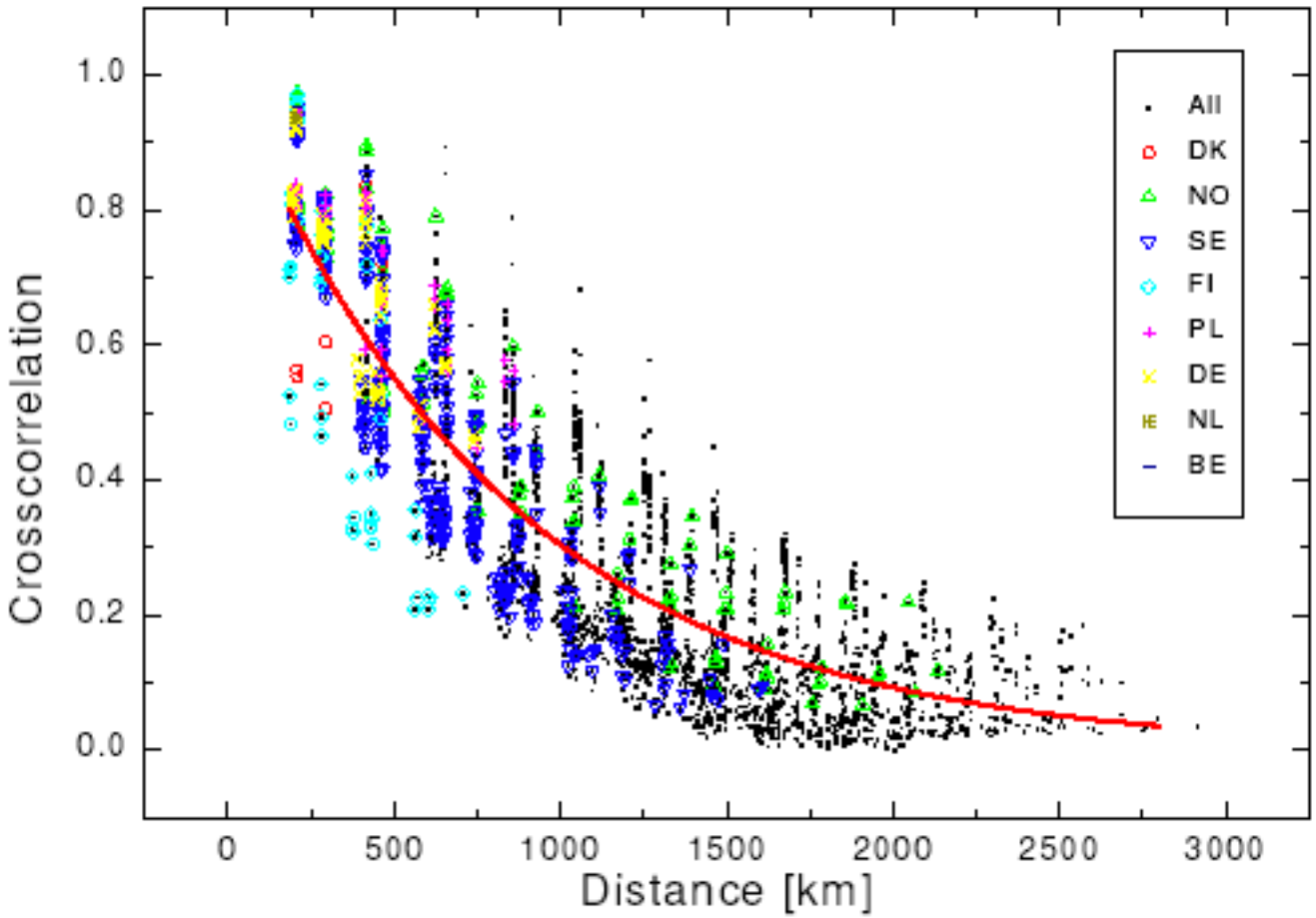
Figure 1: The wind resource of Northern Europe in m/s at 10m height, averaged from Reanalysis data for 1978. The arrows are the mean wind vector at every Reanalysis grid point.



Size comparison with South Australia

Cross-correlations between 34 years of NWP 12-hourly data for Northern Europe

(Giebel (2000) Riso National Lab, Denmark)



Predicted annual wind energy for Northern Europe for 34 years

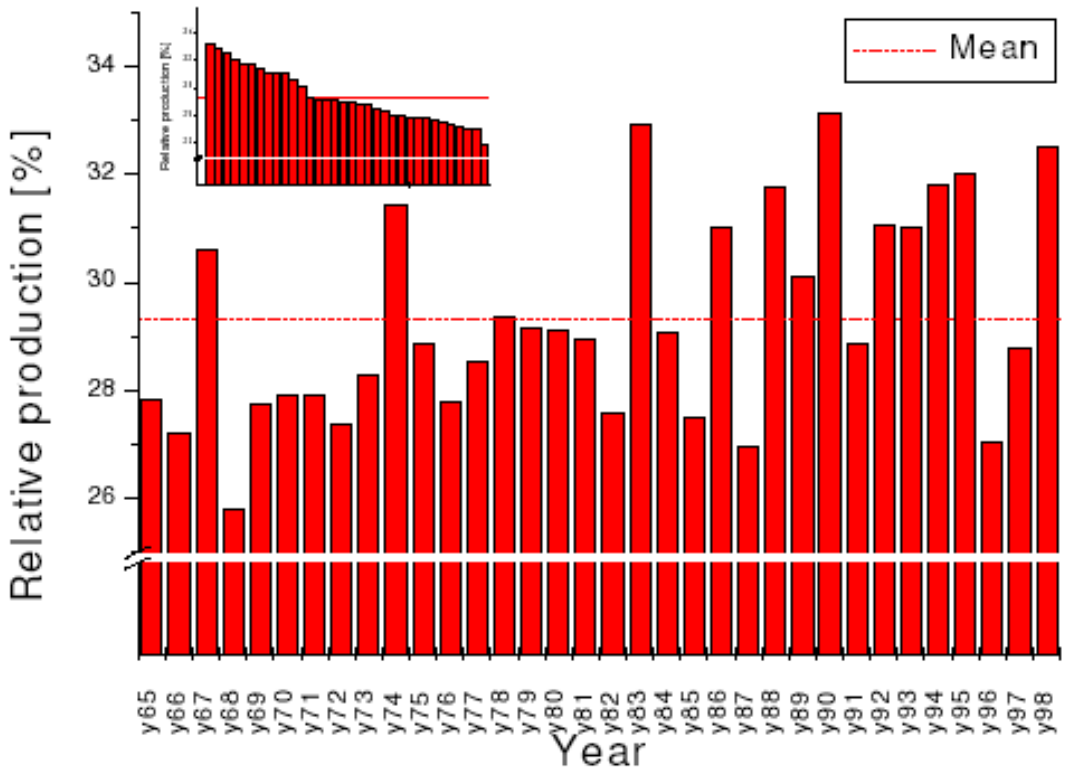


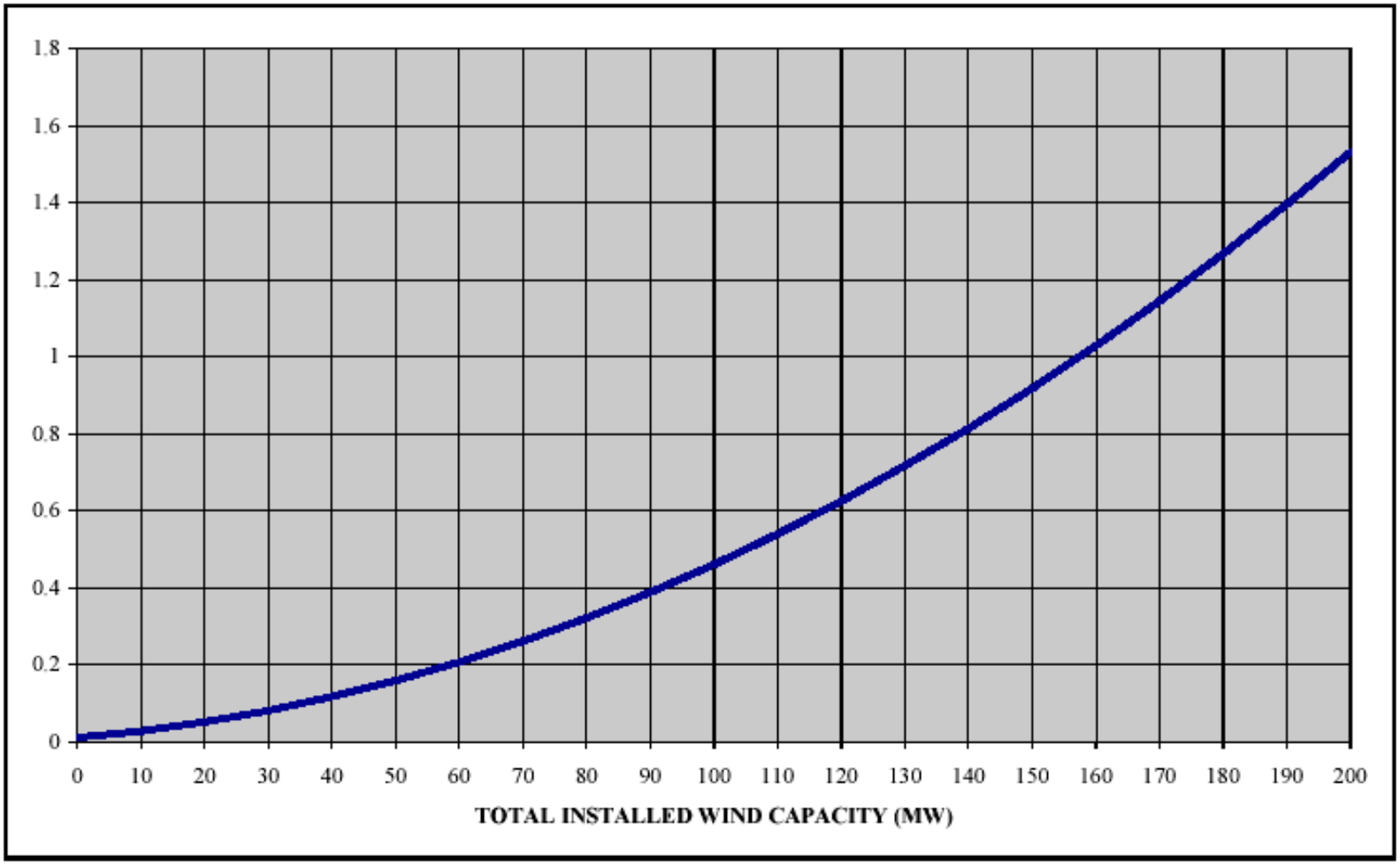
Figure 2: Mean wind power production in Northern Europe for 34 years as a percentage of installed capacity. In the inset: the same graph, ordered by size.

(Giebel (2000) - Riso National Lab, Denmark)

NEMMCO concerns about intermittent generation (NEMMCO, 2003)

- Forecast errors:
  - Five minute dispatch forecast (spot price)
  - Pre-dispatch & longer term (PASA & SOO) forecasts
- Frequency control in normal operation:
  - Frequency regulating service costs ~5 $/MWH?
- Security control:
  - Will wind farms ride-through system disturbances?
  - Will system inertia be reduced?
- Interconnection flow fluctuations:
  - Exceeding flow limit may cause high spot price or place system security at risk

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



Note: Without diversity & with centralised unit commitment

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
    - eg CSIRO Windscape

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 irregular & hard to predict
- Value of wind energy in the spot market:
  - Will depend on how regularly wind farms are producing when spot prices are high

Derivative pricing for wind energy

- Wind farms may have to accept a lower CFD price than “flat contract” due to uncertainty in production:
  - Daily, Seasonal, Annual
- Wind farms may similarly have to accept a lower REC price
- Pricing outcomes would be improved by liquid secondary markets in CFDs & RECs

Conclusions

- Intermittent generation:
  - Frequent starts, fluctuating & uncertain output
- Deleterious effects can be reduced through equipment & market design and forecasting
  - Use best available technology
  - Enhance & exploit diversity
    - A group rather than individual responsibility
  - Improve output forecasting (after diversity):
    - Trends and likelihood & timing of significant changes
  - Improve treatment of uncertainty in NEC