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Complementary Resources For Managing Variability and Uncertainty In Renewables – from wholesale markets to the Dx network and 'Smart' Homes

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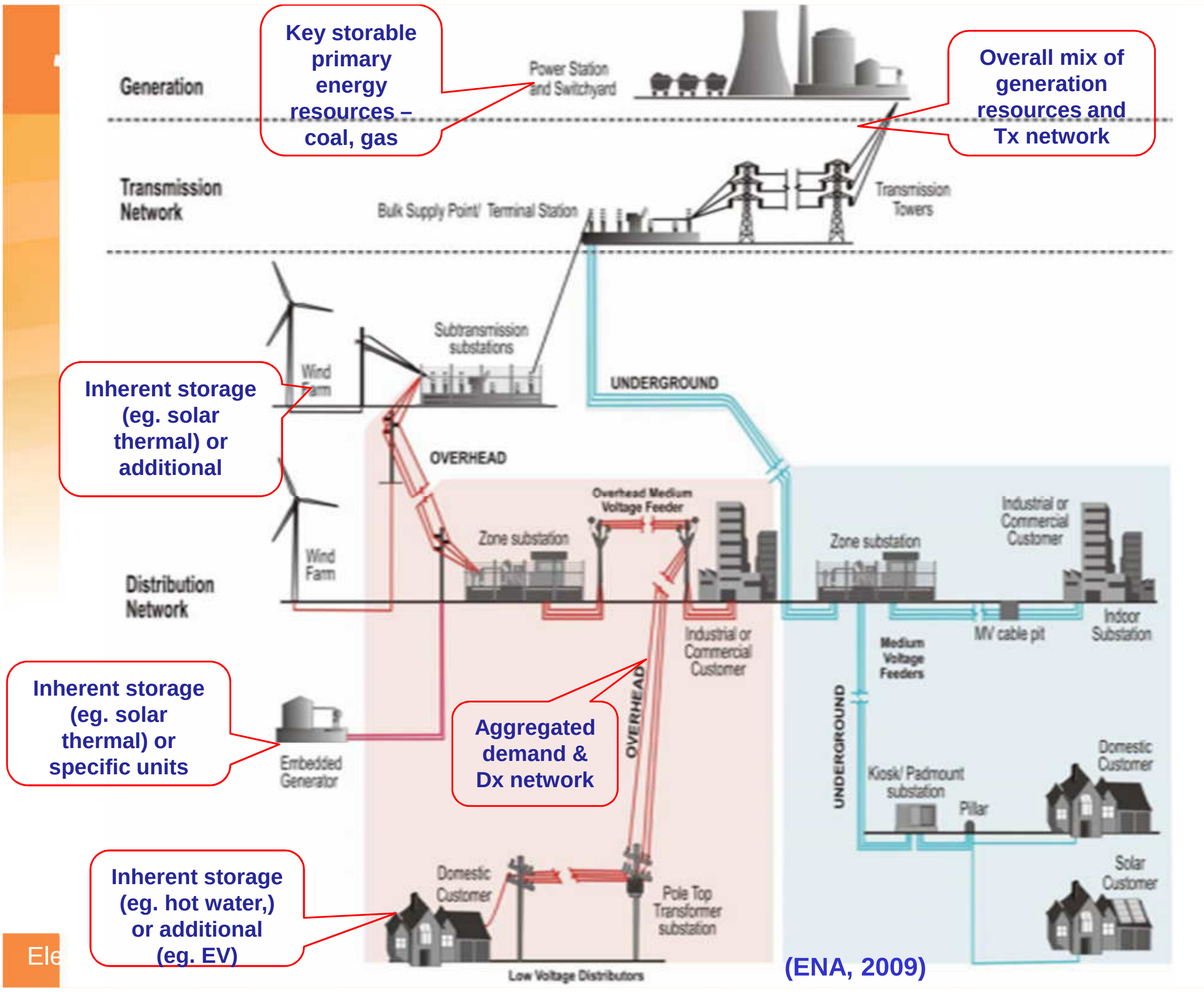
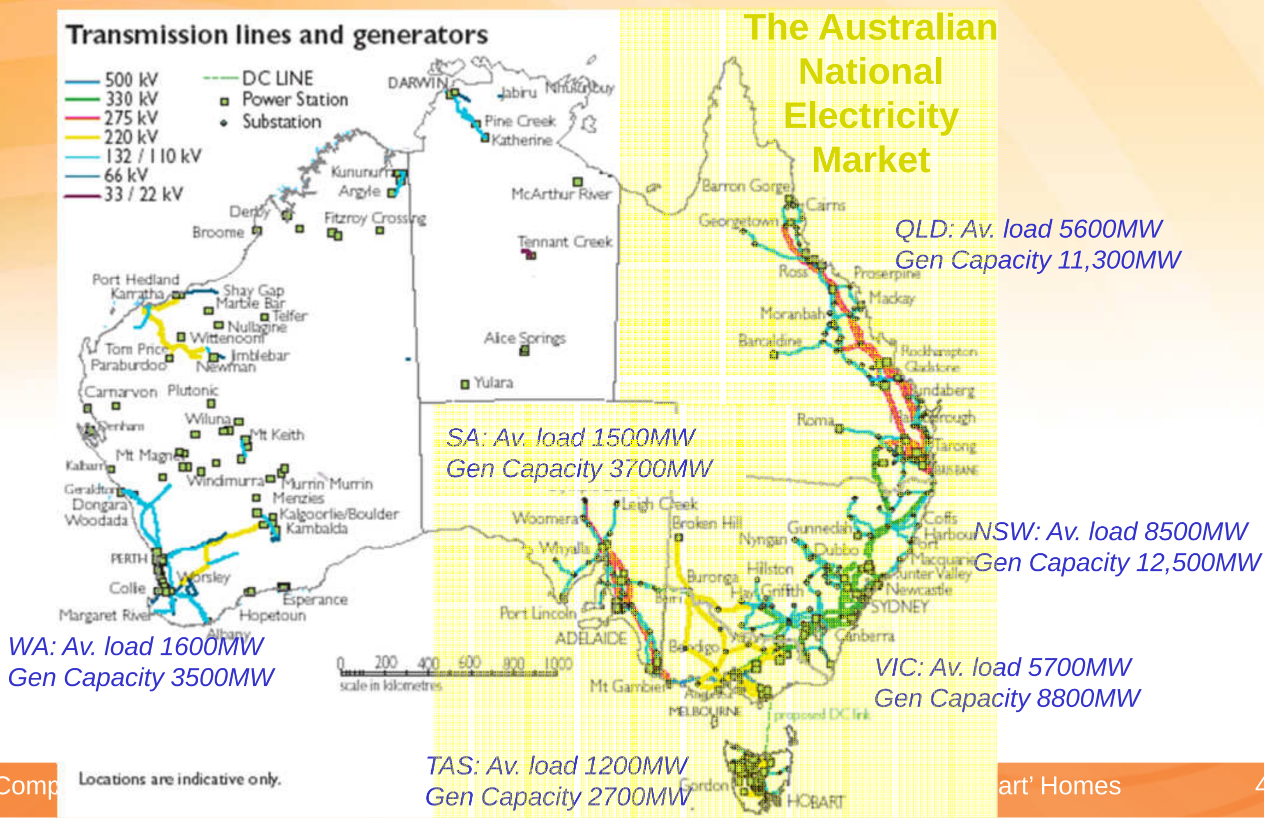
Working definitions

- Resource
  - "An available supply that can be drawn on when needed.
  - The ability to deal with a difficult or troublesome situation effectively"
- Energy resource
  - "anything that can be used as a source of energy"
- Energy Storage
  - "the storing of some form of energy that can be drawn upon at a later time to perform some useful operation"
  - *One of a range of possible **complementary resources** for successful electricity industry operation with high penetrations of variable and somewhat unpredictable renewable generation within an industry where supply must equal demand at all times and all locations within network*



NEM: Aust's largest environmental (externalities) market



Motivations for new technologies, approaches

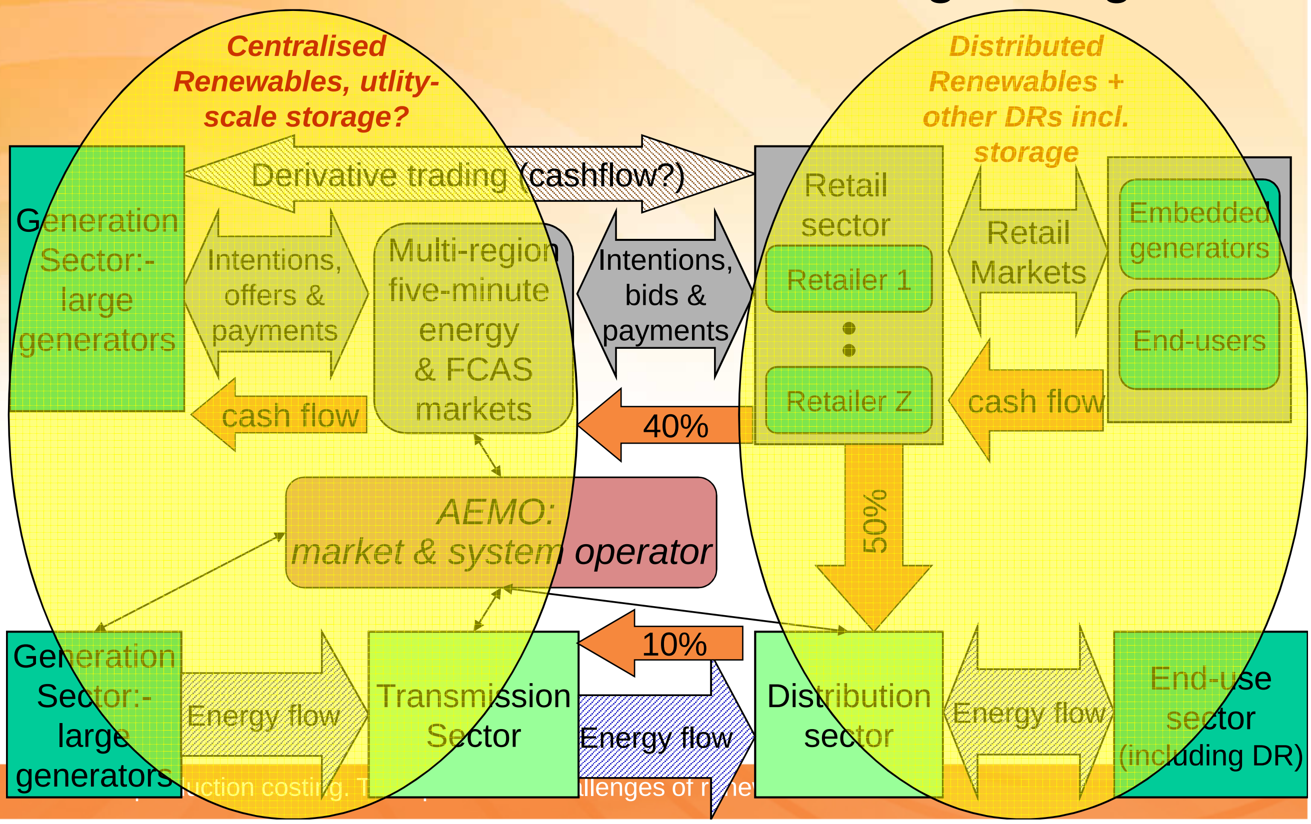
- Peak demand growth and associated costs
- Changing reliability and ‘quality of supply’ requirements
- NEM env. externality costs likely outweigh direct costs
- … however, social and economic benefits of delivered energy services outweigh both direct & env. costs

Coal-fired generation in NSW (2009-10) Note: supplying >90% of state electricity	**$/MWh estimate**
Direct Long Run Marginal Cost	*$50-55 (Acil Tasman report to AEMO, 2009)*
Direct Short Run Marginal Cost (fuel, variable O&M)	$10-14 (Acil Tasman as above)
External Health damage costs (PM10, SOx, NOx)	$13 (mid-range estimate of ATSE Externalities Study, 2009)
External Climate Change damage cost	$65 (Stern Review estimate of $75/tCO2)

National Electricity Law: *Overall objective for the National Electricity Market (NEM)*

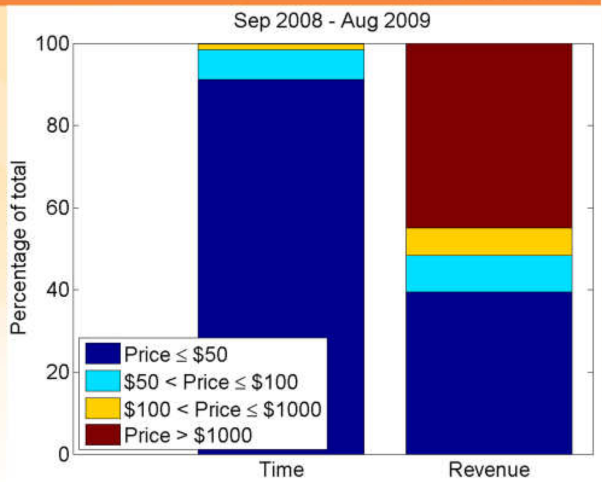
- *NEL Section 7:*
  - *The national electricity market objective is to promote efficient investment in, and efficient use of, electricity services for the long term interests of consumers of electricity with respect to price, quality, reliability and security of supply of electricity and the reliability, safety and security of the national electricity system*
- Key issues
  - Lack of environmental and wider sustainability objectives is a **design choice:** *If societal desire that NEM contribute to such objectives then governments have to implement ‘external’ policies that drive such changes: eg. eRET, Feed-in tariffs*
  - …and the NEM needs to facilitate technical, institutional and behavioural change towards such changes
  - within (former) explicit objectives of technology, participant neutrality
  - … and economic efficiency residing within reliability and security objectives

Two 'worlds' for renewables & storage integration

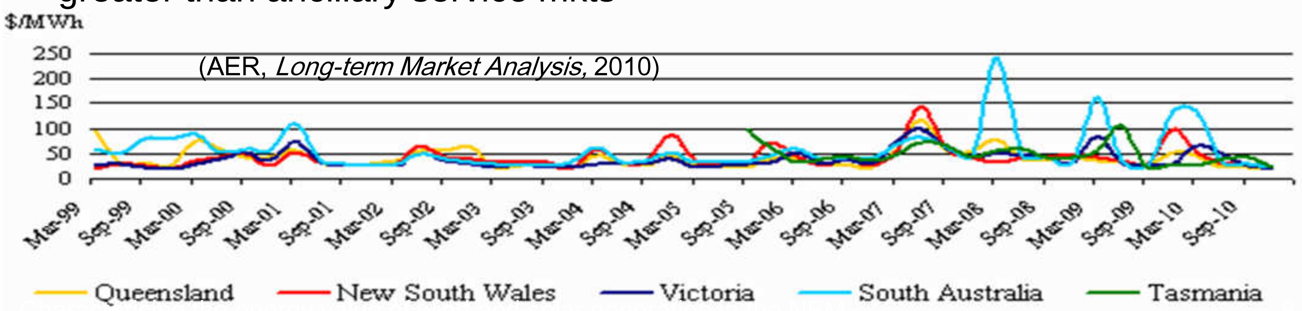


NEM energy markets

- Largely the same rules but different regional contexts… and dynamics
- Three key markets
  - Regional wholesale spot markets
  - Regional wholesale frequency control ancillary services (FCAS) markets
  - Regional wholesale derivative mkts
- Extreme price events play very critical role in overall spot-market revenue… high incentive for derivative contracting
- Spot market revenue typically 100X greater than ancillary service mkts



(Cutler et al, *Wind in SA*, 2010)



(AER, *Long-term Market Analysis*, 2010)

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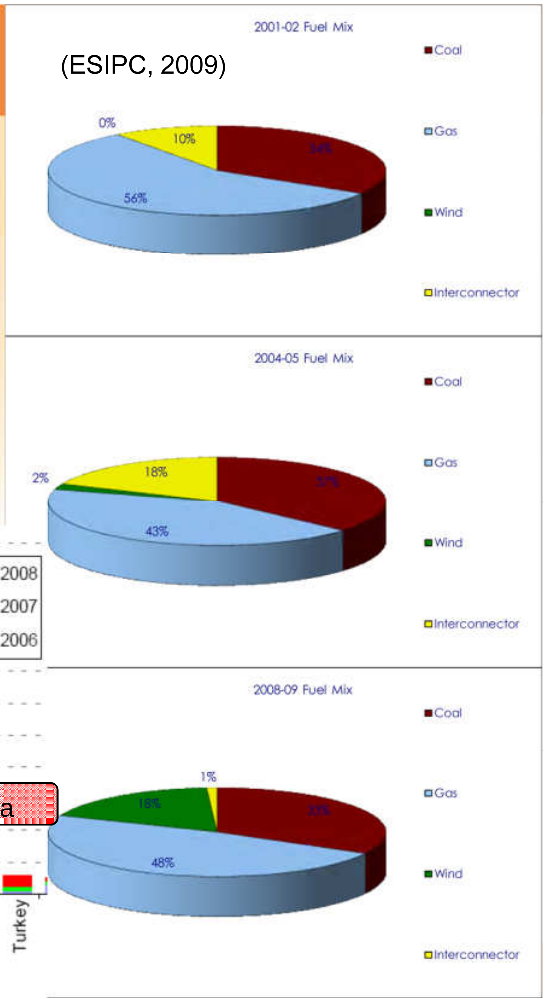
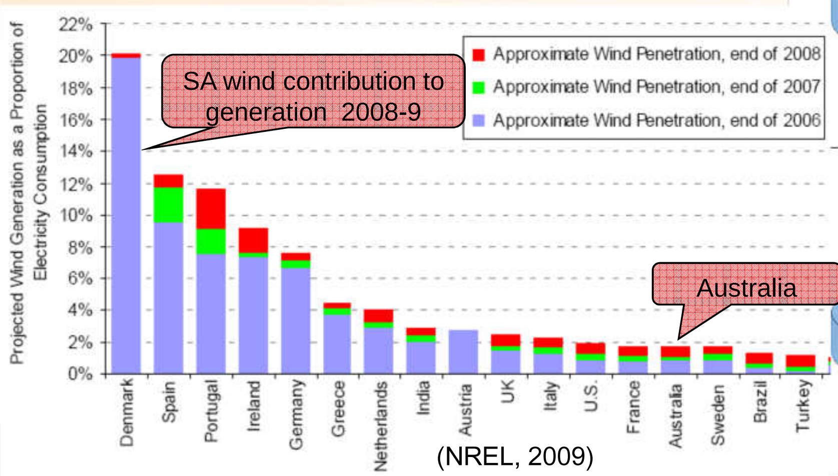
South Australia

- A world leading jurisdiction for assessing the potential value of complementary resources wrt intermittent renewables
  - A large and rapid deployment of wind with a world leading penetration
  - Excellent solar resource
  - High wholesale spot/ancillary service market transparency





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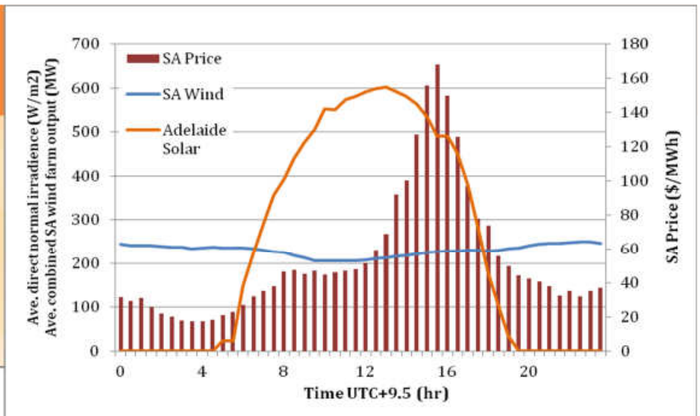
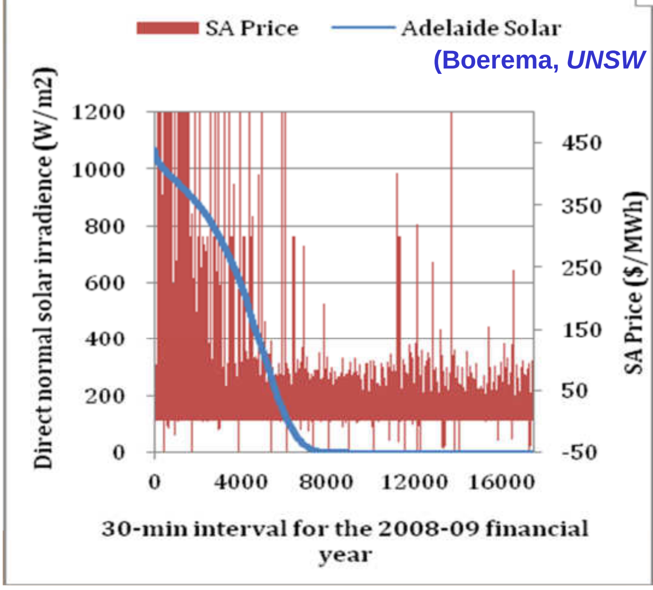
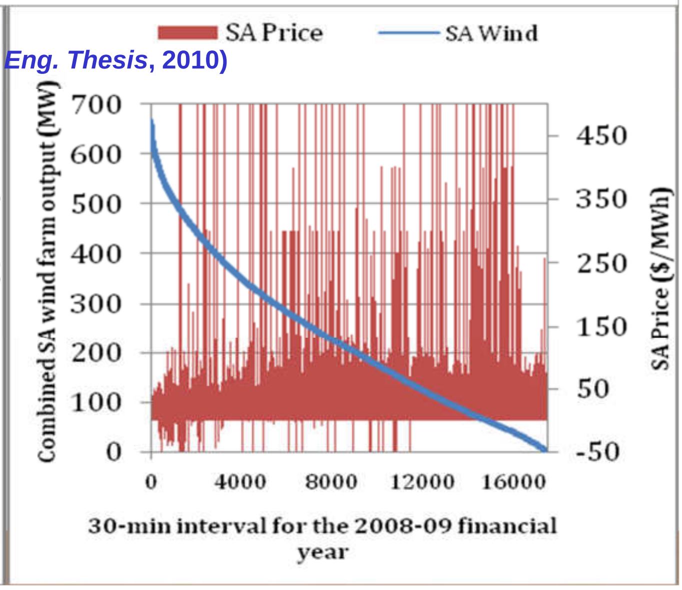
Renew gen. and price

- In 2008-9, large tracking PV plant may have earned spot revenue >$100/MWh or 2X Wind $/MWh
- Key driver is correlation with demand (key price determinant)



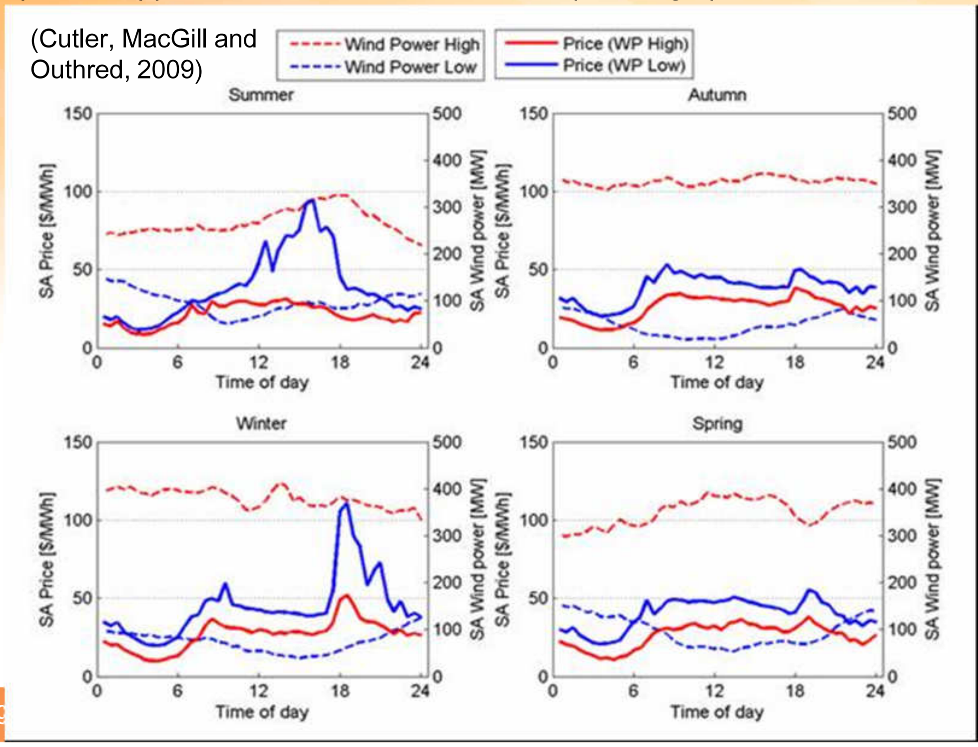


(Boerema, *UNSW Eng. Thesis*, 2010)



However, wind gen in SA now a price driver itself

- Top quartile and bottom quartile average wind gen. for week-days and associated SA prices (note that prices capped at $415/MWh to avoid infrequent high price events dominating results)



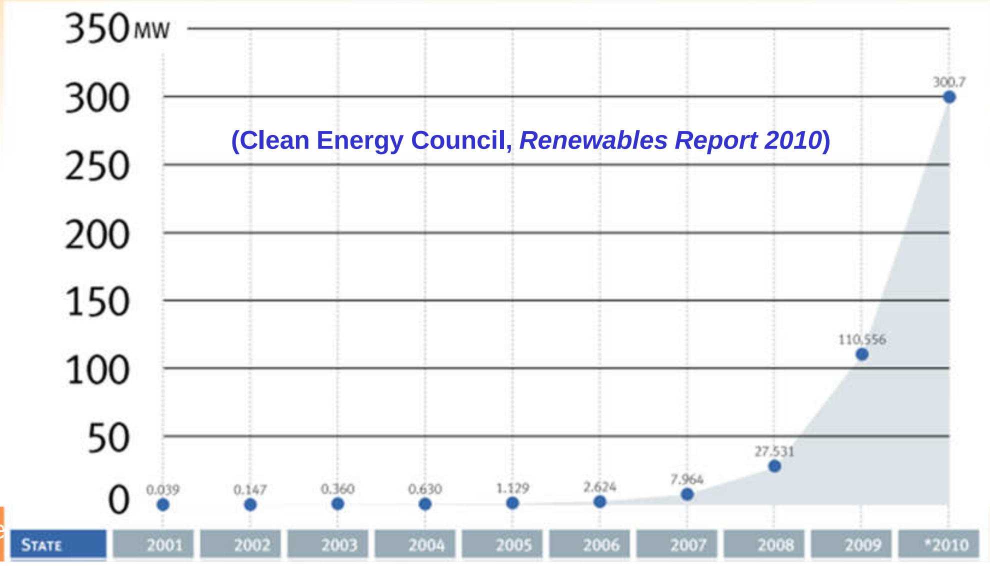
Wind’s energy value

- Energy value of wind declines as penetrations increase
  - An ‘efficient’ market signal – generation without inherent energy storage has lower value than conventional generation with storable primary energy sources (coal, gas, hydro, diesel)
- Wind in SA currently being managed by conventional generation in SA (and NEM more widely)
  - Significant ‘storage’ competition in the wholesale space

Period (Cutler, et al, 2011)	All wind farms ($/MWh)	All other generators ($/MWh)
Financial year 2008-9	46.6	73.5
Financial year 2009-10	47.4	90.1

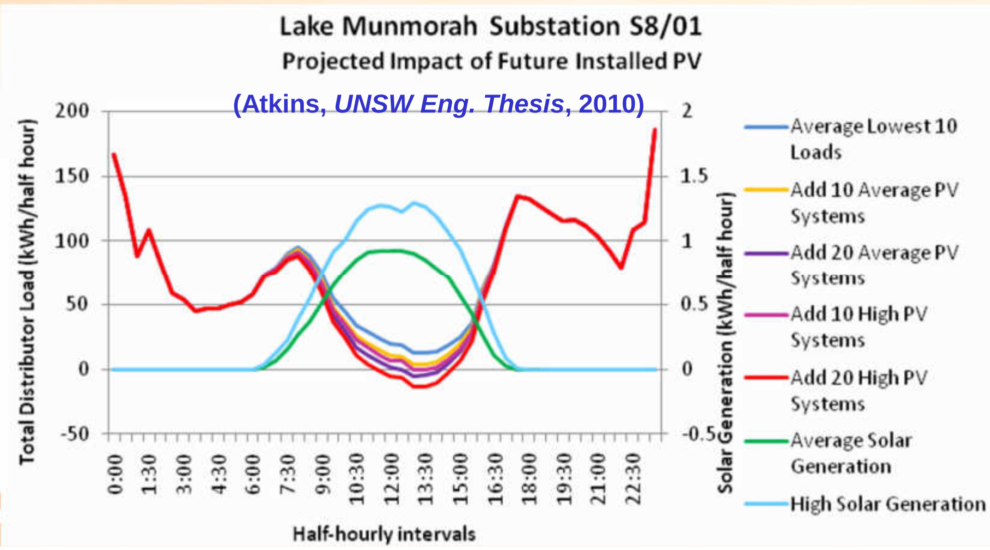
Distributed renewables … have taken off

- High recent growth in PV deployment under various Fed/State Govt incentives– almost all residential systems
- Penetration levels in some regions of the Dx network becoming significant – solar cities, demographics, developer strategies



Growing Dx network implications

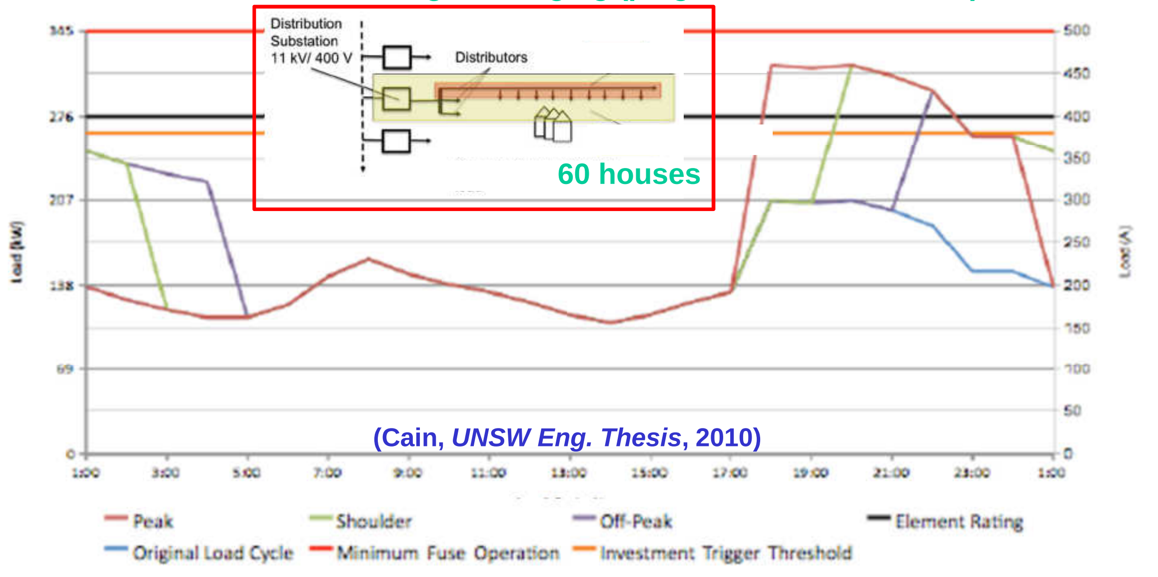
- Voltage regulation - larger min-max load range
- Reverse flows – possible protection challenges
- ‘Power quality’ as seen by DNSPs – decreased P/Q
- *Impacts depend on specific network profiles, PV deployment*



… within increasingly complex Dx context

- Peak demand growth with air-conditioning loads
- Other possible technology deployments eg. EVs

Potential impact of 50% EV penetration onresidential distributor loads with unmanaged charging (plug in when car returns)

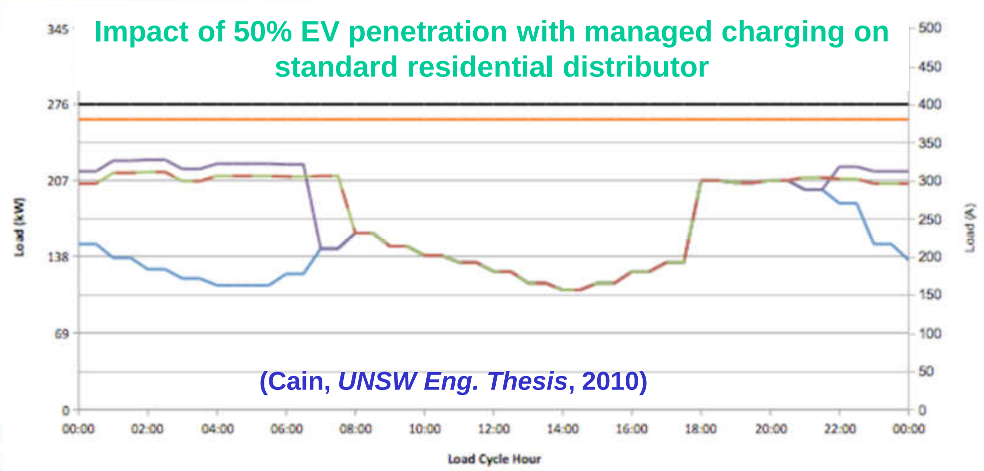


(Cain, *UNSW Eng. Thesis*, 2010)

Possible management options

- Commercial feeder demand profiles generally better complement PV than residential profiles
- Excellent opportunities to manage EV charging
- Potential synergies between distributed PV and EVs depend on specific network profiles, car use patterns

eg. Commercial feeders with PV and commuter EVs?



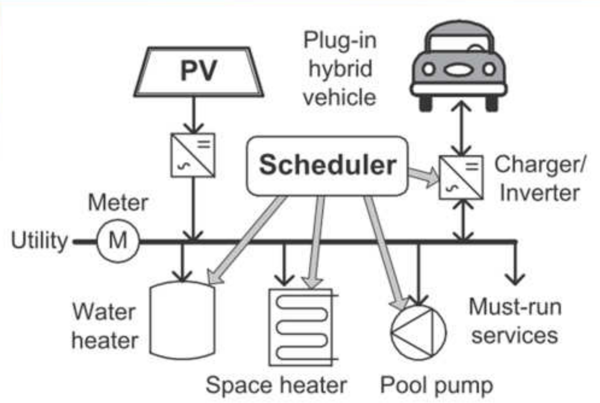
Residential opportunities

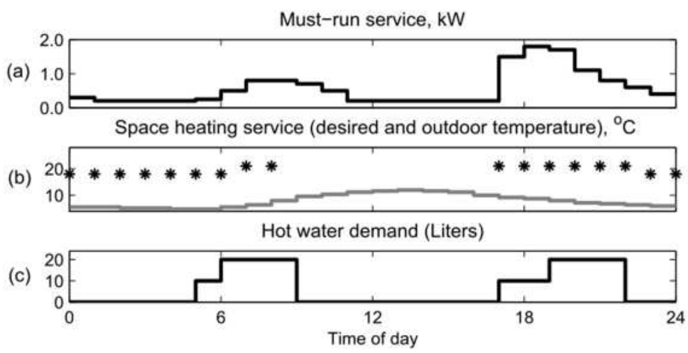
- Widespread recent uptake of domestic PV
- Wide range of potential distributed resources with inherent energy storage
  - some limited applications eg. off-peak hot water
- Growing number of direct energy storage options
- However, current arrangements limit application
  - Immature metering – often only accumulation, fails to measure some key aspects of 'power quality'
  - Economically inefficient tariffs wrt both networks and energy – primarily 'flat' rate although growing use of TOU
- …. but this may be changing

'smart' homes

- Simulated case studies of homes with 'enabled' distributed resources
  (Pedrasa, Spooner, MacGill, 2009)

DER	Energy service	Operating properties
Plug-in hybrid vehicle	Mobility (or car charging)	5.9 kWh capacity, 3.0 kW maximum charging/discharging rate, 90% charging/discharging efficiency, may be discharged down to 30% of capacity, 0.1% coulomb loss per hour
Space heater	Space heating	1.8 kW maximum heating power
Water heater	Hot water	Storage capacity is 80 liters and the heating element is rated 1.2 kW
Pool pump	Pool maintenance	1.1 kW
PV system		2.0 kW peak output

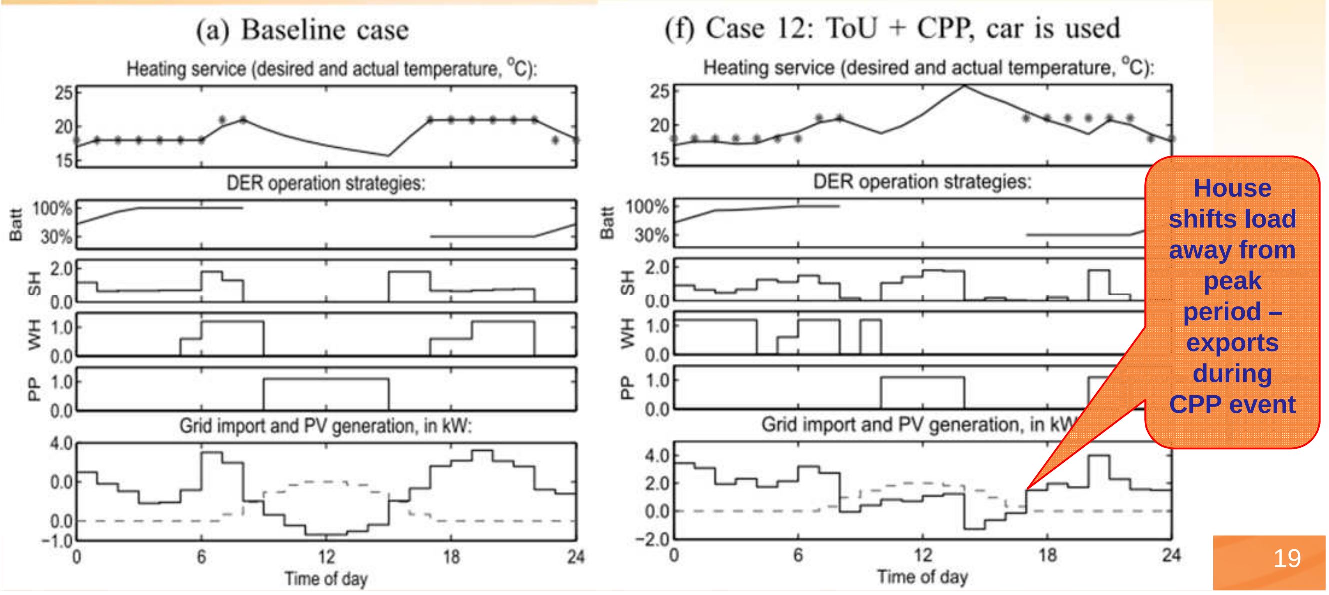




Loads and VTG PHEV can be scheduled to maximise net benefit of energy services s.t. different tariff arrangements

Tariff ($\lambda_e(t), \lambda_{cap}$)	Rate (\$/kWh)
Time of Use (ToU)	
Peak (2 – 8 PM)	0.3025
Shoulder (7 AM – 2 PM, 8 – 10 PM)	0.1089
Off-peak (10 PM – 7 AM)	0.0605
Capacity charge (\$/kW)	0.11325
Feed-in (net)	0.60
Critical peak price (CPP)	
Medium alert (5 – 8 PM)	1.00

(Pedrasa, *UNSW PhD Thesis*, 2011)



Note: Inappropriate tariffs can lead to unhelpful 'smart home' scheduling wrt wider industry objectives

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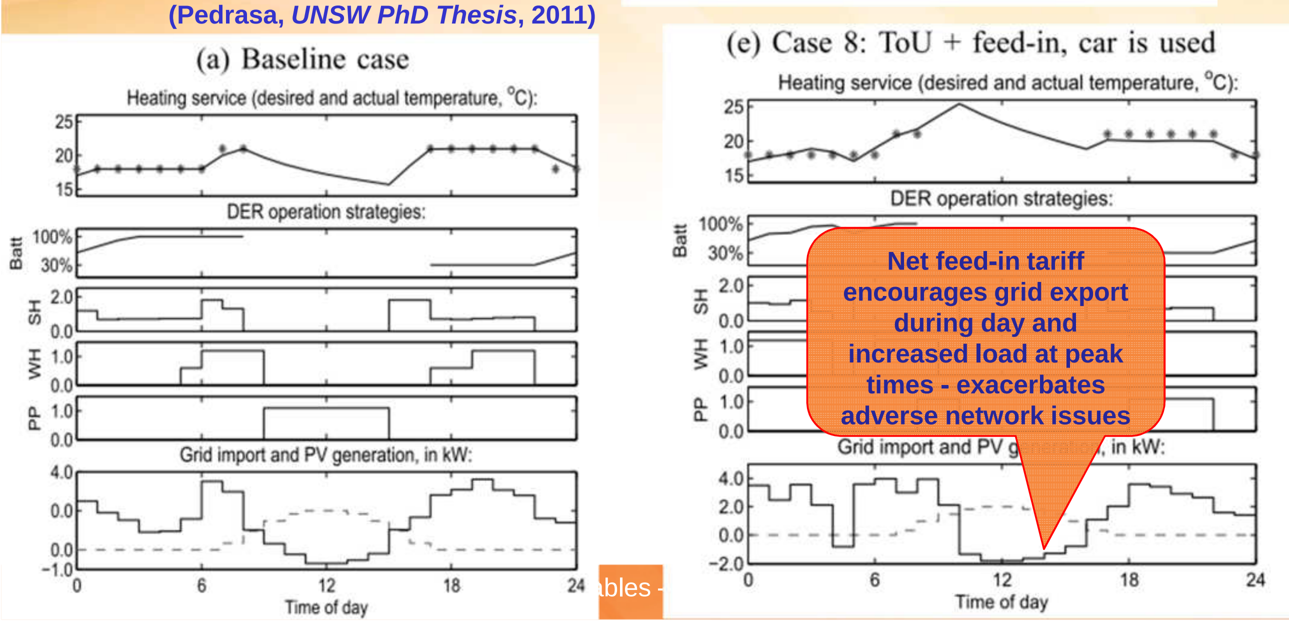

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In conclusion, Australian NEM and the 'potential 'energy' value of renewables and energy storage

- Relatively sound wholesale market design provides reasonable commercial signals on time & location varying, uncertain energy value
- Wind generation in SE Australia doesn't appear particularly correlated with demand (the most significant price driver);
  - solar better correlated – potentially useful complementary resource for NEM
- … and offers less 'energy value' than more dispatchable gen
  - *lacks energy storage in industry that must maintain supply = demand at all times and all locations in network*
- Tx & Dx Network arrangements inherently complex …. need attention
  - Interface between regulated network and competitive market arrangements
- Domestic PV not well correlated with typical demand profiles
- Promising opportunities for EVs – synergies with intermittent renewables complex and very context specific (time & location)
- *Most important value for renewables and necessary 'complementary resources' still mainly 'missing' in NEM – price on env. impacts*

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Thank you… and *questions*

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