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Prospects for wind energy in Australia

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Alternative Technology Association, 14/10/08

www.ceem.unsw.edu.au

Outline

- Global energy-related challenges:
  - Energy security, fossil fuel prices, climate change
- Implications for the stationary energy sector
- Complex technological systems – the stationary energy sector
- Wind energy resource & technology issues
- Issues in integrating large amounts of wind energy into the Australian electricity industry
- Small wind turbines
- Conclusions

Background

- Humans face serious energy-related challenges:
  - Fossil fuel flow constraints:
    - "Peak-oil" now & in future "peak-gas", "peak-coal", "peak-uranium"
  - Energy security concerns:
    - Unequal distribution of energy resources among nation states
  - Increasing risk of dangerous climate change:
    - Anthropogenic CO_2 & other climate change gases
- These challenges are primarily matters of equity:
  - Intra-generational: rich versus poor
  - Inter-generational: old versus young & future generations
  - *Our best hope is frugality but we prefer to party*

Implications for the stationary energy sector (non-transport energy use)

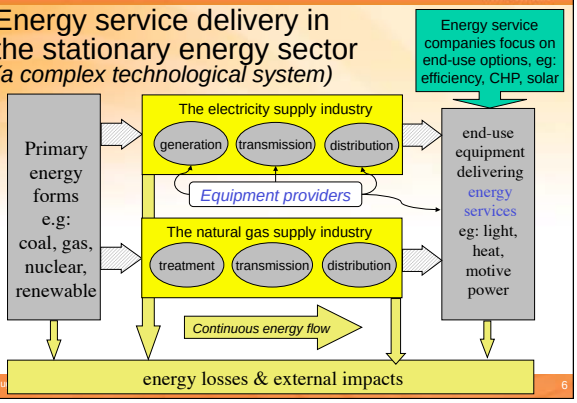
- Need to rapidly de-carbonise the sector:
  - "*…solution to global warming must include phase-out of coal except for uses where the CO_2 is captured and sequestered*" *(Hansen letter to Rudd, 27/3/08)*
- CCS not commercially available for at least 15yr:
  - *"we think that 2020 is the earliest it [ccs] can really be commercialised"*(John Boshier, National Generators Forum, ABC 7.30 Report, 7/4/08)
- Key near-term options are:
  - Frugality & improved end-use efficiency
  - Coal-to-gas & renewable energy technologies

Trend to gas-fired generation in the NEM: committed capacity & expected gas use

(ESIPC-SA APR, 2008)

	Currently	2009	2010
Total Capacity	6500 MW	8500 MW	9700 MW
Fuel consumption	160 PJ	220 PJ	280 PJ

Energy service delivery in the stationary energy sector *(a complex technological system)*



What is technology? (www.iiasa.ac.at)

Software & orgware are critical issues in complex technological systems such as an electricity industry

The Art of Knowing and Doing

The study of **technology** concerns *what* things are made and *how* things are made. Technology, from the Greek *science of* (practical) *arts,* has both a *material* and an *immaterial* aspect.

Technology = Hardware + Software + "Orgware"

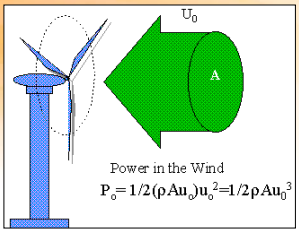
Hardware: Manufactured objects (artifacts)

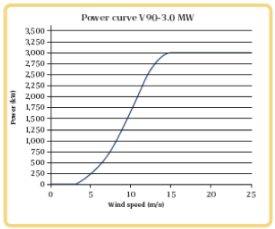
Software: Knowledge required to design, manufacture, and use technology hardware

"Orgware": Institutional settings and rules for the generation of technological knowledge and for the use of technologies

Technology's most important characteristic: ***Continuous change >>***

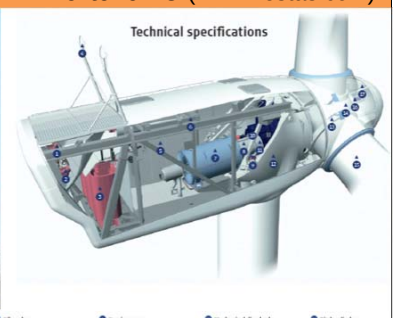
Wind power density & wind turbine conversion curve

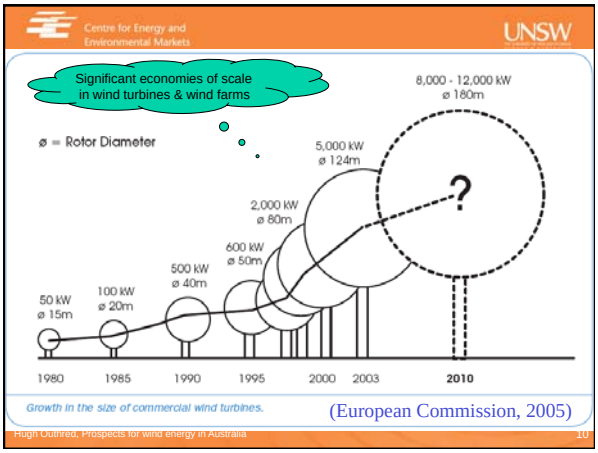




- Doubling wind speed increases wind power density 8 times
- A wind turbine is designed with a varying conversion efficiency of up to ~50% between 5 and 10 m/s

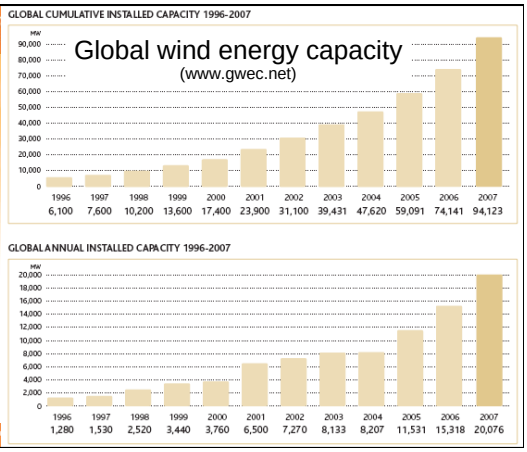
A modern 3MW wind turbine (www.vestas.com)





(European Commission, 2005)

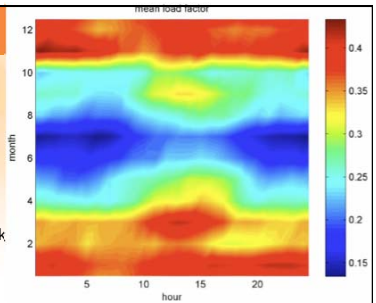
Global wind energy capacity (www.gwec.net)



UK wind capacity factor as function of:

1. Season & time of day (picture right)
2. Load level (table below)

(National Grid, Winter Outlook 2008/9)



		Wind output is % of installed capacity									
		0%-10%	10%-20%	20%-30%	30%-40%	40%-50%	50%-60%	60%-70%	70%-80%	80%-90%	90%-100%
Demand is % of annual maximum	0%-10%	0	0	0	0	0	0	0	0	0	0
	10%-20%	0	0	0	0	0	0	0	0	0	0
	20%-30%	0	0	0	0	0	0	0	0	0	0
	30%-40%	0	0	0	0	0	0	0	0	0	0
	40%-50%	430	225	145	86	54	29	27	16	4	0
	50%-60%	628	396	252	174	172	128	106	85	34	0
	60%-70%	699	469	325	258	206	170	132	122	62	3
	70%-80%	626	412	304	211	160	168	127	115	50	3
	80%-90%	188	166	142	92	79	89	80	73	42	3
	90%-100%	39	31	26	24	14	10	10	10	3	1

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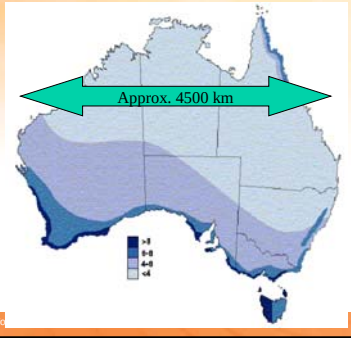
Australian wind resource

(Estimate of background wind (m/s) – Australian Greenhouse Office)



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Some Wind Farms in Australia


Mt Millar, Tarong Energy


Wattle Point, Dave Clark


Blayney, Eraring Energy


Woolnorth, Hydro Tas


Albany, Verve Energy

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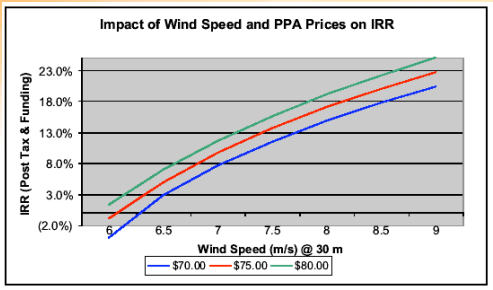
Wind farms marginal at $70/MWH in 2002

(PWC, 2002) *Need 100+ $/MWh in 2008*



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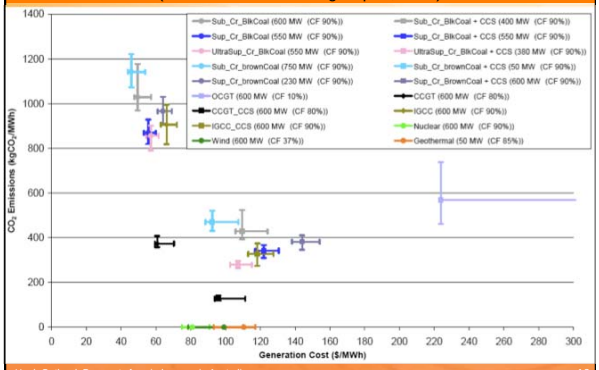
Cost & CO2 coefficients for new generation

(ESIPC Annual Planning Report, 2008)



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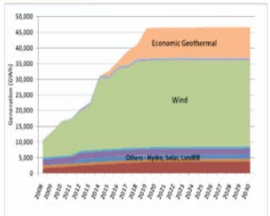
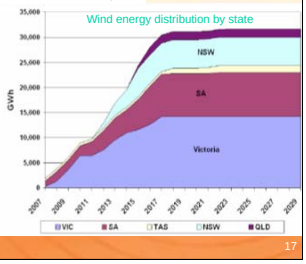
Proposed MRET target of 20% by 2020

- Rules still to be finalised but possibly >45TWH pa in 2020
- A scenario for resulting renewable energy generation shown below
- Possible high wind penetration in SA + Vic

(IES, *NSW Privatisation Conference*, 2008)





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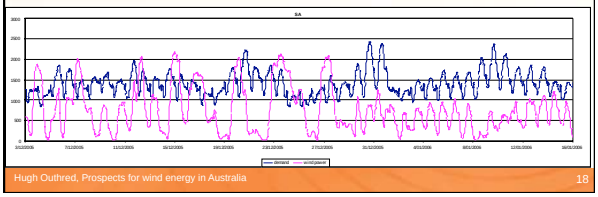
Wind energy in the Australian NEM

- Presently ~1GW, but 8GW likely in <10 years, including ~2.5GW in South Australia (diag below)
- NEMMCO is installing an Australian Wind Energy Forecasting System purchased from Anemos
- AWEFS will be integrated into the NEM forecasting process (pre-dispatch, STPASA, MTPASA, SOO)



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Decision-making framework for a restructured electricity industry (EI)

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	▪ Engineering design to allow industry components to function as single, industry-wide machine when connected together
Commercial regime	▪ Decentralised decision-making according to commercial criteria within a market context ▪ Includes formally designed markets ▪ *Needs adequate competitive pressures*

Scope of the National Electricity Market

Market regions:
- Queensland
- New South Wales & ACT
- Victoria
- South Australia
- Tasmania

NEM regions are on state borders, generation/load zones are joined by national transmission flow paths (NTFPs)

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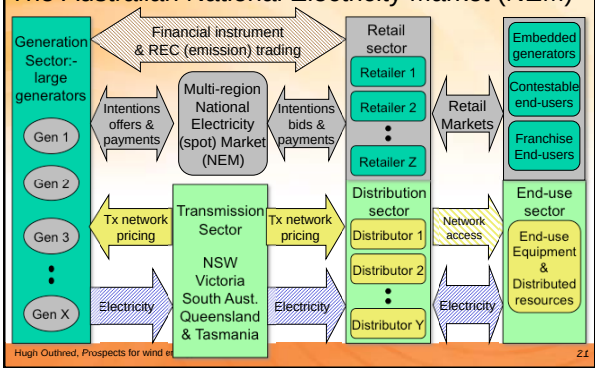
The Australian National Electricity Market (NEM)



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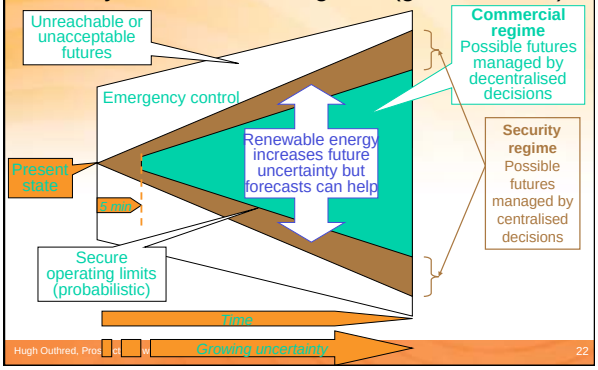
Security & commercial regimes (global & local)



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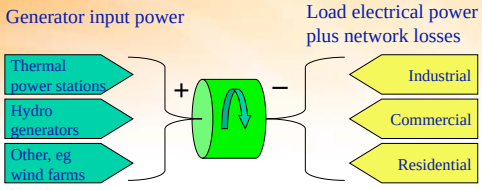
Supply-demand balance in the electricity industry



- Frequency is a measure of supply-demand balance:
  - Always varying due to fluctuations in energy flows

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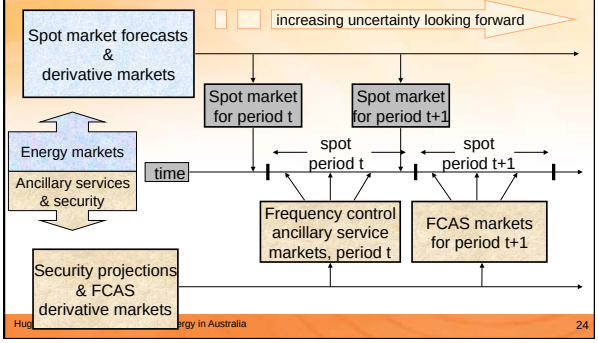
Managing supply-demand balance in NEM



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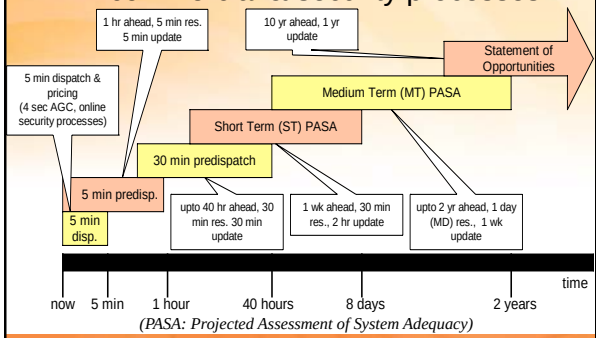
NEM commercial & security processes



(PASA: Projected Assessment of System Adequacy)

Source: NEMMCO; S Thorncraft

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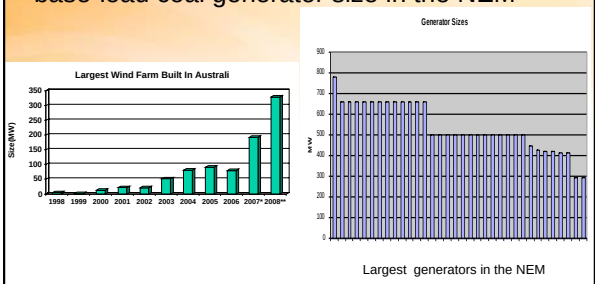
Australian wind farm size *compared to* base-load coal generator size in the NEM



Largest generators in the NEM

* Under construction ** Planning Approved

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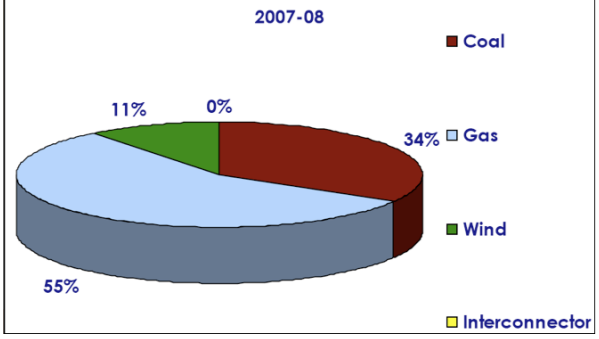
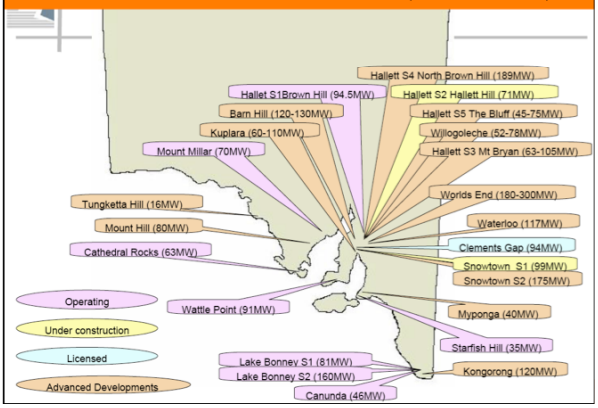
Electricity generation in South Australia

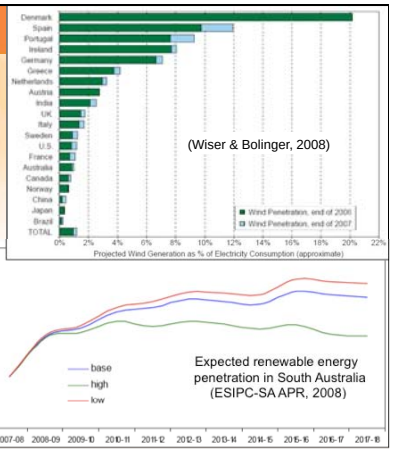
(ESIPC Annual Planning Report, 2008)



Wind farms in South Australia (ESIPC APR, 2008)



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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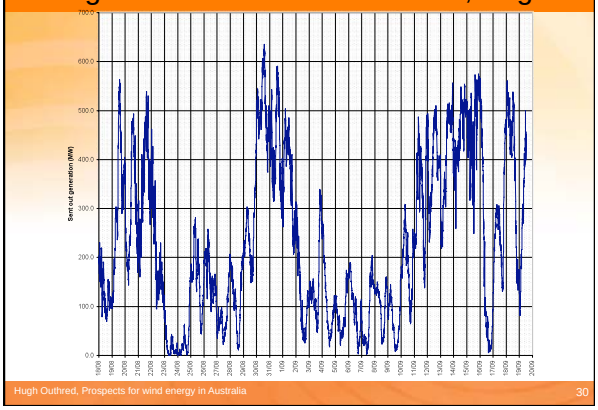
Wind generation in South Australia, Aug 08



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Wind generation in South Australia, Aug 08

- The aggregate output of wind farms in South Australia varied from -2.6 MW to 635.5 MW
- The maximum variation from one 5 minute interval to the next was 155 MW
- The maximum change in other generation required to meet demand and the variation in wind from one 5 minute interval to the next was 214 MW
- Wind generation contributed up to 51% of customer demand
- There were 143 dispatch intervals where the spot price for energy in SA was negative

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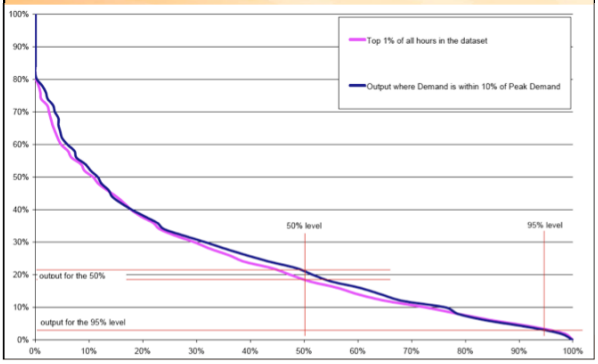
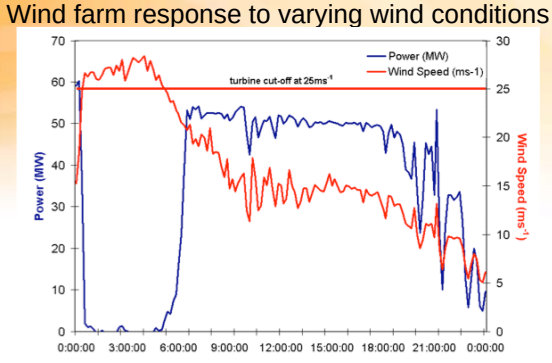
SA wind output at high demand (ESIPC 2008)



NEM income for SA wind & other generators
(ESIPC-SA APR 2008)

Year	Volume Weighted Price for Wind Generators		Volume Weighted Price for Other SA Generators	
	Full Year ($/MWh)	Summer ($/MWh)	Full Year ($/MWh)	Summer ($/MWh)
2004–05	NA	NA	39.25	32.62
2005-06	32.57	39.59	43.91	67.50
2006-07	49.69	51.55	58.71	67.21
YTD 2007-08	66.99	63.94	108.25	149.92

Wind farm response to varying wind conditions



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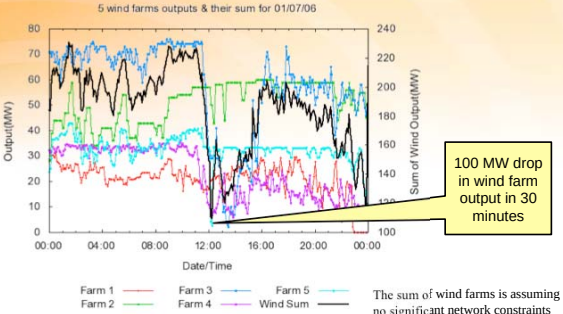
Example of swing down for 5 wind farms



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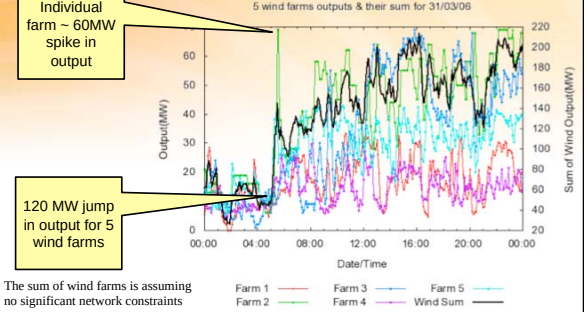
Example of swing up for 5 wind farms



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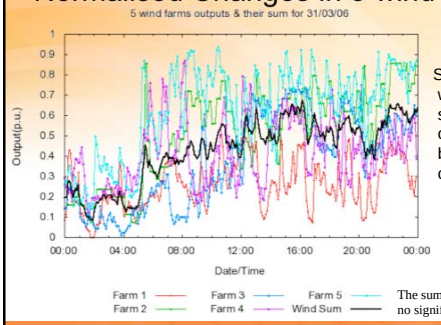
Normalised Changes in 5 wind farms



Summed output of 5 wind farms smoother than that of each wind farm but large & rapid changes still occur

The sum of wind farms is assuming no significant network constraints

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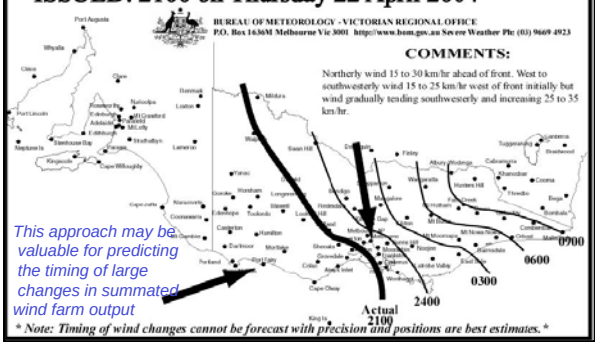
WIND CHANGE FORECAST CHART

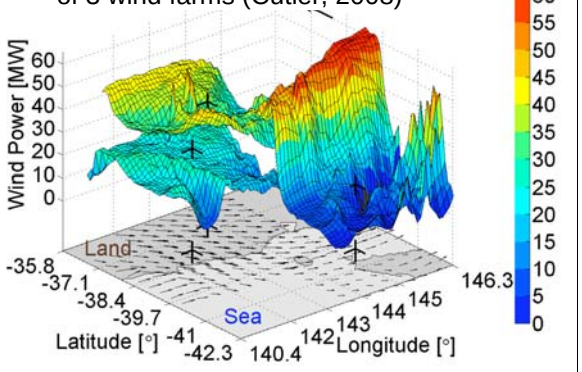
ISSUED: 2100 on Thursday 22 April 2004



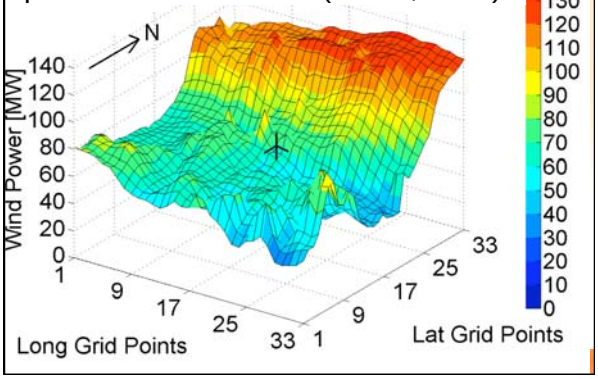
This approach may be valuable for predicting the timing of large changes in summated wind farm output

** Note: Timing of wind changes cannot be forecast with precision and positions are best estimates. **

Visualising possible power output of 3 wind farms (Cutler, 2008)



Visualising possible aggregated power of 3 wind farms (Cutler, 2008)



Key electricity industry issues for high-penetration renewable energy #1

- Structural issues:
  - Robust security regime with security-constrained dispatch
  - Efficient commercial regime (operation & investment)
  - Effective regulation of network services
  - Compatible arrangements for gas industry
- Development issues:
  - Innovation in renewable energy technologies
  - Forecasting for security & commercial regimes
  - Active end-user participation (value, timing, efficiency)
  - Education & training in all relevant areas

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Key electricity industry issues for high-penetration renewable energy #2

- Auction-style, security-constrained markets:
  - For spot energy, ancillary services **& derivatives**
  - Active end-users supported by ESCOs & equity policies
- Efficient network service regime:
  - Augmentation; availability & quality; distributed resources
- Renewable energy forecasting tools for:
  - Security, commercial & governance regimes
- Internalisation of un-costed fossil fuel externalities:
  - Carbon taxes or rigorous emissions trading scheme
  - Development & deployment of low emission technologies

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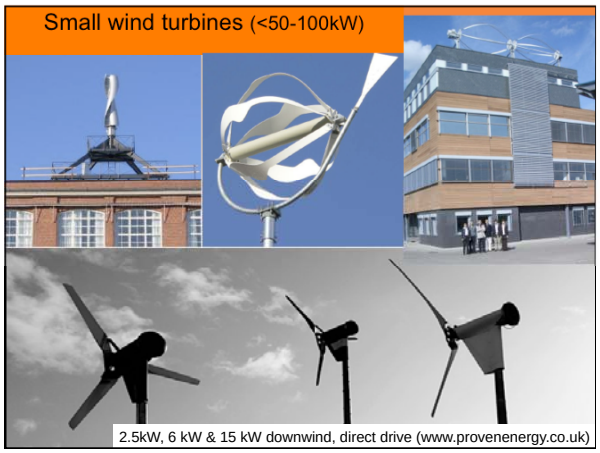
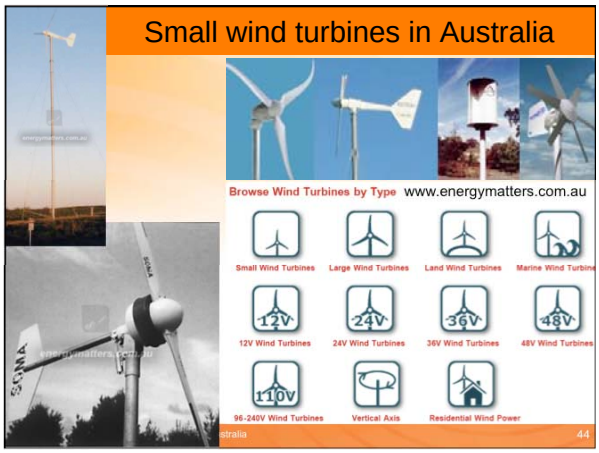
Small wind turbines (<50-100kW)



2.5kW, 6 kW & 15 kW downwind, direct drive (www.provenenergy.co.uk)

Small wind turbines in Australia



Residential wind turbine invention, Graeme Attey, Perth

(http://www.youtube.com/watch?v=WZ5kX5Yw4eY)
(http://www.abc.net.au/news/stories/2007/06/27/1963676.htm?section=business)

Small wind turbines in UK (<50kW), 2008 Carbon Trust Study (www.carbontrust.co.uk)

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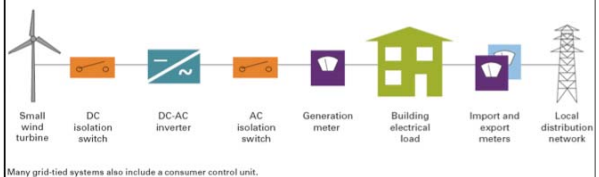
Figure 13: Simplified schematic of a grid-tied small turbine installation



Many grid-tied systems also include a consumer control unit.
Systems vary between manufacturers and installers so this is an example rather than typical case.

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Small wind turbines in UK, 2008 Carbon Trust Study (www.carbontrust.co.uk)

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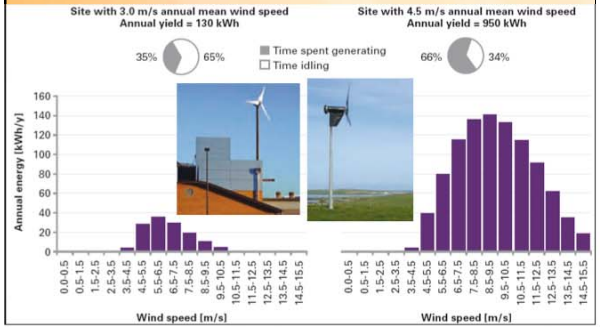

Shear profiles: rural & urban sites

(www.carbontrust.co.uk)

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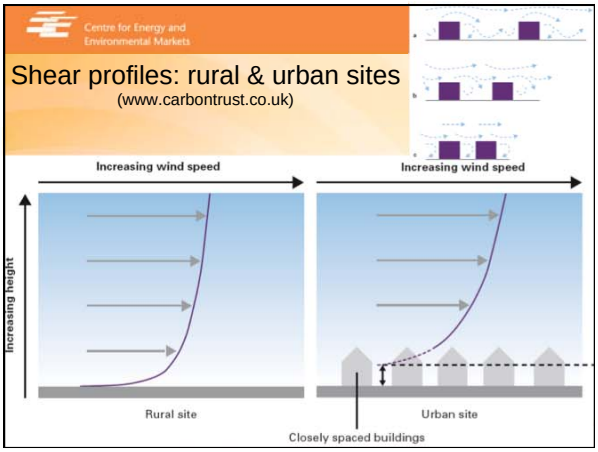
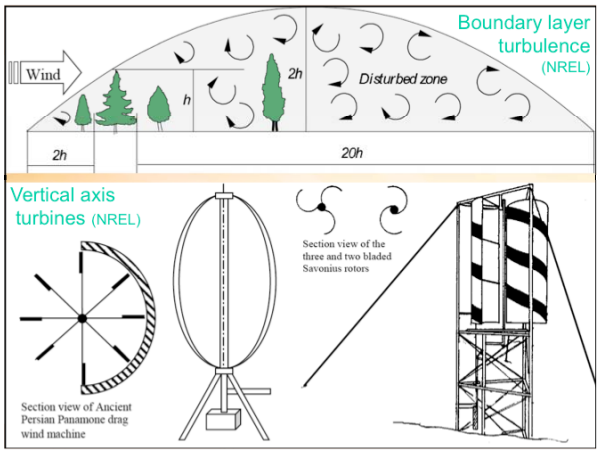
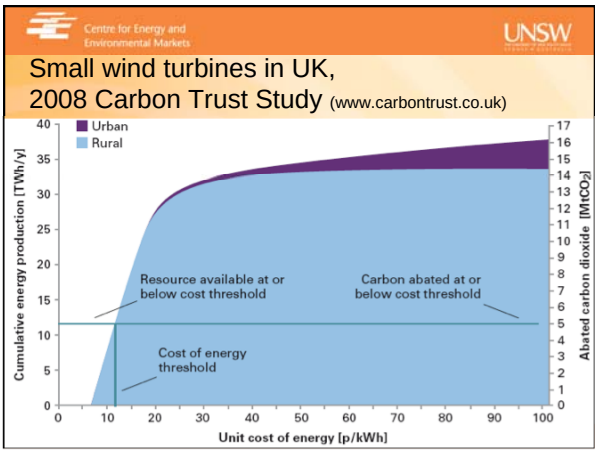
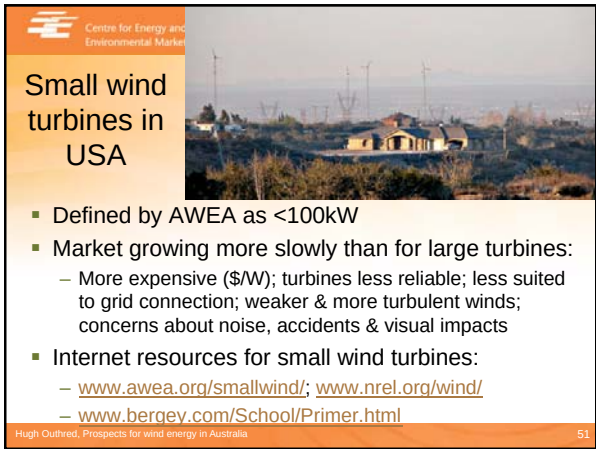



Boundary layer turbulence (NREL)
Wind
2h
h
Disturbed zone
2h
20h
Vertical axis turbines (NREL)
Section view of the three and two bladed Savonius rotors
Section view of Ancient Persian Panamone drag wind machine


Centre for Energy and Environmental Markets
UNSW
Small wind turbines in UK, 2008 Carbon Trust Study (www.carbontrust.co.uk)
Urban
Rural
Cumulative energy production [TWh/y]
Abated carbon dioxide [MtCO2]
Resource available at or below cost threshold
Carbon abated at or below cost threshold
Cost of energy threshold
Unit cost of energy [p/kWh]


Centre for Energy and Environmental Markets
Small wind turbines in USA
Defined by AWEA as <100kW
Market growing more slowly than for large turbines:
More expensive ($/W); turbines less reliable; less suited to grid connection; weaker & more turbulent winds; concerns about noise, accidents & visual impacts
Internet resources for small wind turbines:
www.awea.org/smallwind/; www.nrel.org/wind/
www.bergey.com/School/Primer.html
Hugh Outhred, Prospects for wind energy in Australia
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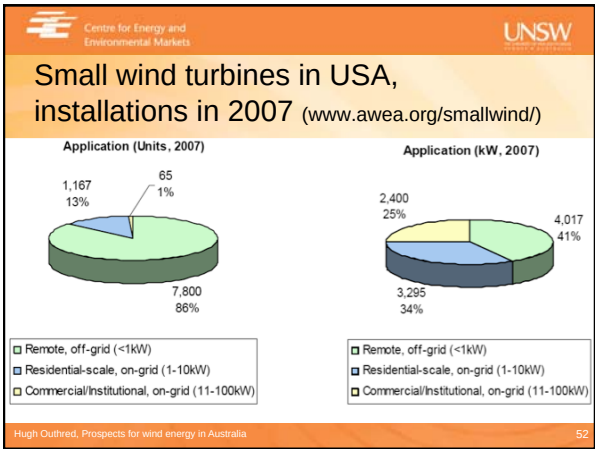
Centre for Energy and Environmental Markets
UNSW
Small wind turbines in USA, installations in 2007 (www.awea.org/smallwind/)
Application (Units, 2007)
1,167
13%
65
1%
7,800
86%
Application (kW, 2007)
2,400
25%
4,017
41%
3,295
34%
Remote, off-grid (<1kW)
Residential-scale, on-grid (1-10kW)
Commercial/Institutional, on-grid (11-100kW)
Hugh Outhred, Prospects for wind energy in Australia
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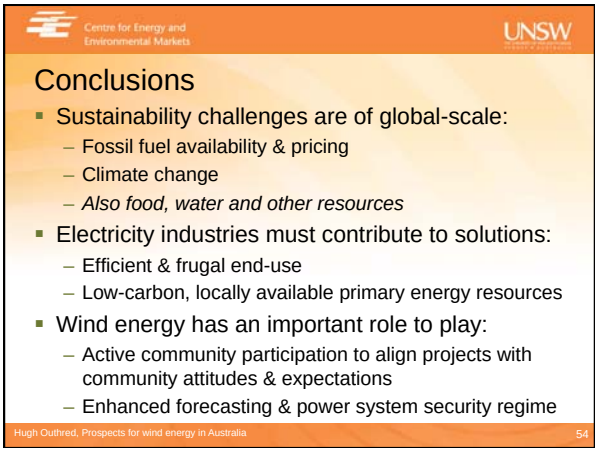
Small wind turbines in USA (www.nrel.gov)
53


Centre for Energy and Environmental Markets
UNSW
Conclusions
Sustainability challenges are of global-scale:
Fossil fuel availability & pricing
Climate change
Also food, water and other resources
Electricity industries must contribute to solutions:
Efficient & frugal end-use
Low-carbon, locally available primary energy resources
Wind energy has an important role to play:
Active community participation to align projects with community attitudes & expectations
Enhanced forecasting & power system security regime
Hugh Outhred, Prospects for wind energy in Australia
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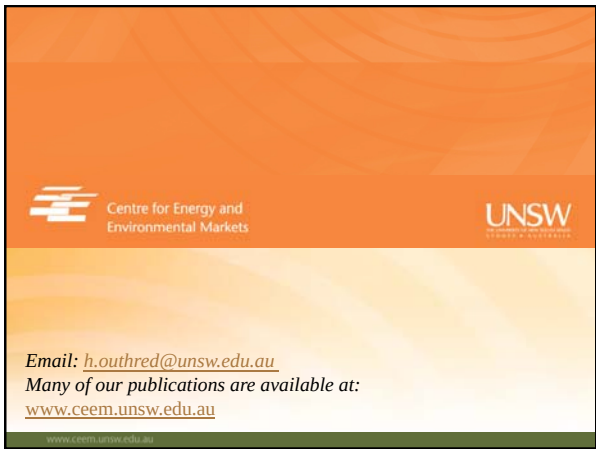
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