



Centre for Energy and Environmental Markets



Challenges in integrating renewable energy into electricity industries

Hugh Outhred

Email: h.outhred@unsw.edu.au

ISES-AP 2008, 27/11/08

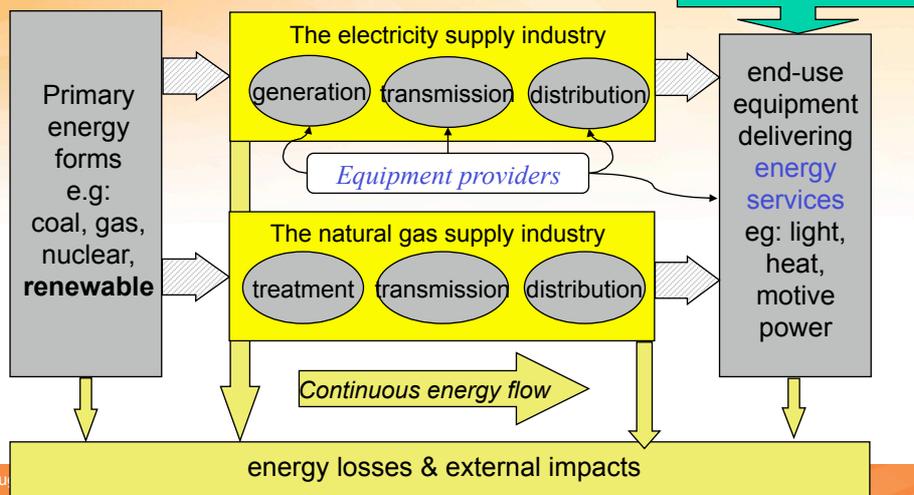
www.ceem.unsw.edu.au



Centre for Energy and Environmental Markets



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



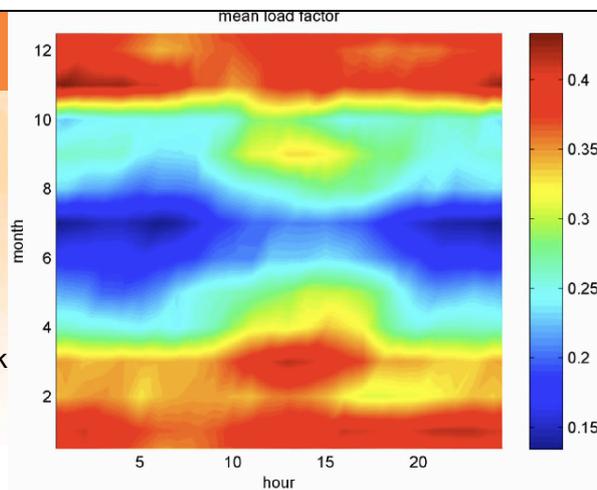


Features of wind & solar energy fluxes

- Non-storable, stochastic primary energy fluxes:
 - Not available when wind or insolation low
- Generation type & size:
 - Wind & solar thermal electric: large & free-standing
 - Solar PV: small, building-integrated, electronic interface
- Can possibly contribute to:
 - Local voltage & waveform control
 - System security management
 - *Subject to rating, fault ride-through capability & coordination between multiple generating units*



UK wind capacity factor as function of:
 1. Season & time of day (right)
 2. Load level (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





Centre for Energy and Environmental Markets

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.

What is technology?

(www.iiasa.ac.at)

Technology = Hardware + Software + "Orgware"

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

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 >>**

Hugh Outhred, Prospects for wind energy

Centre for Energy and Environmental Markets

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)

Hugh Outhred, Prospects for wind energy in Australia





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

Governance regime	<ul style="list-style-type: none"> ▪ Formal institutions, legislation & policies ▪ <i>Informal social context including politics</i>
Security regime	<ul style="list-style-type: none"> ▪ Responsible for core integrity on local or industry-wide basis, with power to override
Technical regime	<ul style="list-style-type: none"> ▪ Engineering design to allow industry components to function as single, industry-wide machine when connected together
Commercial regime	<ul style="list-style-type: none"> ▪ Decentralised decision-making according to commercial criteria within a market context ▪ Includes formally designed markets ▪ <i>Needs adequate competitive pressures</i>

Man

7



Technical regime

- Objective: *“plug & play” capability for the millions generation, network & end-use “components” of an electricity industry “machine”*:
 - Implemented through design rules & operating guidelines
- Connection requirements:
 - Technical performance standards
- Operation requirements:
 - Fault-ride through, centralised control if/when required





Commercial regime

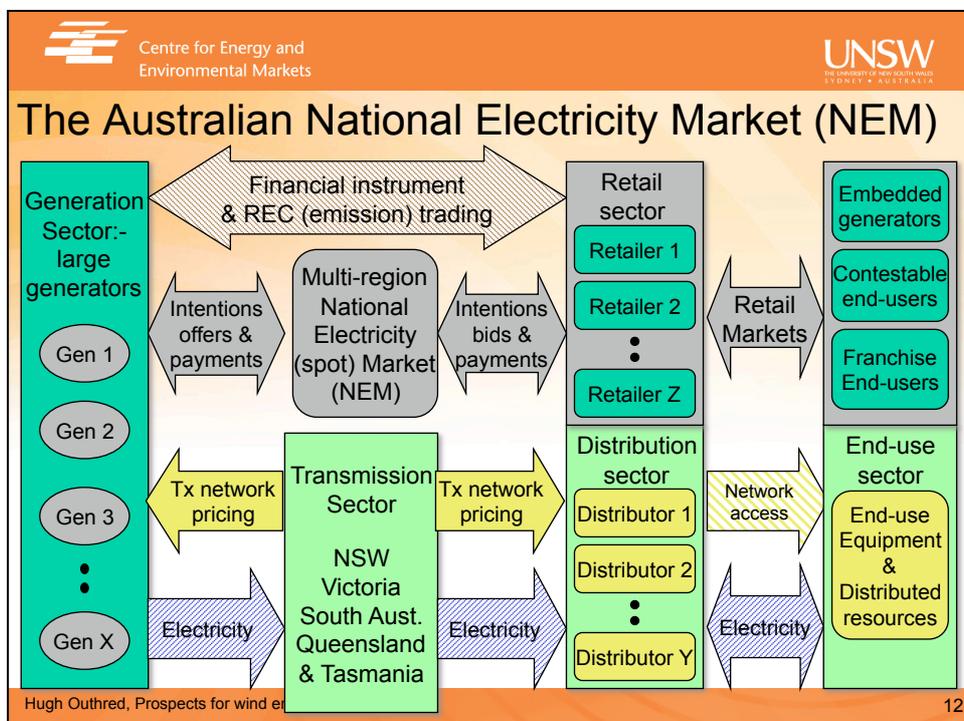
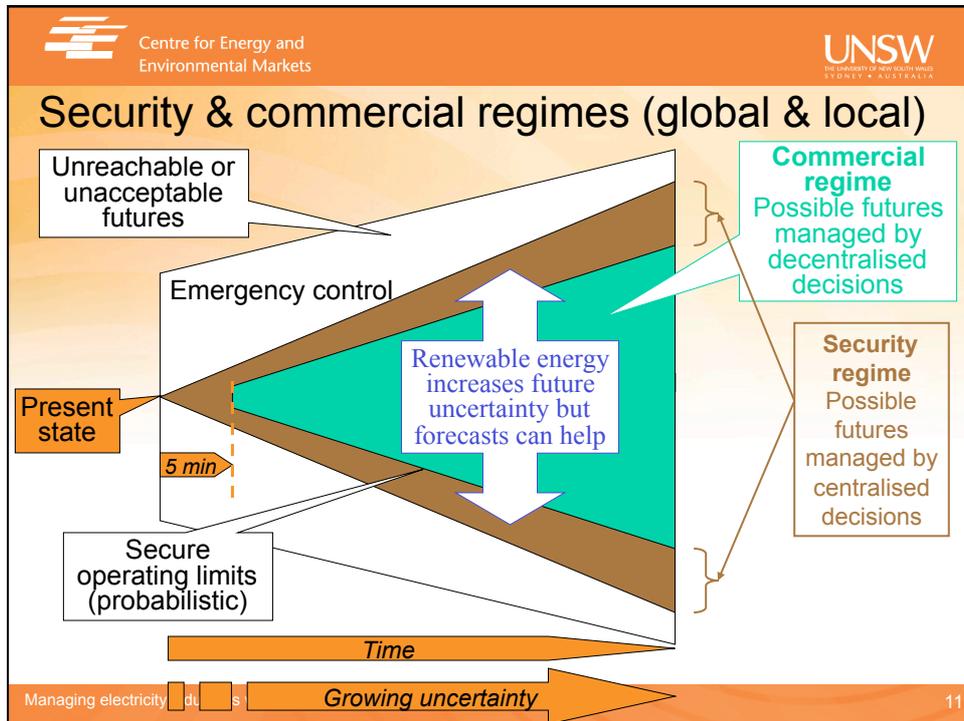
- Objective: *economic operation of existing resources & investment in new resources:*
 - Requires effective coordination of decentralised decisions
- Operation of existing resources (commitment & dispatch):
 - Requires effective & efficient spot & ancillary service markets
- Investment in new resources (resource adequacy):
 - Requires efficient & effective derivative markets

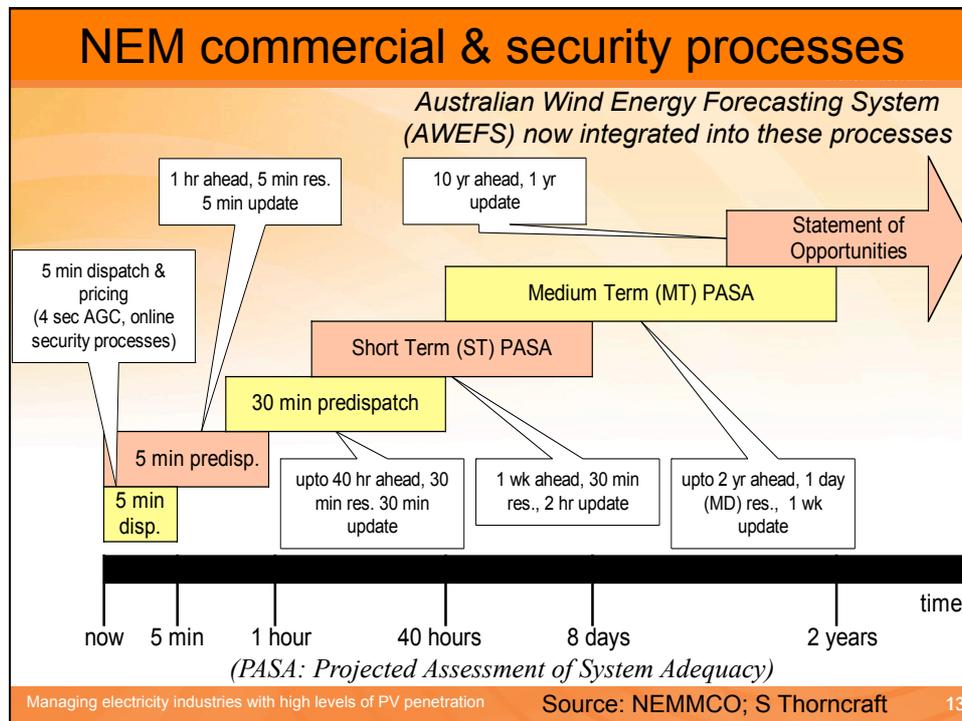


Security regime

- Objective: *Continuity of end-use energy service delivery subject to willingness to pay:*
 - Requires an ability to maintain electrical energy flow
- Short-term security:
 - Power system operator interventions to maintain power system within secure operating envelope
 - Requires capability & protocols
- Long-term security (resource adequacy):
 - Investment in appropriate generation, network & demand-side resources, considering primary resource availability & direct & indirect costs







Capability & protocols for wind energy & security management in the NEM

- Australian Wind Energy Forecasting System:
 - Procured & operated by NEMMCO
 - Produces forecasts from 5 minutes to 2 years & beyond
 - Has potential to forecast solar energy as well as wind
- Technical requirements for NEM wind farms:
 - Fault ride through, voltage & waveform management
 - Semi-dispatch capability for control by NEMMCO
 - Verified simulation models
- Security management protocols:
 - Rules under which NEMMCO & NSP's can intervene



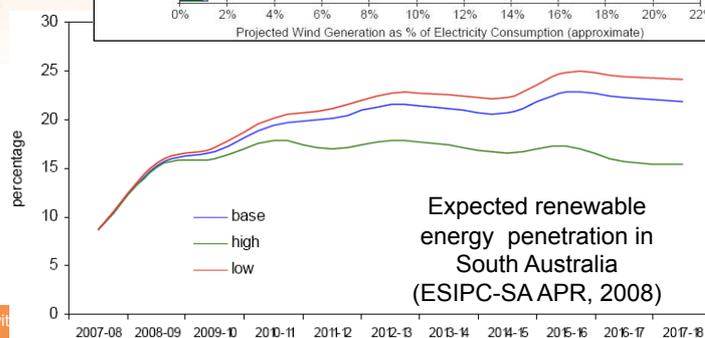
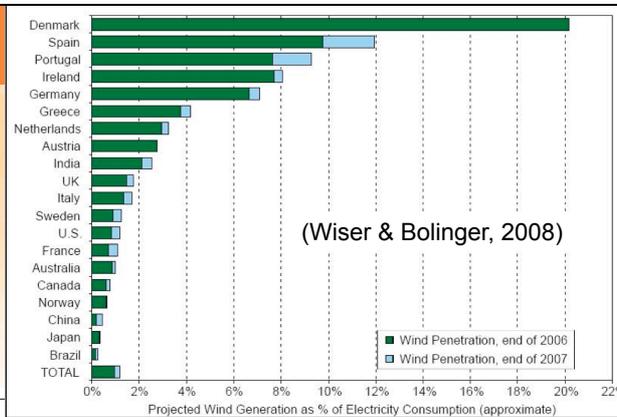


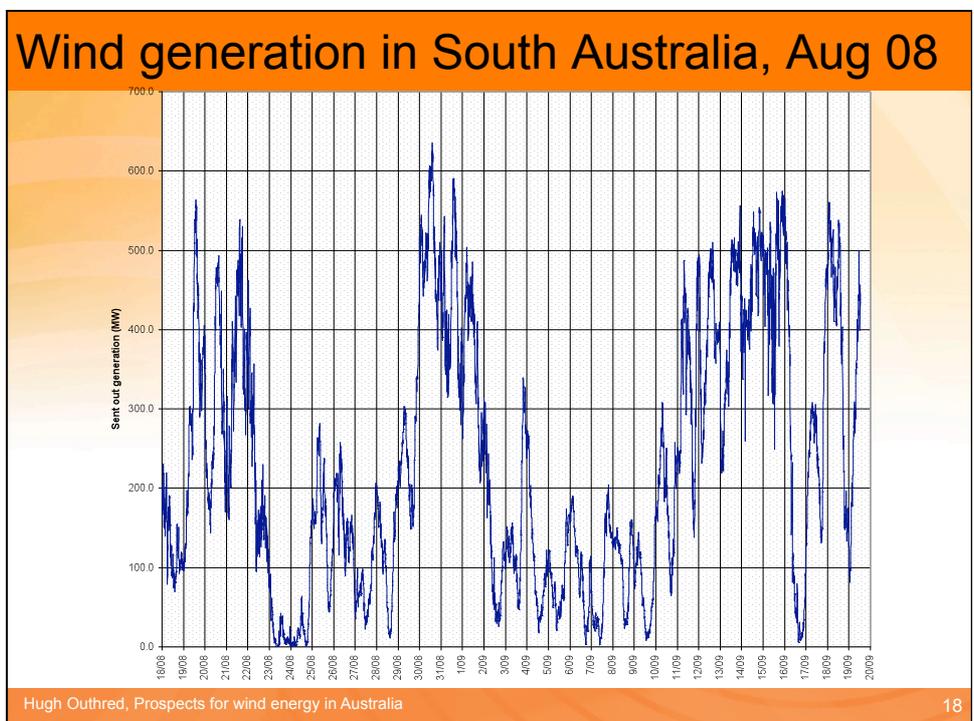
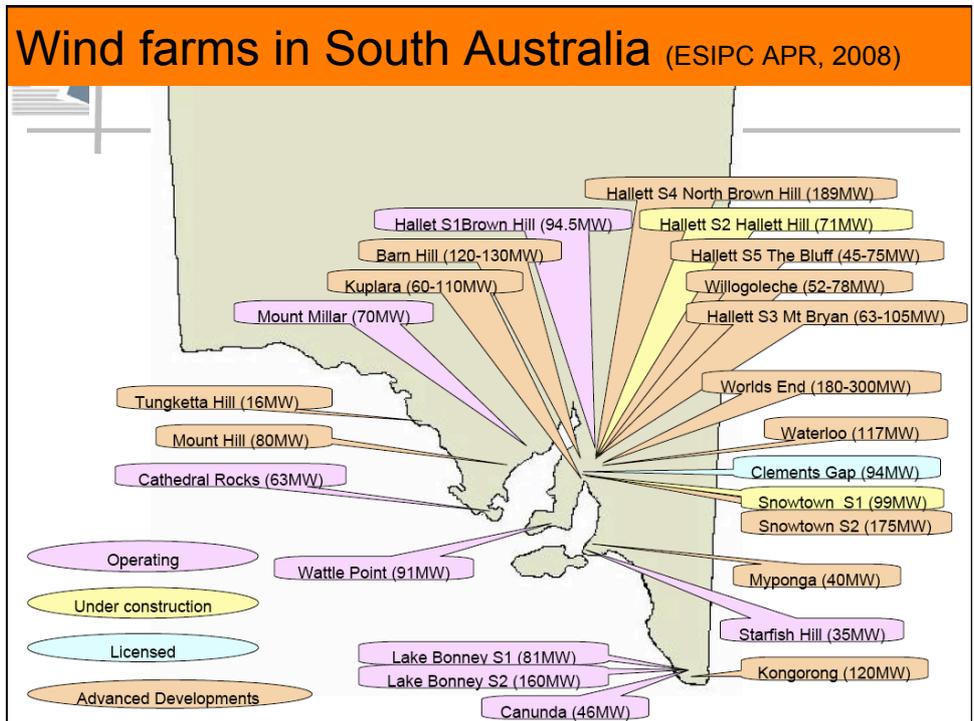
Issues for high levels of penetration

- High penetration at the local distribution level:
 - Low diversity between converted renewable energy fluxes
 - Management issues (+/-): voltage fluctuations, flow constraints, harmonics, islanding
- High penetration at the regional transmission level:
 - Medium diversity between converted RE fluxes
 - Management issues (+/-): voltage fluctuations, flow constraints, resource mix, system security
- High penetration at the system-wide level:
 - High diversity between converted RE fluxes
 - Management issues (+/-): resource mix, system security



Wind penetration (%energy) globally & for South Australia







Centre for Energy and Environmental Markets UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY • AUSTRALIA

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

Centre for Energy and Environmental Markets UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY • AUSTRALIA

NEM wind penetration by state (NEMMCO, 2008)

Region	Wind Farm Data (MW) Sourced NEMMCO Internet			Total	Native MD MW Sourced from SOO	
	Existing	Committed	Proposed		Summer(07/08)	Winter (07)
SA	742	128	650	1520	3069	2490
TAS	140	0	129	269	1428	1838
VIC	134	294	2027	2455	9380	7951
NSW	16	162	1611	1789	14140	13998
QLD	12	0	0	12	9524	7979
NEM	1044	584	4417	6045	34533	33570

Managing electricity industries with high levels of PV penetration 20



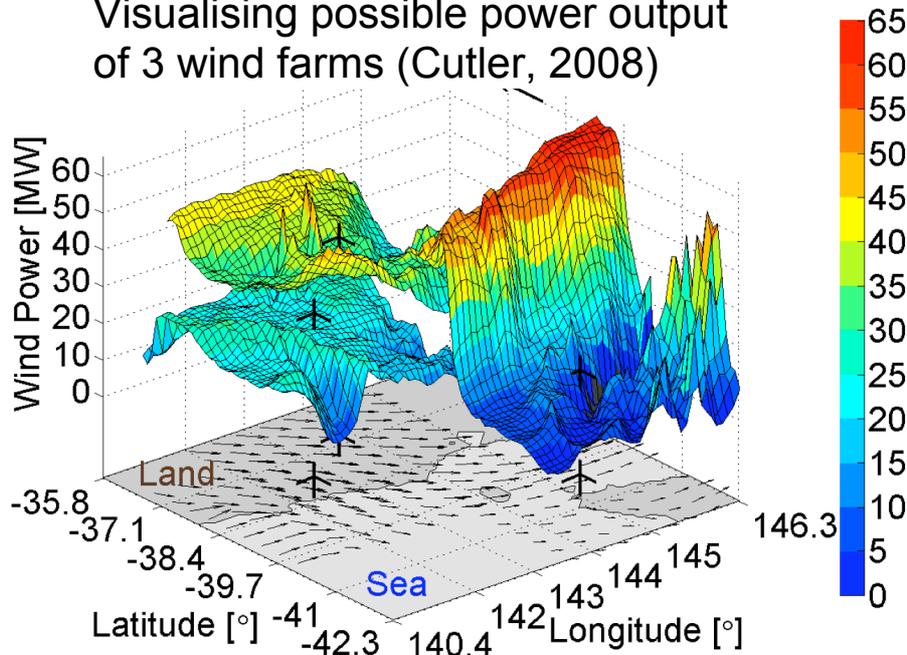


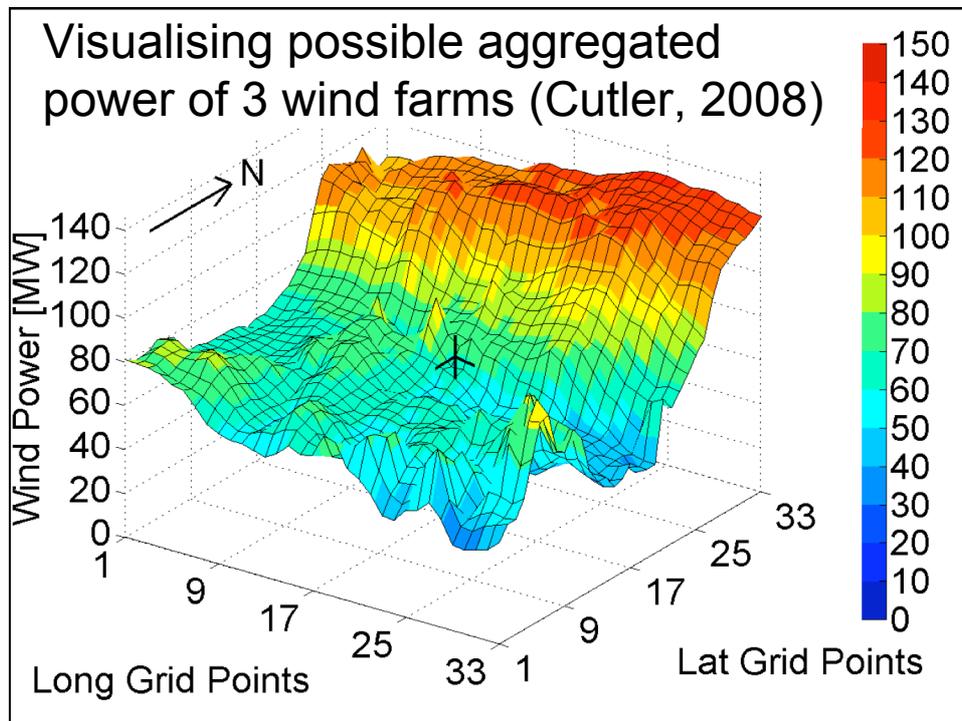
Low-pressure cell over southern Australia

(BoM, 2006)



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





Conclusions

- PV penetration still small at regional & system levels
- However, capabilities & protocols & simulation models required if penetration rises
- The PV industry should be preparing for this now & commence discussions with network service providers & power system operators





THE UNIVERSITY OF NEW SOUTH WALES • SYDNEY • AUSTRALIA

The Role of PV in Smart Grids

 Centre for Energy and Environmental Markets

 UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY • AUSTRALIA

Email: h.outhred@unsw.edu.au
Many of our publications are available at:
www.ceem.unsw.edu.au

www.ceem.unsw.edu.au



Centre for Energy and Environmental Markets

Hugh Outhred, Managing electricity industries with high levels of PV