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An Australian Perspective on Electricity Industry Restructuring & Sustainability

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Electricity restructuring is challenging

“the significant problems we face cannot be solved by the same level of thinking that created them”

Albert Einstein

“the greatest obstacle is not ignorance - it is the illusion of knowledge”

Daniel J Boorstin

Features of the electricity industry

- Consists of a *supply side* & a *demand side,* both capital intensive with long asset lives:
  - Electricity supply industry (traditional monopoly)
    - Provides (imperfect) availability & quality of supply
  - End-use equipment & user premises (private)
    - Operates according to end-user requirements
- Provides continuous *energy conversion*:
  - From primary to end-use energy forms:
    - All stages in the energy conversion chain matter
  - To deliver *essential (end-use) energy services*
    - Valued more by their absence than their presence (value can greatly exceed the cost of provision)

Challenges of electricity industry operation & planning

- Continuous energy flow is infused with risk:
  - Can't cost-effectively store electrical energy
- *Temporal risks to energy service delivery:*
  - Short term (operation) to long term (investment)
- *Location risks to energy service delivery:*
  - Network constraints can restrict energy flow
- Techniques to manage risk:
  - Physical aggregation of uncertainties by network
  - Industry decision making (collective & individual):
    - Operation and investment

The context of restructuring:- decision making under uncertainty

- No uncertainty implies no decision, hence:
  - – Uncertainty inevitable & wrong decisions possible
- Key characteristics of a decision maker:
  - – Autonomy (authority to make a decision)
  - – Accountability (exposure to costs & benefits)
- Key characteristics of a decision:
  - – Extent to which it constrains outcomes; autonomy
- Decision making processes:
  - – Individual vs group; human vs automated

The role of markets in decision making

- Markets as coordinated decision making:
  - Participants maximise their commercial outcomes
  - Market design aims to align participant self-interest with societal interest
  - Some markets achieve this without formal design
- Electricity restructuring requires formal market design due to industry characteristics:
  - Flow industry; capital intensity; shared nature; externalities; essential service
  - *A strongly interdisciplinary problem*

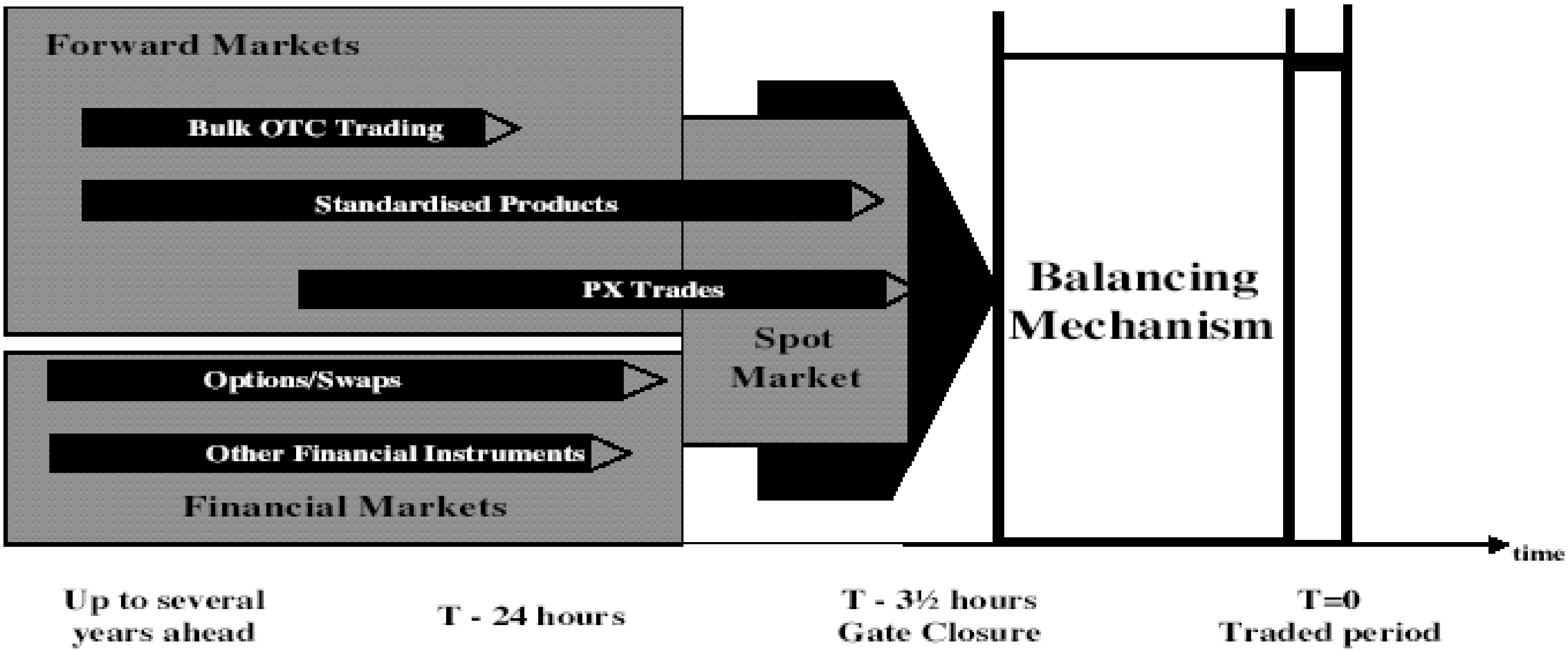
Decision-making & risk allocation in the electricity industry

- Some centralised decision-making inevitable:
  - Instantaneous & continuous energy flow
  - Network, generation & end-use services hard to separate
- Some decentralised decision-making inevitable:
  - Demand-side of the industry privately owned
- Centralised risk allocation to:
  - System & market operators, NSPs, regulators, politicians
- Decentralised risk allocation to:
  - Generators, retailers & **end-users**
- *Difficulties arise because decisions & risks interact:*
  - *Bilateral contracts cannot manage shared risk well*

Electricity market designs

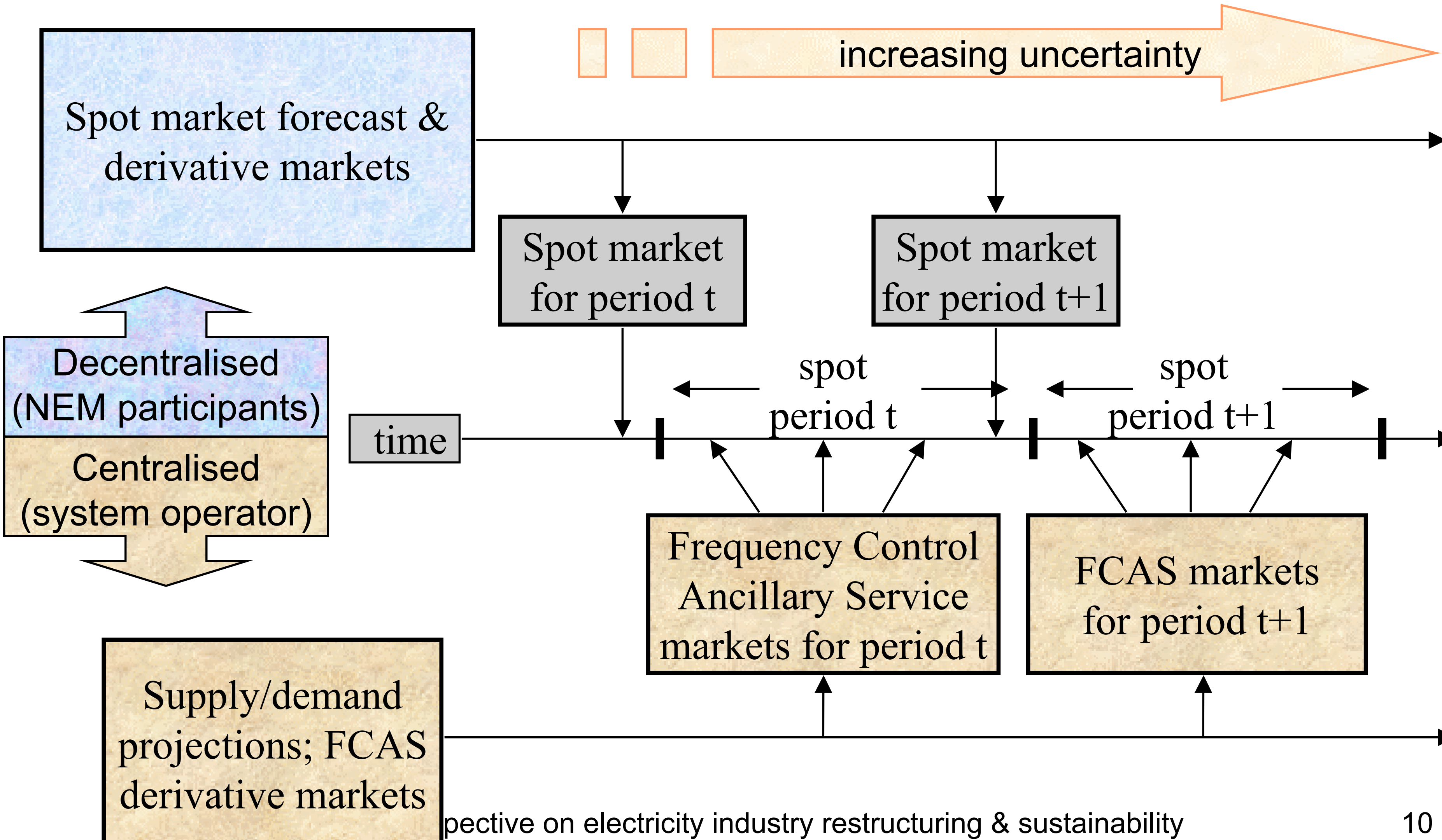
- Net pool (eg UK NETA):
  - Focus on pseudo-deterministic bilateral trading:
    - *Which assumes perfect network (no location risk)*
  - Uncertainty regarded as short-term deviations from pre-determined long-term future:
    - System operator typically given only one day's notice of bilateral trading positions
- Gross pool (eg Australian NEM):
  - Focus on total industry & stochasticity
    - Assumes uncertainty grows with forward projection
    - Ancillary services, spot market, projections of supply-demand balance

Key features of NETA
(Ofgem 1 year review of NETA, July 2002)

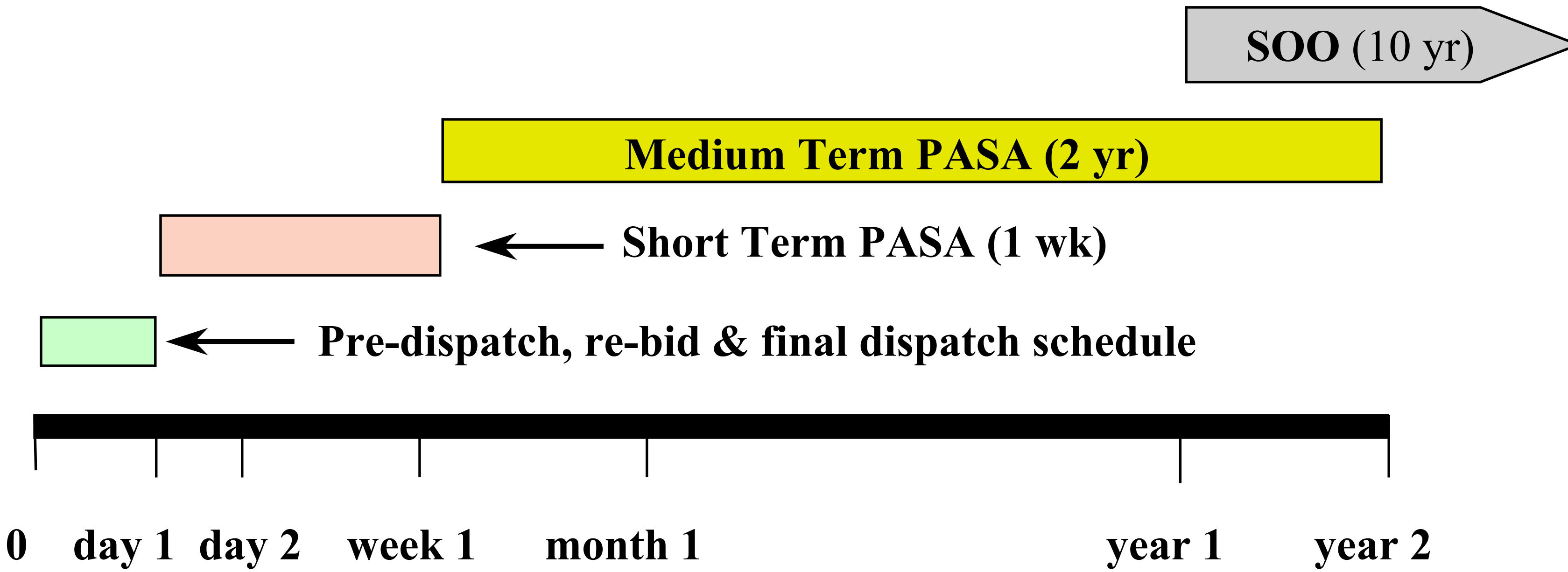


Managing temporal uncertainty in the NEM:

individual & group, automated & human decision making



Dispatch, Pre-dispatch, PASA & SOO in the NEM (source: NEMMCO)



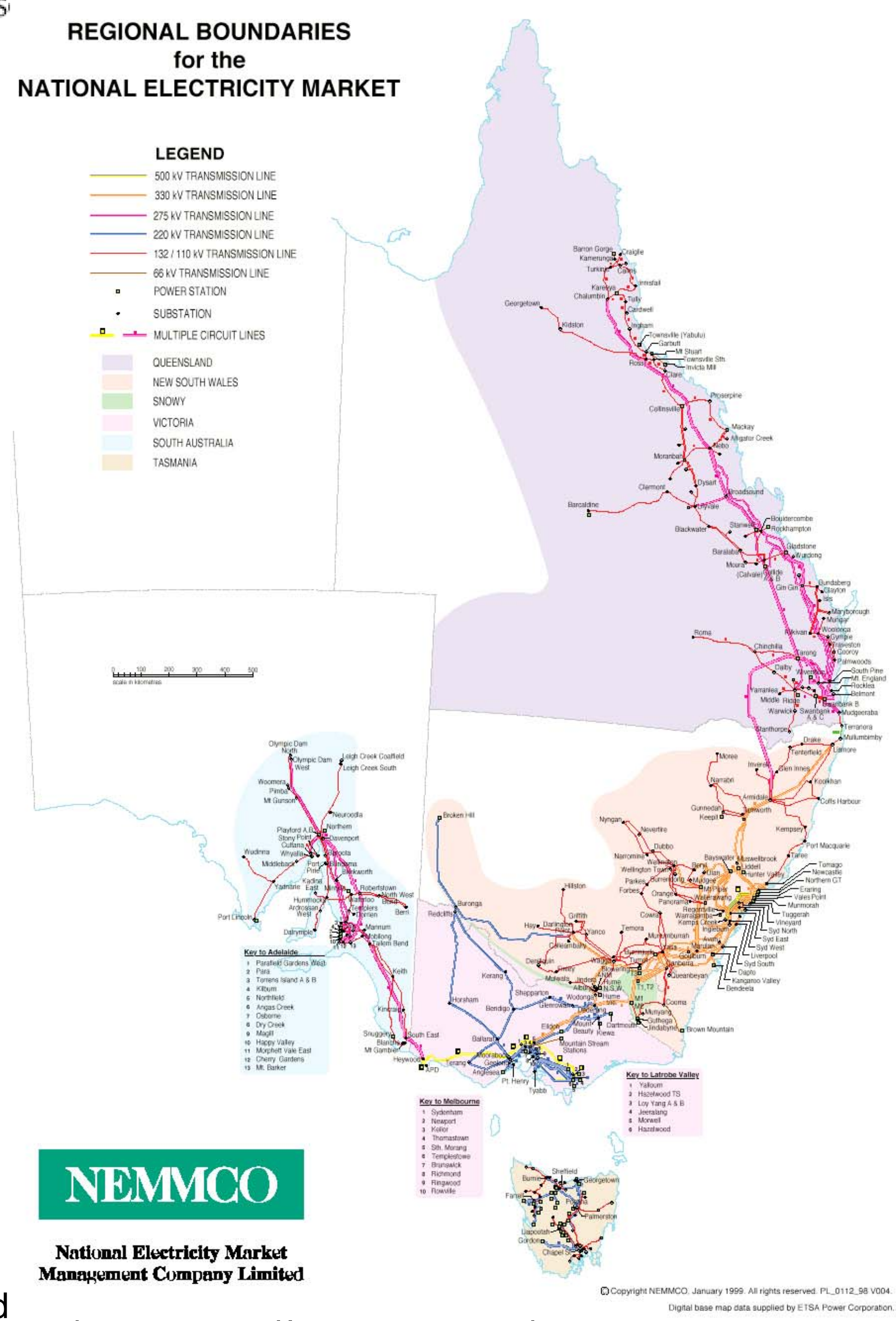
Statement of opportunities (SOO) is intended to inform generation and network investment decisions (10 year horizon, yearly update)

MT Projection of System Adequacy (PASA) is intended to inform near-term reliability assessment and reserve trader processes (2 year horizon, weekly update)

Scope of the NEM

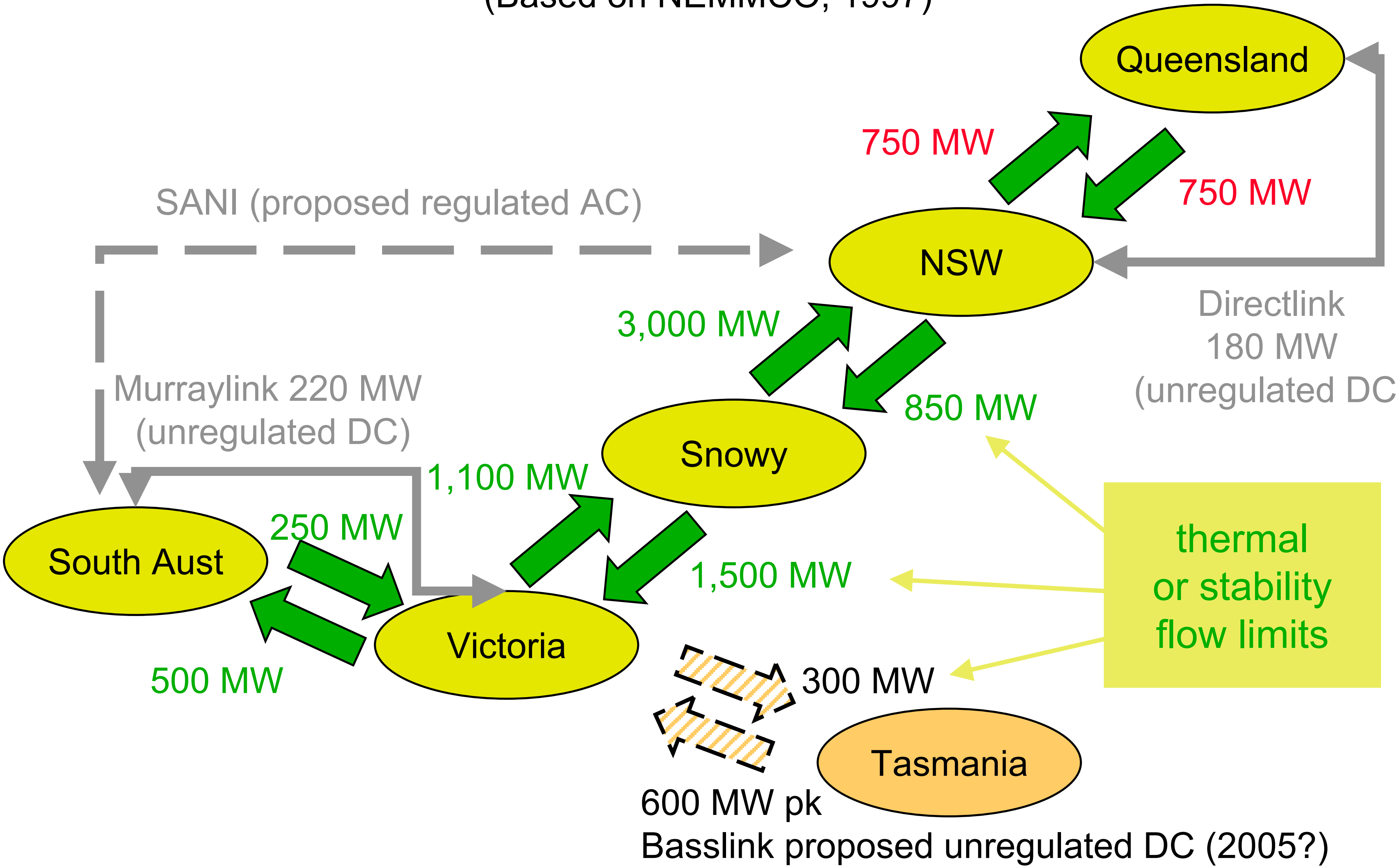
- Queensland
- New South Wales & ACT
- Victoria
- South Australia
- Tasmania (on connection to the mainland)

NEM regions are indicated, and their boundaries need not be on state borders (e.g. two regions in NSW)



NEM regional spot market model

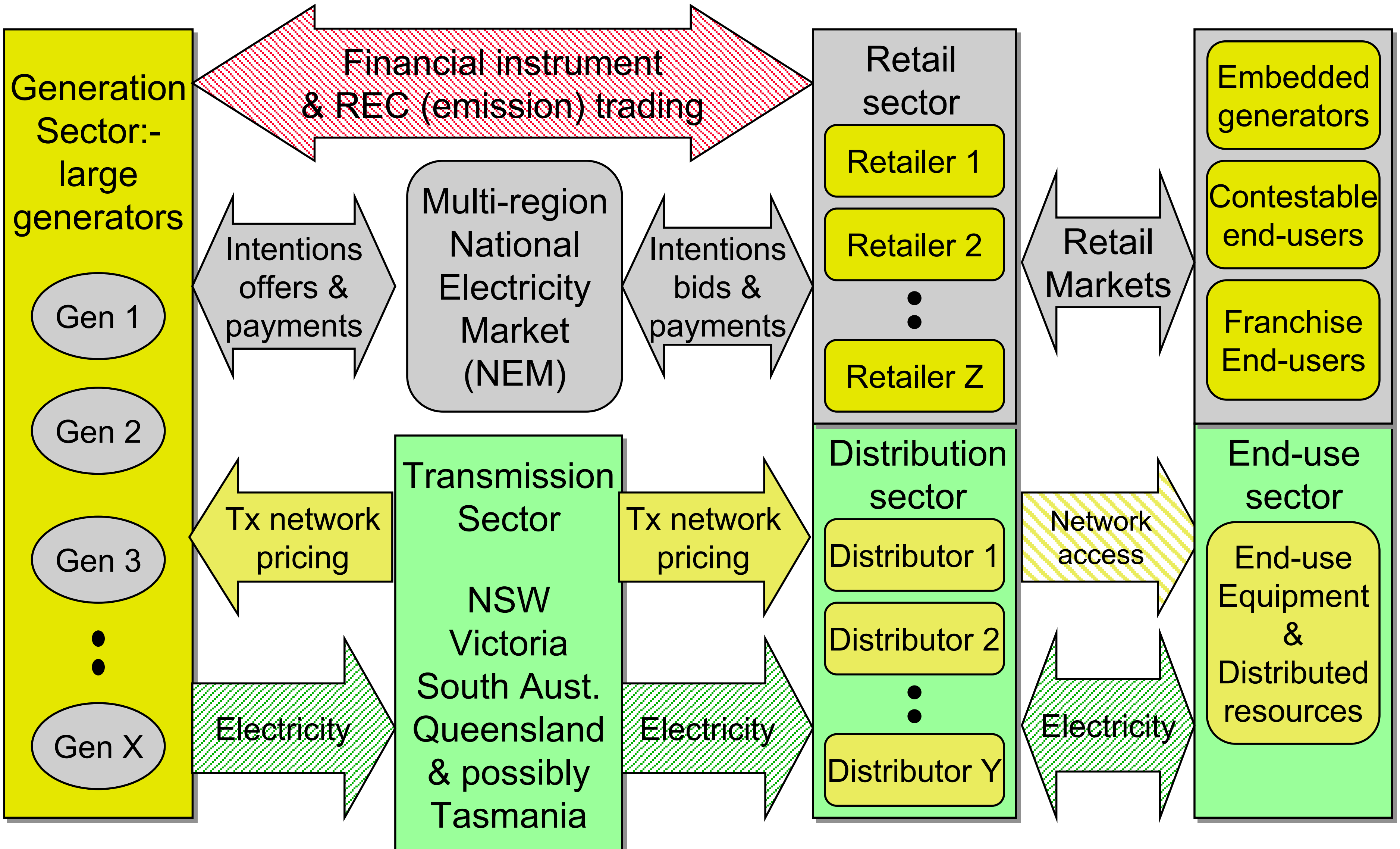
(Based on NEMMCO, 1997)



Key NEM features

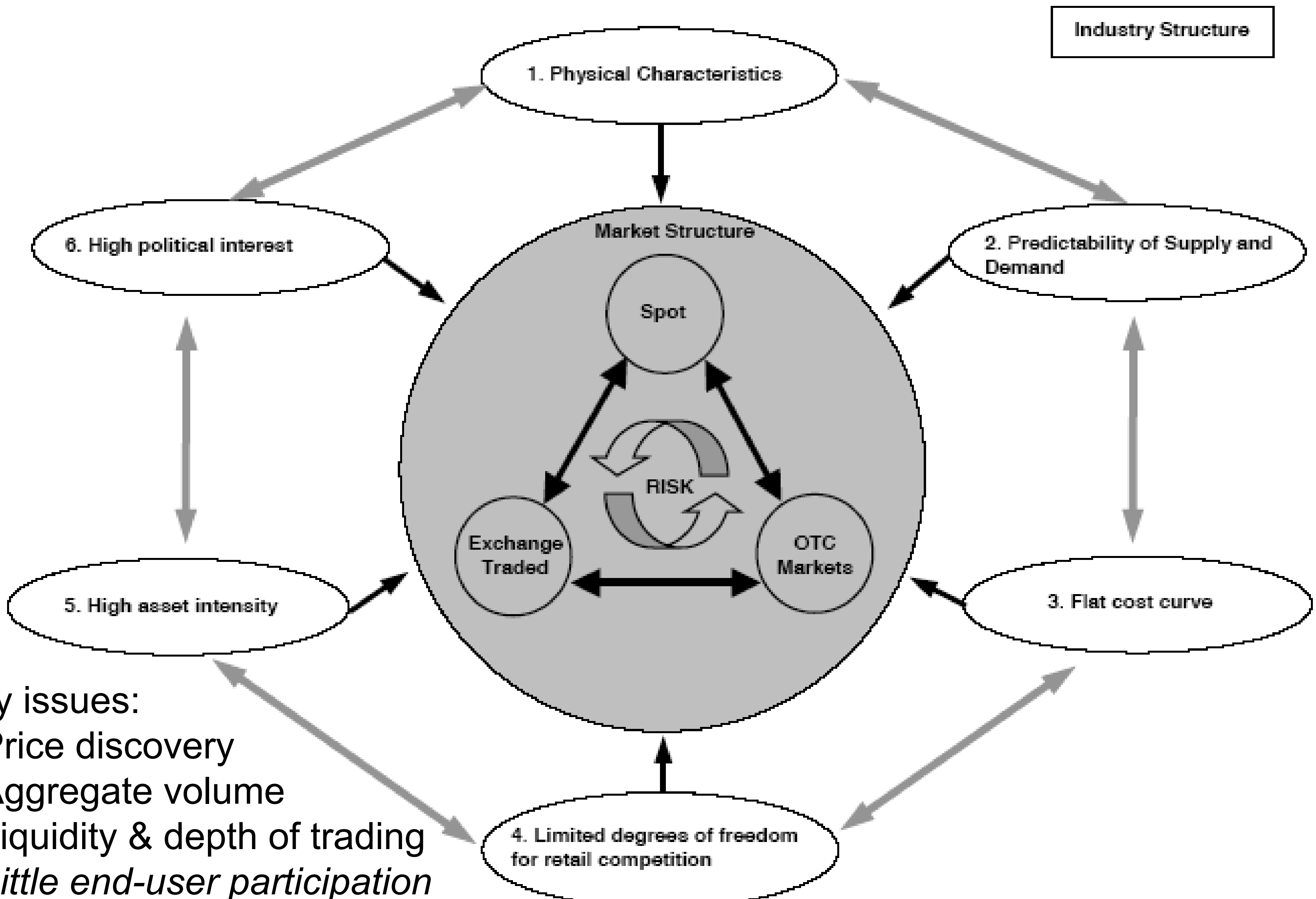
- NEM covers all participating states:
  - A multi-region pool with intra-regional loss factors
  - Ancillary services, spot market & projections
  - Auctions of inter-regional settlement residues
  - Operated by NEMMCO (owned by states)
- Compulsory participants in NEM:
  - All dispatchable generators & links > 30 MW
  - Network service providers & retailers
- Contestable consumers may buy from NEM

Example: industry structure in NEM States



Financial risk management in the NEM

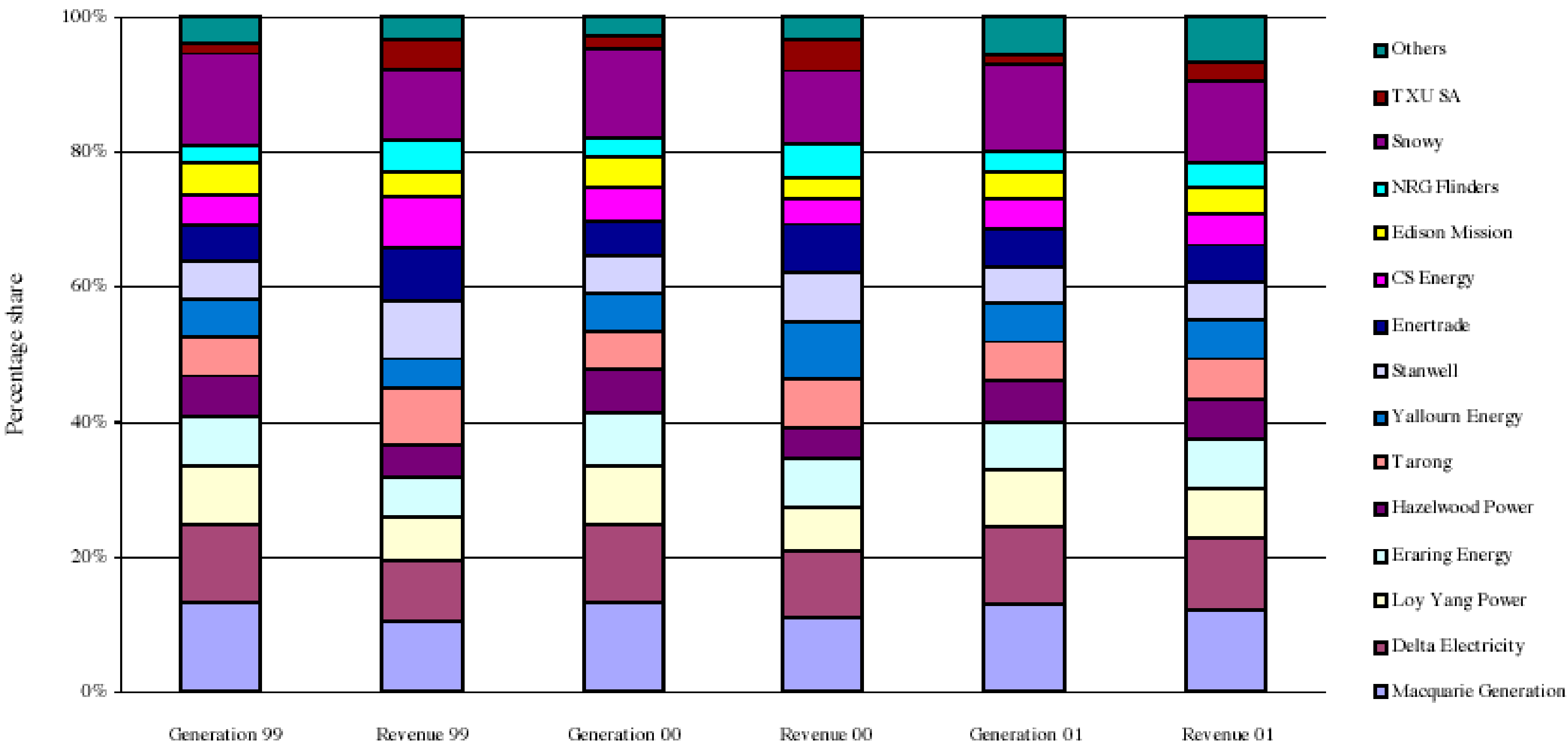
(Bach Consulting & SIRCA, Report for NEMMCO, June 2002)



Key issues:

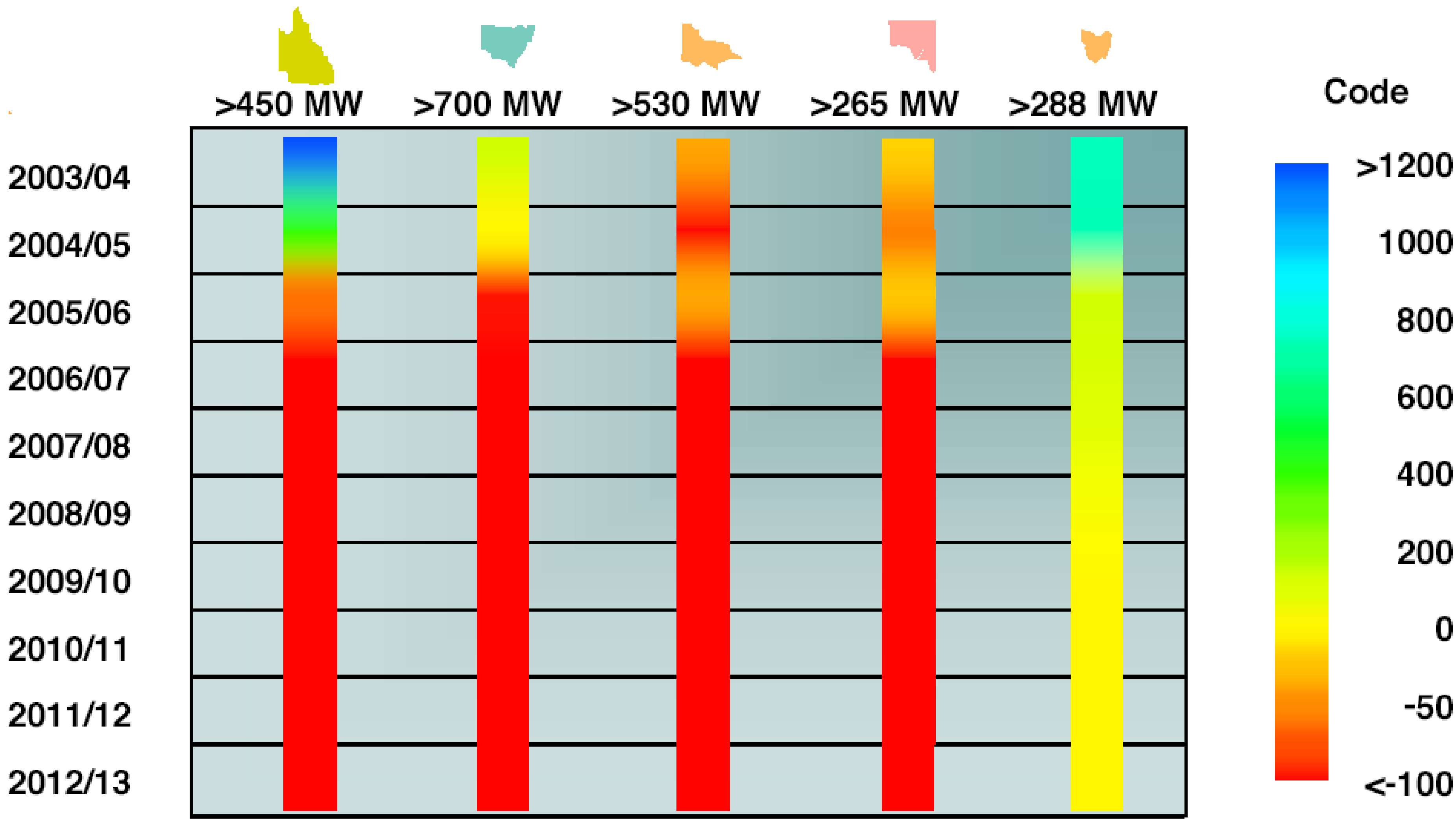
- Price discovery
- Aggregate volume
- Liquidity & depth of trading
- *Little end-user participation*

NEM: overall market shares by annual energy & spot market revenue (NECA, Performance of the NEM, June 02)

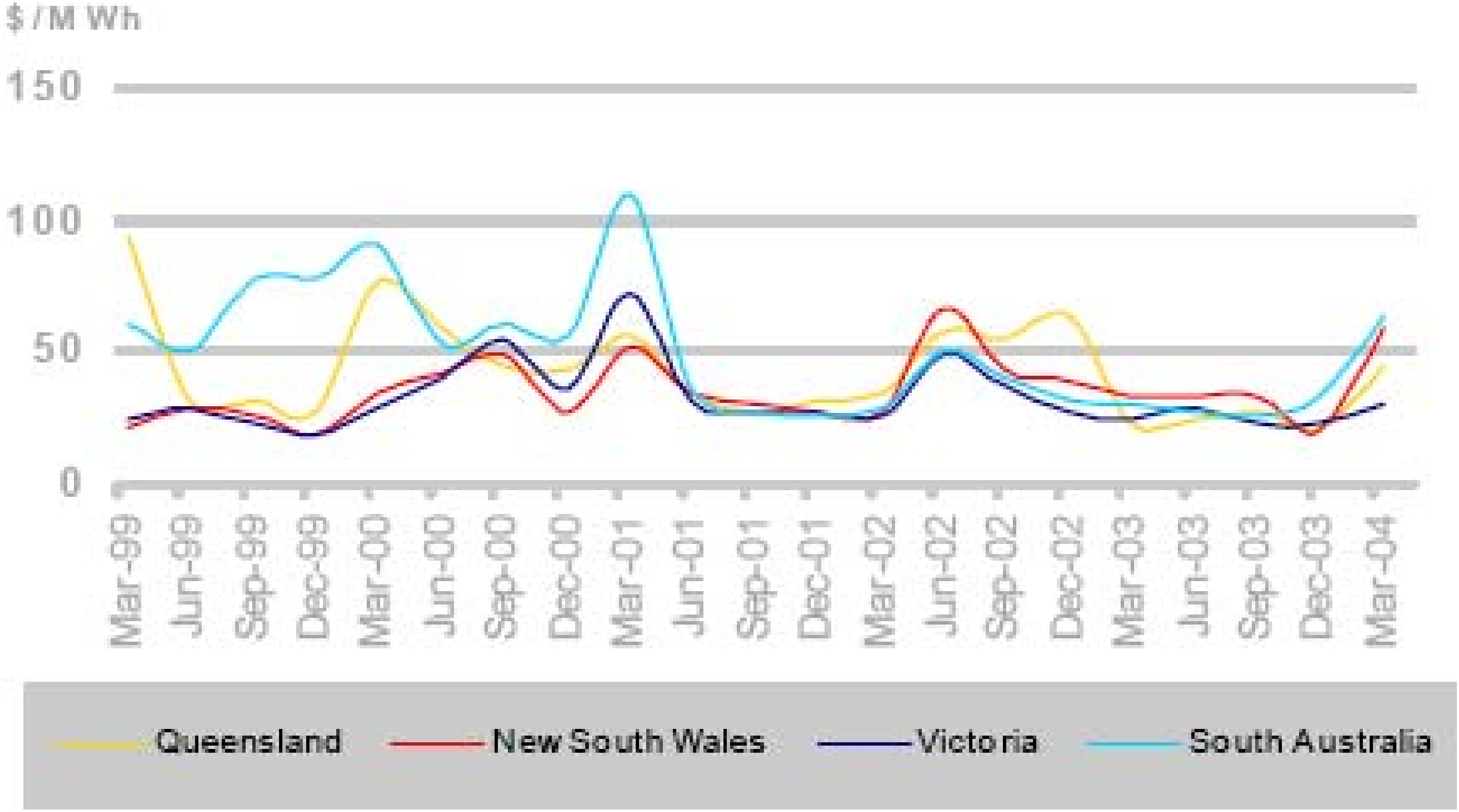


Forecast surplus reserves for NEM Jurisdictions

(Medium growth + extreme (10% POE) weather, NEMMCO SOO, July 03)

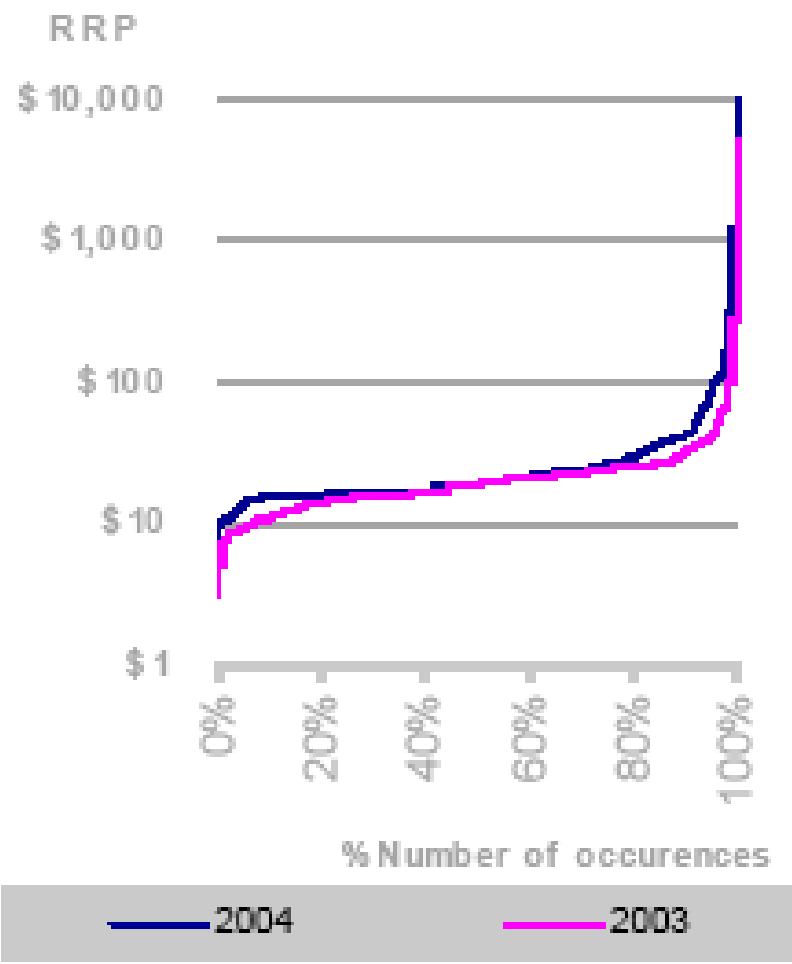


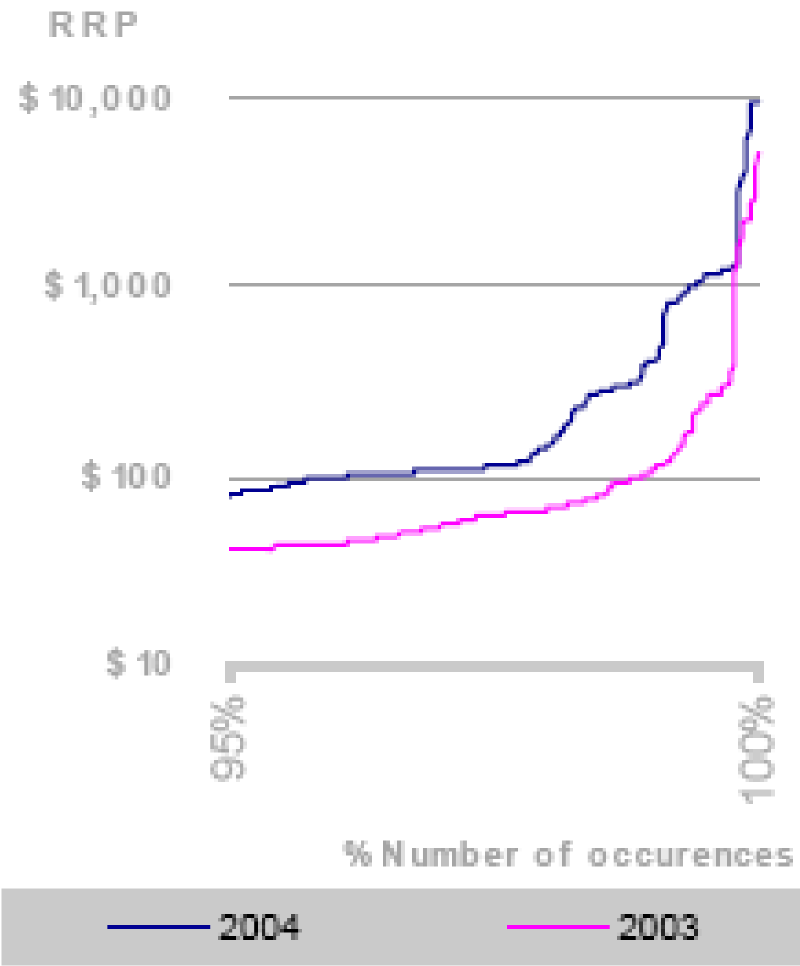
Smoothed NEM Regional Ref Prices (RRPs) since market inception (NECA, 04Q1 Stats, 2004)



Spot price duration curve, NSW region Jan-March 2003 & 2004

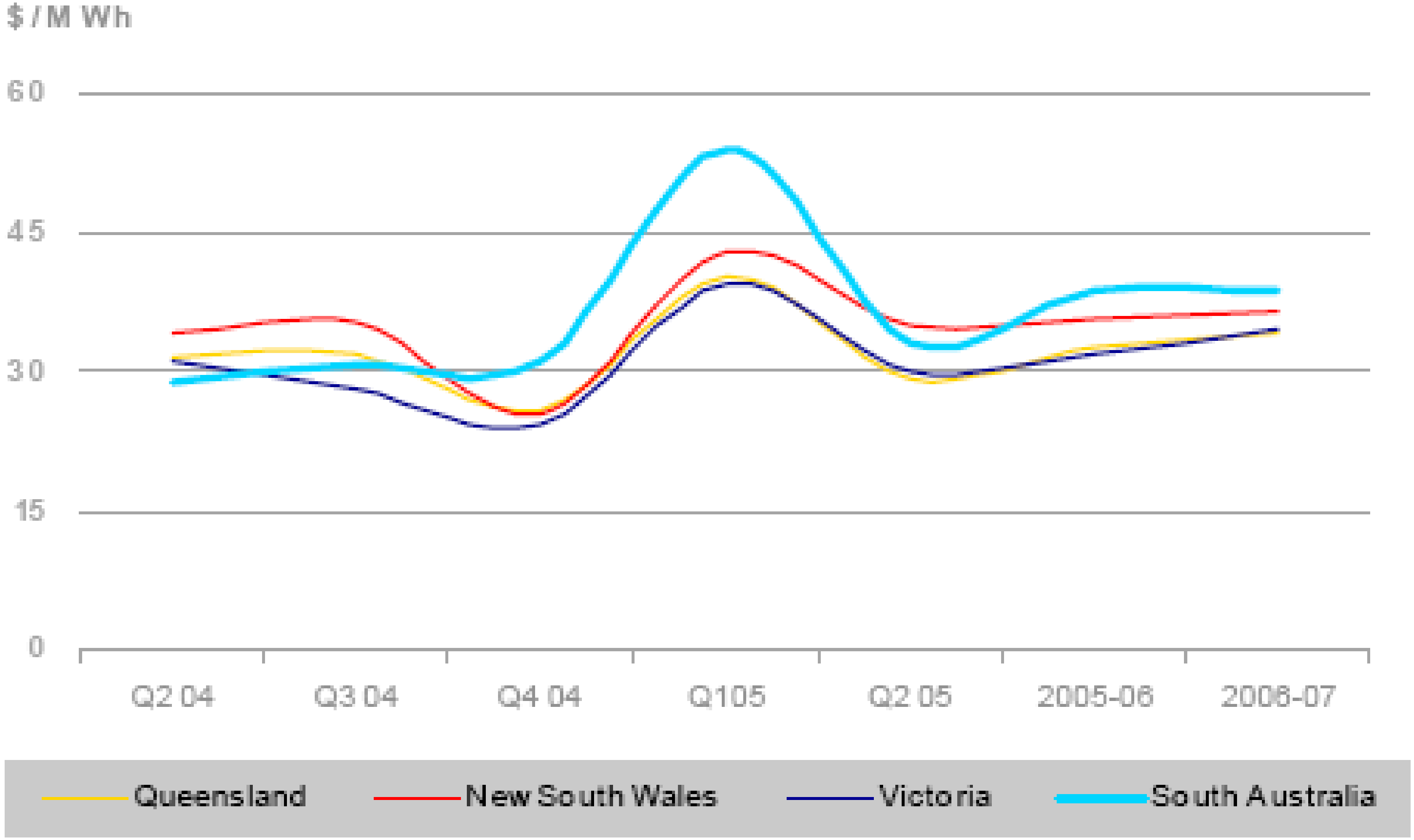
(NECA, 04Q1 Stats, 2004)





Annual average RRP flat contract prices

(NECA, 04Q1 Stats, 2004)



Australia: COAG restructuring process

- 1990-2:
  - COAG agreed to consider reform (1990)
  - Industry Commission report (1991):
    - Poor investment decisions:- excess capacity
    - Cross subsidies in electricity pricing; excess staffing
    - Recommended a competitive ‘national grid’
  - National Grid Management Council formed:
    - Implement COAG policy on electricity restructuring
  - National Grid Protocol, First Issue (Dec 1992)
- 1993
  - NGMC ‘Paper trial’ trading experiments:
    - Interconnected regional pools:
      - Including network losses & interconnector constraints
    - Assessed centralised commitment, capacity contracts, CFDs

Australia: COAG restructuring process

- 1994-98:
  - Competition policy & amendments to TPA
  - Development of National Electricity Code
  - Separate NSW & Victorian electricity markets
  - NEM trading experiments & trader education
  - NEM1 commenced May 1997 (joint NSW & Vic)
  - Queensland market commenced Nov 97
  - NEM commenced 13 December 1998
- 2002:
  - COAG energy market review recommends further enhancements

Key features of '95 NEM simulation model

- Implemented key features of the NEM rules:
  - NEM bid and offer structure & network loss functions
  - Multi-region spot market with embedded network model
  - 1 & 2 day ahead STFMs with embedded network model
  - Short term PASA with broadcast warnings of constraints
- Provided a sufficiently realistic trading environment:
  - Key participant characteristics
  - Uncertainty in availability, weather
  - Reporting on trading activity & simple decision support
- Operated faster than real time:
  - 2 weeks of trading per day with 3 hour spot market period
- Used for education as well as formal experiments

Technology types in ‘95 NEM simulation model

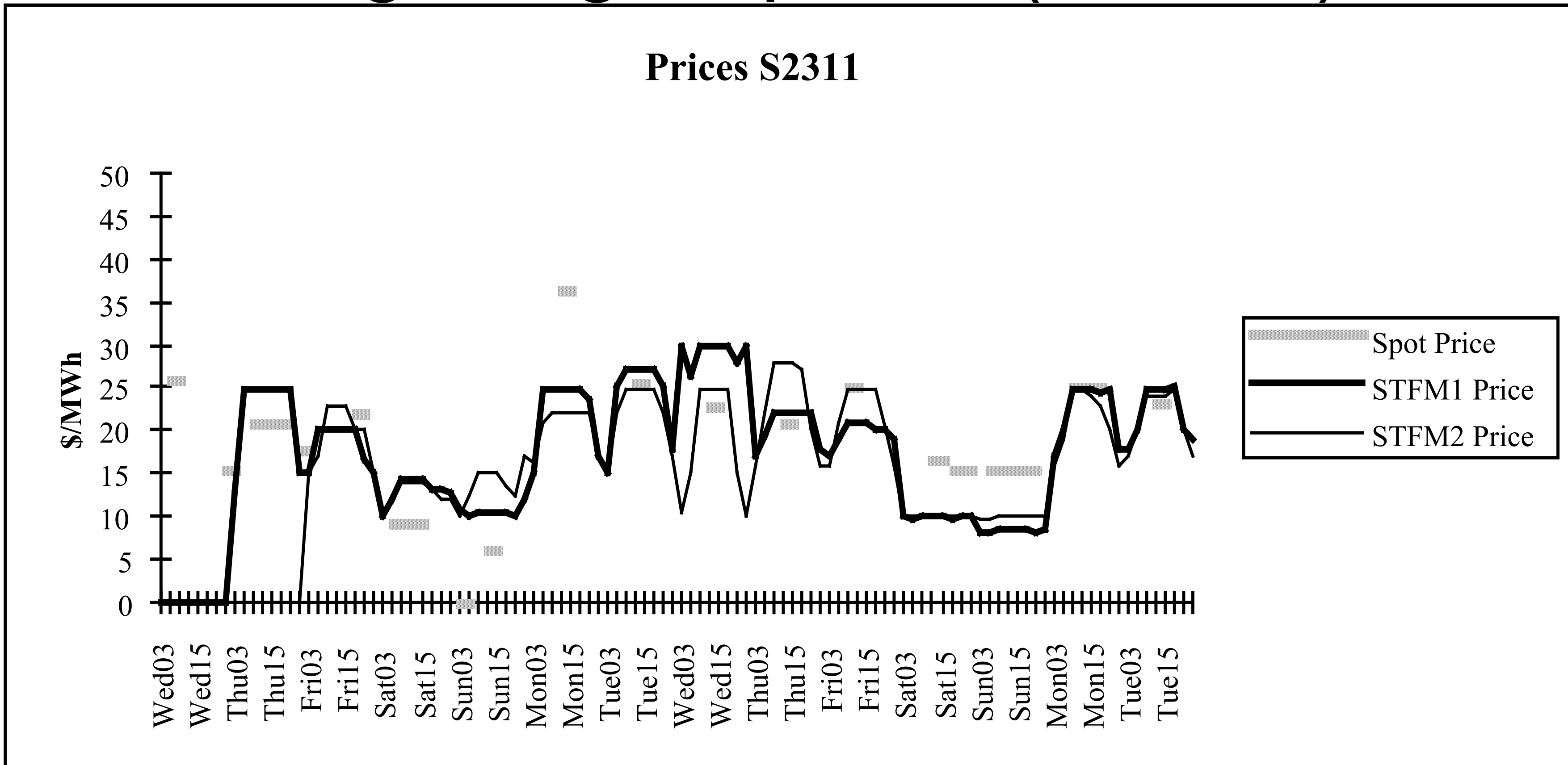
- Thermal plant (subject to outages):
  - Fast start generators (instantaneous start)
  - Slow start generators:- all other thermal plant
    - Max & min load; hot, warm & cold start-up times
    - Start-up costs; fixed & variable operating costs
    - Mean time to fail, mean time to repair, cost of repair
- Hydro generator:
  - Headpond capacity & initial level, inflow rate, pumping
- Demand side participants (uncertain temperature):
  - Retail tariff load (daily & weekly patterns, temp. coef’t)
  - Demand management (pseudo-generator with op. cost)
- Reserve participant (small thermal plant)

Key data items: 5 regions, 8 generators, 7 consumers

A	**Therm A1**, LF 0.97 8x350 SS (10-20) 2x50 FS (30, 150)	**Therm A2**, LF 0.98 10x350 SS (10-20) 1x50 FS (30)	**DemDM A1**, LF 1.0 5000 MW Pk 400 DM (25-500)	
B	**Therm B1**, LF 0.96 9x500 SS (11-20) 3x50 FS (30, 150)	**Therm B2**, LF 0.95 10x600 SS (11-20) 3x50 FS (30, 150)	**DemDM B1**, LF 1.0 4500 MW Pk 500 DM (25-500)	**DemDM B2**, LF 1.1 3600 MW Pk 500 DM (25-500)
C	**Hydro C1**, LF 0.99 3500 MW 25 GWh/d		**DemDM C1**, LF 1.0 1400 MW Pk 600 DM (30-60)	
D	**Therm D1**, LF 0.97 8x500 SS (5-10) 5x50 FS (30, 150)	**Therm D2**, LF 0.98 5x500 SS (5-10) 5x50 FS (30, 150)	**DemDM D1**, LF 1.0 2400 MW Pk 250 DM (25-500)	**DemDM D2**, LF 1.0 4000 MW Pk 500 DM (25-500)
E	**Therm E1**, LF 0.97 9x200 SS (11-20) 4x50 FS (30)		**DemDM E1**, LF 1.0 2000 MW Pk 300 DM (25-500)	

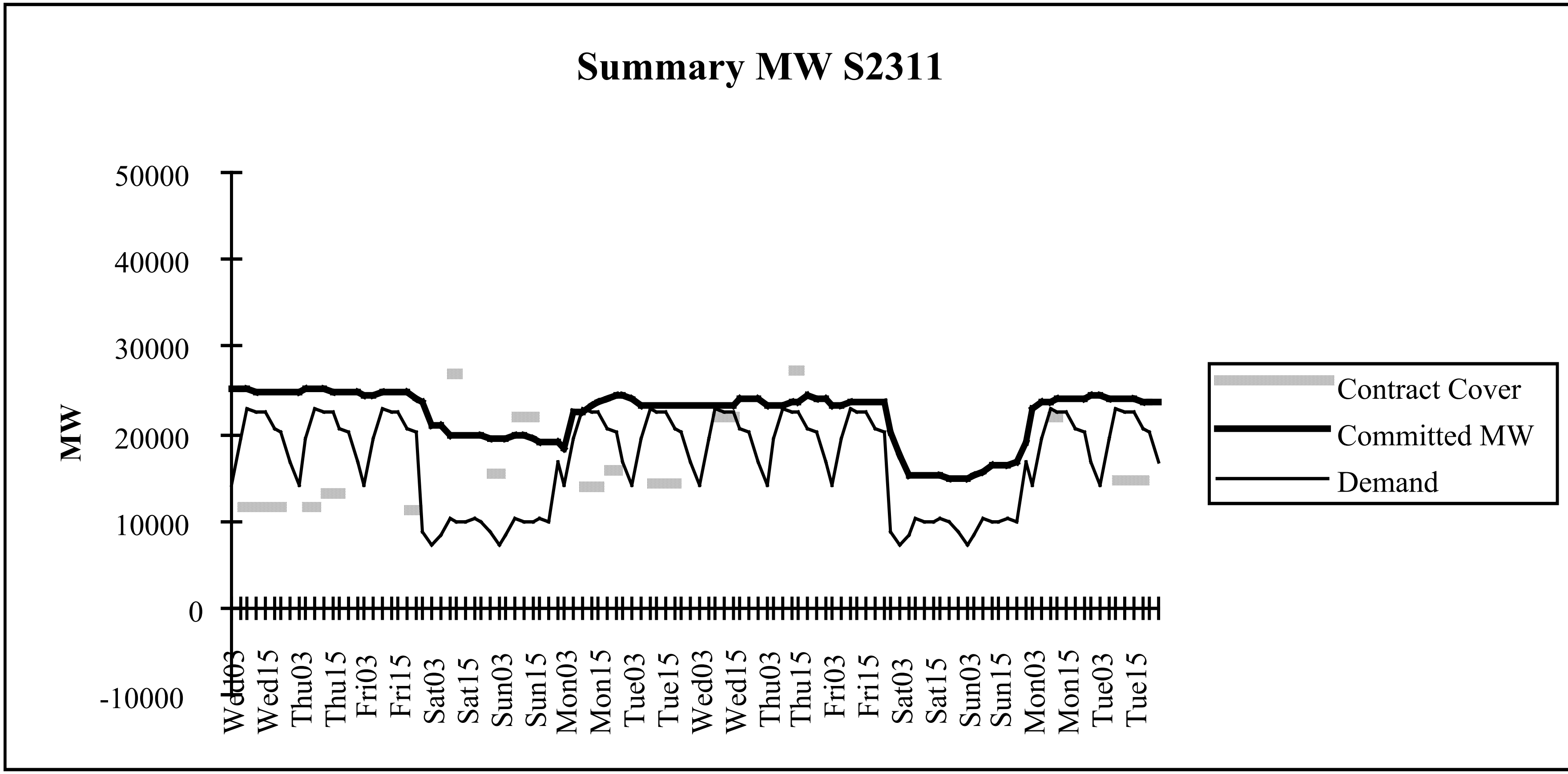
Note: SS = slow start; FS = fast start; DM = demand management; LF = loss factor
8x350 SS (10-20) = 8x350 MW SS, with inc. op. costs of 10 to 20 $/MWh

Simulation results: single region prices ($/MWh)



Occasional zero spot prices. After the initialisation phase, the STFM prices provide reasonable predictions of average spot prices

Simulation results: single region quantities



Contract cover is a compromise between generator interests and demand side interests. Some contract speculation evident on the final Monday. Generators de-committing at weekends but not overnight.

Outcomes from simulation experiments

- A sophisticated simulation package can adequately represent NEM market trading conditions:
  - Operational focus; two weeks of simulated trading per day
  - Suitable for exploring operation of market rules & for training
- Experiments demonstrate that generators can exercise market power if insufficient competition:
  - Only under outage conditions for single region experiments:
    - Largest generation participant then had ‘must run’ plant
  - Most of the time in each region for five region experiments:
    - Single or larger generation participant in each region had ‘must run’ plant because of tie-line flow constraints
  - Forward contract cover can protect a buyer from the effects of spot market power unless hedge contract prices also high

COAG Response to 2002 Energy Market Review

(MCE Communique, 1/8/03)

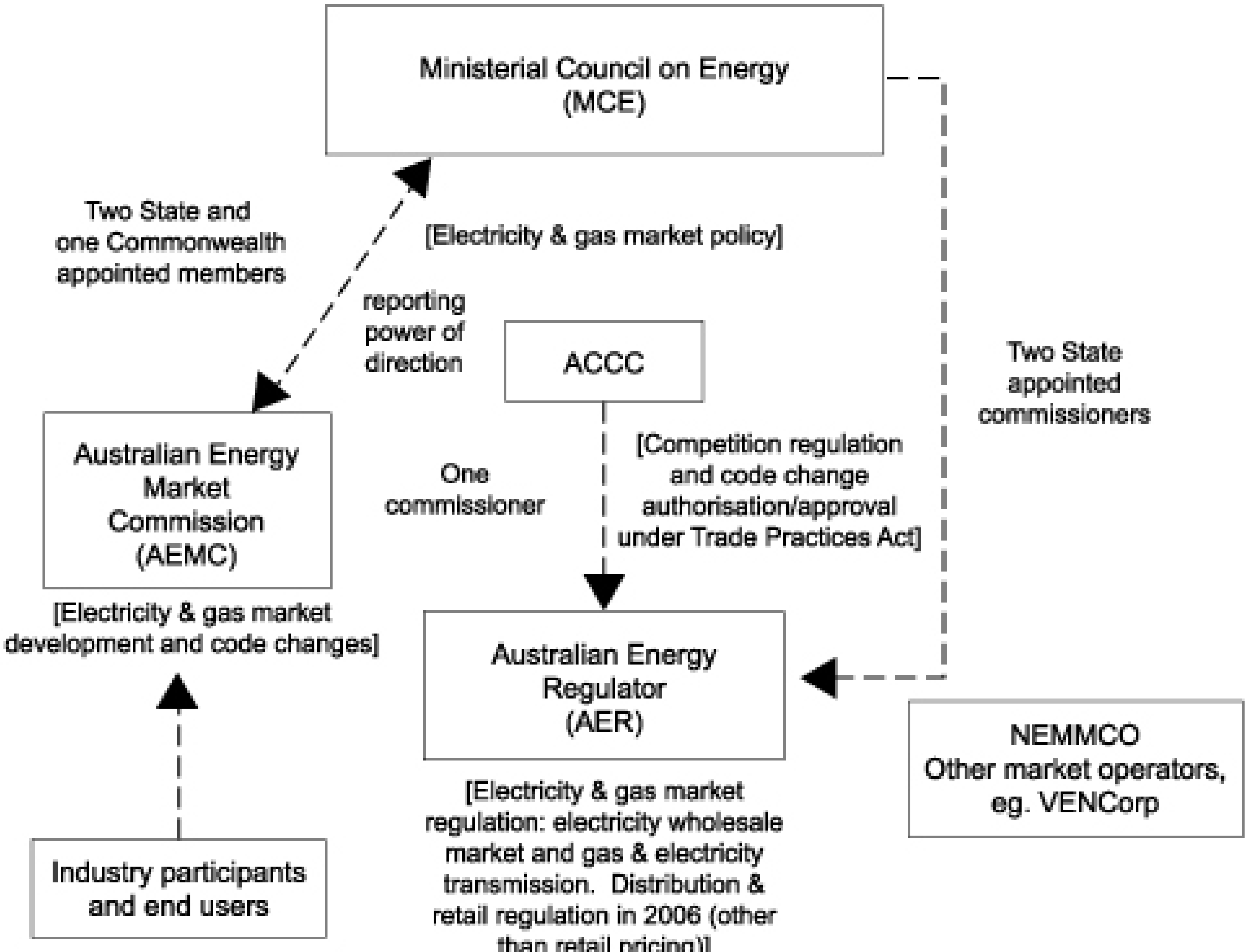
- Recommended the establishment of:
  - A single energy market governance body
  - A new national legislative framework
  - Two new statutory commissions from 1/7/04:

    (electricity (& later gas) wholesale market & transmission)

    - Australian Energy Market Commission (AEMC):
      - Rule making & market development, replacing NECA
    - Australian Energy Regulator (AER)
      - Wholesale market & transmission regulation & possibly distribution & retail; partly taking over ACCC role
- Undertake comprehensive transmission review & consider national planning function

Energy market governance & institutions

(Allens Arthur Robinson, December 2003)

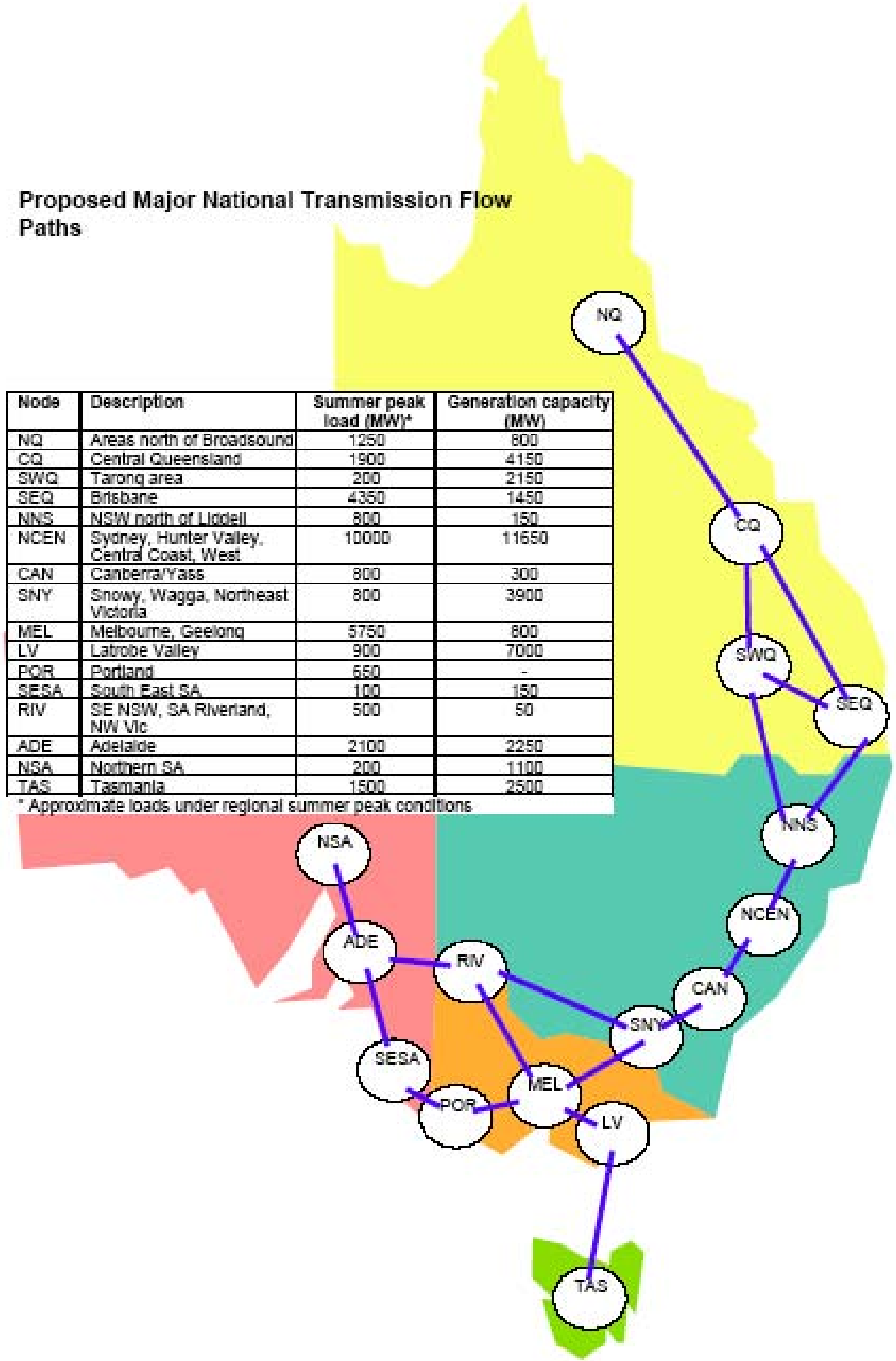


Electricity transmission: ANTS

- An integrated overview:
  - Future constraints on major transmission paths
  - Information on augmentation options
  - Incorporated into SOO & complimentary to projection of supply-demand balance

  (www.mce.gov.au)

Proposed Major National Transmission Flow Paths



Node	Description	Summer peak load (MW)*	Generation capacity (MW)
NQ	Areas north of Broadsound	1250	800
CQ	Central Queensland	1900	4150
SWQ	Tarong area	200	2150
SEQ	Brisbane	4350	1450
NNS	NSW north of Liddell	800	150
NCEN	Sydney, Hunter Valley, Central Coast, West	10000	11650
CAN	Canberra/Yass	800	300
SNY	Snowy, Wagga, Northeast Victoria	800	3900
MEL	Melbourne, Geelong	5750	800
LV	Latrobe Valley	900	7000
POR	Portland	650	-
SESA	South East SA	100	150
RIV	SE NSW, SA Riverland, NW Vic	500	50
ADE	Adelaide	2100	2250
NSA	Northern SA	200	1100
TAS	Tasmania	1500	2500

* Approximate loads under regional summer peak conditions

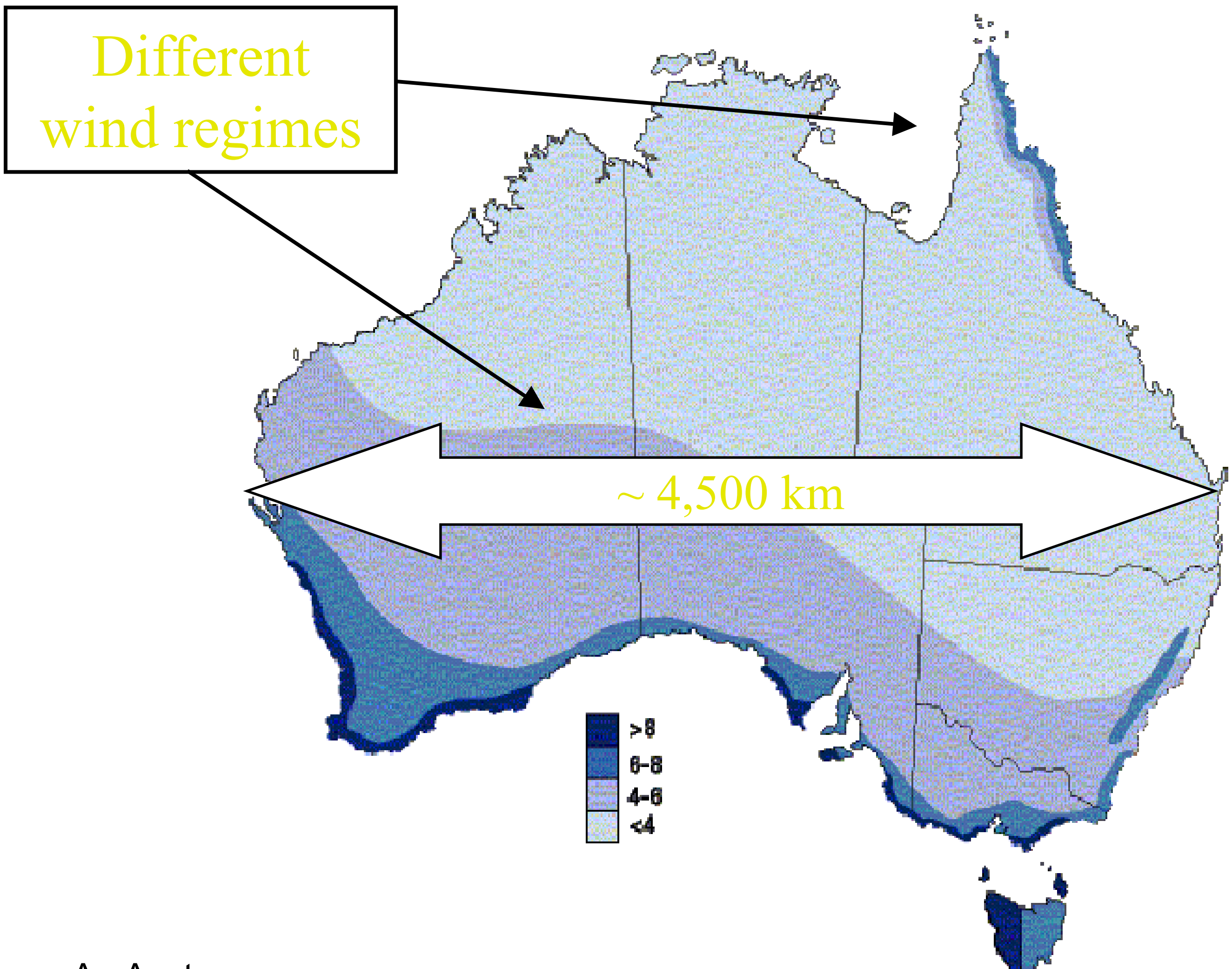
Electricity transmission - boundary review:

"A new process to be developed for assessing wholesale market regional boundaries, while maintaining jurisdictional boundaries for retail customer pricing"

- Challenge in meeting this objective:
  - Must manage power system security as well as provide commercial signals with risk management instruments
  - Security constraints easier to apply between rather than within market regions
  - Location risk is commercialised across boundaries between regions
  - Different wholesale & retail market boundaries would make it difficult to manage risk commercially

Australian wind resource

(Simple estimates of background wind – AGO)



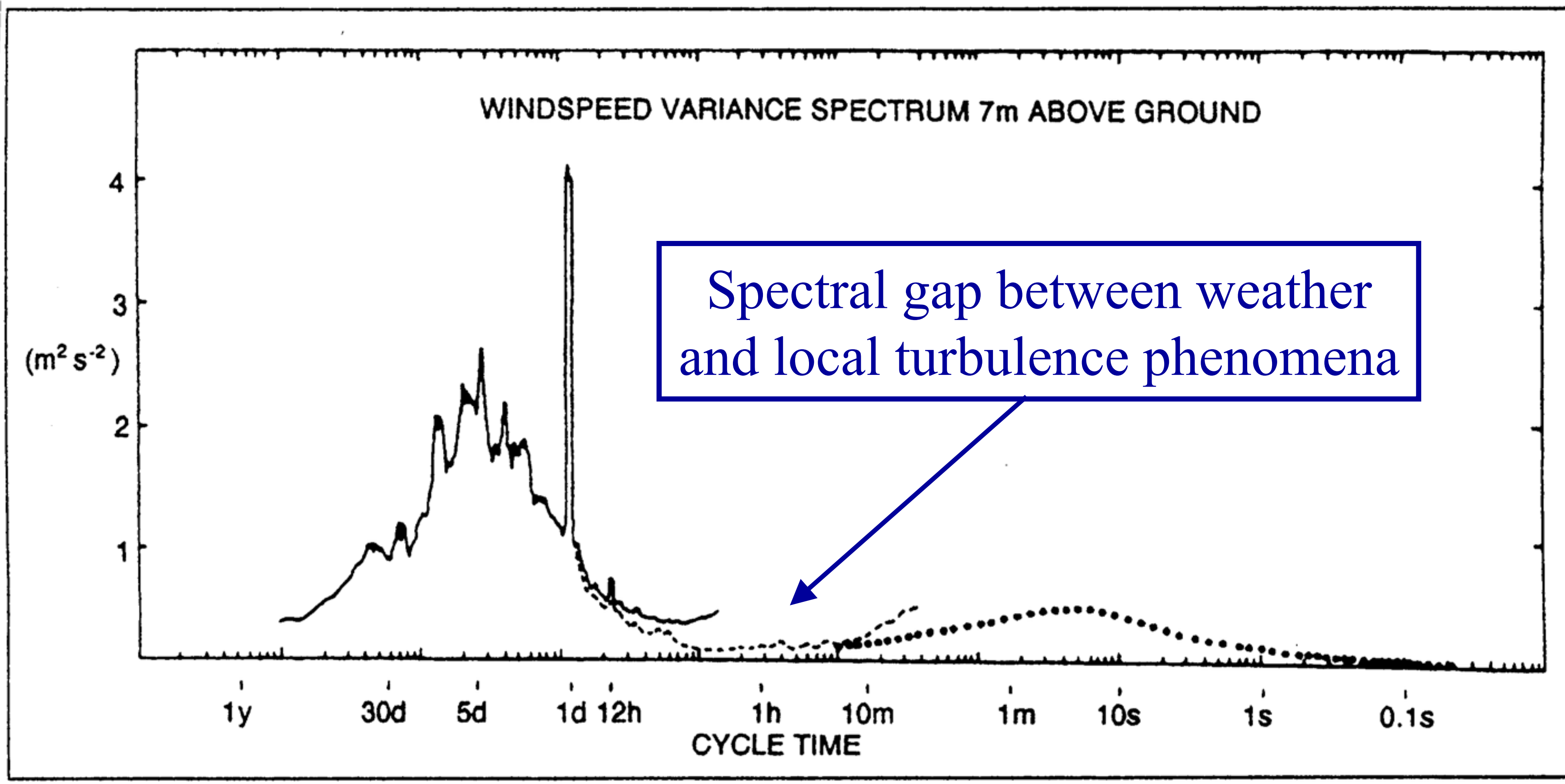
Intermittent generation in the National Electricity Market

- National Electricity Code (NEC) definition of intermittent generation:
  - "A generating unit whose output is not readily predictable, including, without limitation, solar generators, wave turbine generators, wind turbine generators and hydro generators without any material storage capability"
- Issues identified by NEMMCO:
  - Forecasting; Frequency Control Ancillary Services (FCAS); voltage control; management of network flows

NEMMCO concerns about wind energy (NEMMCO, 2003)

- Frequency control in normal operation:
  - Frequency regulating service costs ~5 $/MWH
- Security control - largest single contingency
  - Will wind farms ride-through disturbances?
- Interconnection flow fluctuations:
  - Exceeding flow limit may cause high spot price
- Forecast errors due to wind resource uncertainty:
  - Five minute dispatch forecast (spot price)
  - Pre-dispatch & longer term (PASA & SOO) forecasts

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



(Sorensen, 2001, Fig 2.110, p194)

Forecasting the output of wind farms

key issue: rapid changes in output of groups 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:
  - Extrapolative model best predictor of *expected* output (but not rapid changes)
- > 3 hours - NWP model:
  - Best predictor of rapid changes of grouped output?

Conclusions

- NEM is a workable multi-region market for a large, weak network:
  - Good treatment of temporal risks
  - Hub & spoke approximation to LMP
- The NEM governance arrangements reflect multiple jurisdictions and implement separation of powers principles
- The NEM is not biased against wind energy
- Improvements still needed, particularly in end-user participation & location risks