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Achieving Resource Adequacy in the Australian National Electricity Market

www.ceem.unsw.edu.au

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Outline

- Resource adequacy: managing risks to the continuity of end-use energy service delivery
- Decision-making framework & regimes for achieving resource adequacy
- Managing boundaries between decision-making regimes
- Australian experience to date & future prospects
- Conclusions

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Key definitions for this presentation

- What are the key electricity industry objectives?
  - *Technical:* Maintaining the flow of end-use energy services by maintaining near-continuity of energy flow through the electricity industry conversion chain
  - *Economic:* Achieving the above in an economically efficient manner, from short-term to long-term future
  - *Social & environmental:* Achieving the above in a socially & environmentally acceptable manner
- What is (short- & long-term) resource adequacy?
  - Acceptably low risks to the flow of end-use energy services for individual end users *(reliability of supply)* & to the electricity industry overall *(energy conversion chain security)*

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Key challenges to resource adequacy

- Year by year (operation):
  - Managing increasingly volatile energy flows through a complex conversion chain while minimising cost & risk
  - Growing environmental risks - heatwave, drought, fire
- Years to decades (investment):
  - Urgent reductions in climate change emissions:
    1. End-use efficiency, frugality & responsive demand
    2. Near-term supply options: gas; wind; biomass; solar
    3. Long-term supply options: gas & coal with CCS; nuclear; geothermal
  - Network investment to accommodate the above

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Key policies for NEM & stationary energy sector more broadly

- Continue EI restructuring to logical conclusion:
  - Direct end-user participation in NEM (rethink retailing):
    - Ancillary service, spot energy & derivative markets
    - AMI: Interval metering of energy, availability & voltage quality with information held in single NEM-wide database
  - Refined NEM ancillary service & energy spot markets
  - Single set of NEM-wide, auction-style derivative markets
- Continue gas industry restructuring to maximise compatibility with NEM
- Introduce efficient emission permit trading or taxes:
  - If permits, all should be auctioned

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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*
- Issues with this objective as stated:
  - Ambiguity of the wording with respect to interpretation of terms & trade-offs between sub-objectives
  - Scope of application & potential boundary issues

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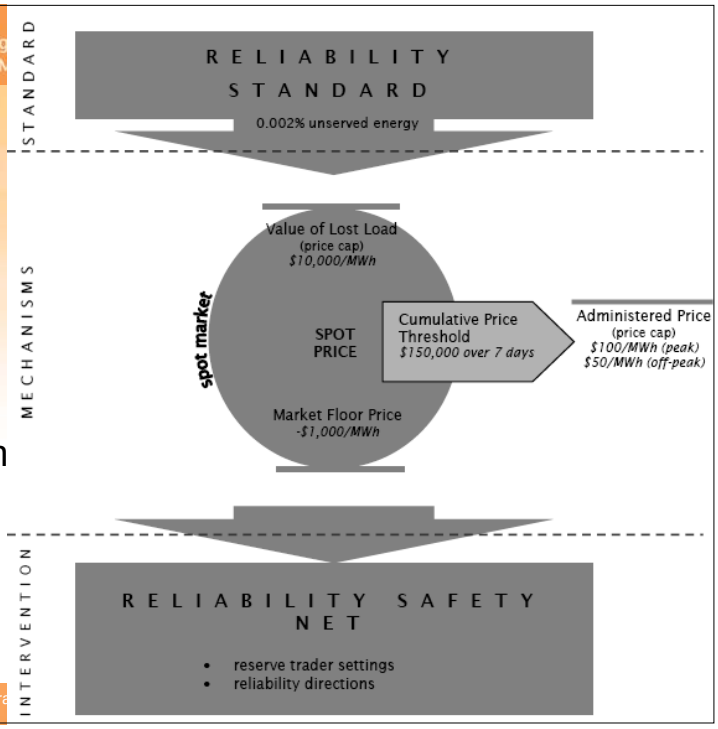
NEM transmission level reliability target, spot market mechanisms & intervention to meet it (AEMC Reliability Review, 2006)



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NEM forecast & actual low reserve conditions

(hours/year) (AEMC Comprehensive Reliability Review, 2006)

	Year	Qld	NSW	VIC	SA
Forecast duration below the threshold (hours)	2004 – 2005	17.5	0	0	6
	2003 – 2004	11.5	4.5	17.5	645
	2002 – 2003	2.5	3.5	7	115.5
	2001 – 2002	1	0	0	45.5
	2000 – 2001	188	8	67	716
	1999 – 2000	43	33	145	699
Actual duration below the threshold (hours)	2004 – 2005	0	2	0	0
	2003 – 2004	0	1	4	6
	2002 – 2003	0	1	0	0
	2001 – 2002	0	0	0	0
	2000 – 2001	0	0	3	24
	1999 – 2000	5	4	36	88

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Contributions to unavailability of supply for small end-users (USA data, AEMC, 2006)

Contributor	Average unavailability per customer year	
	(minutes)	(%)
Generation/transmission	0.5	0.5
132 kV	2.3	2.4
66kV and 33kV	8.0	8.3
11kV and 6.6kV	58.8	60.7
Low voltage	11.5	11.9
Arranged shutdowns	15.7	16.2
Total	**96.8 minutes**	**100.0**

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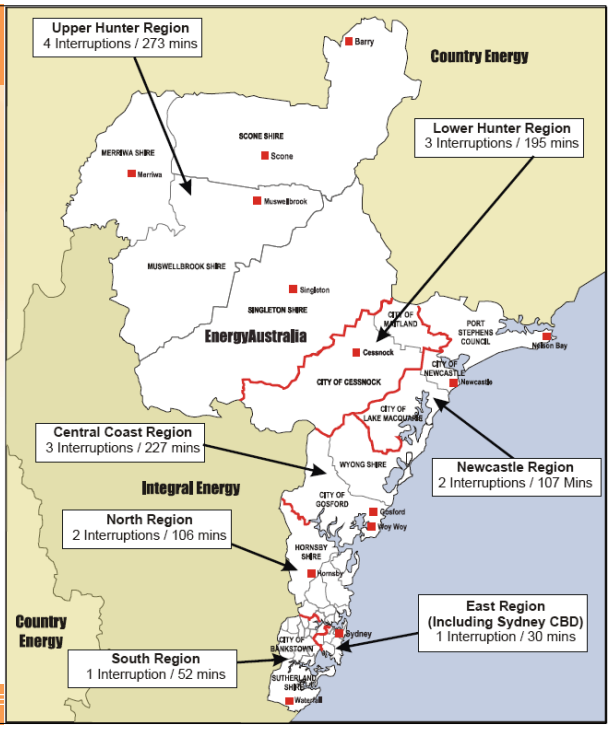
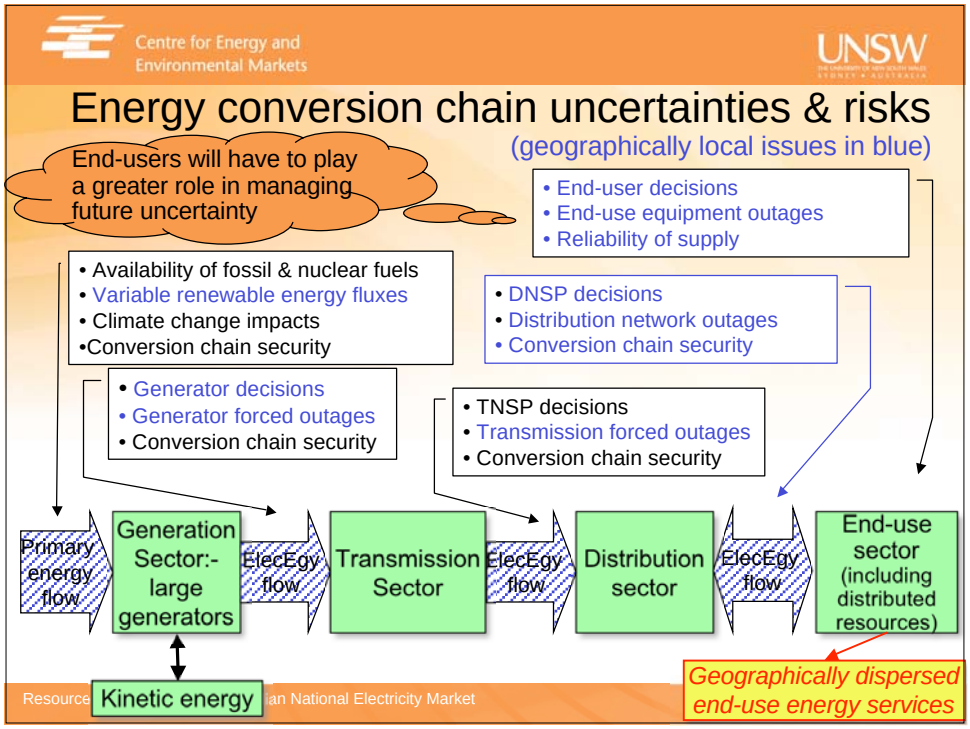
5-year average reliability in EnergyAustralia regions

(EnergyAustralia Electricity Network Standards, 2004)

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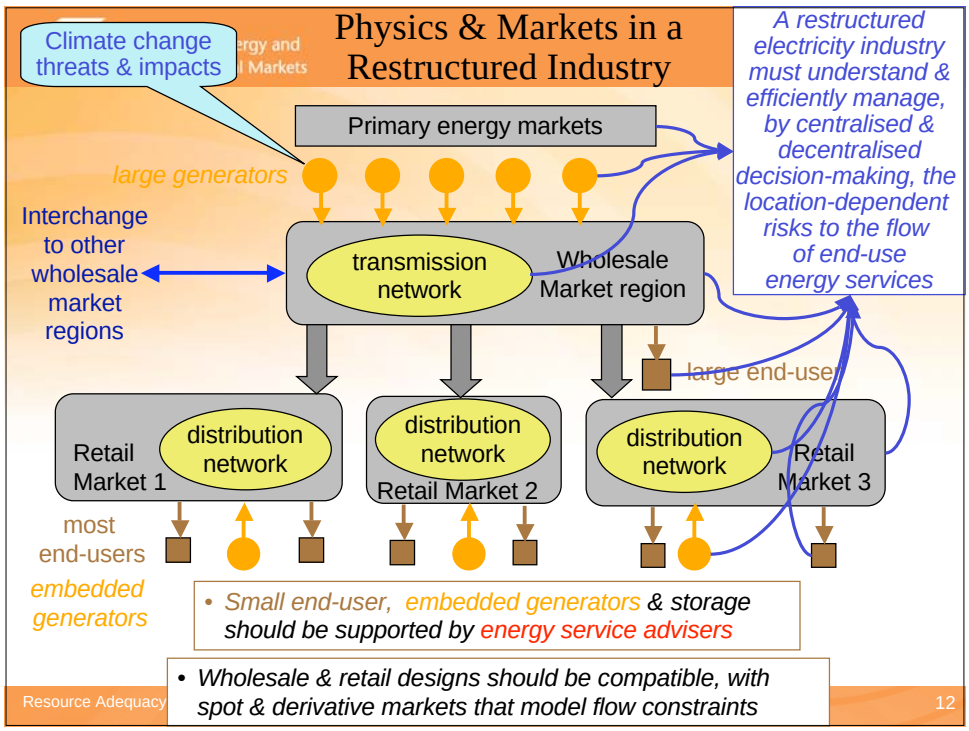
Energy conversion chain uncertainties & risks
(geographically local issues in blue)
End-users will have to play a greater role in managing future uncertainty
• End-user decisions
• End-use equipment outages
• Reliability of supply
• Availability of fossil & nuclear fuels
• Variable renewable energy fluxes
• Climate change impacts
•Conversion chain security
• DNSP decisions
• Distribution network outages
• Conversion chain security
• Generator decisions
• Generator forced outages
• Conversion chain security
• TNSP decisions
• Transmission forced outages
• Conversion chain security
Primary energy flow
Generation Sector:- large generators
ElecEgy flow
Transmission Sector
ElecEgy flow
Distribution sector
ElecEgy flow
End-use sector (including distributed resources)
Kinetic energy
Geographically dispersed end-use energy services


Climate change threats & impacts
Physics & Markets in a Restructured Industry
A restructured electricity industry must understand & efficiently manage, by centralised & decentralised decision-making, the location-dependent risks to the flow of end-use energy services
Primary energy markets
large generators
Interchange to other wholesale market regions
transmission network
Wholesale Market region
large end-users
Retail Market 1
distribution network
distribution network
Retail Market 2
distribution network
Retail Market 3
most end-users
embedded generators
• Small end-user, embedded generators & storage should be supported by energy service advisers
• Wholesale & retail designs should be compatible, with spot & derivative markets that model flow constraints
Resource Adequacy
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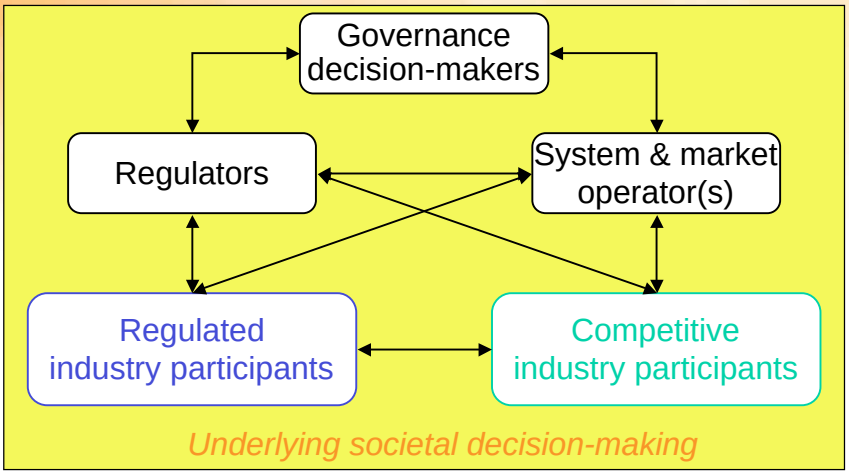
Decision-making framework for a restructured electricity industry



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Decision-making framework for a restructured electricity industry

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	▪ To allow connected industry components to function as industry-wide machine
Commercial regime	▪ To coordinate decentralised decision-making according to commercial criteria ▪ Includes formally designed markets

3-LEVEL GOVERNANCE TEMPLATE (Physical Markets)

I. BROAD ENERGY MARKET POLICY FORMULATION LEVEL
(Efficiency, Reliability, CSOs, etc)
Responsibility of Governments: MCE

(ERIG discussion papers)

II. DETAILED SYSTEM PLANNING, OPERATION & REGULATION LEVEL
(Delegated full power to implement government policy on market-wide basis)

Split between AEMC, NEMMCO, and ACCC (AER) – for the NEM.
Split between IMO and ERA – for the WEM
All these bodies must be genuinely independent statutory authorities.*

III. ENERGY MARKET PRODUCT PARTICIPANTS LEVEL

CONTESTABLE SUPPLY	REGULATED SUPPLY	DEMAND SIDE
Seek full contestability. Minimise market power. Disaggregate supply. Minimise or eliminate government ownership. Competition safeguards.	Any reg. test applies at the planning level. Transmission & distribution investments by competitive tender (both on cost and ROI).	Allow full price signals to flow to users. Load-shedding incentives driven by market. Price incentives for 'smart meters' and more energy efficient equipment.

Signifies functional independence between levels. * For II., RBA-type agreements, separate boards.

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Shared responsibility for risks to energy service flow (security & commercial regimes)

Security regime:
- SCADA & AMI
- On-line security assessment
- Central control
- Reliability policy

Commercial regime:
- Ancillary services, spot energy & derivatives
- Network access

End-use & distributed resources:
- Energy management systems (security)
- Nodal markets & network access

DNSPs, for radial distribution:
- Distribution system automation (security)
- Network access regime

TNSPs, for meshed transmission:
- Managed by ISO (security)
- Arbitrage in nodal markets

Large generators:
- Operation when directed by ISO (security)
- Nodal markets & network access

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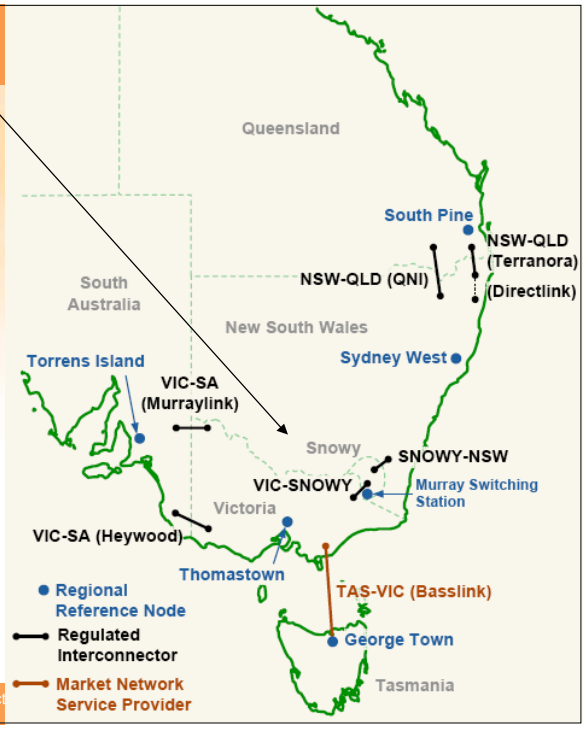
Snowy region may be deleted

NEM regions

(NEMMCO SOO, 2006)



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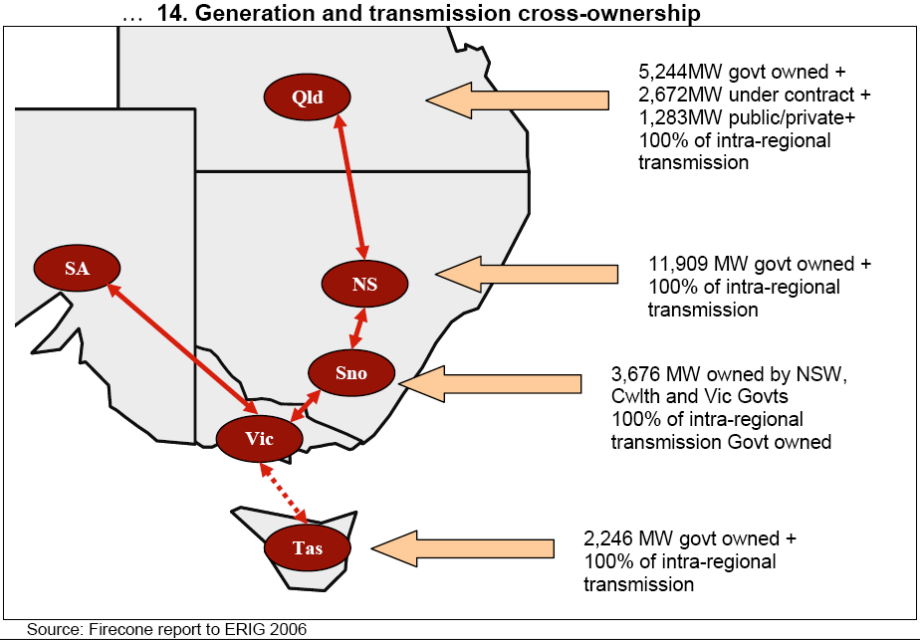
State owned Gen & Tx (also Dx & Retail) (ERIG DPs 0611)

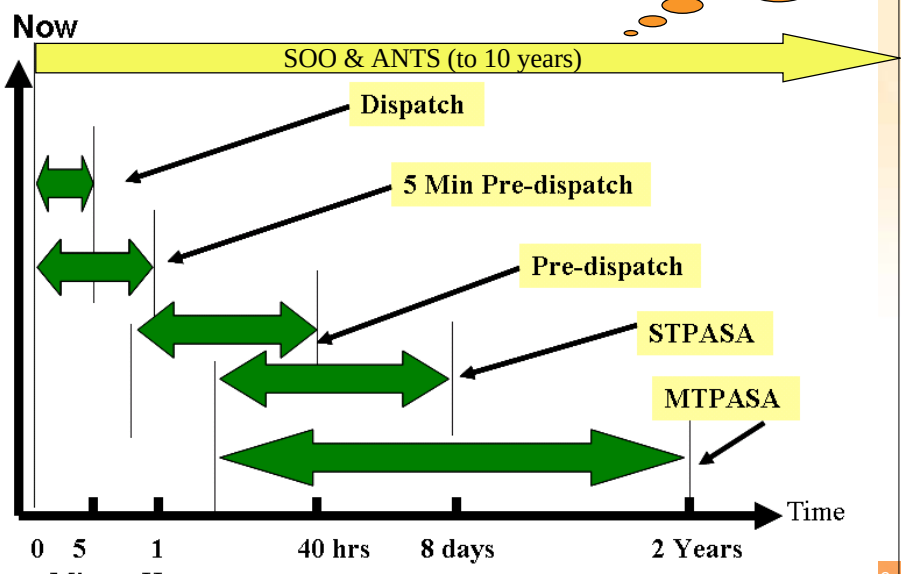
… **14. Generation and transmission cross-ownership**



Source: Firecone report to ERIG 2006

NEMMCO Forecasting Timeframes

but what kind of forecasts?



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A simple typology of uncertainty

(IPCC guidance notes for AR4, 7/05)

Type of uncertainty	Indicative example	Typical approach
▪ Unpredictability	▪ Political behaviour ▪ Chaotic complexity	▪ Diverse scenarios ▪ Ranges from many model runs
▪ Structural uncertainty	▪ Model inadequacy: incomplete, errors…	▪ Specify assumptions & investigate their validity
▪ Value uncertainty	▪ Data missing, wrong, inappropriate, poorly understood, varying	▪ Validate by whatever means are available

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The art of forecasting

- "Prediction is difficult, especially about the future" (attributed to Niels Bohr)
- Why is this?
  - Science is based on disprovable hypotheses:
    - A currently accepted hypothesis has yet to be proved wrong
    - The most valuable hypotheses are easily disprovable: 2+2 = 4
  - Facts are required to test a hypothesis
  - A fact is what has happened, not what may happen:
    - There are no facts about the future, only predictions
- Thus, forecasting is Art (opinion-based) not Science

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Forecasting approaches #1

- Trend projections of the forecast variable:
  - e.g. assumption of constant exponential growth
  - *Ok if past is a good predictor but not otherwise*
- Econometric projections:
  - Trend projections of assumed causal variables, eg. GDP, population, etc.
  - *Transfers the trend projection problem to the assumed causal variables, hence ok if past is a good predictor but not otherwise*

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Forecasting approaches #2

- End-use analysis
  - Engineering, building-block approach
  - *Can capture detail better than econometric models but may not correctly anticipate technological change*
- System dynamics:
  - Similar to end-use analysis but based on differential equations to incorporate resource constraints
  - *A valuable reminder of resource constraints but unlikely to accurately predict when constraints bind*
- Scenario analysis (stories about possible futures):
  - *Can help assess the potential impact of major change*

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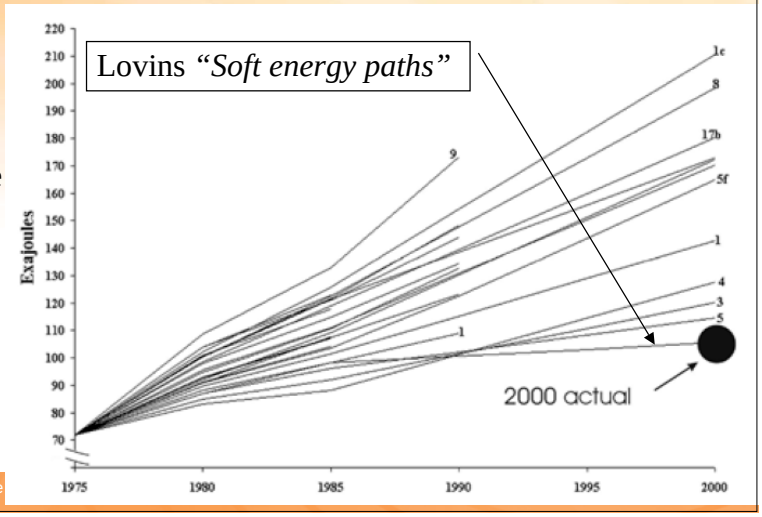
US experience with energy forecasting #1

(Craig et al, What can history teach us? LBNL-50498, may 2002)

The forecast as extrapolation of past behaviour

Forecasts of US energy use from 1970's

illustrates the limitations of extrapolation from the past



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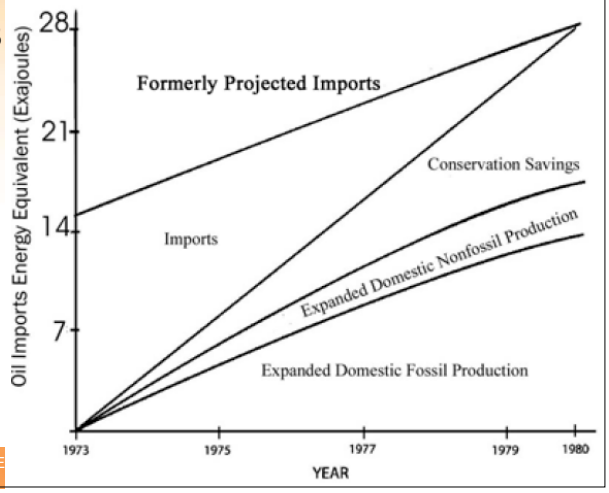
US experience with energy forecasting #2

(Craig et al, What can history teach us? LBNL-50498, may 2002)

The forecast as sales pitch #A

Project independence,1973
"Self sufficiency by 1980 through conservation & expanded production"

actual imports higher in 1980 than in 1973



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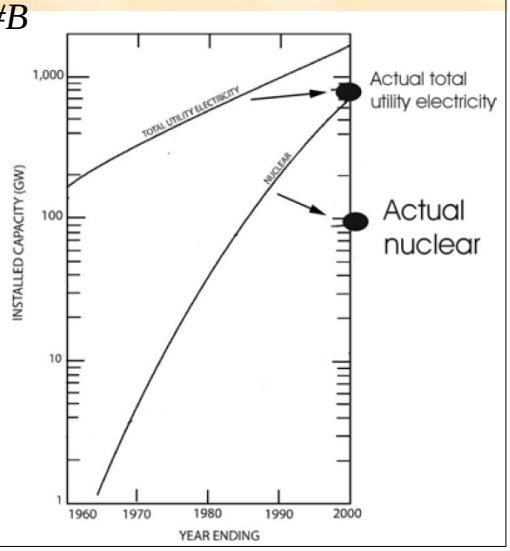
US experience with energy forecasting #3

(Craig et al, What can history teach us? LBNL-50498, may 2002)

The forecast as sales pitch #B

Atomic Energy Commission 1962 forecast of future US nuclear power requirement.

In practice there were no new orders from 1980 due in part to the 1970's oil shocks & the Three Mile Island accident.



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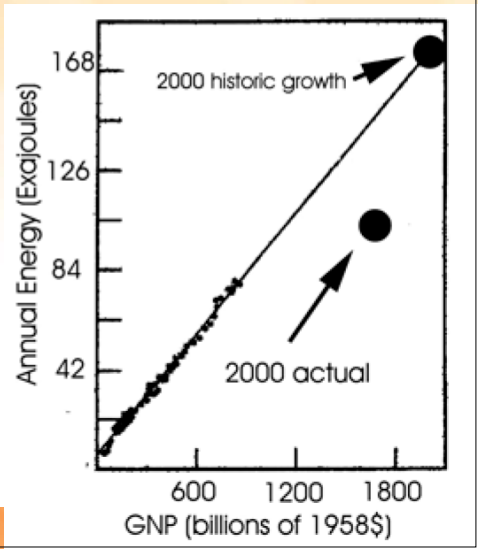
US experience with energy forecasting #4

(Craig et al, What can history teach us? LBNL-50498, may 2002)

Limitations of econometric forecasting

The historical relationship between US GNP & energy changed in the 1970's & the rate of GNP growth slowed



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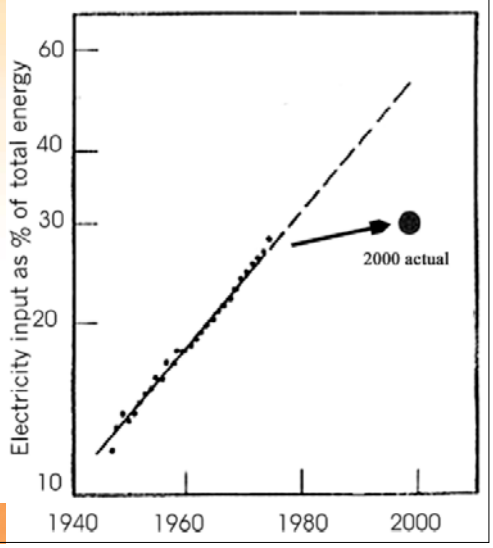
US experience with energy forecasting #5

(Craig et al, What can history teach us? LBNL-50498, may 2002)

Limitations of end-use analysis

Failure to predict the end of a rising trend in the fraction of total primary energy used to generate electricity



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US experience with energy forecasting #6

(Craig et al, What can history teach us? LBNL-50498, may 2002)

Experts are not objective: traditionalist vs reformist opinion of forecasts

Study	Quality[a]		Attention[a]		Influence[a]	
	Trad.	Refor.	Trad.	Refor.	Trad.	Refor.
Ford Energy Policy Project	D	A-	A	B	A	A-
Project Independence Report	C	E	B	B	C	D
ERDA-48 and ERDA 76-1	D	E	D	C	D	D
MOPPS	C	D	D	D	E	E
Ford-MITRE Study	B	B	C	D	A	A-
Lovins "soft paths"	E	A-	A	A	A	A-
WAES Study	C	B	C	C	C	B
CIA assessment of int'l energy	C	B	B	B	B	A
CONAES	B	C	C	C	D	D
Stobaugh and Yergin	D	A	A	A	A	A
RFF-Mellon Study	A	B-	D	D	D	E
Ford-RFF Study	A	A	D	D	D	C

[a]Participants assigned letter grades to each study, from A (highest) to E (lowest).

Trad., traditionalist group; Refor., reformist group (see text for details); ERDA, Energy Research and Development Administration; MOPPS, Market Oriented Program Planning Study; MITRE Corporation; WAES , Workshop on Alternative Energy Strategies ; CONAES, National Academy of Sciences Committee on Nuclear and Alternative Energy Strategies; RFF, Resources for the Future

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US experience with energy forecasting #7

(Craig et al, What can history teach us? LBNL-50498, may 2002)

Recommendations

- Document *[all identified]* assumptions
- Choose an approach that fits the purpose
- Beware of obsession with technical sophistication
- Watch out for discontinuities & irreversibility
- Do not assume fixed laws of human behaviour
- Use *[a set of]* scenarios
- Use combined approaches
- Expect the unexpected & design for uncertainty
- Communicate effectively
- Be modest *[forecasters tend to be prisoners of their own world view]*

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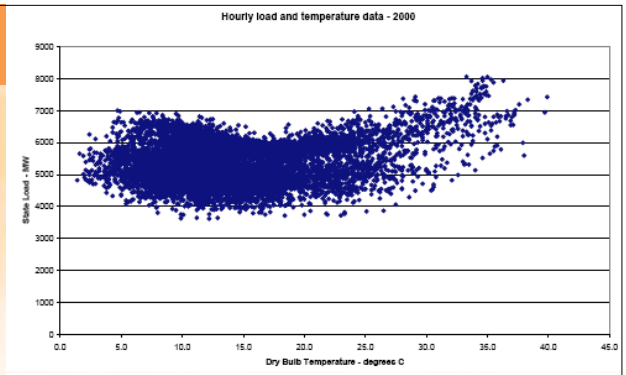
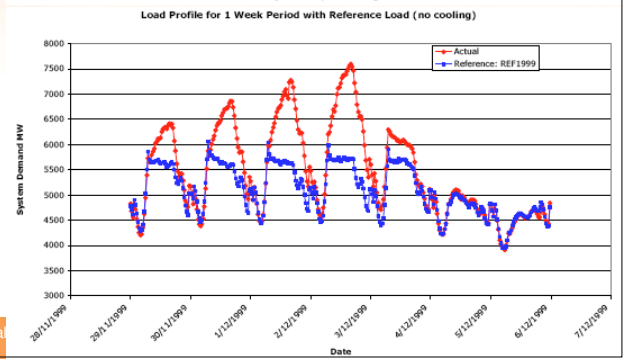
Temperature-sensitive load (Victoria) size & variability

(Energy Efficient Strategies, 2004)





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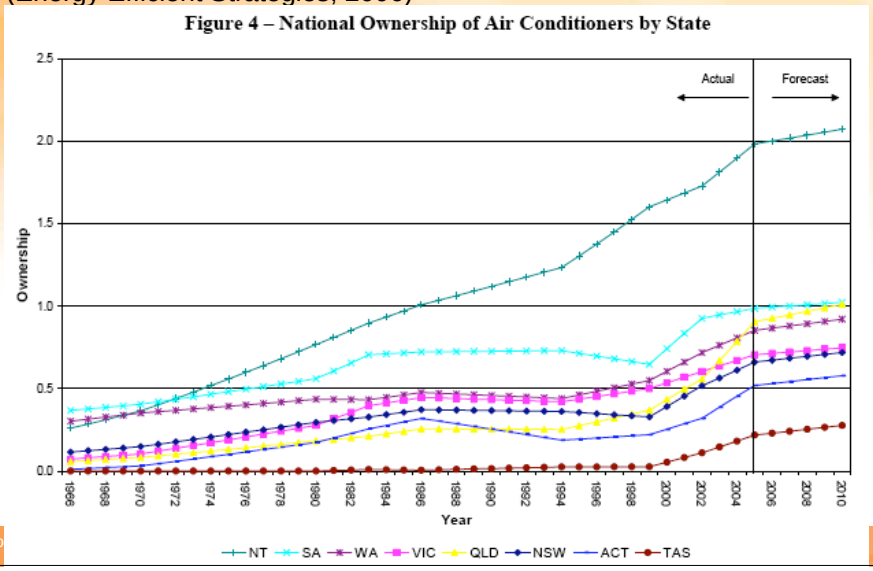
Air conditioner ownership (no. per house)

(Energy Efficient Strategies, 2006)



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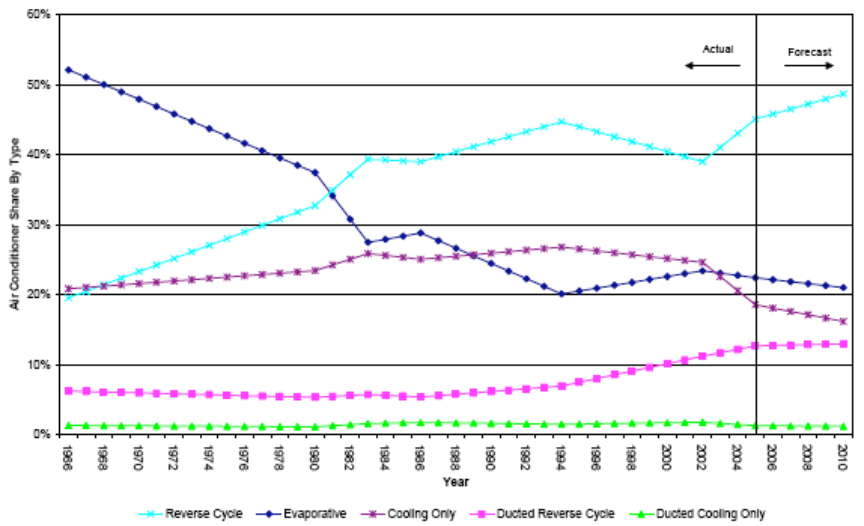
Air conditioner market shares by type

(Energy Efficient Strategies, 2006)

Figure 5 – National Share of Air Conditioner Type



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Each non-A/C residential owner subsidises each residential A/C owner over $70 pa

(H Colebourn, EA, 2006)

	Non A/C	A/C	Total
Average annual energy MWh	5.1	7.0	
No. Customers, Millions	0.57	0.75	1.32
Annual Energy	35%	65%	
Proportion of revenue thru tariffs	37%	63%	
Revenue FY06 $M	157	273	430
Demand on network kW	1.8	4.1	
Proportion of demand	25%	75%	
Marginal cost of supply (90%) $M	97	290	387
Balance reallocated $M	16	27	43
Total cost reflective $M	113	317	430
"Cross subsidy" $M	44	-44	
Annual customer charge	$ 277	$362	326
… subsidy per customer	$ 78	-$ 59	
… proportion of cost reflective	139%	84%	

Figure 2.9 ANTS Verification Studies, Unaugmented Market Simulation Case, Generation Expansion by Region (NEMMCO SOO, 2006)

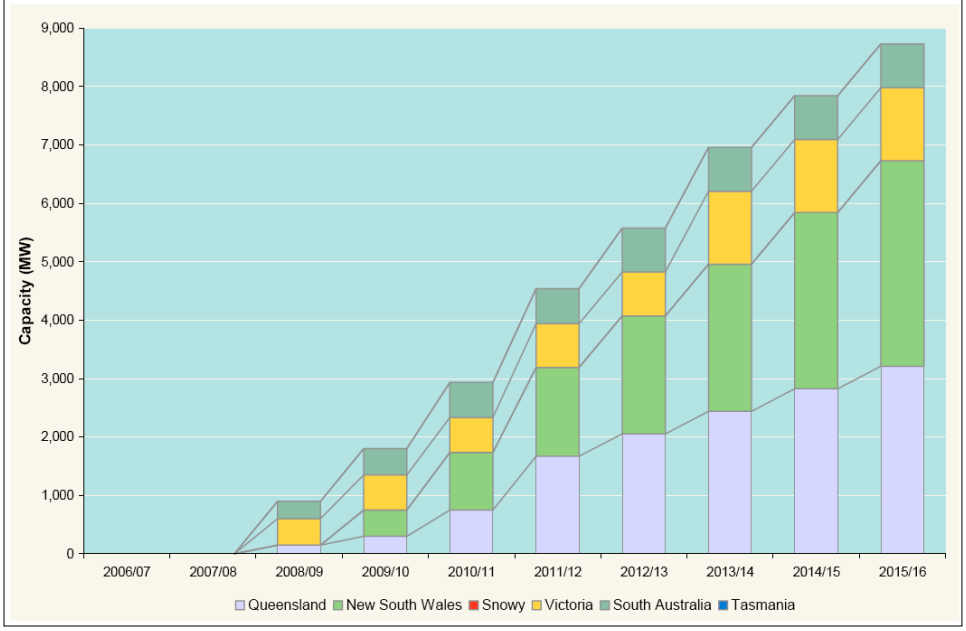
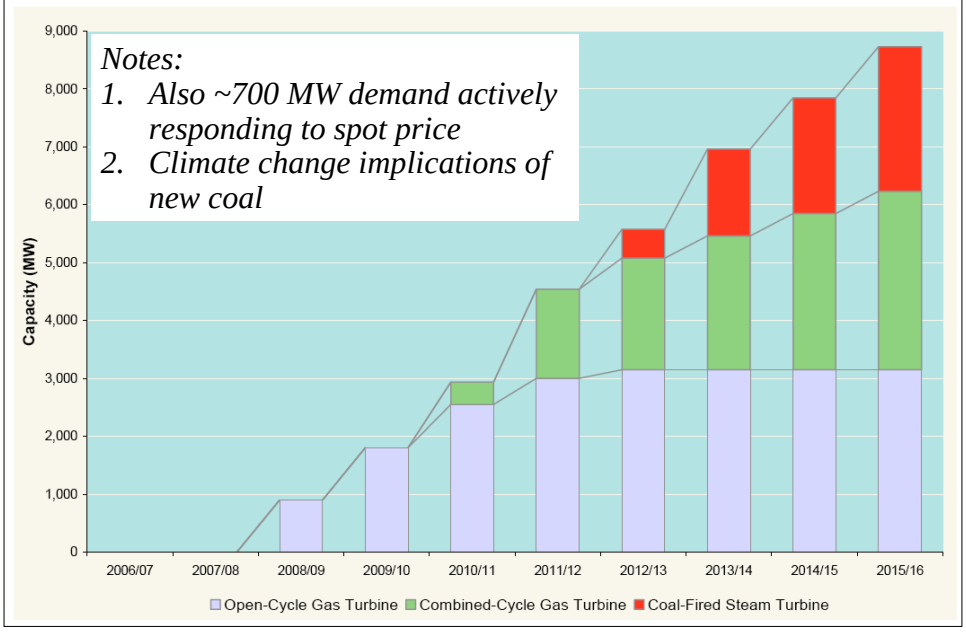


Figure 2.10 ANTS Verification Studies, Unaugmented Market Simulation Case, Generation Expansion by Technology (NEMMCO SOO, 2006)



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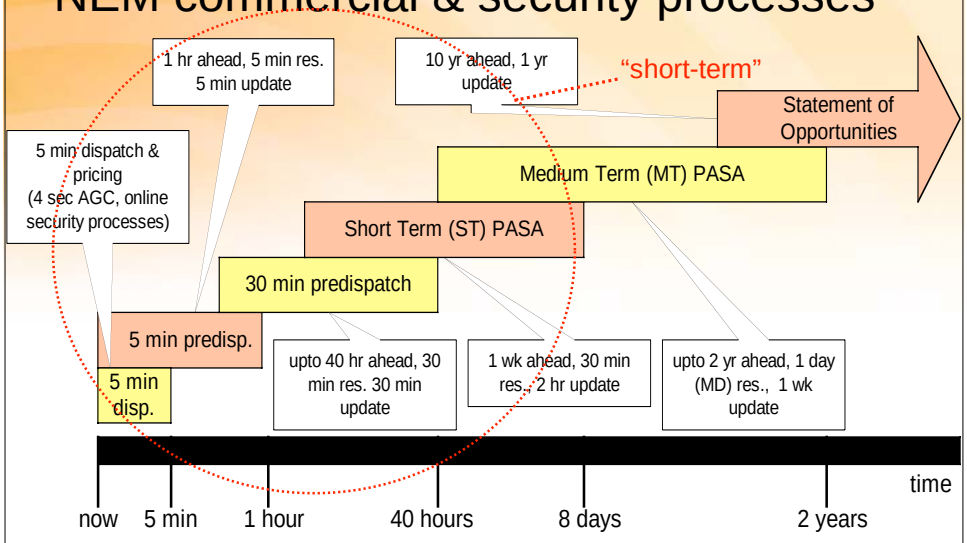
NEM commercial & security processes



Resource Adequacy in the Australian National Electricity Market Source: NEMMCO 37

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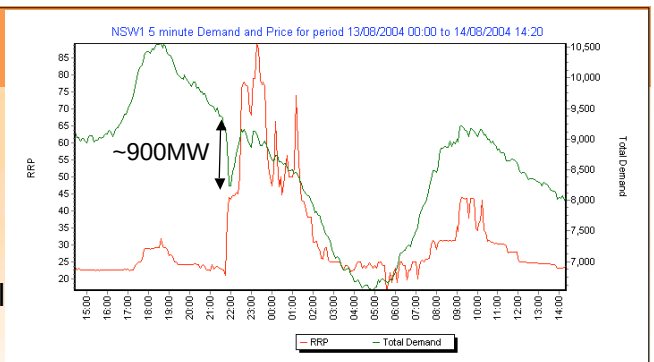
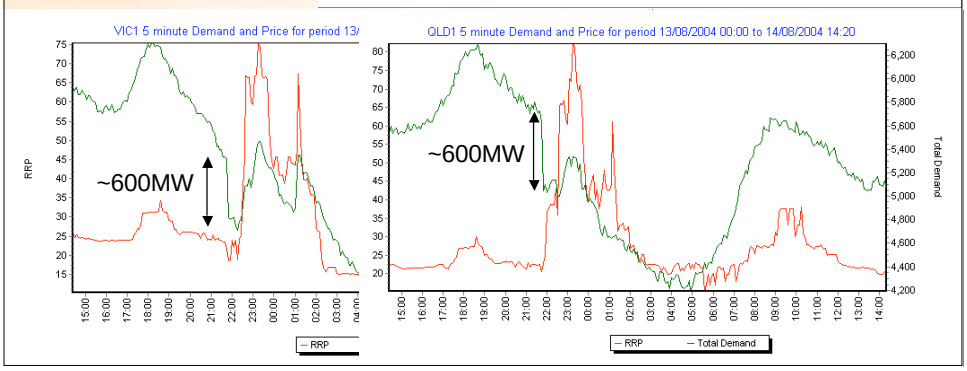
Transgrid CT failure @ 2142 13/8/04 led to 3100 MW gen trip. Frequency fell to 48.9Hz, ~2100 MW load shed in NSW, Ql Vic & SA





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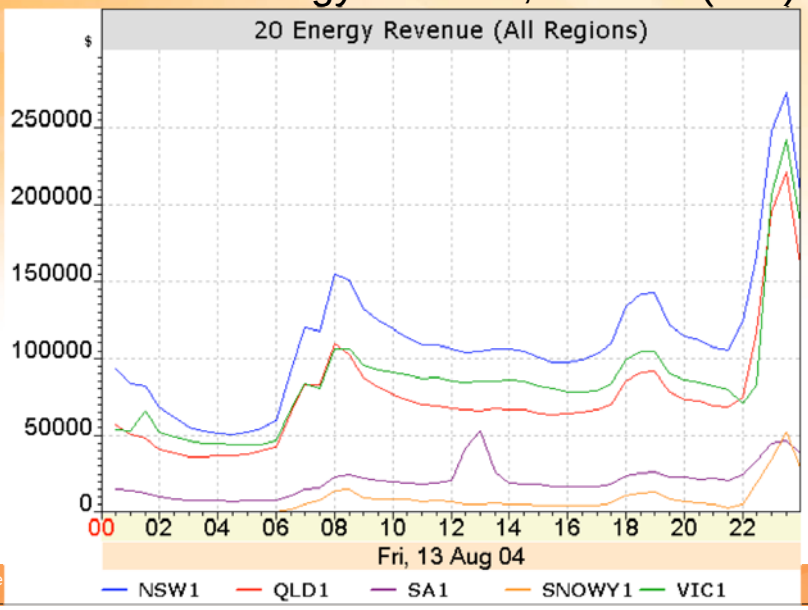
NEM energy revenue, 13/8/04 (IES)



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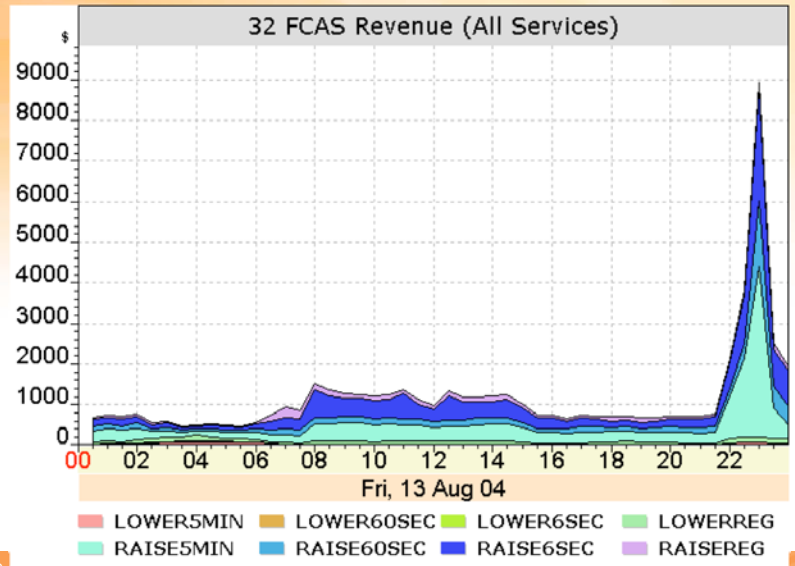
NEM FCAS revenue 13/8/04 (IES)



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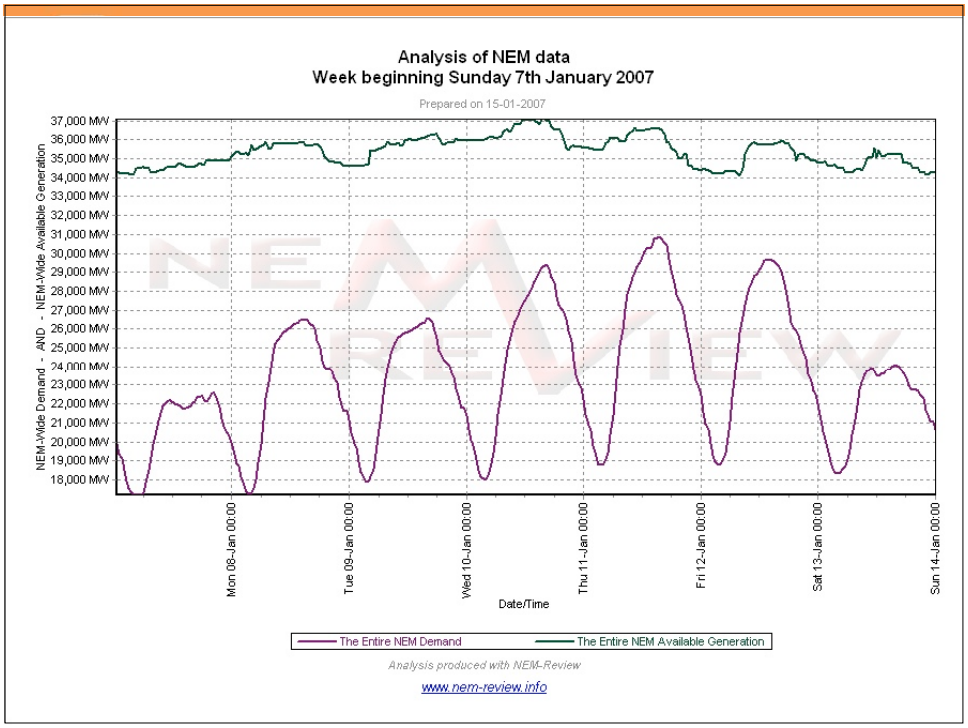
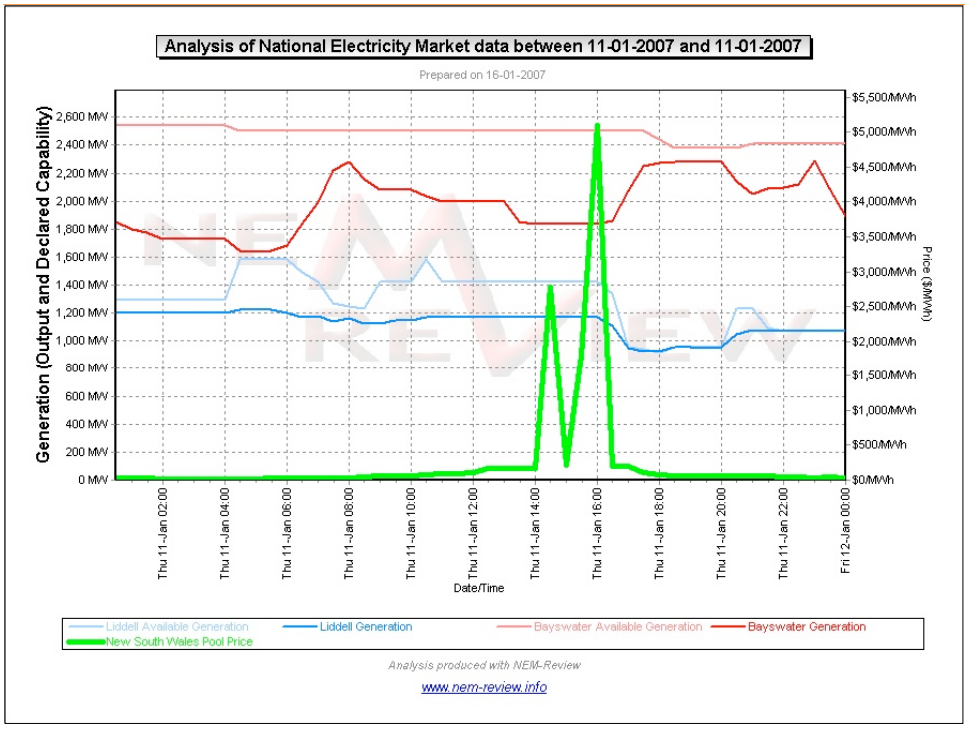

Analysis of NEM data
Week beginning Sunday 7th January 2007
Prepared on 15-01-2007
NEM-Wide Demand - AND - NEM-Wide Available Generation
37,000 MW
36,000 MW
35,000 MW
34,000 MW
33,000 MW
32,000 MW
31,000 MW
30,000 MW
29,000 MW
28,000 MW
27,000 MW
26,000 MW
25,000 MW
24,000 MW
23,000 MW
22,000 MW
21,000 MW
20,000 MW
19,000 MW
18,000 MW
Mon 08-Jan 00:00
Tue 09-Jan 00:00
Wed 10-Jan 00:00
Thu 11-Jan 00:00
Fri 12-Jan 00:00
Sat 13-Jan 00:00
Sun 14-Jan 00:00
Date/Time
The Entire NEM Demand
The Entire NEM Available Generation
Analysis produced with NEM-Review
www.nem-review.info


Analysis of National Electricity Market data between 11-01-2007 and 11-01-2007
Prepared on 16-01-2007
Generation (Output and Declared Capability)
2,600 MW
2,400 MW
2,200 MW
2,000 MW
1,800 MW
1,600 MW
1,400 MW
1,200 MW
1,000 MW
800 MW
600 MW
400 MW
200 MW
0 MW
Price ($/MWh)
$5,500/MWh
$5,000/MWh
$4,500/MWh
$4,000/MWh
$3,500/MWh
$3,000/MWh
$2,500/MWh
$2,000/MWh
$1,500/MWh
$1,000/MWh
$500/MWh
$0/MWh
Thu 11-Jan 02:00
Thu 11-Jan 04:00
Thu 11-Jan 06:00
Thu 11-Jan 08:00
Thu 11-Jan 10:00
Thu 11-Jan 12:00
Thu 11-Jan 14:00
Thu 11-Jan 16:00
Thu 11-Jan 18:00
Thu 11-Jan 20:00
Thu 11-Jan 22:00
Fri 12-Jan 00:00
Date/Time
Liddell Available Generation
Liddell Generation
Bayswater Available Generation
Bayswater Generation
New South Wales Pool Price
Analysis produced with NEM-Review
www.nem-review.info

16 Jan 2007: Blackout in Victoria

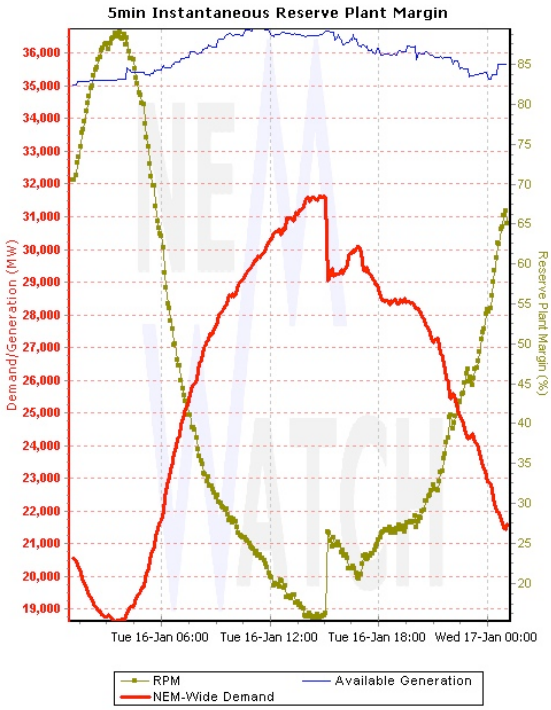
(Assistance from NEM Watch & Stuart Thorncraft)

Contributing factors:

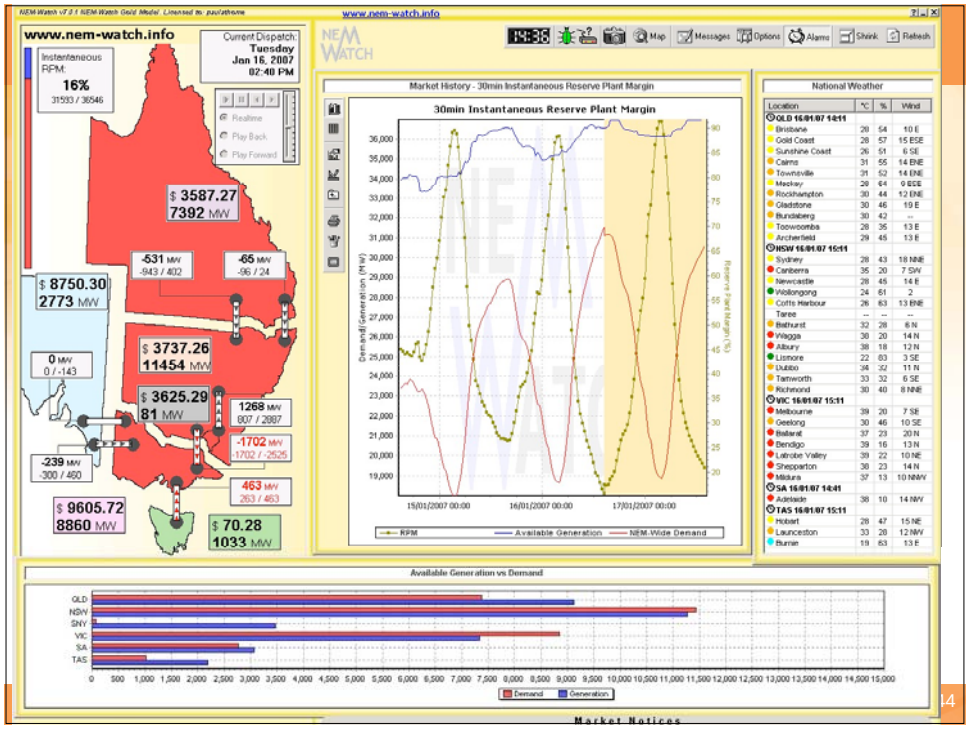
- Record demand due to high temperature
- 3 tx lines tripped due to bushfires

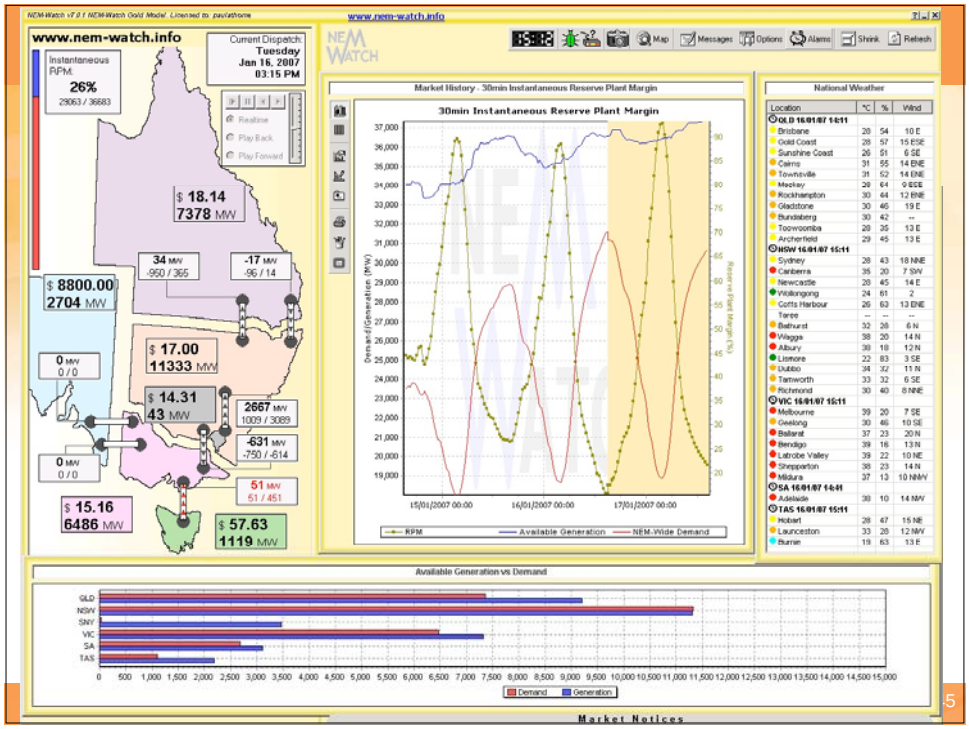
Outcomes:

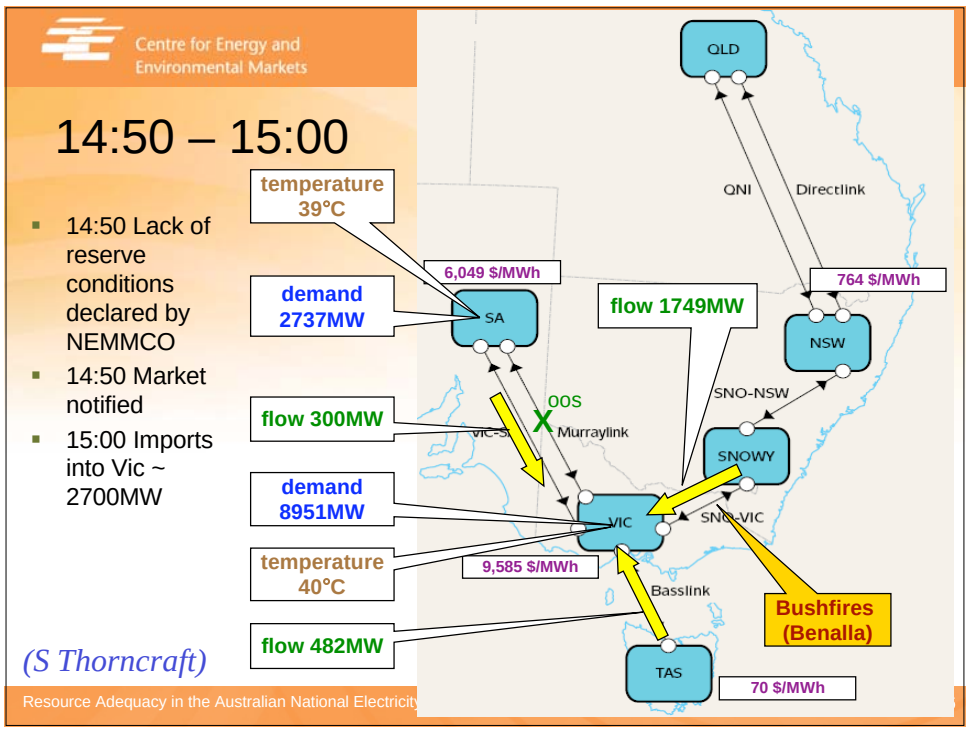
- System separation
- 2600MW load shed & restored

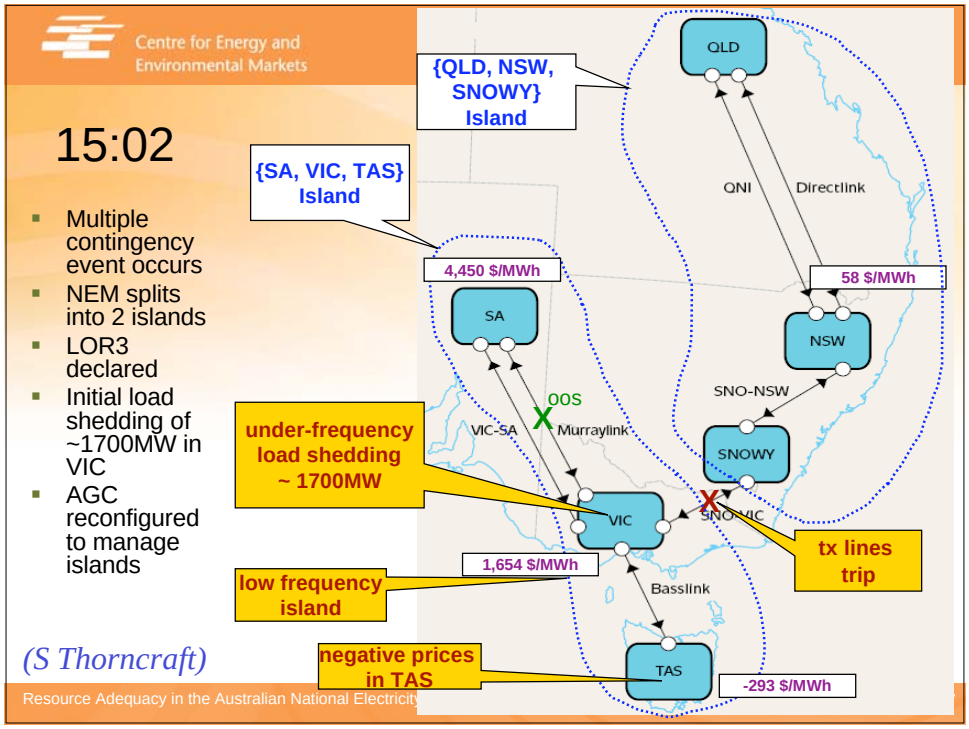


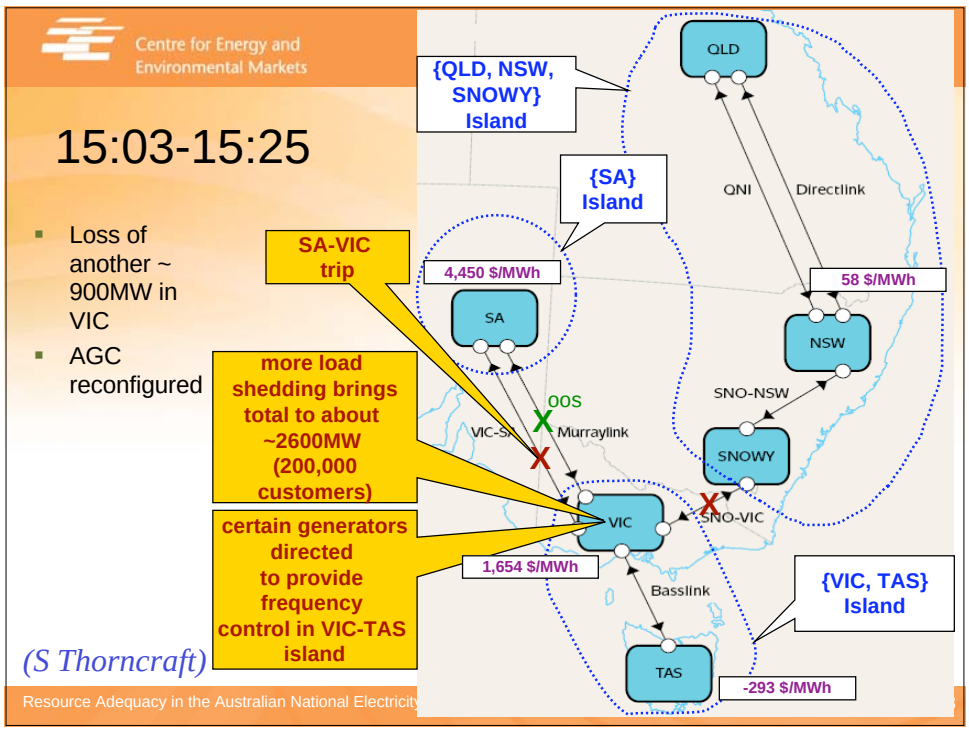
Resource Adequacy in the Australian National Electr

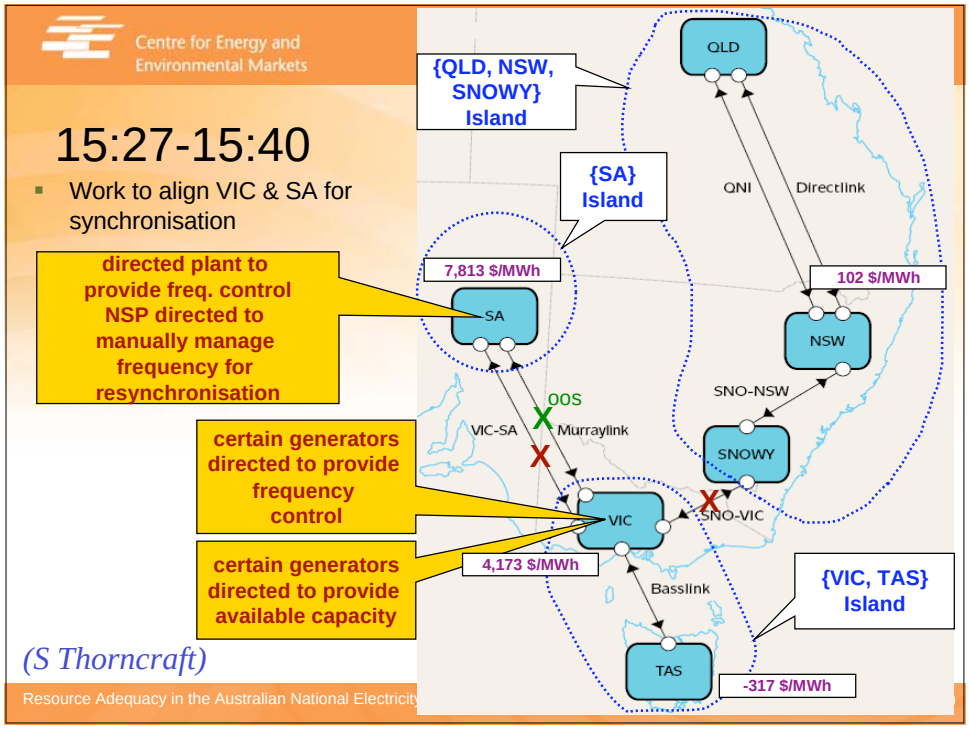


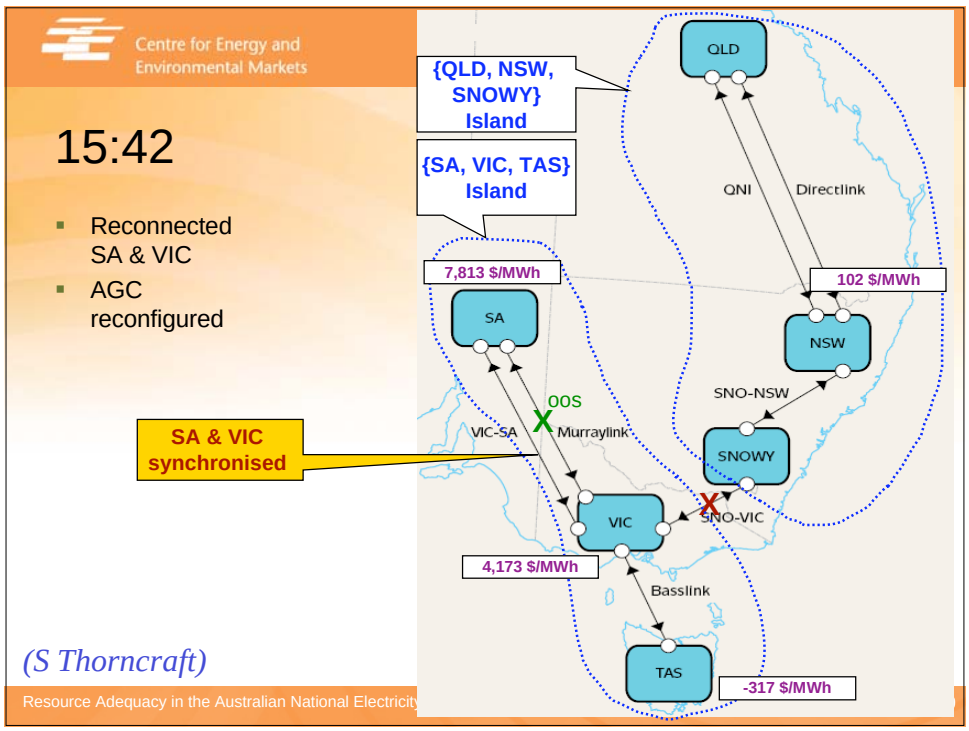

www.nem-watch.info
Current Dispatch
Tuesday
Jan 16, 2007
03:15 PM
Instantaneous RPM
26%
$ 18.14
7378 MW
$ 8800.00
2704 MW
$ 17.00
11333 MW
$ 14.31
43 MW
$ 15.16
6486 MW
$ 57.63
1119 MW
30min Instantaneous Reserve Plant Margin
National Weather
Available Generation vs Demand
Market Notices


Centre for Energy and Environmental Markets
14:50 – 15:00
14:50 Lack of reserve conditions declared by NEMMCO
14:50 Market notified
15:00 Imports into Vic ~ 2700MW
temperature 39°C
demand 2737MW
flow 300MW
demand 8951MW
temperature 40°C
flow 482MW
6,049 $/MWh
flow 1749MW
764 $/MWh
9,585 $/MWh
70 $/MWh
QLD
QNI
Directlink
SA
NSW
SNO-NSW
OOS
Murraylink
SNOWY
VIC
SNO-VIC
Basslink
Bushfires (Benalla)
TAS
(S Thorncraft)
Resource Adequacy in the Australian National Electricity


Centre for Energy and Environmental Markets
15:02
Multiple contingency event occurs
NEM splits into 2 islands
LOR3 declared
Initial load shedding of ~1700MW in VIC
AGC reconfigured to manage islands
(S Thorncraft)
Resource Adequacy in the Australian National Electricity
{QLD, NSW, SNOWY} Island
{SA, VIC, TAS} Island
under-frequency load shedding ~ 1700MW
low frequency island
negative prices in TAS
tx lines trip
QLD
QNI
Directlink
58 $/MWh
NSW
SNO-NSW
SNOWY
SNO-VIC
4,450 $/MWh
SA
OOS
VIC-SA
Murraylink
VIC
1,654 $/MWh
Basslink
TAS
-293 $/MWh


Centre for Energy and Environmental Markets
15:03-15:25
Loss of another ~ 900MW in VIC
AGC reconfigured
(S Thorncraft)
Resource Adequacy in the Australian National Electricity
SA-VIC trip
more load shedding brings total to about ~2600MW (200,000 customers)
certain generators directed to provide frequency control in VIC-TAS island
{QLD, NSW, SNOWY} Island
{SA} Island
{VIC, TAS} Island
QLD
QNI
Directlink
58 $/MWh
NSW
SNO-NSW
SNOWY
SNO-VIC
4,450 $/MWh
SA
OOS
Murraylink
VIC
1,654 $/MWh
Basslink
TAS
-293 $/MWh


Centre for Energy and Environmental Markets
15:27-15:40
Work to align VIC & SA for synchronisation
directed plant to provide freq. control NSP directed to manually manage frequency for resynchronisation
certain generators directed to provide frequency control
certain generators directed to provide available capacity
{QLD, NSW, SNOWY} Island
{SA} Island
{VIC, TAS} Island
QLD
QNI
Directlink
7,813 $/MWh
102 $/MWh
SA
NSW
SNO-NSW
OOS
VIC-SA
Murraylink
SNOWY
VIC
SNO-VIC
4,173 $/MWh
Basslink
TAS
-317 $/MWh
(S Thorncraft)
Resource Adequacy in the Australian National Electricity

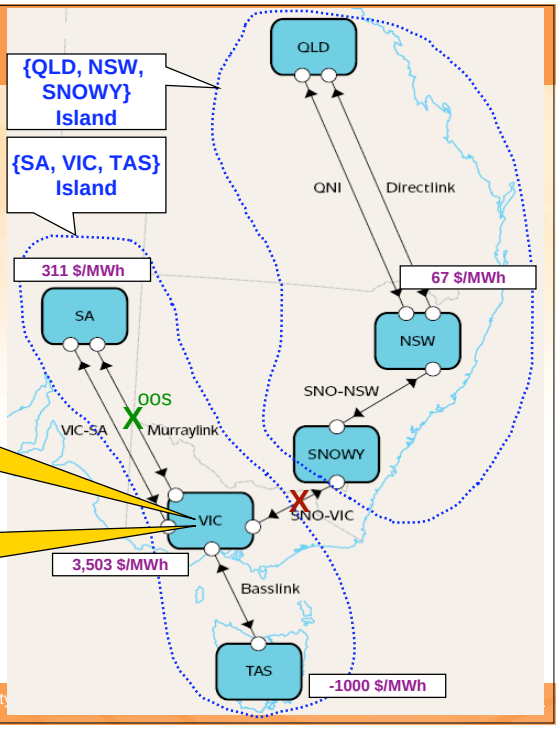

Centre for Energy and Environmental Markets
15:42
Reconnected SA & VIC
AGC reconfigured
SA & VIC synchronised
{QLD, NSW, SNOWY} Island
{SA, VIC, TAS} Island
QLD
QNI
Directlink
7,813 $/MWh
102 $/MWh
SA
NSW
SNO-NSW
OOS
VIC-SA
Murraylink
SNOWY
VIC
SNO-VIC
4,173 $/MWh
Basslink
TAS
-317 $/MWh
(S Thorncraft)
Resource Adequacy in the Australian National Electricity

Centre for Energy and Environmental Markets

15:49-16:12

- load restoration (potlines & some customer load)
- system declared secure
- ...but insufficient reserves to restore all load

(S Thorncraft)



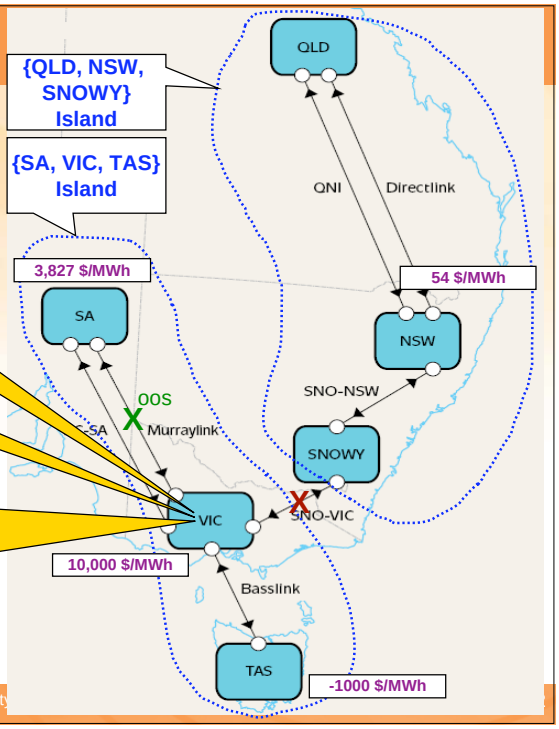
Resource Adequacy in the Australian National Electricity

Centre for Energy and Environmental Markets

16:20-16:54

- load shedding to assist frequency control
- offline generator brought online
- VoLL override conditions in place

(S Thorncraft)

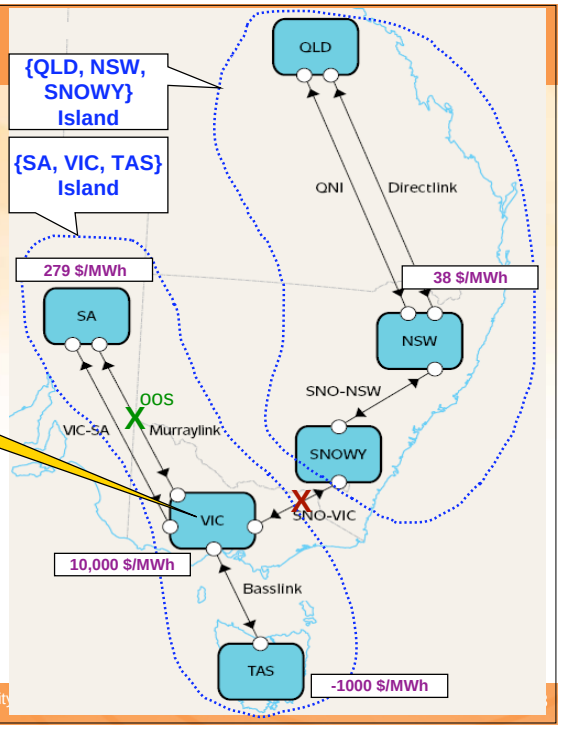


Resource Adequacy in the Australian National Electricity

Centre for Energy and Environmental Markets

17:25-17:55

- System stabilised
- load restoration process
- VoLL override still in place



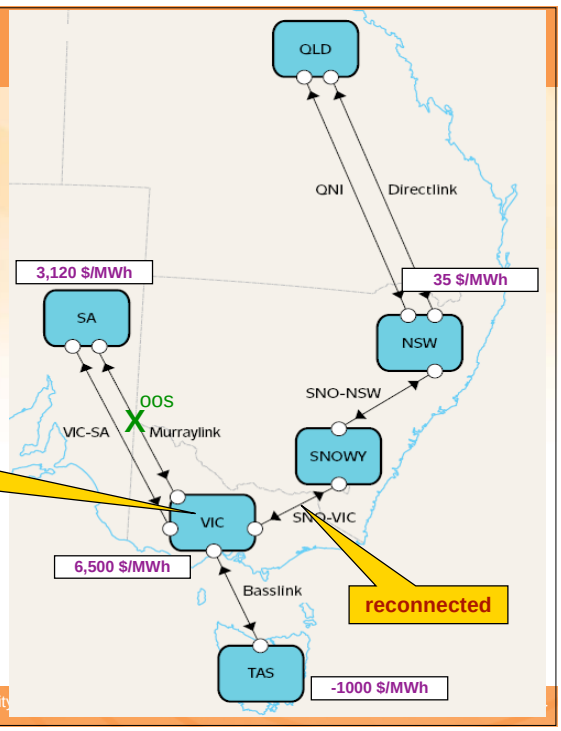
(S Thorncraft)

Resource Adequacy in the Australian National Electricity

Centre for Energy and Environmental Markets

17:57-18:15

- System reconnected
- Load restoration
- LOR3 withdrawn



(S Thorncraft)

Resource Adequacy in the Australian National Electricity

Centre for Energy and Environmental Markets

UNSW

16 January 2007 Outcomes

- Victoria cabinet met to consider power rationing
- Load shedding estimated to cost Melbourne ~$10m
- Spot market revenues earned by participants:
  - very high in Victoria due to VoLL override
  - negative revenue in Tasmania due to negative price – why?
- Very high ancillary service prices due to local sourcing of ancillary service providers
- **…But** market proceeded and core system returned to normal in around 3 hours
- Market incentives seem to be aligned with what was needed physically

Resource Adequacy in the Australian National Electricity Market 55

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UNSW

Energy Reform Implementation Group Review: initial thinking (www.erig.gov.au)

- Proposed overarching goal:
  - Economic efficiency (productive, allocative, dynamic)
- Proposed government role:
  - Adopt a nationally consistent approach
  - Set supply standards, including reliability
  - Design governance regime to deliver overarching goal
  - Eliminate barriers to entry in competitive industry sectors
  - Emulate competitive market outcomes in regulation
  - *End direct government participation in the industry*

Resource Adequacy in the Australian National Electricity Market 56

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UNSW

Energy Reform Implementation Group Review: initial thinking continued

- Market structure:
  - Prefer private ownership; not concerned about vertical re-integration; retain energy-only market
  - Fully remove retail price caps & expose end-users to volatile spot prices
- Transmission:
  - Don't over-invest to remove all flow constraints
  - Introduce a formal national network development plan
  - Integrate reliability & economic investment tests
- Energy financial market concerns:
  - Retail price caps; govt. ownership; lack of carbon price

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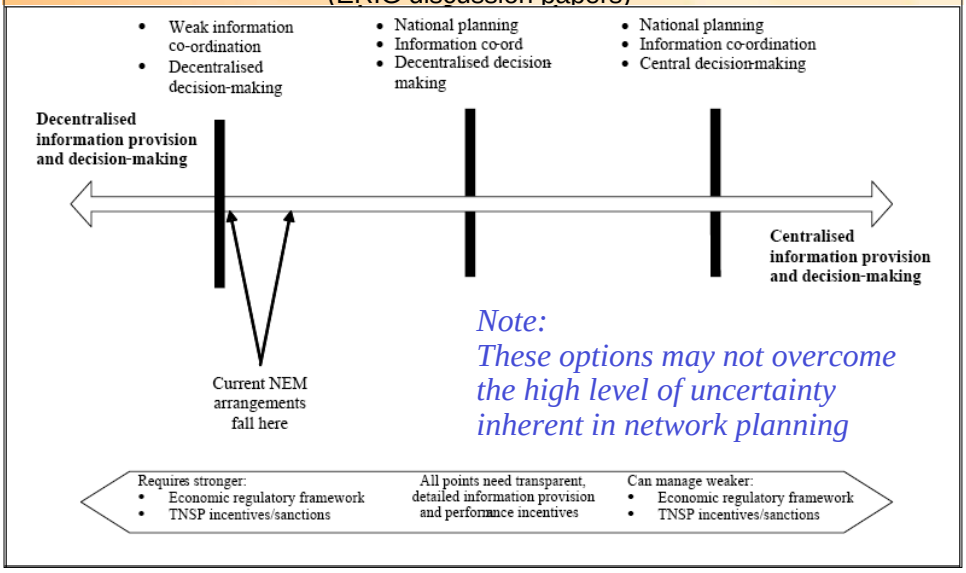
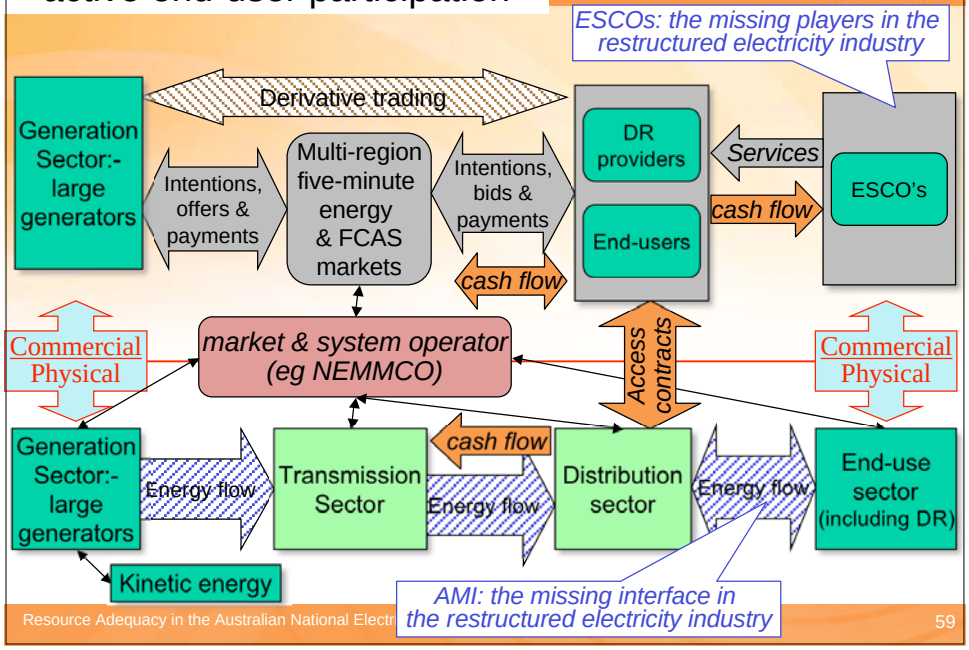
UNSW

Transmission planning options

(ERIG discussion papers)



Enhanced NEM structure with active end-user participation



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Key policies for NEM & stationary energy sector more broadly

- Continue EI restructuring to logical conclusion:
  - Direct end-user participation in NEM (rethink retailing):
    - Ancillary service, spot energy & derivative markets
    - AMI: Interval metering of energy, availability & voltage quality with information held in single NEM-wide database
  - Refined NEM energy & ancillary service markets
  - Single NEM-wide, auction-style derivative market
- Continue gas industry restructuring to maximise compatibility with NEM
- Introduce efficient emission permit trading:
  - All permits should be auctioned

Resource Adequacy in the Australian National Electricity Market 60

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Conclusions

- Broad approach needed to achieve a coherent approach to resource adequacy:
  - Governance, security, technical & commercial regimes
- Strengths of the Australian NEM approach:
  - Consistent & effective security, technical & commercial regimes (governance not bad)
- Weaknesses of the Australian NEM approach:
  - Government-owned businesses remain contentious
  - Retail price caps still in place for some small end-users
  - Network investment remains contentious
  - Incoherent & ineffective climate change policy
- Weaknesses can be reduced or eliminated

Resource Adequacy in the Australian National Electricity Market 61

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Many of our publications are available at:
www.ceem.unsw.edu.au

www.ceem.unsw.edu.au