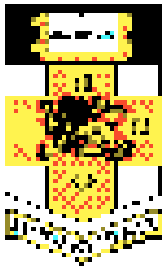

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

THE AUSTRALIAN CRC FOR RENEWABLE ENERGY LTD

Fundamentals of Electricity Industry Restructuring

National Electricity Market Design and Performance

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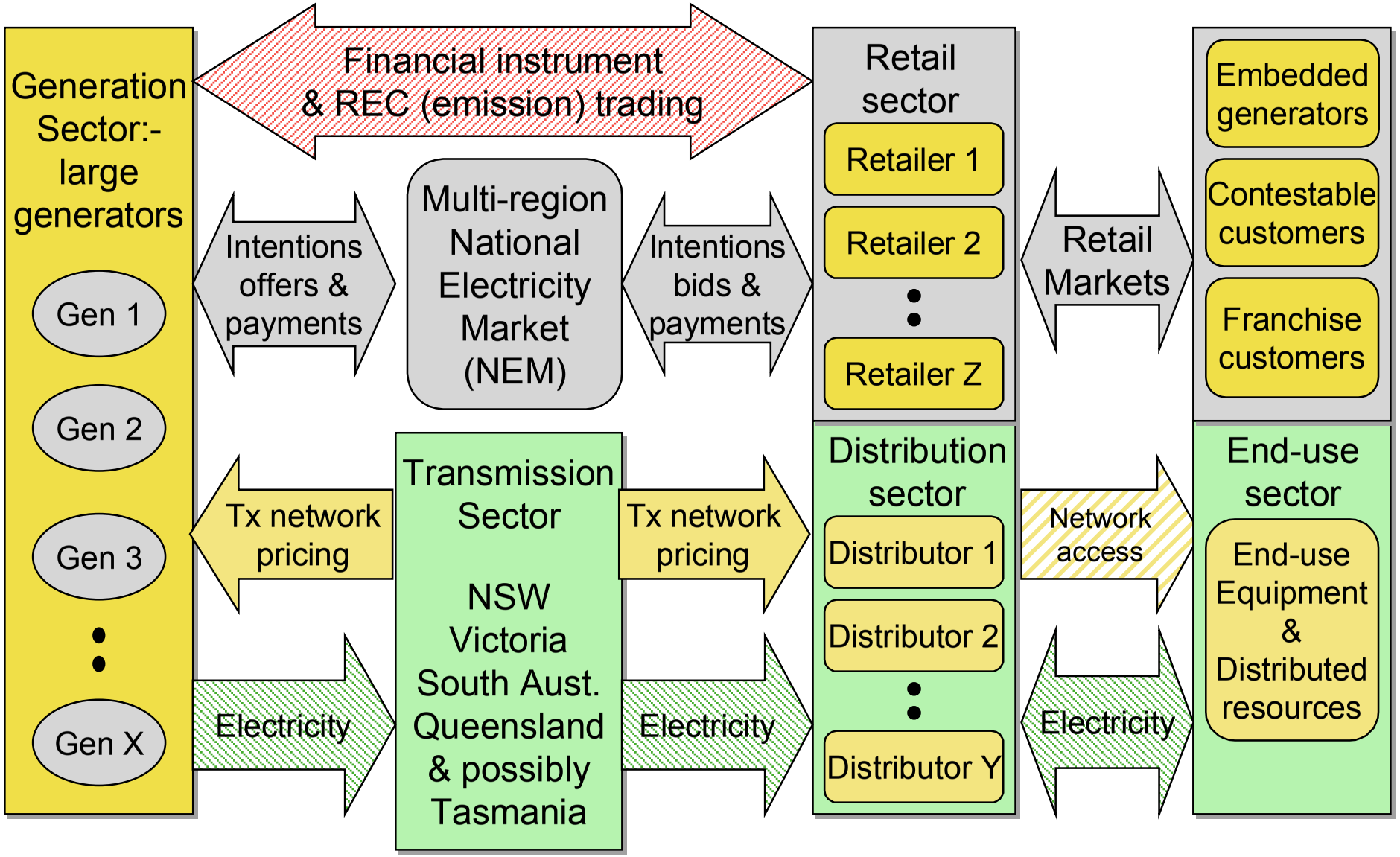
Electricity industry structure in SE Australia



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 generators & dispatchable links > 30 MW
  - Network service providers & retailers
- Contestable consumers may buy from NEM

Region boundaries & inter-connectors

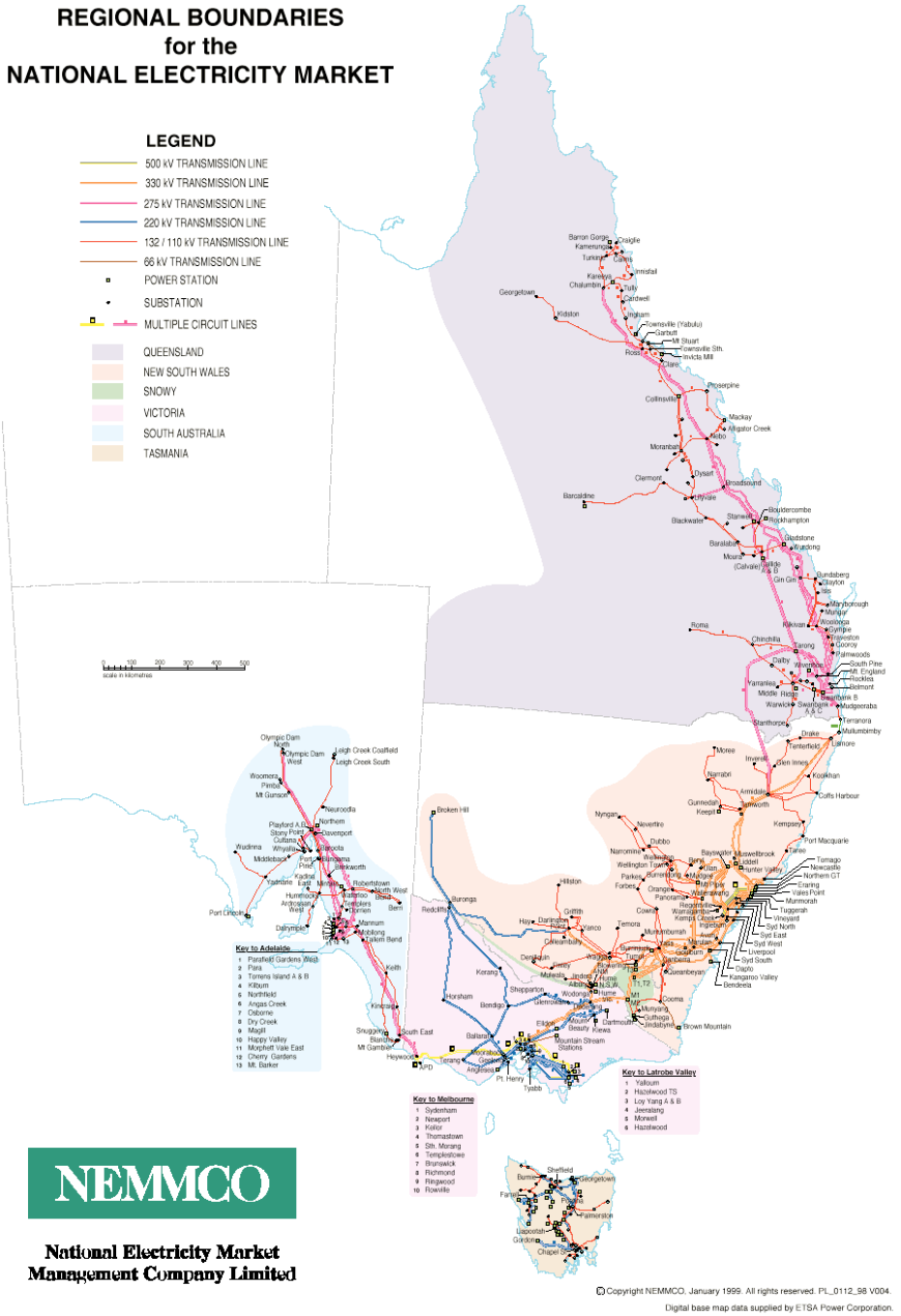
- Regions boundaries selected so that:
  - Transmission constraints are rare within a region
  - Frequently-occurring constraints are placed on region boundaries
- Region boundaries to be reset as required:
  - Whenever a constraint occurs > 50 hours/year
- Unregulated inter-connectors are allowed:
  - If dispatchable so that it can bid like a generator:
    - 'Directlink' the first (operating since July 200):
      - 180 MW DC link between NSW & Queensland regions

States participating in the National Electricity Market (NEM)

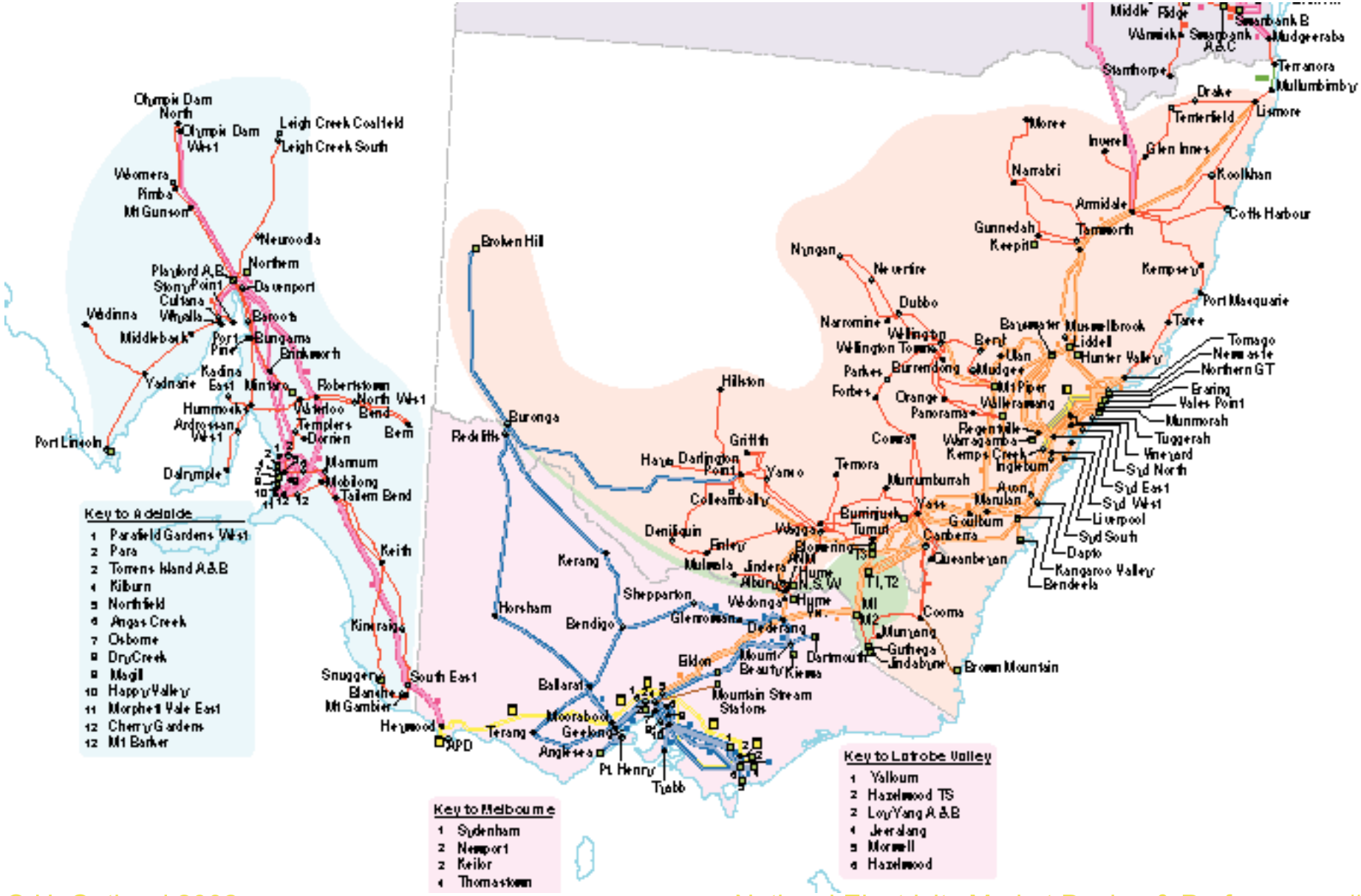
- Queensland
- New South Wales & ACT
- Victoria
- South Australia
- Tasmania (on connection to the mainland)

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

Queensland was expected to have 3 NEM regions, but transmission augmentation is removing the associated flow constraints

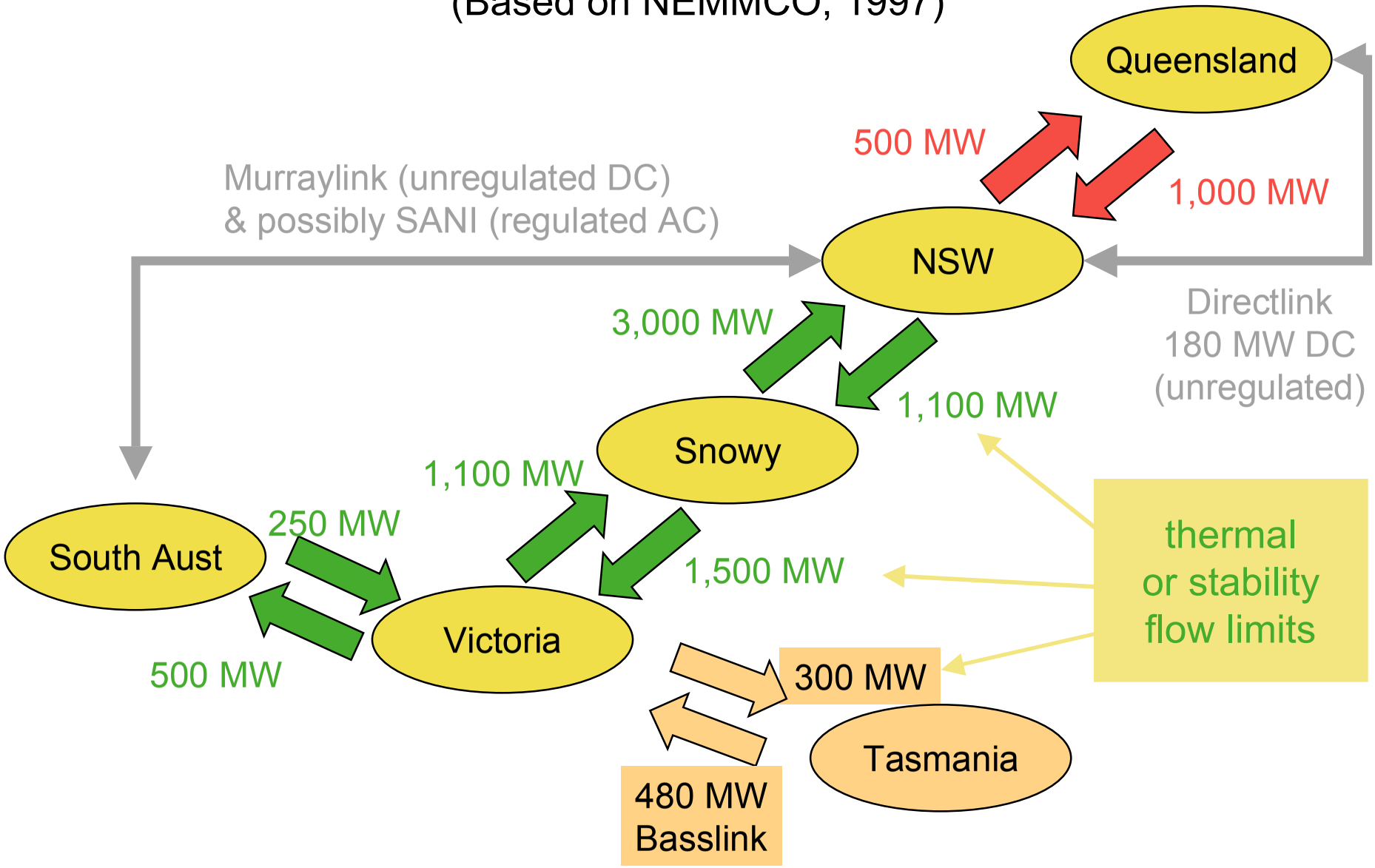


NSW, Snowy, Victorian & SA regions of NEM:- transmission & sub-transmission (NEMMCO, 1999)



NEM Model

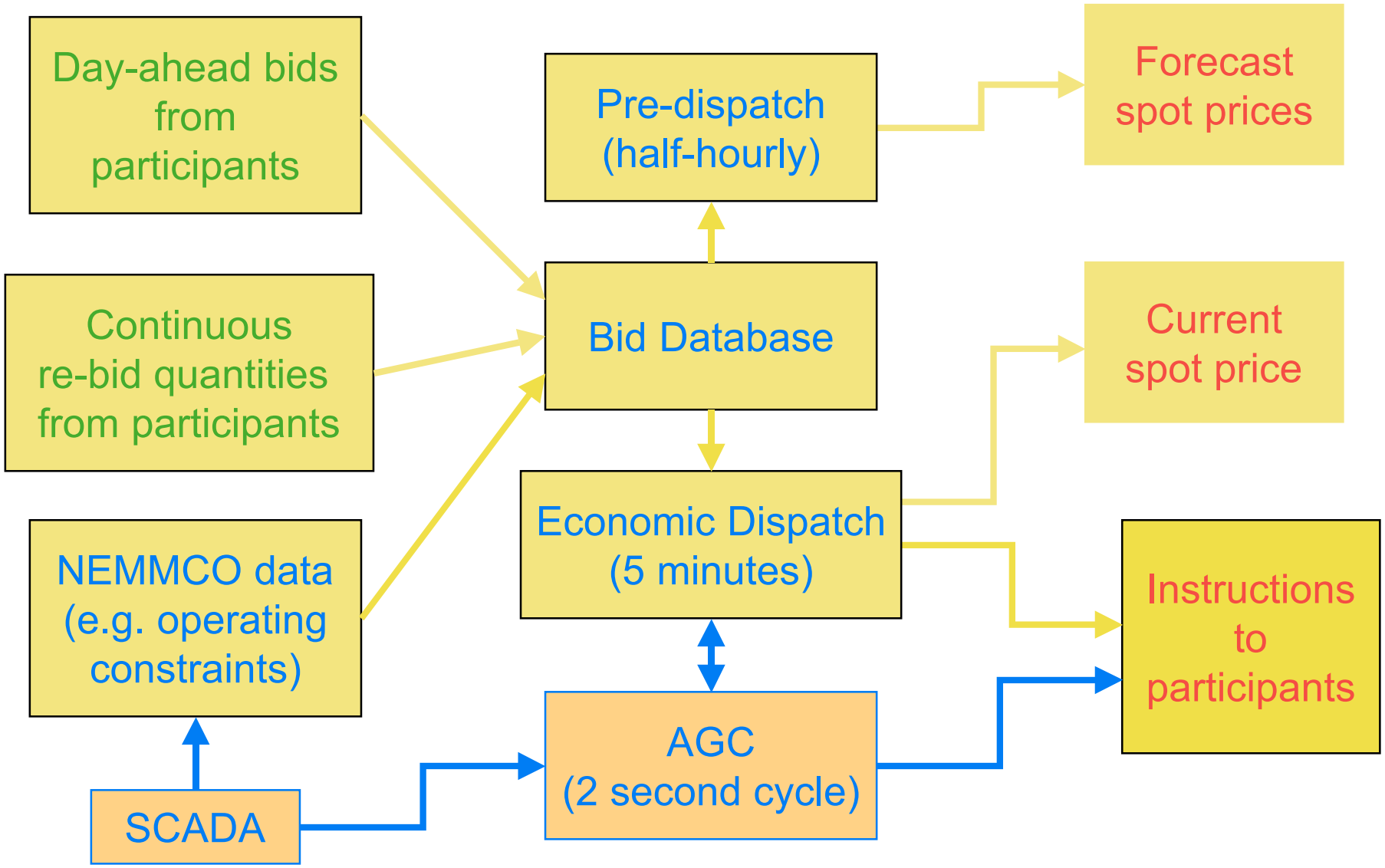
(Based on NEMMCO, 1997)



Spot market offers & bids

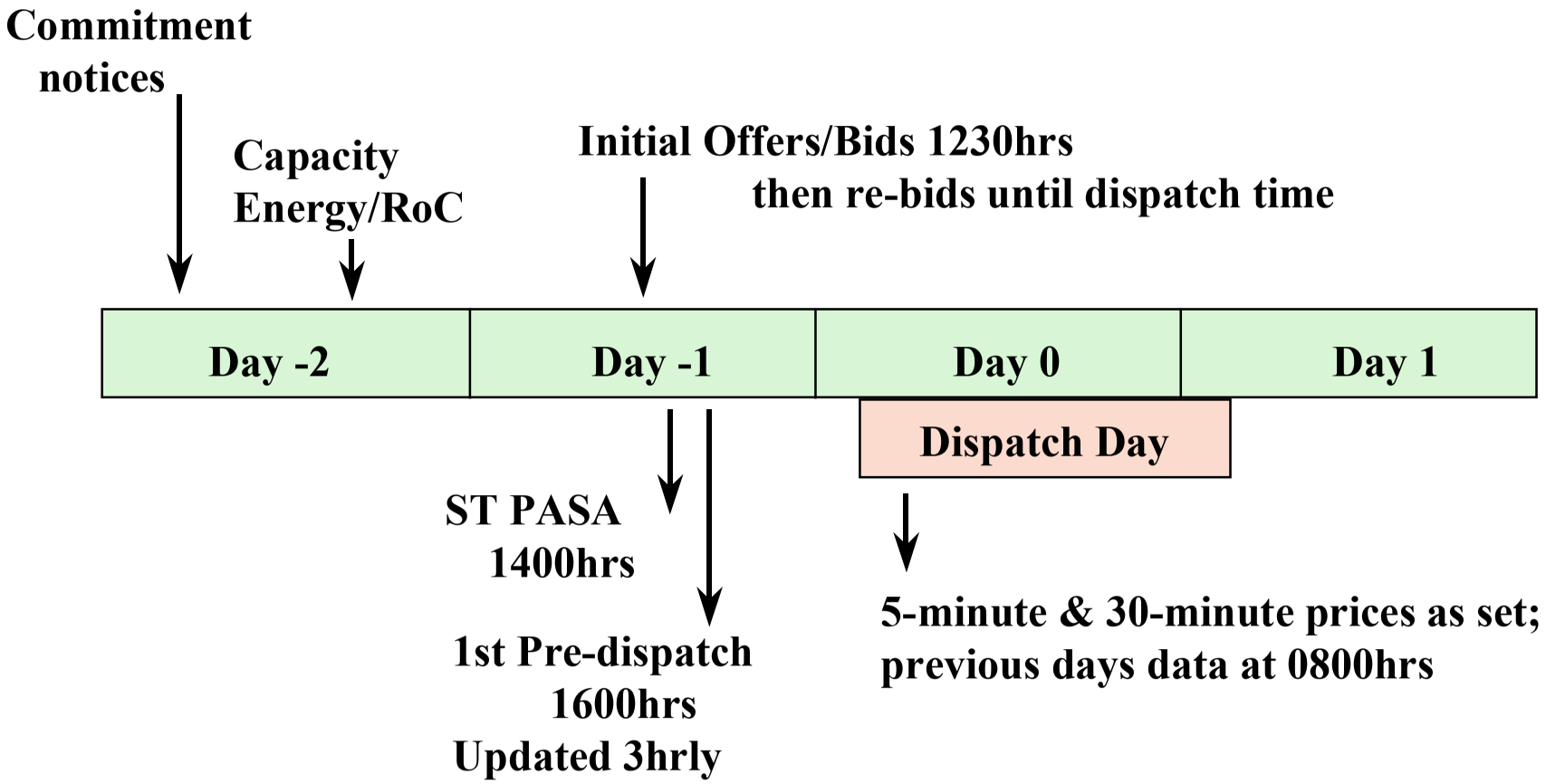
- Generators, retailers & consumers:
  - Price-quantity curve (sell/buy) for each half hour:
    - ≤ 10 daily prices, quantities changeable until dispatch
  - Demand forecasts ‘bid in’ at VOLL
- Dispatchable links between regions:
  - Flow offer curve based on price difference
- Bids & offers ranked to give dispatch stack:
  - Considering loss factors & inter-tie constraints
  - 5 minute prices set by economic dispatch:
    - Half-hourly averages are calculated in ‘real time’

NEM Pre-dispatch, Dispatch & AGC



Bidding & dispatch

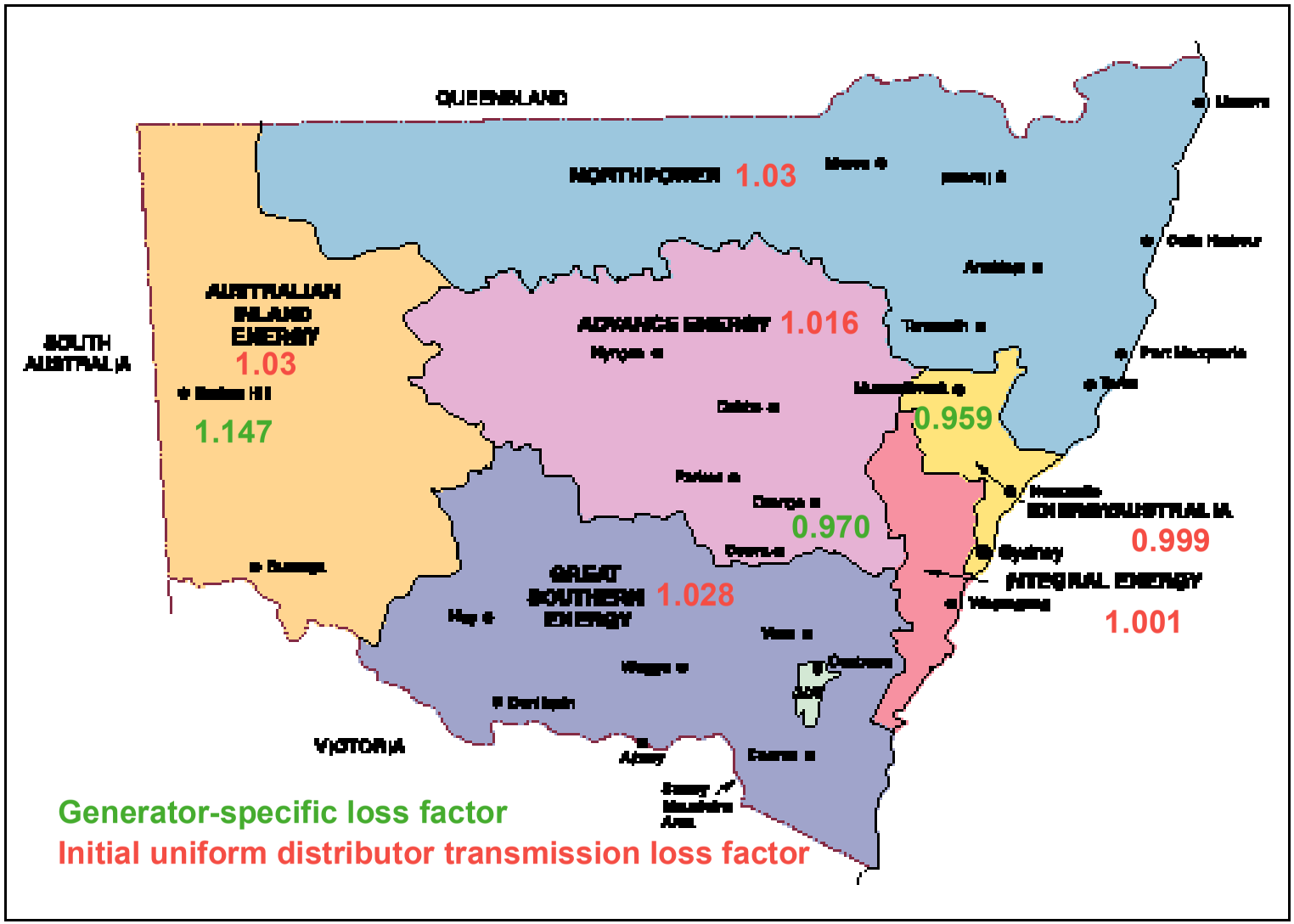
(source: NEMMCO)



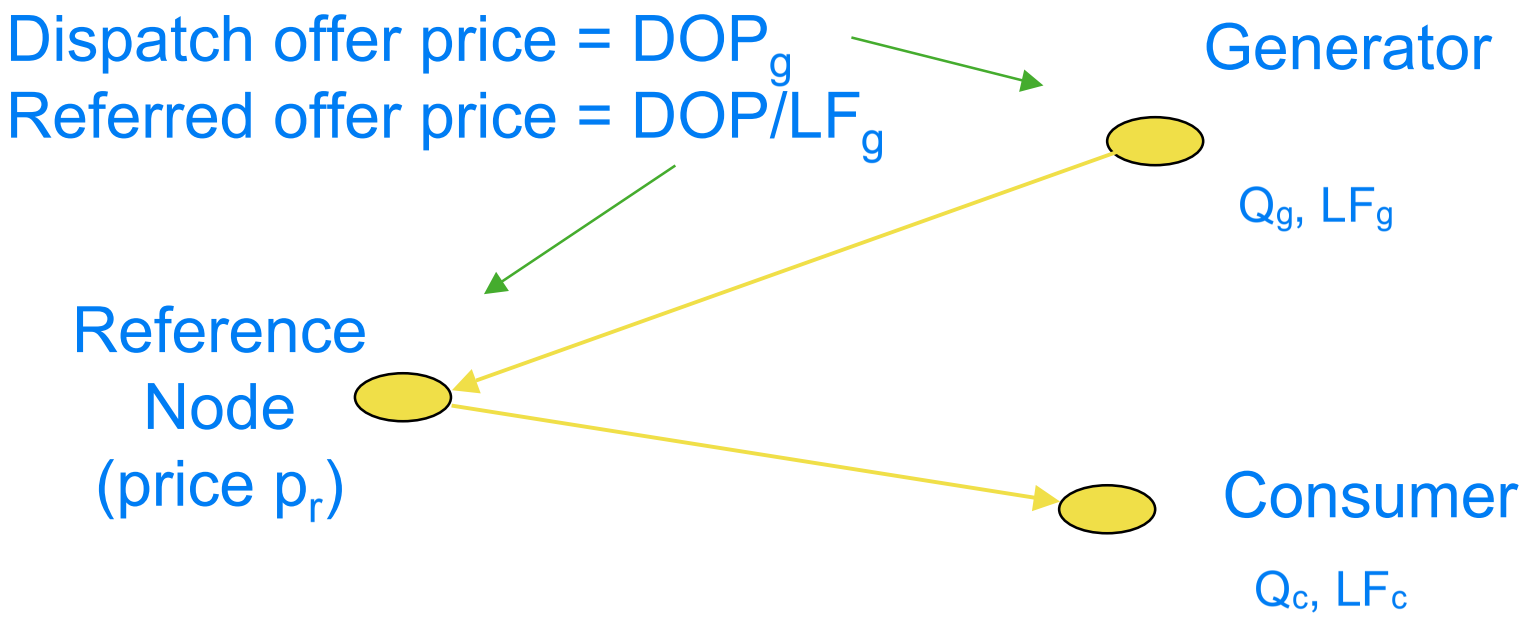
Modelling regulated interconnectors & intra-region location

- Regulated interconnector between 2 regions
  - Modelled by a linearised marginal loss function:
    - A ‘dynamic’ network loss factor that depends on flow
    - Flow limits (security or thermal criteria)
- Locational effects within regions
  - Modelled by ‘static’ network loss factors (LFs)
    - Annual average of estimated half-hour marginal losses for each generator node & group of consumer nodes
  - Intra-regional constraints not modelled but a ‘constrained-on’ generator cannot set price

Service territories of NSW distributors showing transmission loss factors



Effect of intra-regional network loss factors on spot market outcomes



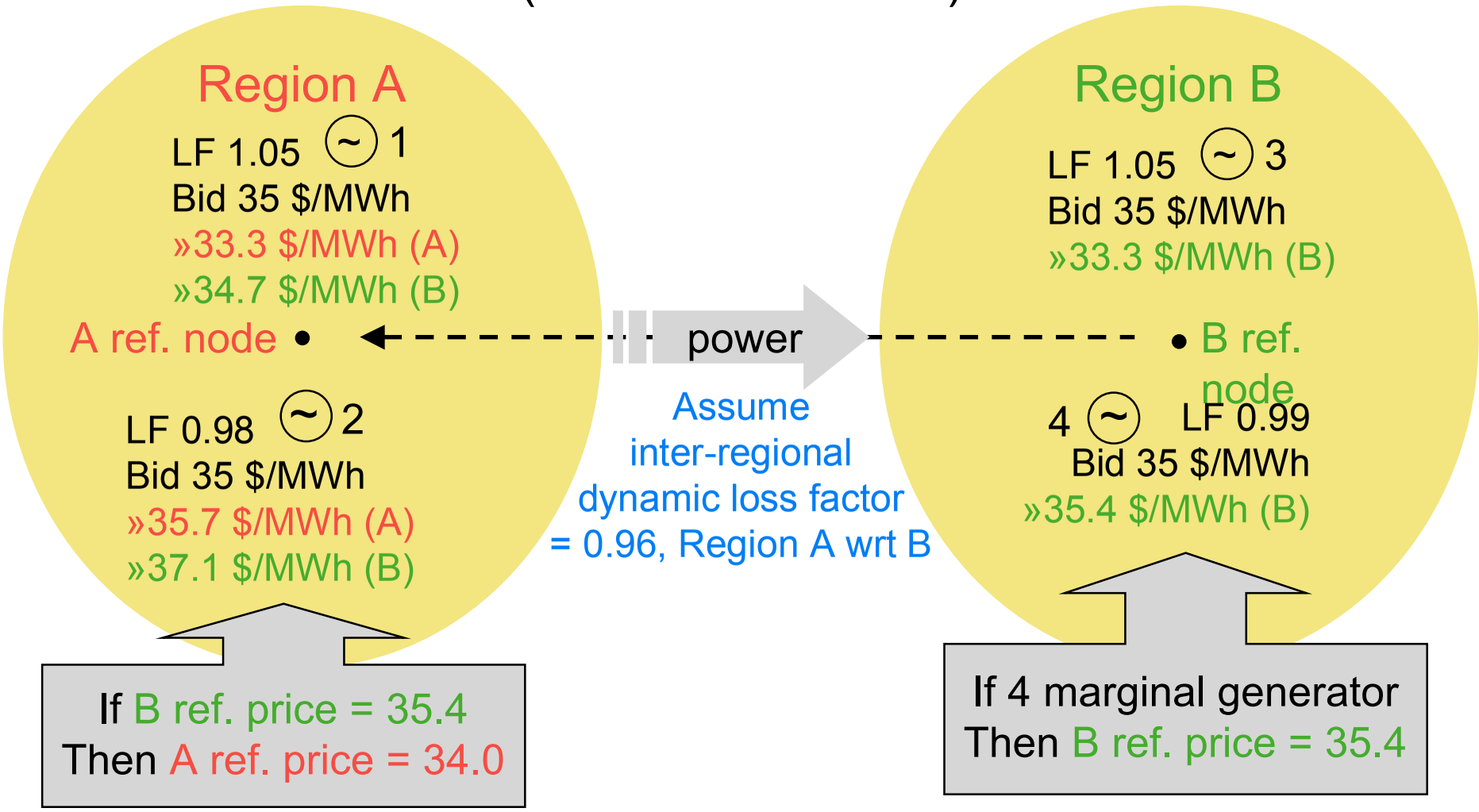
Generator produces Q_g & is paid $p_r \times LF_g \times Q_g$

Consumer consumes Q_c & pays $p_r \times LF_c \times Q_c$

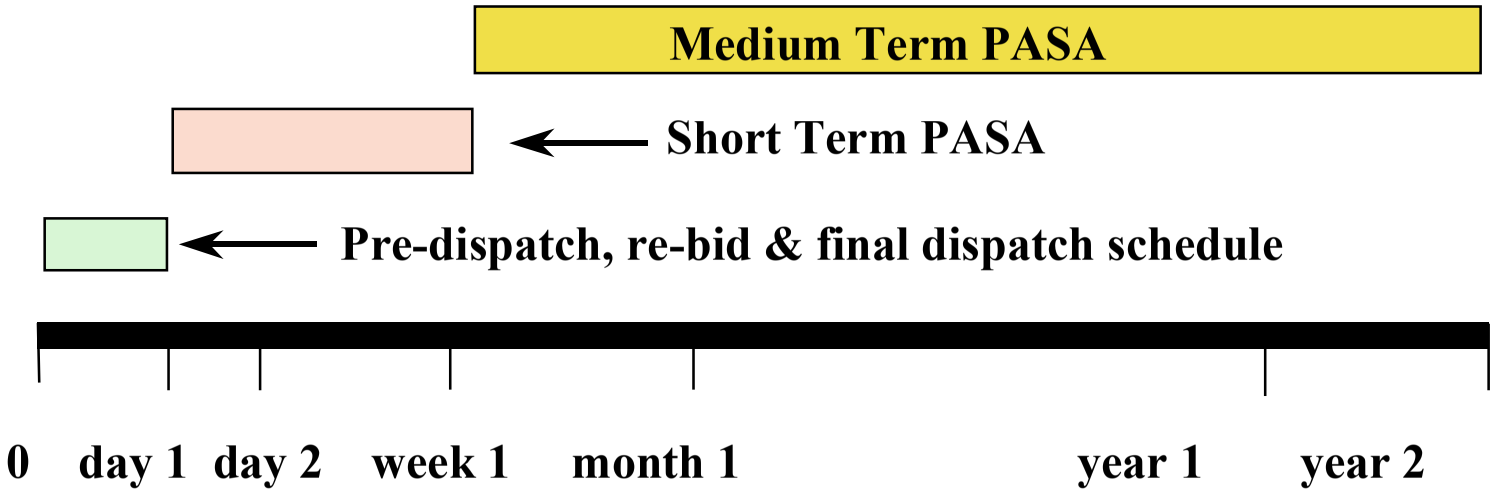
Net income is given to network service provider(s)

Combining dynamic inter- regional & static intra-regional loss factors

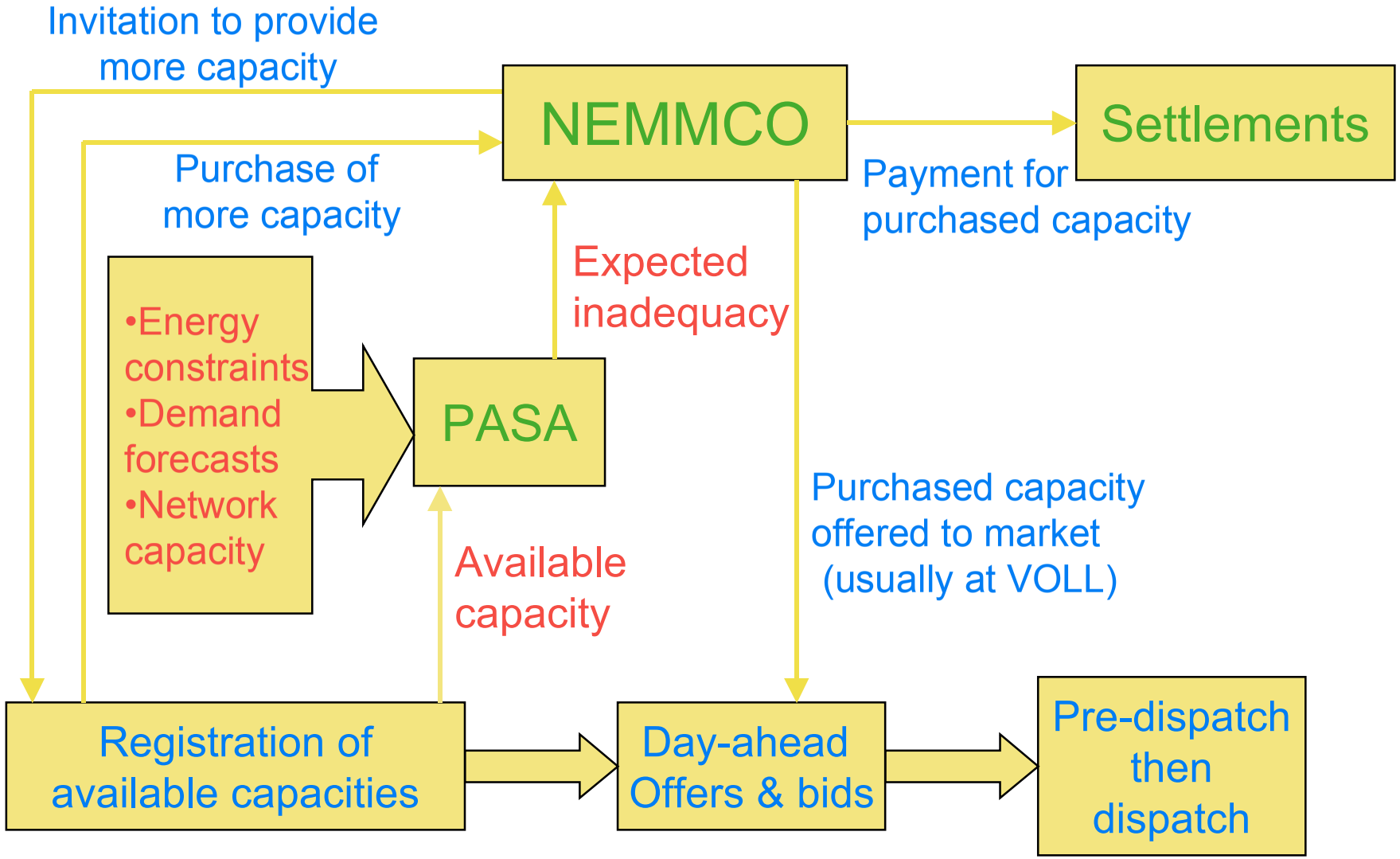
(unconstrained link)



Dispatch, Pre-dispatch & PASA



PASA & reserve trader



VOLL, VoEG & market intervention

- Regional ref. spot price cap at 'VOLL':
  - 'value of lost load', initially $5000/MWh:
    - No single correct number
  - Applies if load is involuntarily curtailed in a region
  - Other regional reference prices ≤ VOLL
- Regional ref. spot price floor at 'VoEG'
  - 'value of excess generation' initially -$1000/MWH
- Cap & floor may be reduced after 24 hours:
  - If (price x hours)> 300,000 $/MW then cap/floor set to ±$300 $/MWH daytime, ±$50 off-peak

Financial instrument trading in support of NEM

- Trading in hedges & options:
  - Bilateral trading
  - Over-the-counter instruments
  - Exchange-traded CFDs
- Inter-regional hedges:
  - Specialised form of financial instrument:
    - to manage regional price difference risks
    - funded by interconnector settlement residues
  - NEMMCO intercon. settlement residue auctions
    - Commenced in 1999

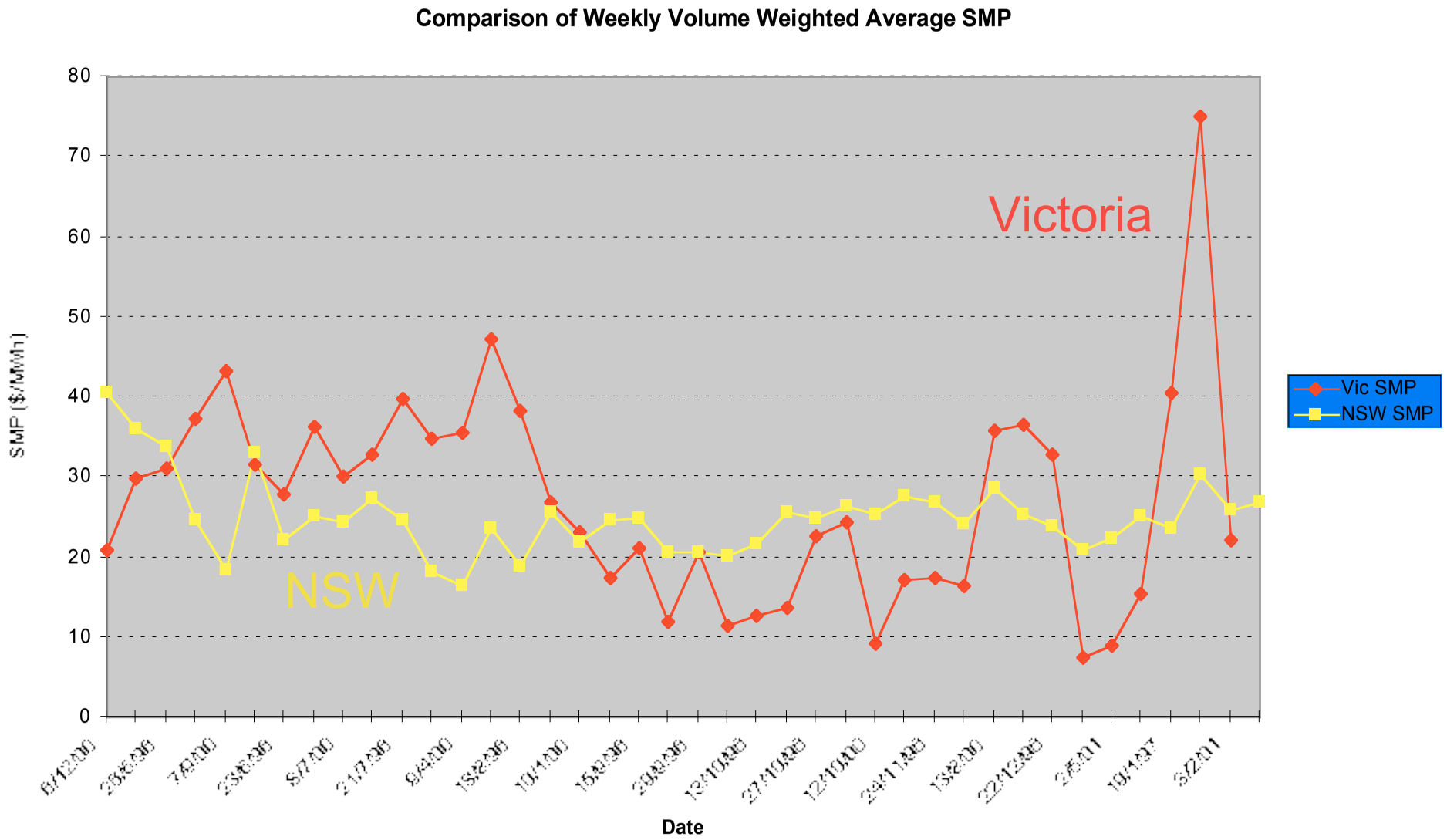
Sydney Futures Exchange CFDs for NSW & Victorian regional reference prices

	Base load electricity futures (since Sept. 1997)	Peak period electricity futures (since March 1999)
Underlying commodity	NEM region energy per calendar month	Monthly energy, 7am-10pm, WWDs
Contract unit	500 MWh	500 MWh
Tick size	$25	$25
Trading horizon	13 months	13 months
Settlement price	Average spot price over the month	Average spot price, 7am-10pm, WWDs

Market performance

- Separate NSW & Victorian markets:
  - June 1996 to May 1997
- Interim National Electricity Market (NEM1) combining NSW & Victorian markets:
  - May 1997 to December 1998
- National Electricity Market (NEM)
  - From December 1998

Separate NSW & Victorian markets
Weekly average prices, 6/96 - 2/97

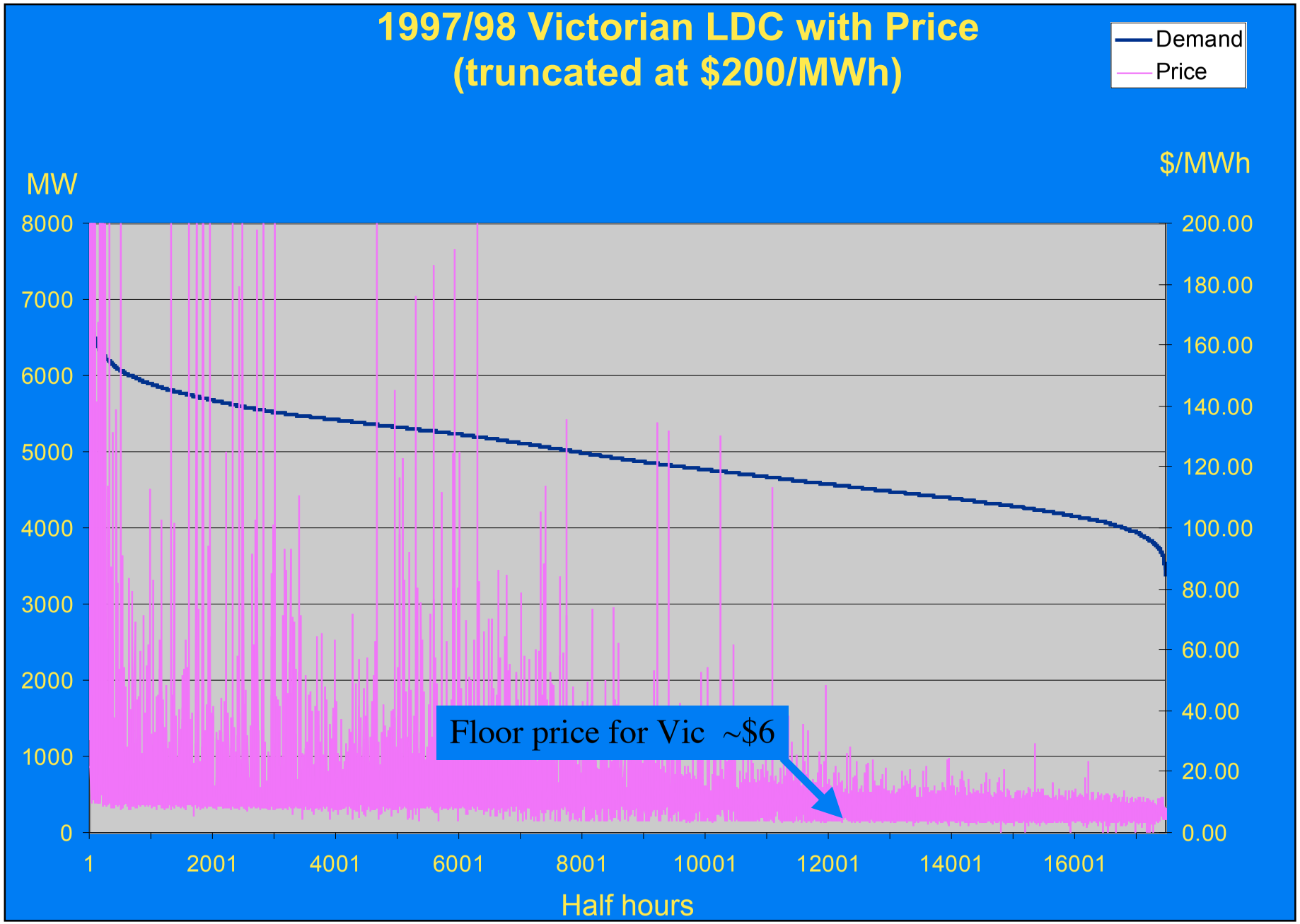


Comments on outcomes in separate NSW & Vic markets

- Long term average prices were similar:
  - Average prices both ~ $23/MWh for 7/96-5/97
- Prices in Victoria more volatile than in NSW:
  - Wider variation in underlying operating costs
  - Inflexible base load plant:
    - Victorian pool price was zero on occasions
  - Victorian market smaller than NSW (~70%)
  - Summer demand more temperature sensitive in Victoria than in NSW

Victorian price-demand relationship

- The following graph shows Victorian demand & price data sorted by demand:
  - Half-hourly data pairs for July 1997 - June 98:
    - prices are in $ per MWh, demand is in MW
- Some correlation between price & demand
- Effective floor price of ~6 $/MWh
- Prices vary for similar load levels
- Prices often low but sometimes high:
  - Less excess base load capacity than in NSW



Daily average prices, 1/97 - 11/97

(NEM1 joint market commenced May '97)

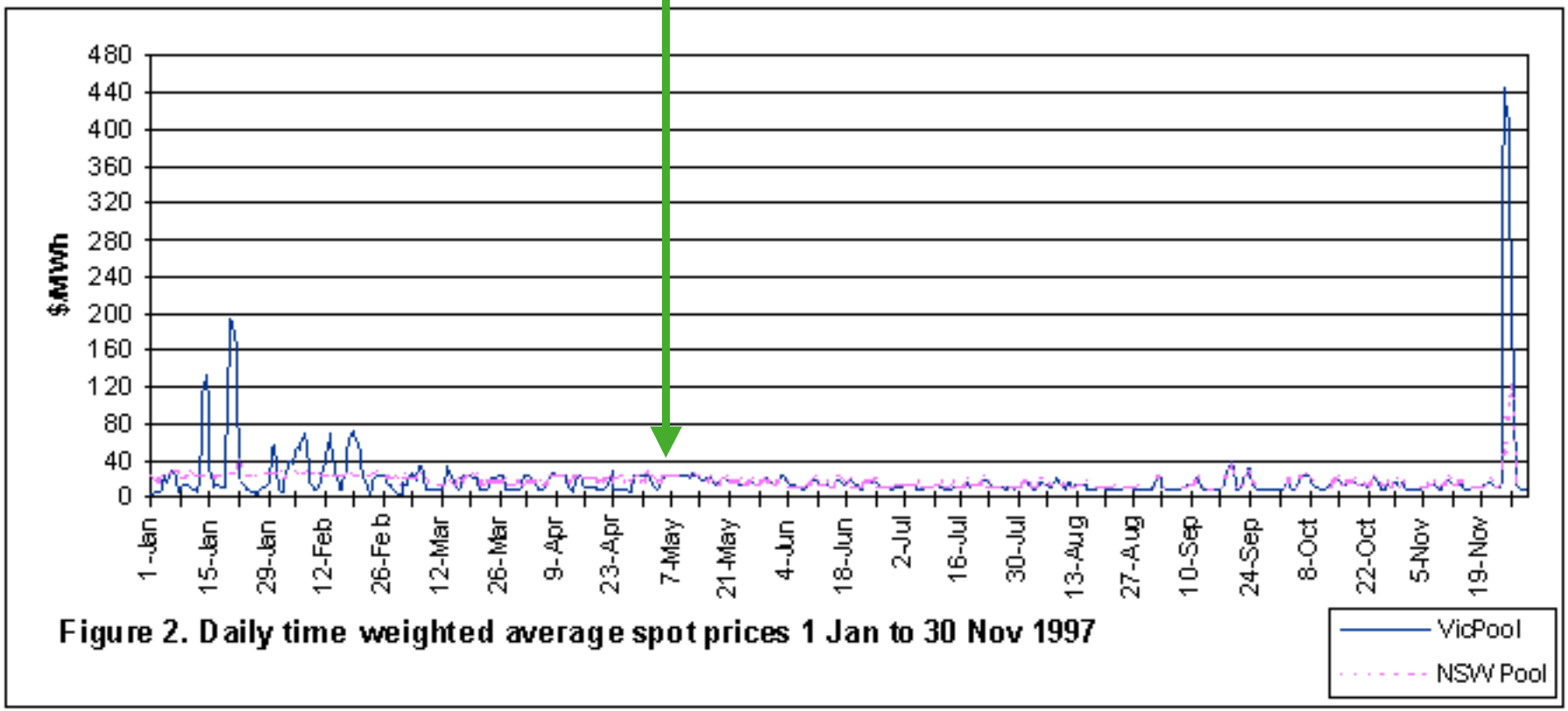


Figure 2. Daily time weighted average spot prices 1 Jan to 30 Nov 1997

Daily average prices, 12/97- 11/98

(change in NSW vesting contracts)

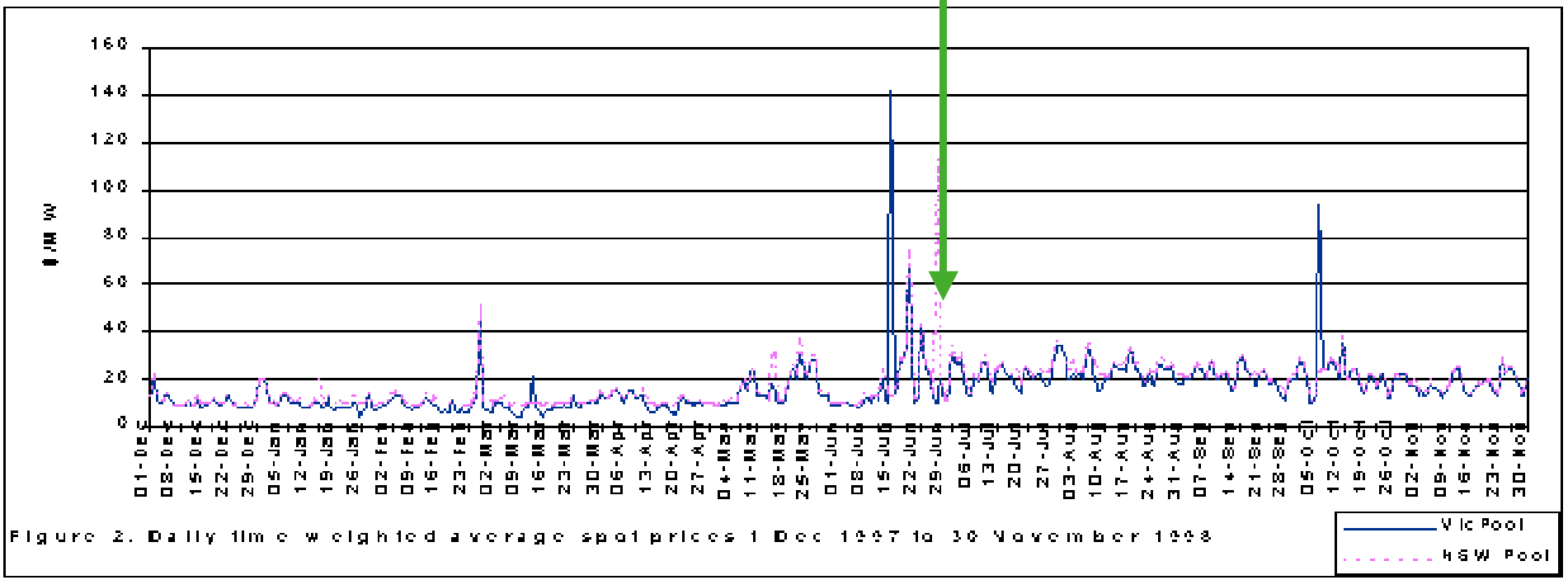
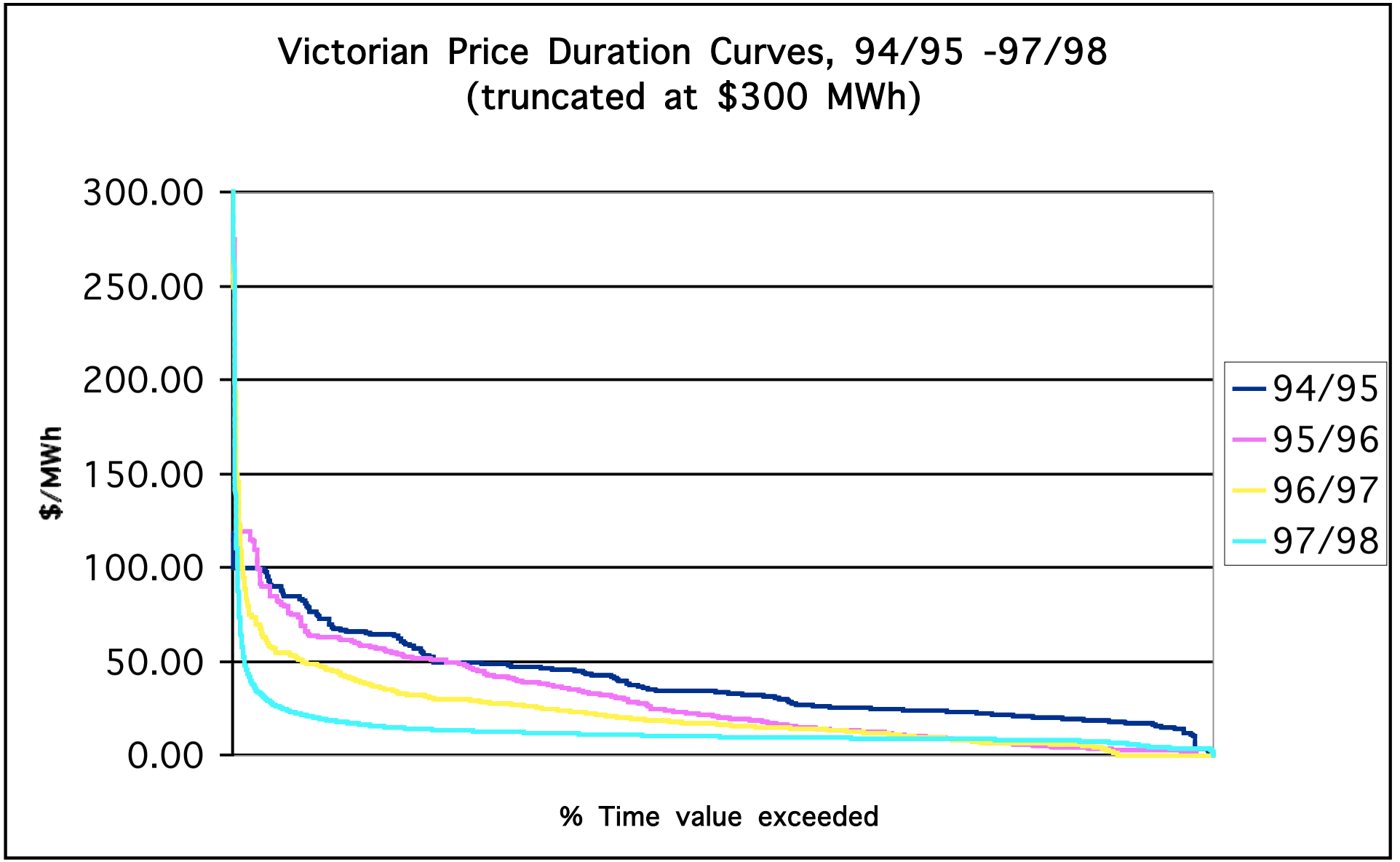


Figure 2. Daily time weighted average spot prices 1 Dec 1997 to 30 November 1998



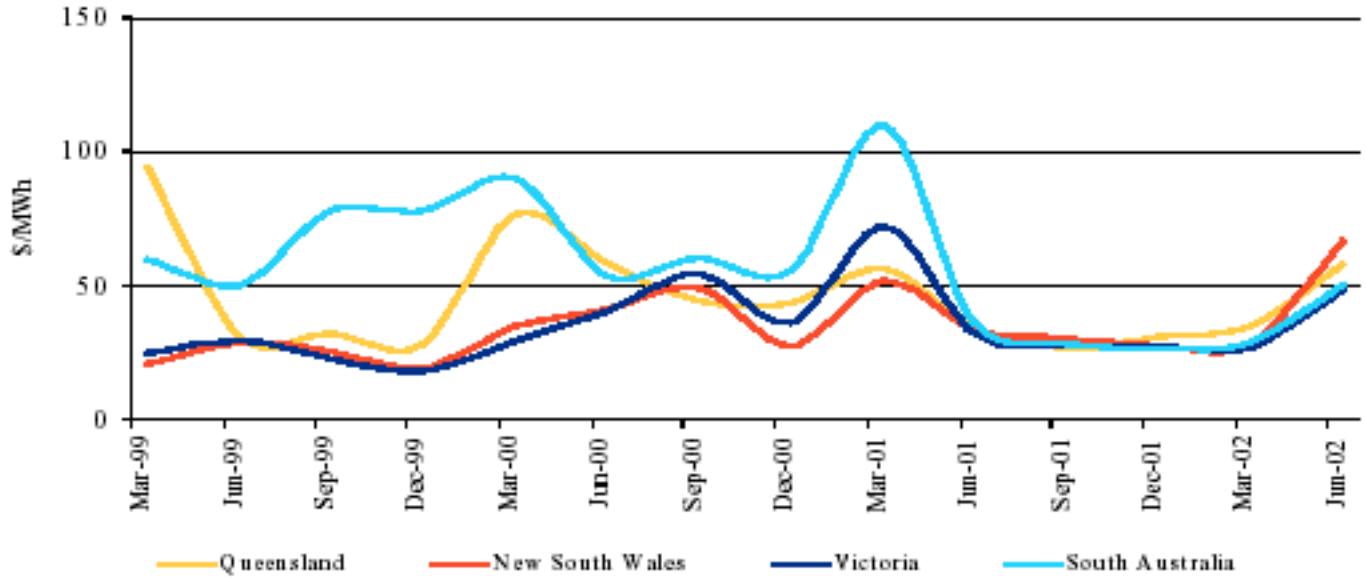
Comments on NEM1

- Prior to NEM1:
  - Prices were more volatile in Victoria than in NSW
- During NEM1:
  - NSW & Victorian spot prices usually similar
  - Average spot prices fell
    - Additional competitive pressures
      - even the Victorian market with 5 competing base load plant may not have been 'fully' competitive
      - Vicpool 3 in 1994 still had one-week offers
  - Net flow on inter-connector from Victoria to NSW

Price history since NEM inception

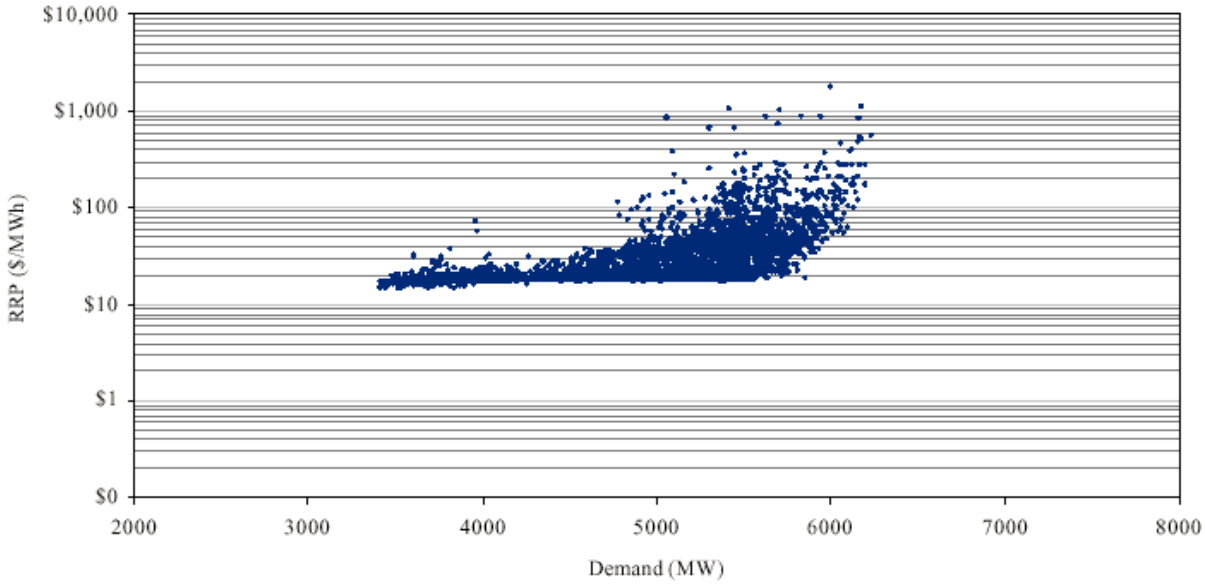
(Quarterly averages, 12/98-6/02) (NECA, 2002)

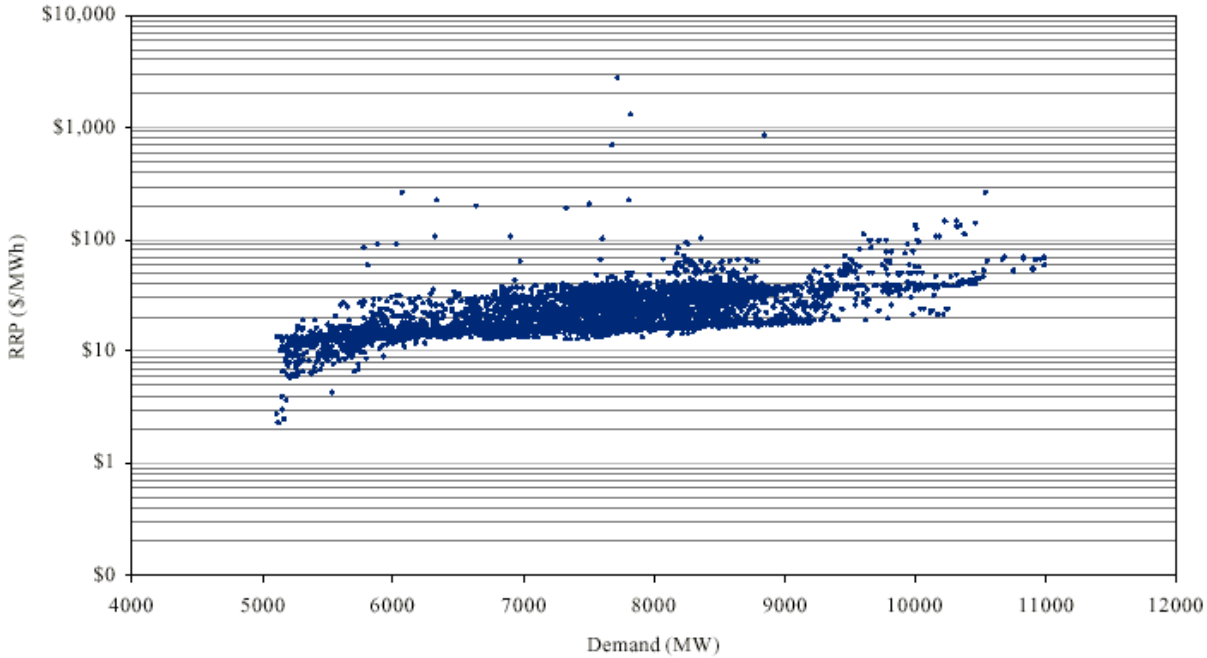
	QLD	NSW	VIC	SA
April - June 2002	58	66	49	50
April - June 2001	34	34	32	36
Change from previous quarter	▲65%	▲137%	▲83%	▲76%
Change from previous year	▲67%	▲96%	▲52%	▲39%



Price-demand plots for NEM Queensland & NSW regions

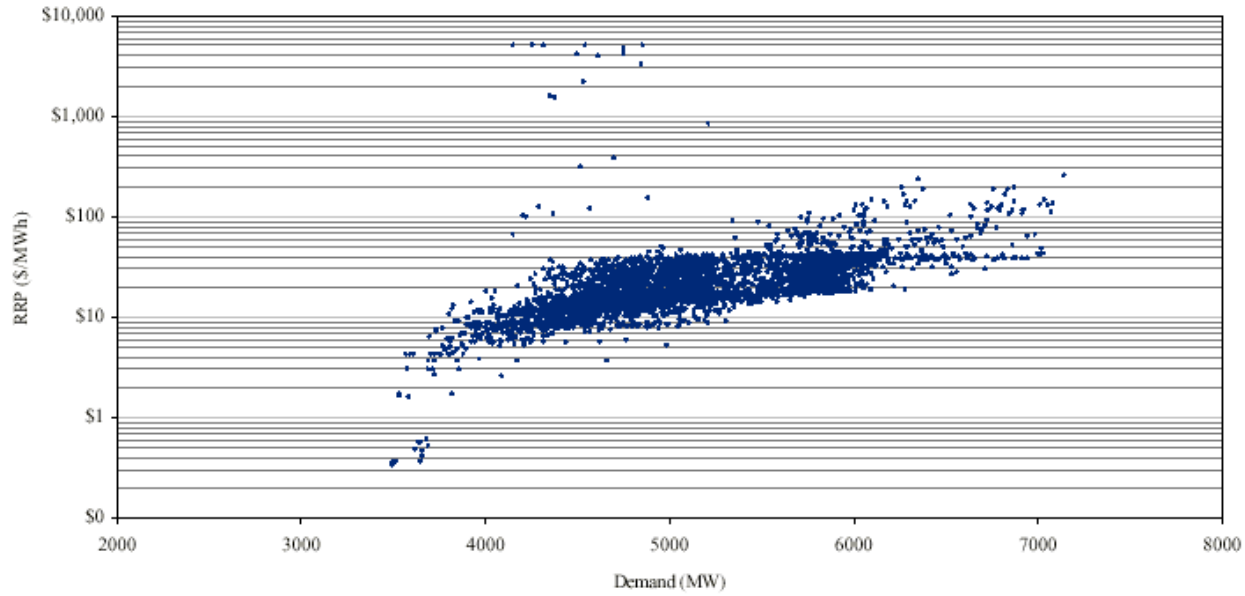
Sept-Dec 2000
($/MWH vs MW)
(NECA, 2000)

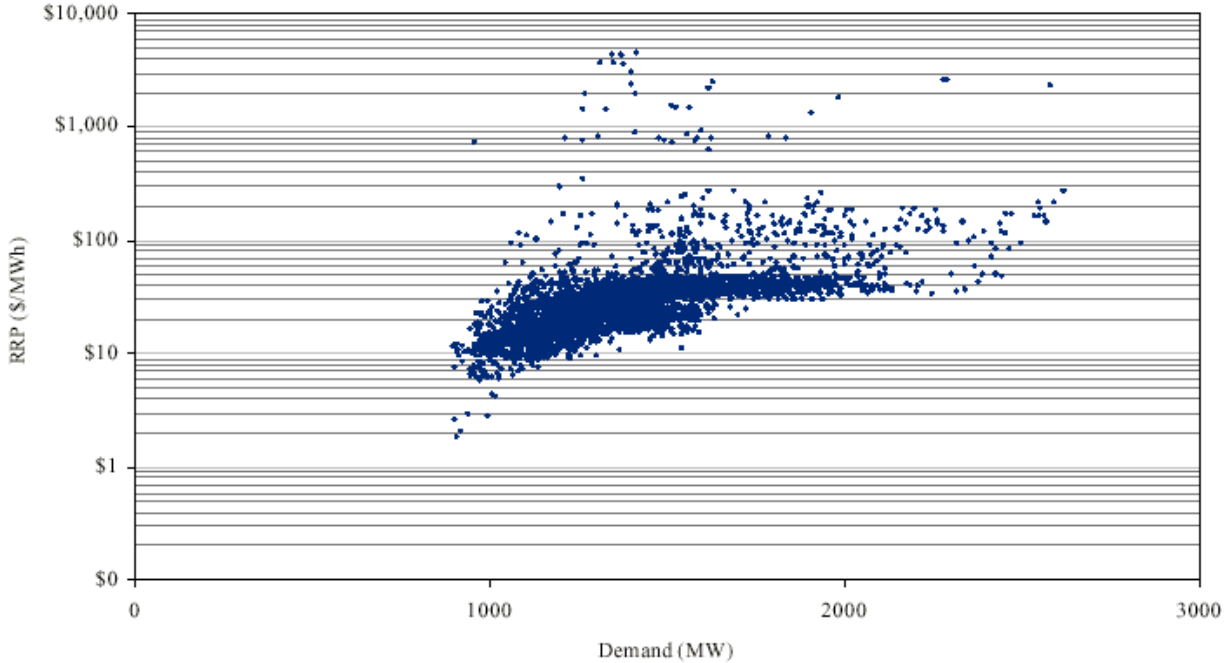




Price-demand plots for NEM Victoria & SA regions

Sept-Dec 2000
($/MWH vs MW)
(NECA, 2001)

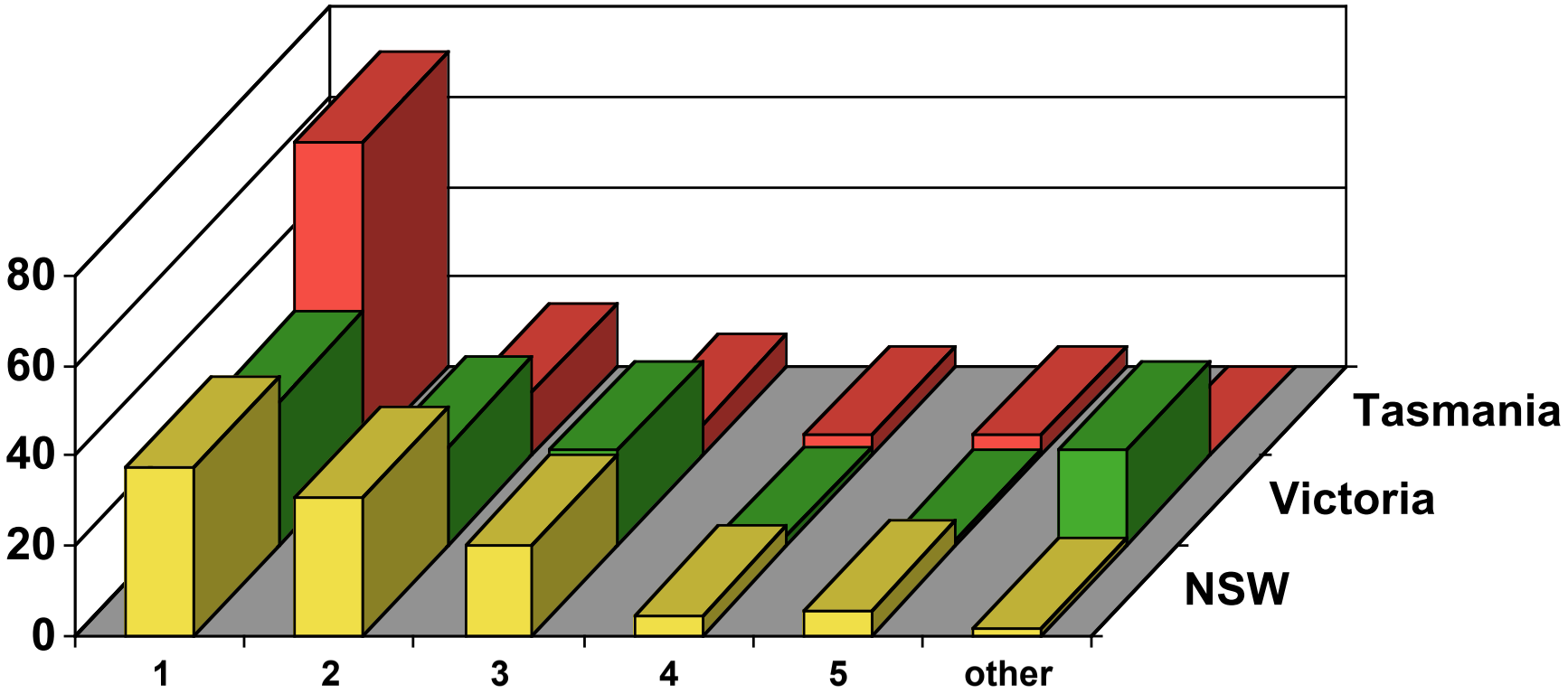




BCA concerns about market power

- BCA concerns about EI restructuring:
  - Insufficient disaggregation of generation:
    - In NSW, Queensland & South Australia
  - New interconnectors face too much uncertainty
  - Network pricing distorted
  - Regulation cumbersome
- However BCA recommends improvement rather than radical change:
  - Market design is basically sound

Generator energy market shares (%) in NSW & Victoria, 1997-98 (ESAA, 1999) & possible Tasmania scenario

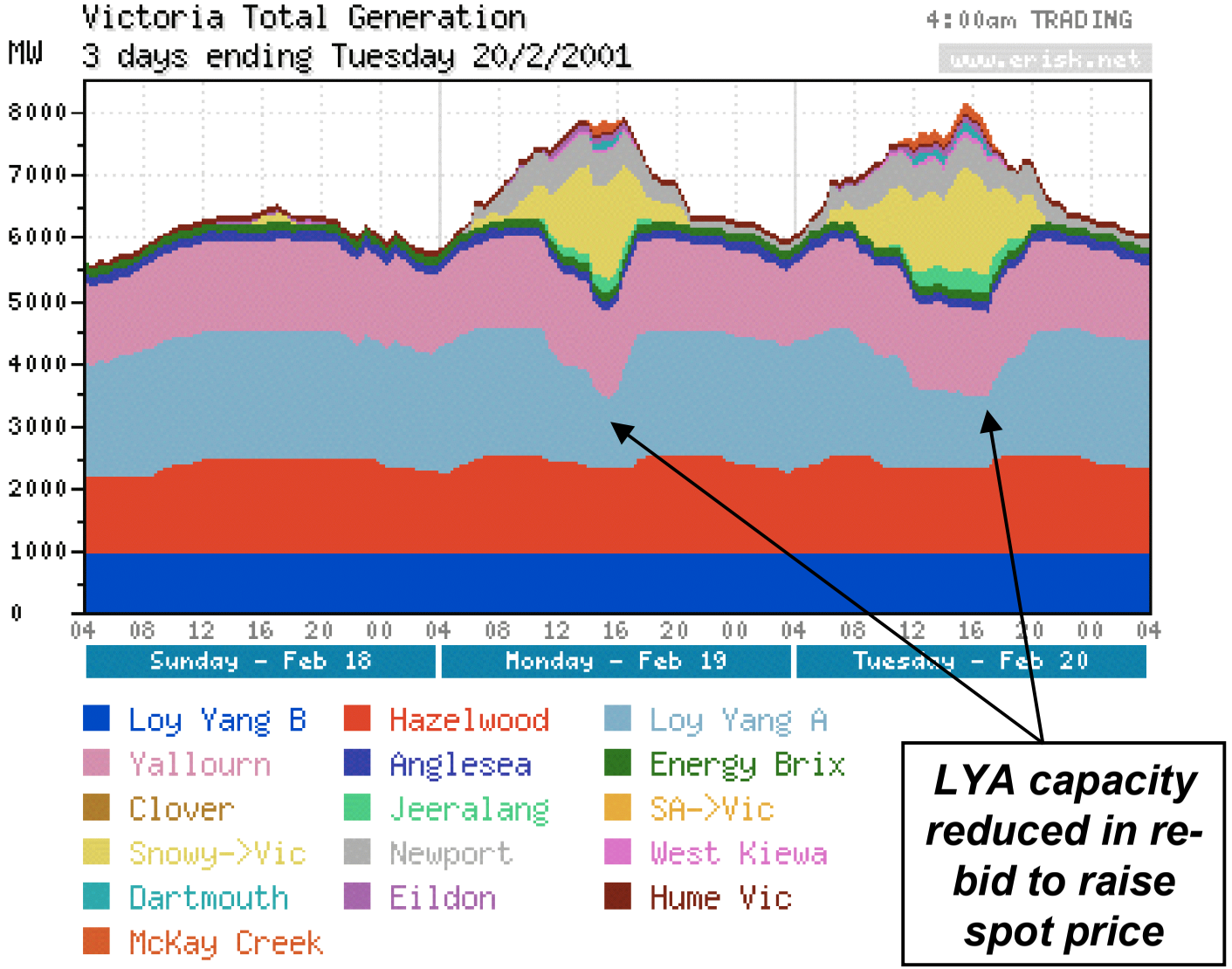


Theory & experience suggest ≤ 20% share to avoid market power

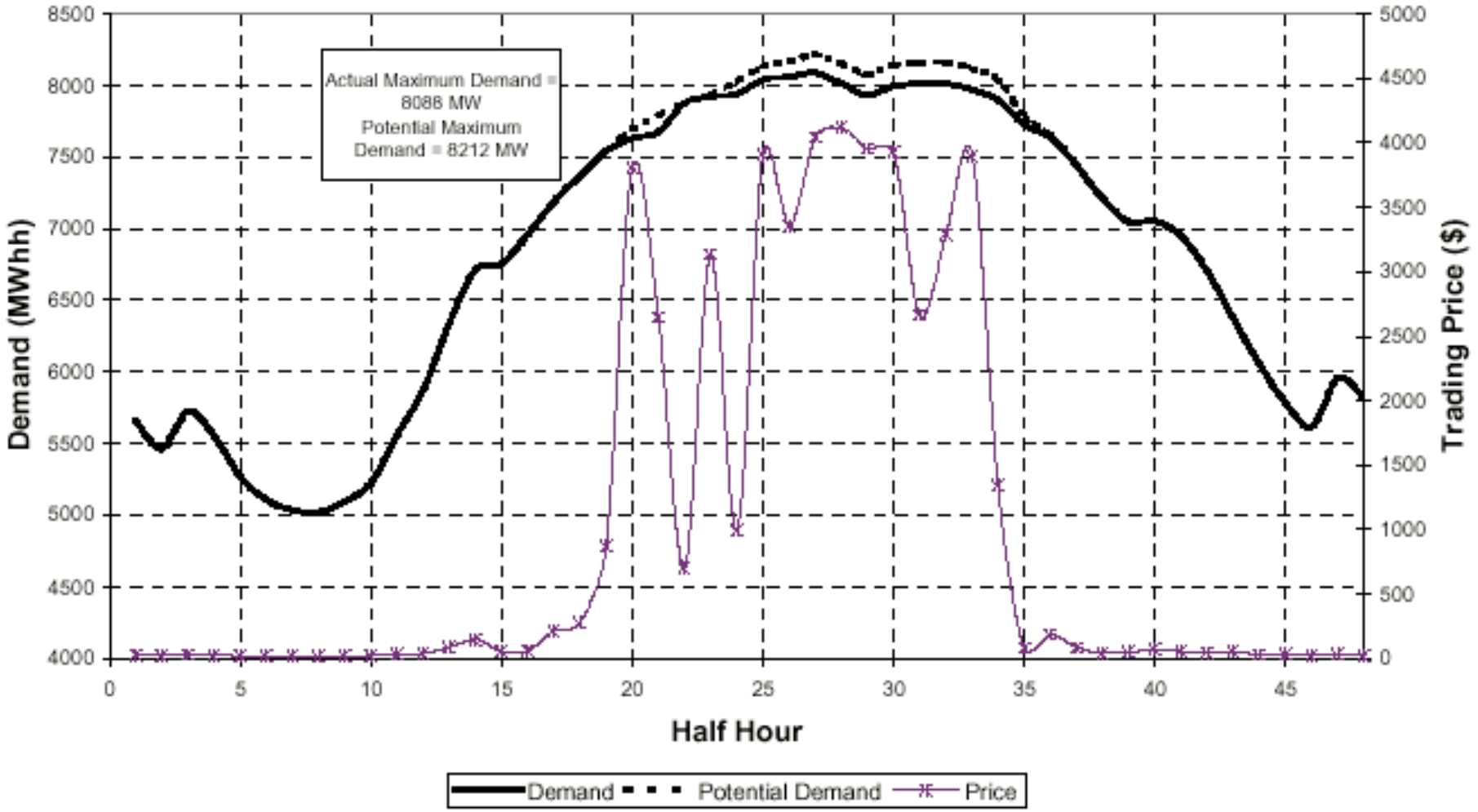
Reducing generation to raise spot market price

(demand-side response: forward contract or reduce demand)

(source: Erisk & Bardak Group quoted by J Washusen, Pareto)



Evidence of demand side response: NEM Victorian region, 8/2/01 (NECA, 2001)



Future directions for NEM

- Improved network representation:
  - More (smaller) market regions
  - More market network service providers
  - Better locational signals for distributed resources
- Improved ancillary service arrangements:
  - Increased use of competitive tendering & "causer pays"
- Improved bidding arrangements
- COAG Review