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Integrating renewable energy into the Australian electricity industry: high penetration challenges

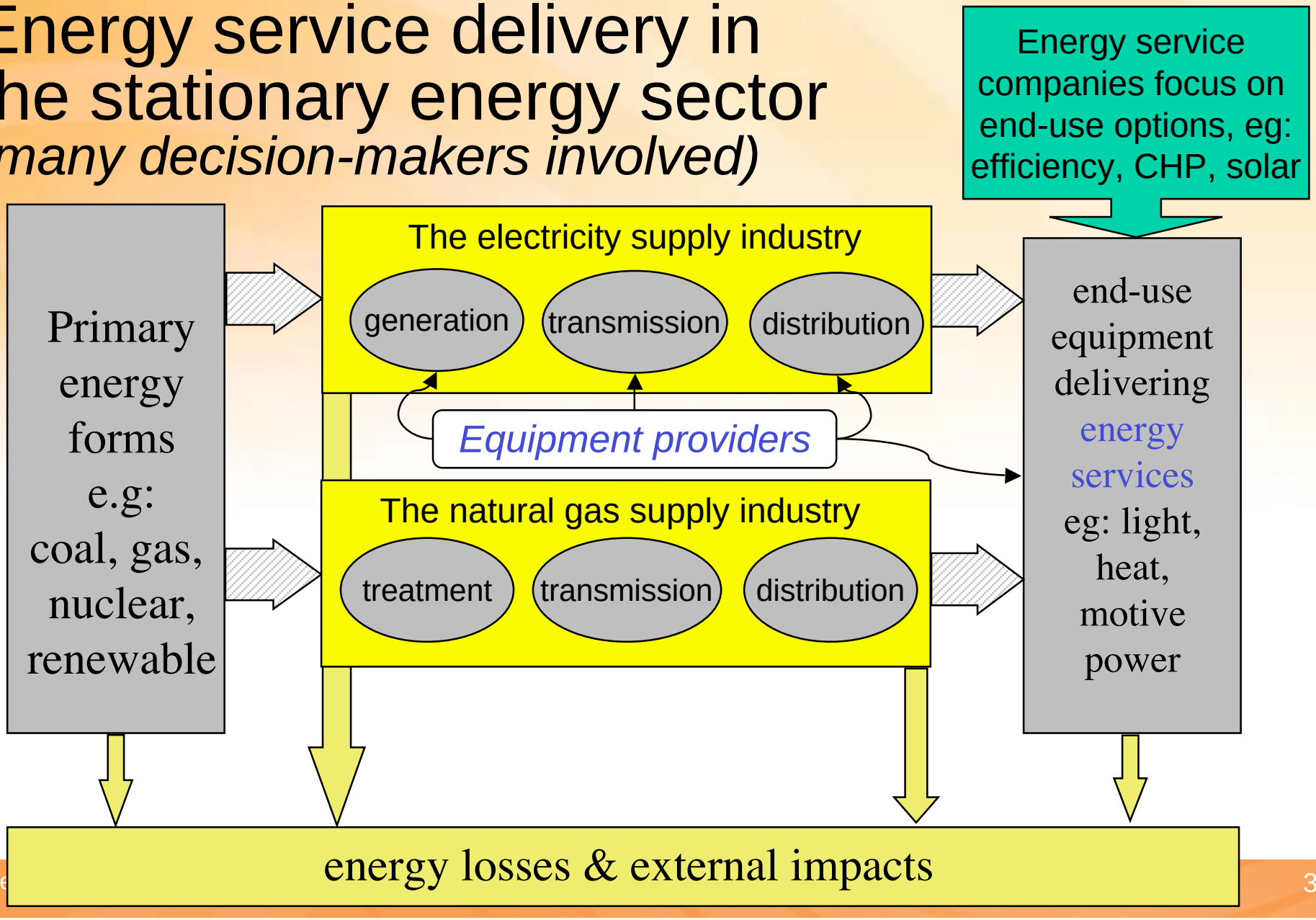
Hugh Outhred

Monash "Green Power" Workshop, Melbourne, 9/5/08

Outline

- The stationary energy sector
- Characteristics of the electricity industry
- The electricity industry design challenge
- Energy flow & climate change constraints
- Characteristics of renewable energy generation
- Key issues for high levels of renewable energy

Energy service delivery in the stationary energy sector
(many decision-makers involved)



Electricity industry characteristics

- Complex & fragile energy conversion chain:
  - Continuous flow from primary to end-use energy forms:
    - Electrical energy is a non-storable intermediate energy form subject to shared network losses & shared flow constraints
  - Some primary energy forms are also flow constrained
  - Industry-wide, “just-in-time” nature & long asset lives:
    - Infused with shared, short-term & long-term risks
  - Network-related, location-specific behavior & risks:
    - Device-related & system security flow constraints & network losses, only some of which are readily commercialized
- Societal infrastructure role:
  - Public as well as private values

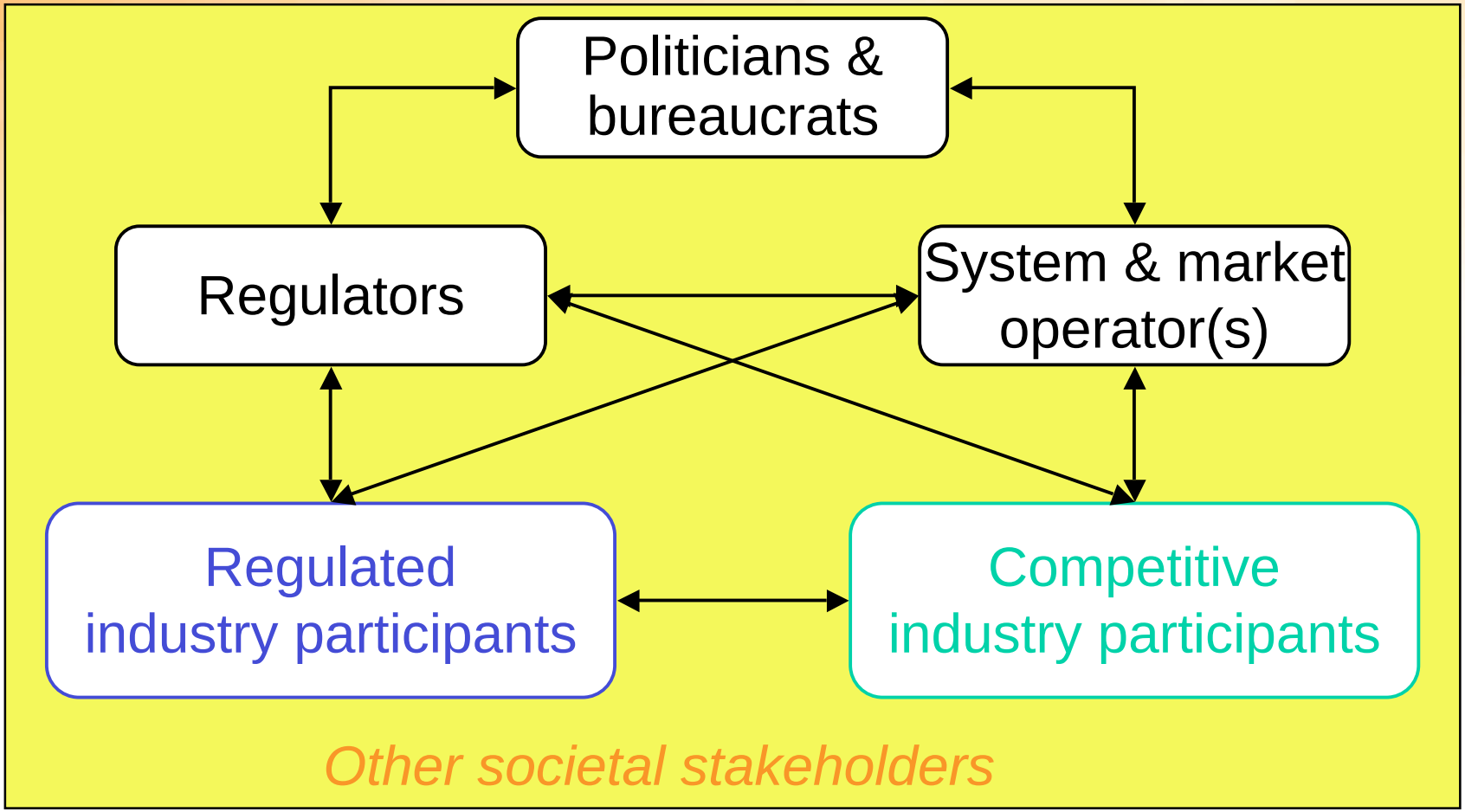
The electricity industry design challenge

- Overarching objective: to design, implement & then improve a “decision-making framework” that:
  - Appropriately allocates tasks to all industry decision-makers, with meaningful incentives & penalties
  - Delivers socially-beneficial future outcomes:
    - From very short-term to very long-term
    - Sensitive to location & to infrastructure role
- Process objective: implement processes that can:
  - Achieve an initial industry design that is adequate
  - Deliver sound implementation of that design
  - Improve the decision-making framework over time

Critical issues in electricity industry design

- Governance & rule-change process:
  - On-going, forward-looking, monitoring & enhancement
- Temporal risk management:
  - Coherent framework from very short to very long term
- Primary energy flow-constraint risk management:
  - Wind & solar energy, natural gas
- Locational risk management:
  - Systematic combination of market representation & regulated network services
- Active end-user participation:
  - To establish time-varying values of energy services

Decision-makers in a restructured electricity industry



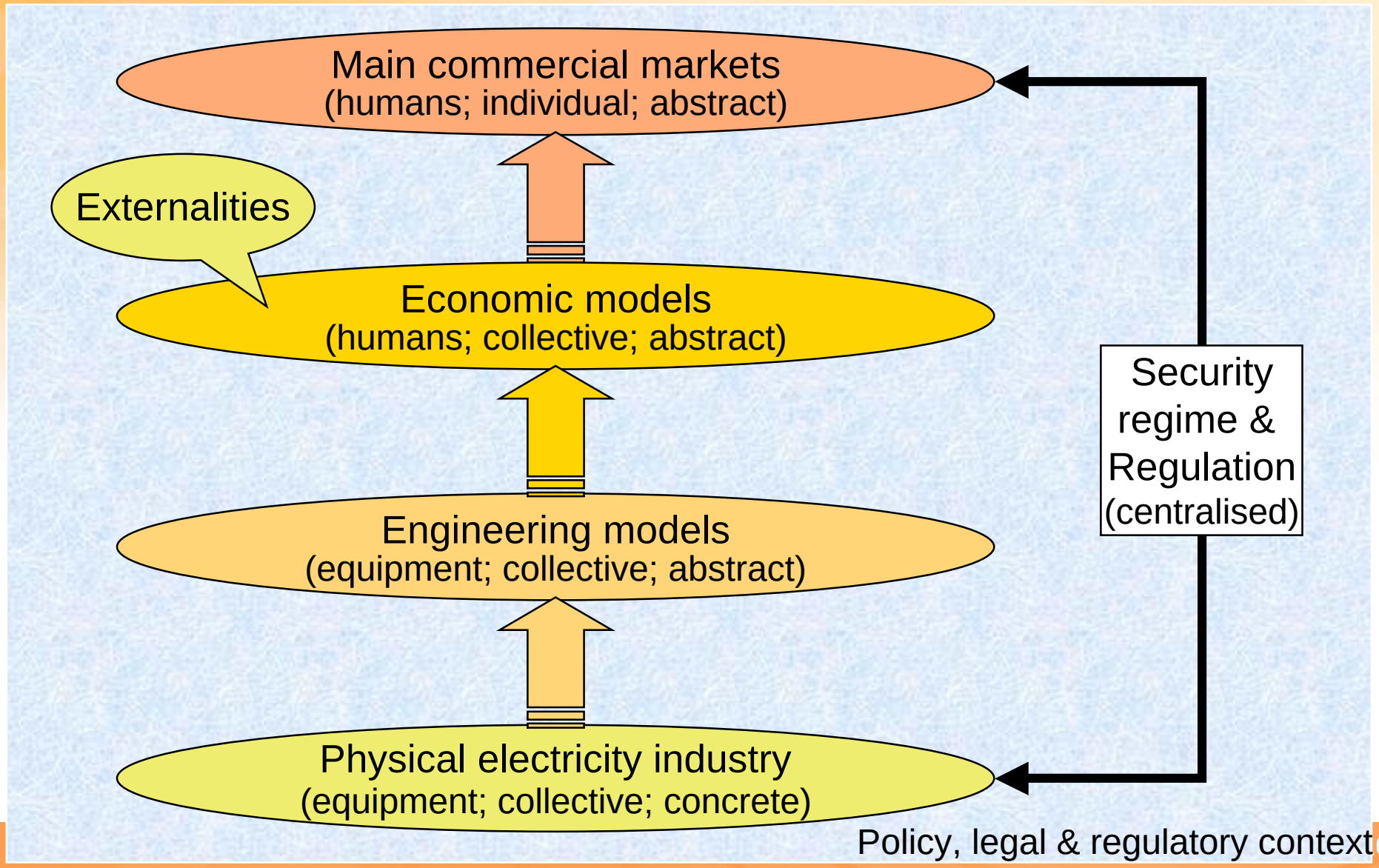
Decision-making framework for a restructured electricity industry (EI)

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	▪ Engineering design to allow industry components to function as single, industry-wide machine when connected together
Commercial regime	▪ Decentralised decision-making according to commercial criteria within a market context ▪ Includes formally designed markets ▪ *Needs adequate competitive pressures*

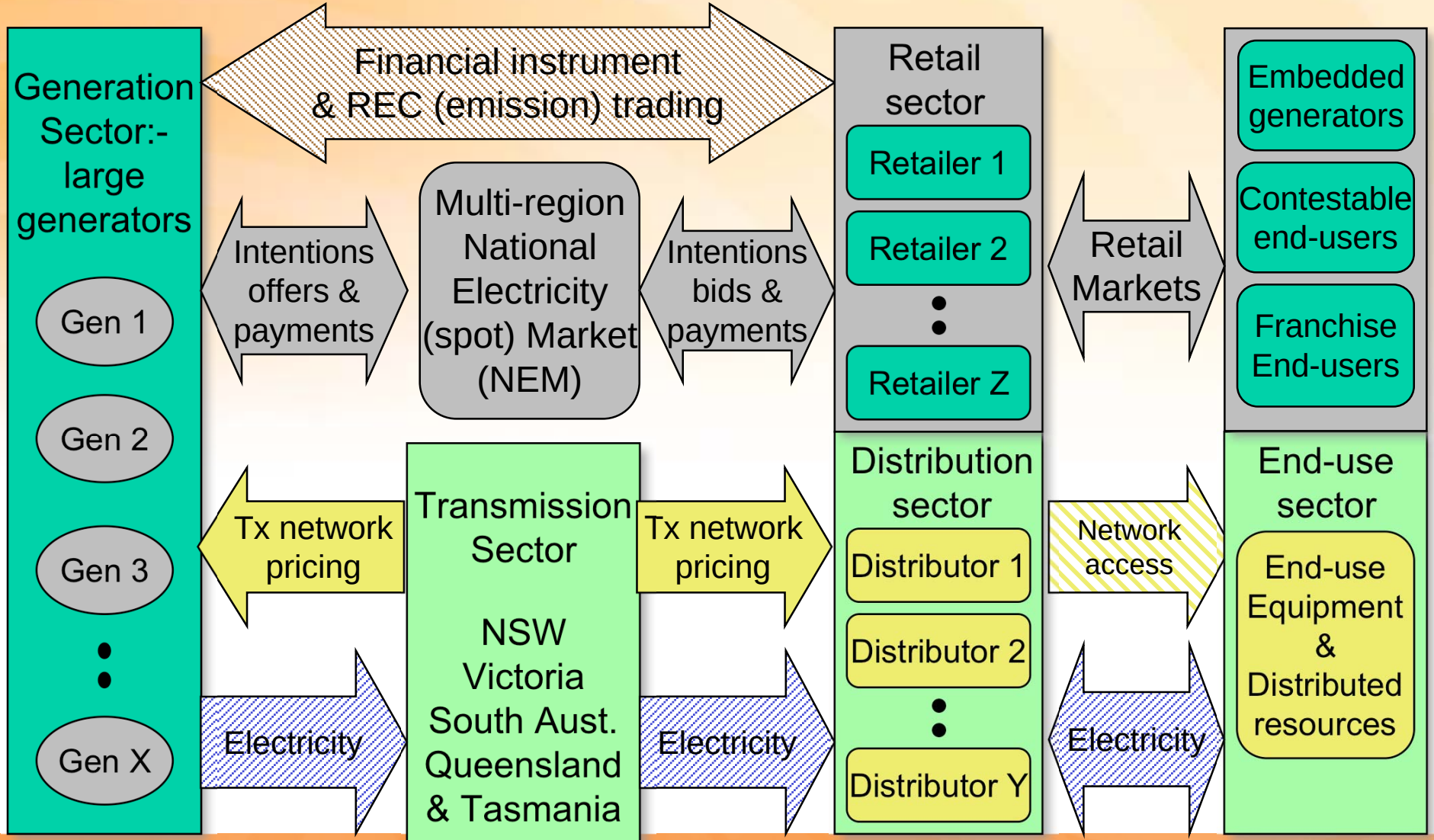
Comparison of decision-making styles

- Engineering decision making *(security & technical regimes):*
  - Assumes participants act in “good faith”
  - Data is best estimate of actual phenomena
  - Criterion is engineer’s interpretation of “public good”
- Commercial decision-making *(commercial regime):*
  - Assumes participants act to maximise their own outcomes
  - Data is probably biased towards participant self interest:
    - *“Under conditions of competition, standards are set by the morally least reputable agent”* (attributed to John Stuart Mill)
  - Criterion is the “private good”
- Governance decision-making:
  - Some stakeholders may have excessive influence

Trading in electricity:- an abstraction from reality



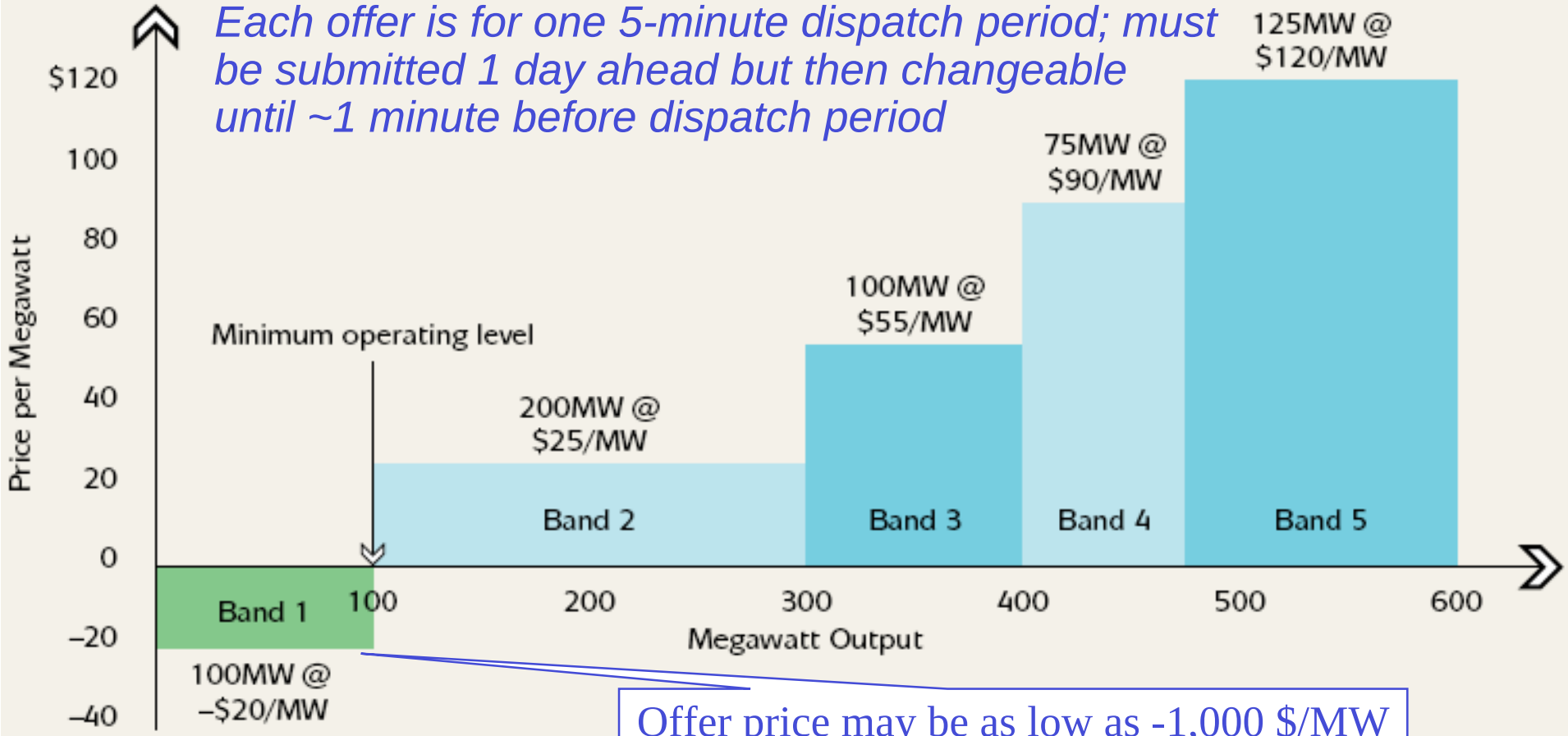
The Australian National Electricity Market (NEM)



Simplified generator energy offer for a particular 5-minute interval (NEMMCO, 2005)

Offer price may be as high as 10,000 $/MW

Each offer is for one 5-minute dispatch period; must be submitted 1 day ahead but then changeable until ~1 minute before dispatch period

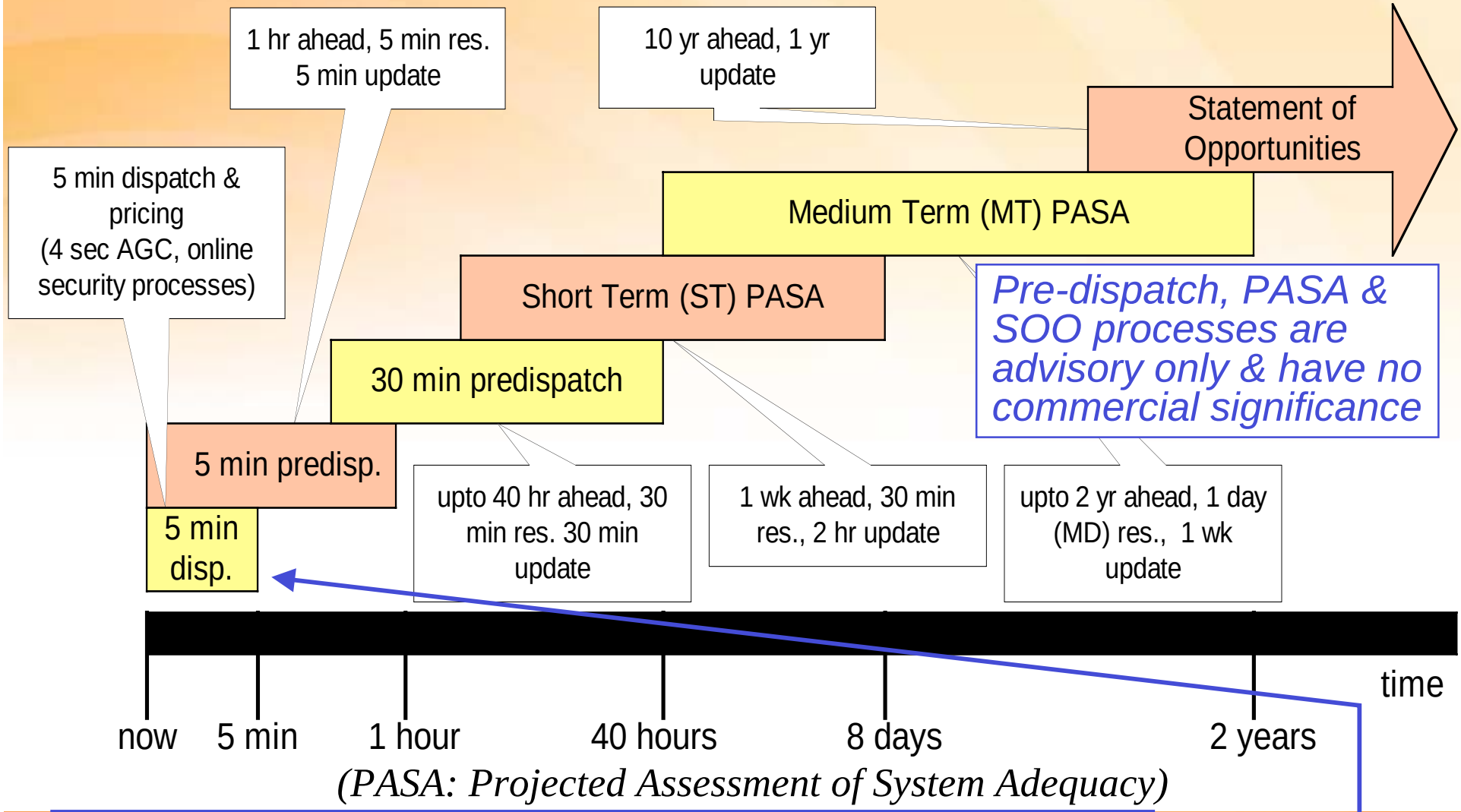


Offer price may be as low as -1,000 $/MW

A simplified representation of bids from a 600 MW generating unit that indicates the capacity the generator is willing to offer to the NEM at a range of prices.

Source: NEMMCO; S Thorncraft

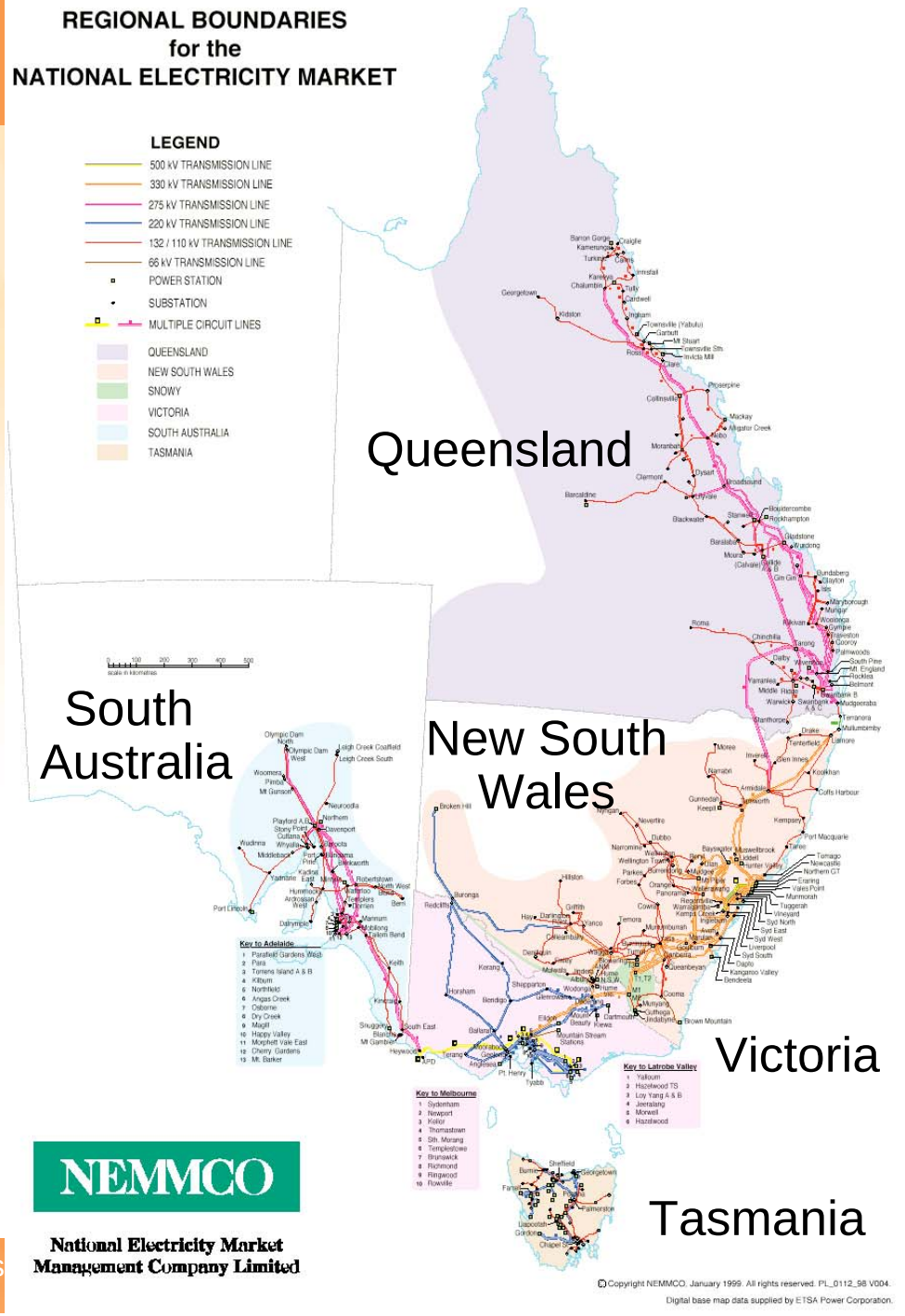
NEM commercial & security processes



Prices for the next 5 minutes are the only commercial prices

Scope of the NEM:

- Serves a population of about 18 million
- Network length ~2,500 miles
- Uniform National Electricity Rules for market & security
- Single state-owned system & market operator (NEMMCO)
- Six market regions with “hub & spoke” approximation to nodal pricing (Snowy region to be removed)



Evolution of Australian electricity industry design

- Conceptual foundation (based in Engineering & Economics):
  - Schweppe et al, *Homeostatic Utility Control,* IEEE, 1980
  - Outhred & Schweppe, *Quality of Supply Pricing,* IEEE, 1980
  - Kaye & Outhred, *A Theory of Electricity Tariff Design,* IEEE, 1989
  - Outhred, *Principles of a Market-Based Electricity Industry,* IEE, 1993
  - Outhred & Kaye, Incorporating Network Effects in a Competitive Electricity Industry, in Einhorn & Siddiqui (eds), *Issues in Transmission Pricing & Technology*, Kluwer, 1996
- Practical implementation:
  - COAG brief to NGMC, 1990: *Design an electricity industry that is economically efficient & environmentally sound*
  - Differing & evolving Victorian & NSW internal market designs, 1994-97, including computer simulation of NEM trading rules at UNSW, 1995-6
  - Australian National Electricity Market (NEM) from 1998

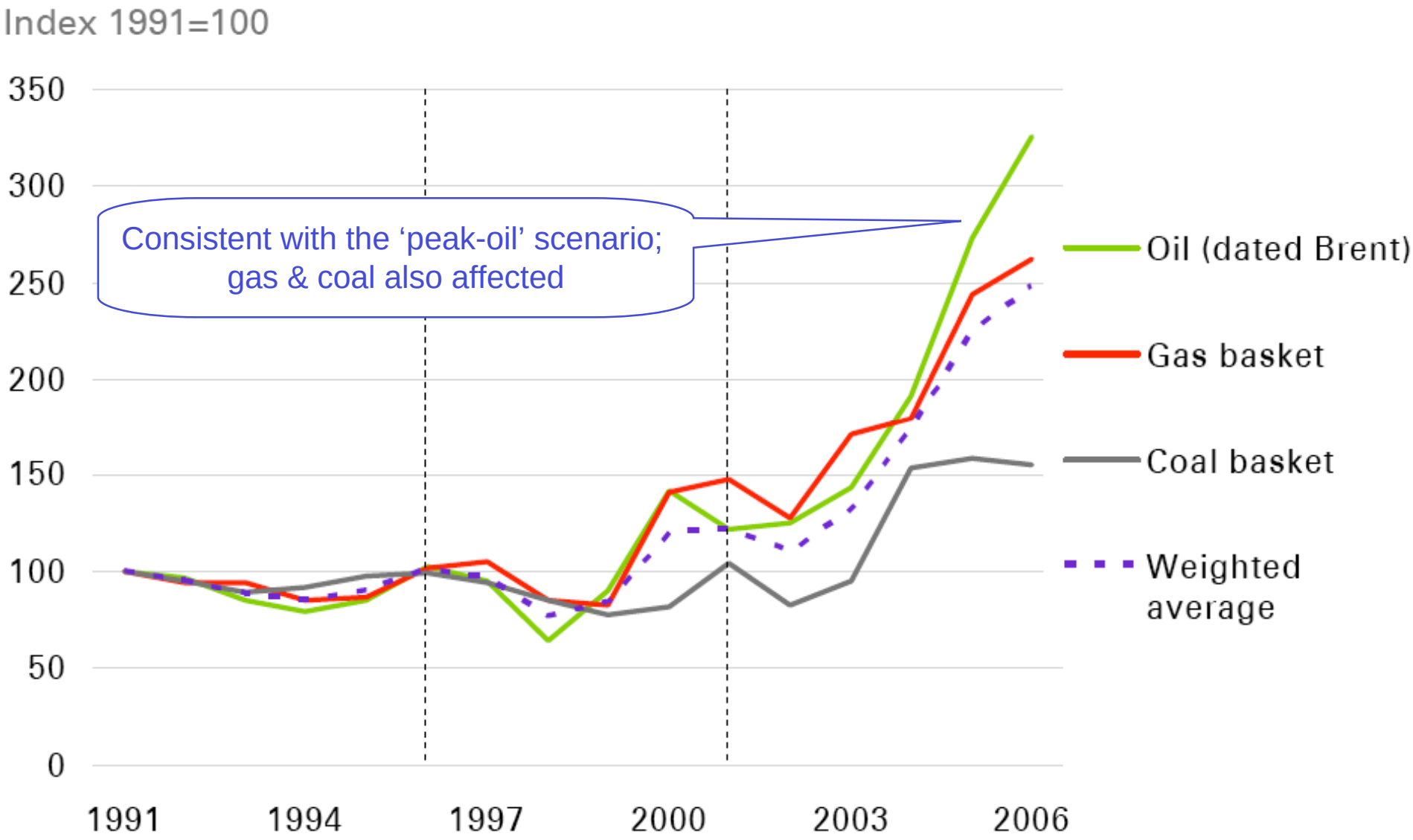
Governance for Australia's stationary energy sector

- Council of Australian Governments (COAG):
  - Ministerial Council on Energy (MCE) develops & submits proposals to COAG for approval (www.coag.gov.au; www.mce.gov.au)
- Australian Energy Regulator (www.aer.gov.au):
  - Monitors energy markets & regulates Network Service Providers
- Australian Energy Market Commission (www.aemc.gov.au):
  - Manages rule change for electricity & gas markets
  - Undertakes investigations for MCE
- Australian Energy Market Organisation (AEMO):
  - Enhanced version of National Electricity Market Management Company (www.nemmco.com.au) that will implement national electricity & gas markets & associated security regimes

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

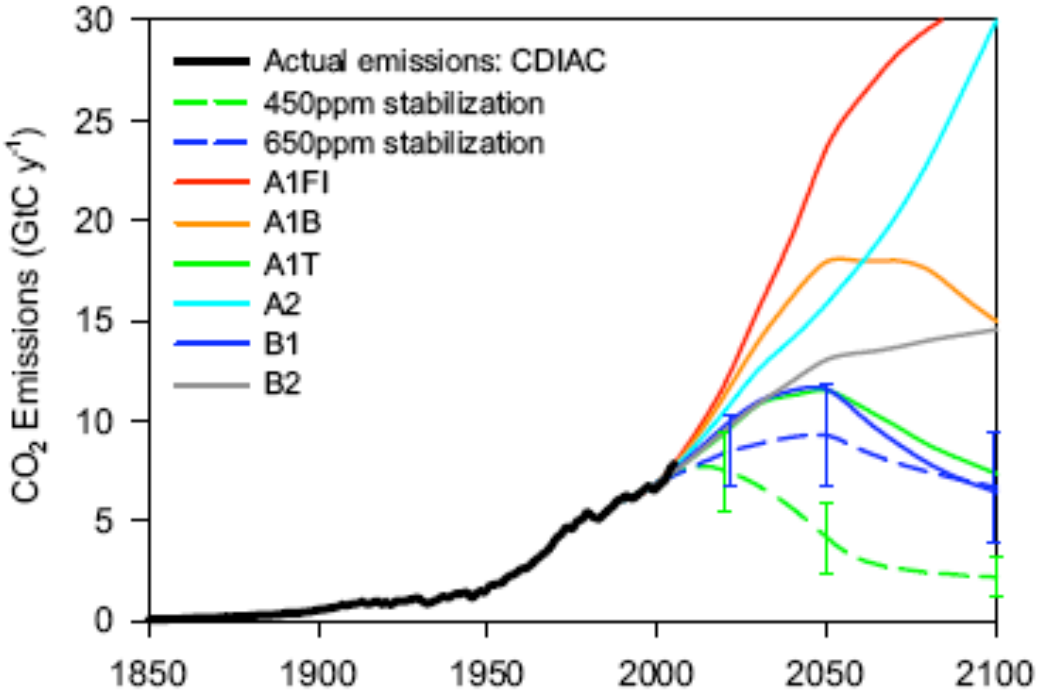
- *NEL Section 7:*
  - *The national electricity market objective is to promote efficient investment in, and efficient use of, electricity services for the long term interests of consumers of electricity with respect to price, quality, reliability and security of supply of electricity and the reliability, safety and security of the national electricity system*
- Features of this objective:
  - Group & individual perspectives; short & long timescales
  - But ambiguous with respect to interpretation & trade-offs between sub-objectives

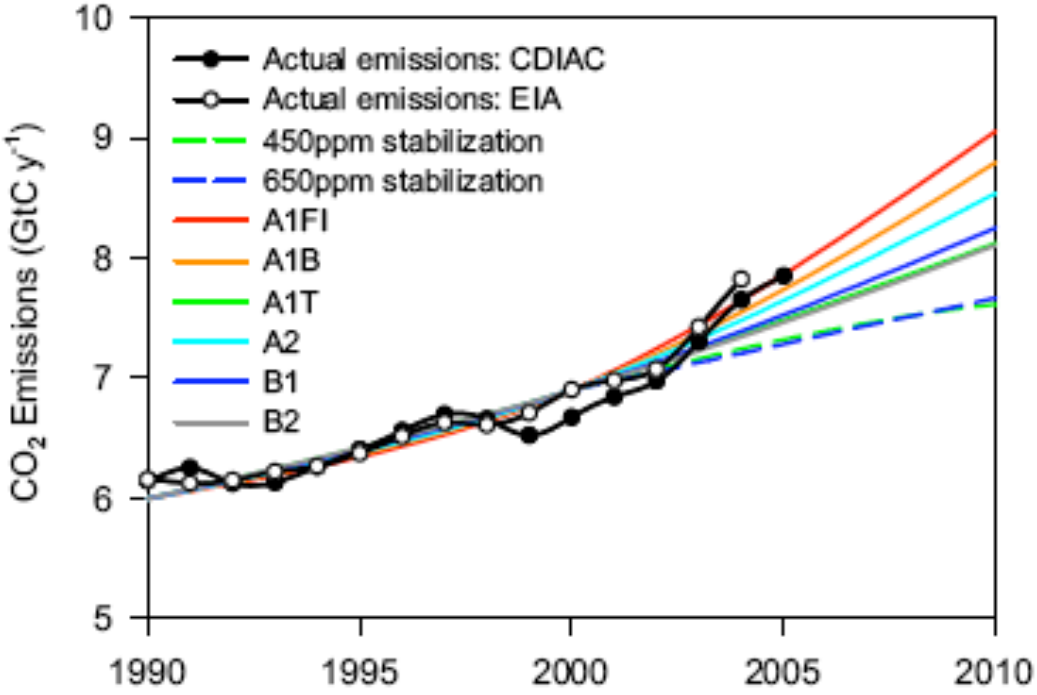
Prices for key energy commodities (BP Review 2007)



Actual emissions at or above "BAU"

(Raupach et al, PNAS, April 2007)





Issues for enhancing EI sustainability

- Energy security & rapid climate change are challenging problems
- Response tasks must largely be delegated to industry participants (companies & individuals)
- Policies must correctly assign incentives & penalties to deliver a rapid, coherent response:
  - Through “socially-organised decision-making”
  - Emphasizing frugality, enhanced end-use efficiency & low emission generation technologies
- Must overcome fierce vested-interest opposition

Socially-organised decision-making

- Most human decision-making occurs within a social (group) context supported by public policy:
  - "Effective policies are those that support socially valued outcomes not only by harnessing selfish motives but also by evoking, cultivating and empowering public spirited motives" (Gintis, Bowles & Fehr (eds), *Moral Sentiments and Material Interests,* MIT press)
  - Electricity industry policy should have both goals
- An electricity industry is a complex technological system:
  - Electricity industry policy should reflect this

What is technology?
(www.iiasa.ac.at)

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

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.

Technology = Hardware + Software + "Orgware"



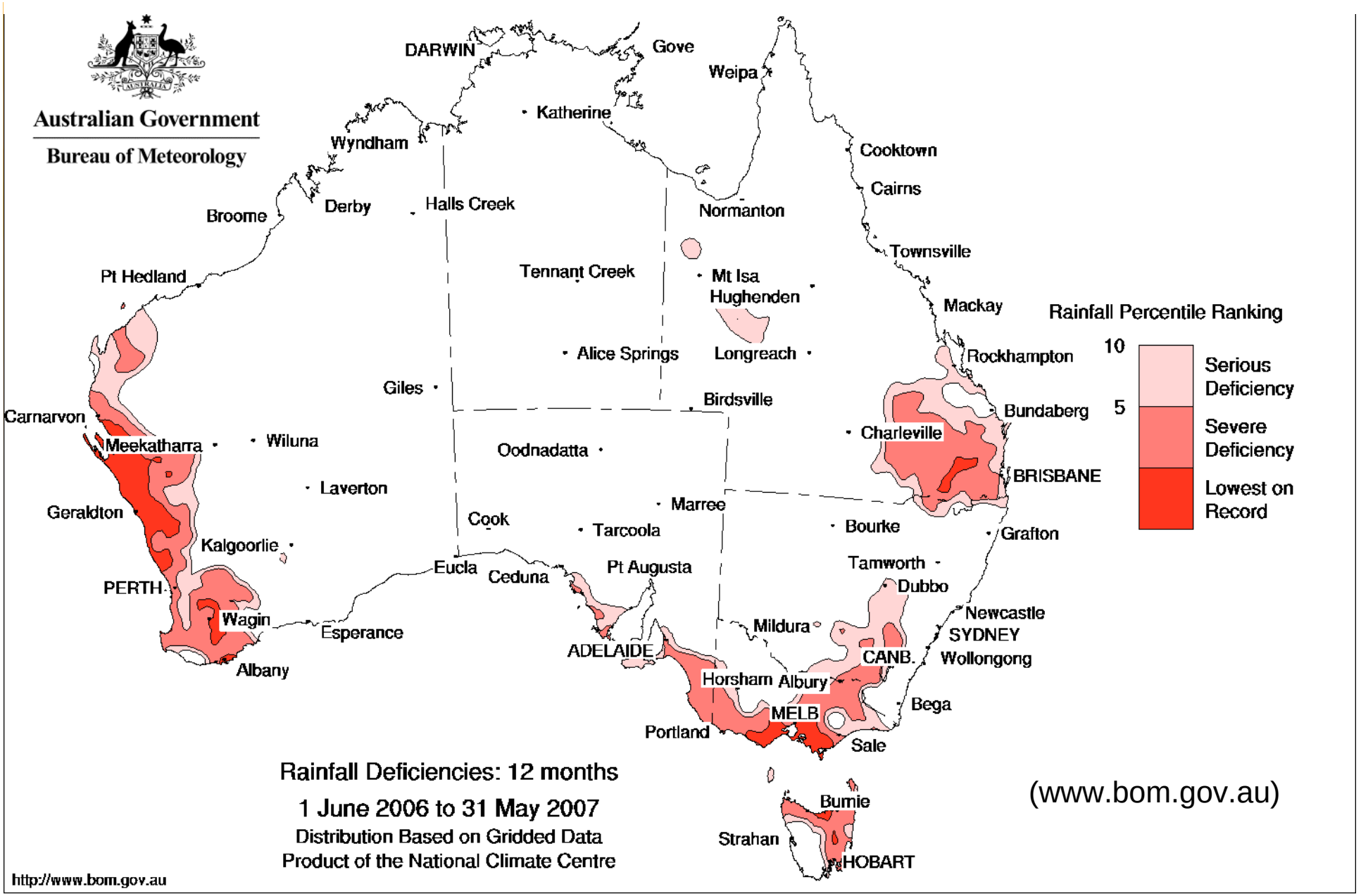

Hardware:	Manufactured objects (artifacts)
Software:	Knowledge required to design, manufacture, and use technology hardware
"Orgware":	Institutional settings and rules for the generation of technological knowledge and for the use of technologies

Technology's most important characteristic: ***Continuous change >>***

Characteristics of renewable energy

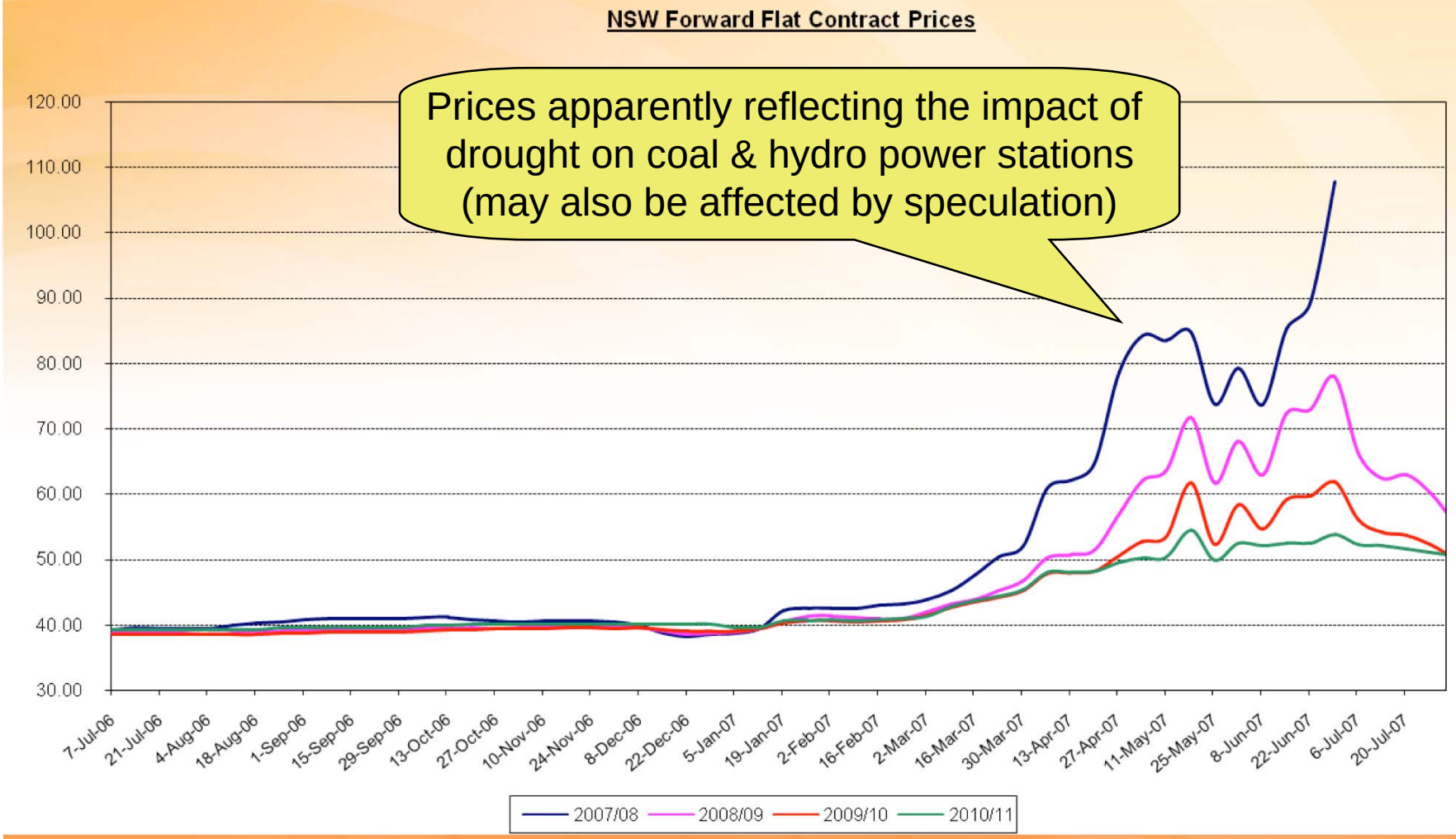
- Energy fluxes with limited storage:
  - Solar, wind, hydro, biomass, geothermal, ocean
- Characteristics of renewable energy forms:
  - Geographical distribution is a function resource type
  - Energy fluxes may be time-varying & uncertain
- Characteristics of renewable energy technologies:
  - Electricity generation, direct end-use or fuels
  - May have economies of scale

Drought & electricity gen'n (coal & hydro)



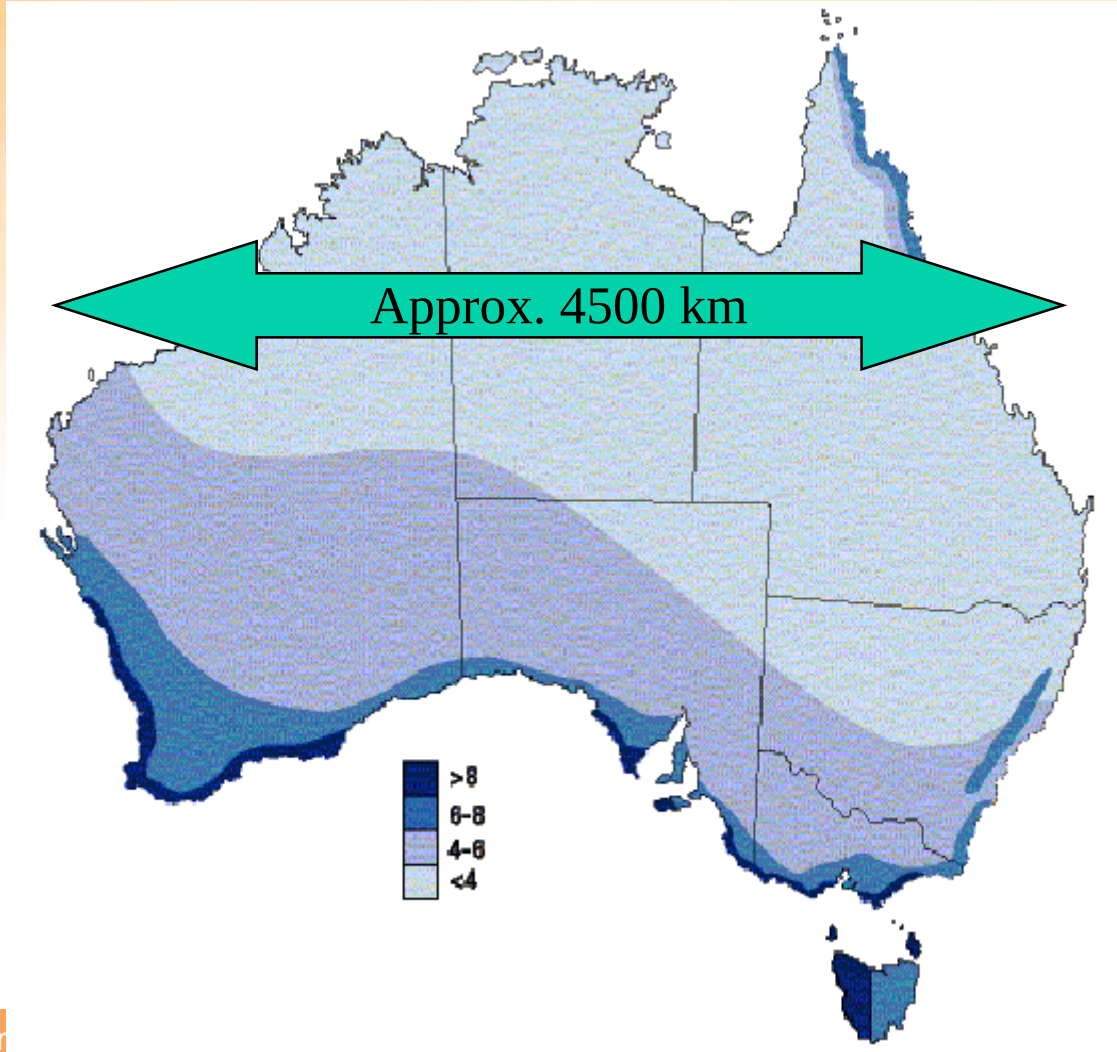
Issued: 01/06/2007

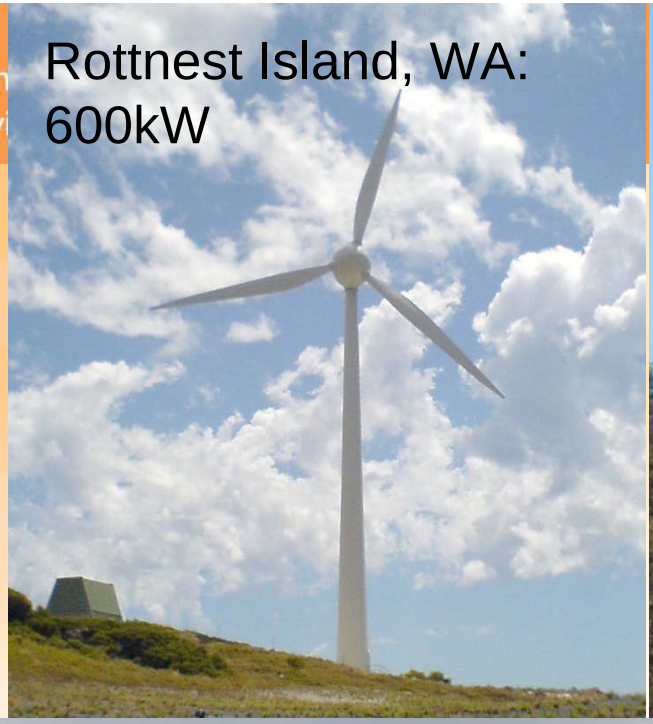
Flat annual CFD prices for NSW (NGF, 2007)



Australian wind resource

(Estimate of background wind (m/s) – Australian Greenhouse Office)





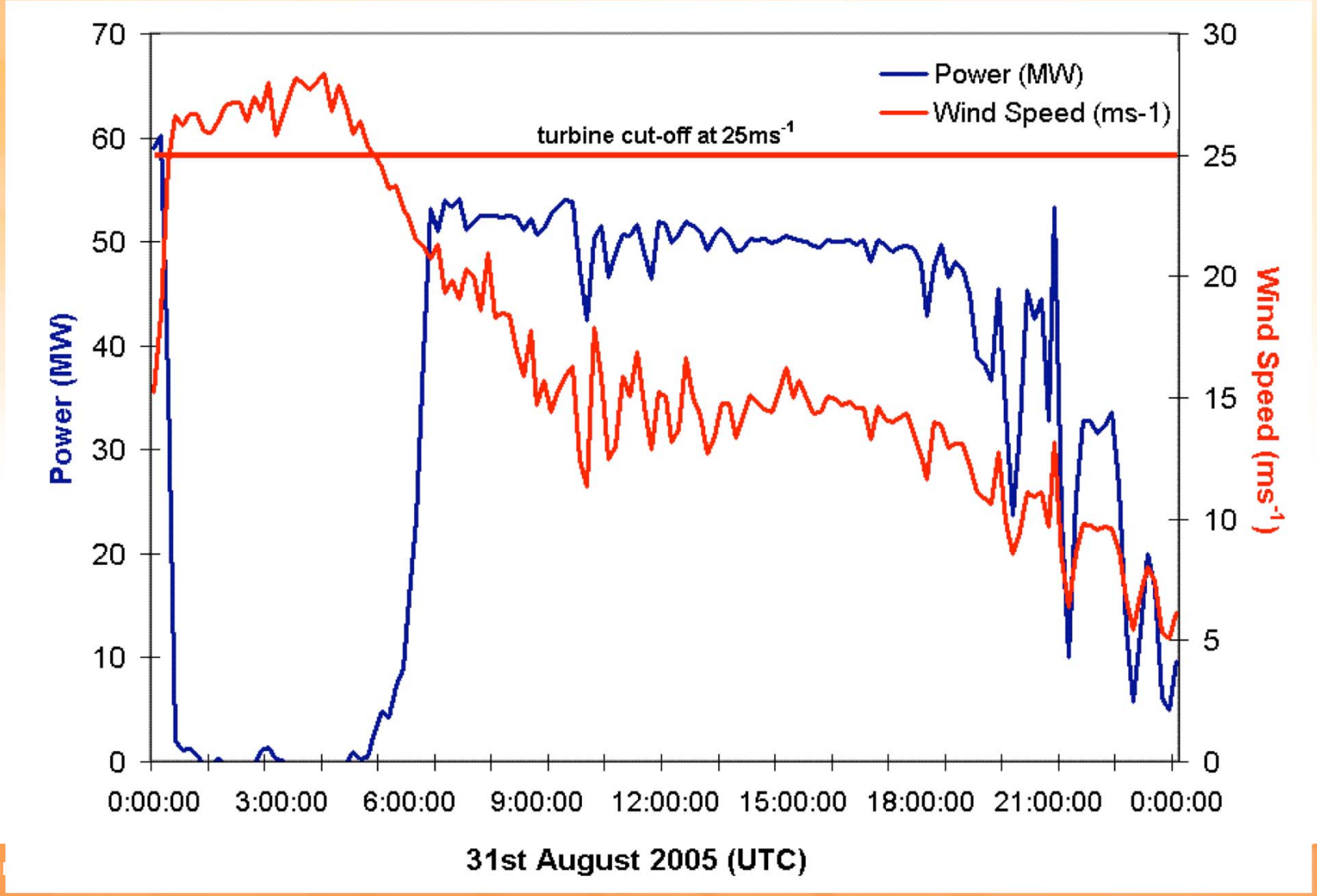
Rottnest Island, WA:
600kW

Emu Downs, Geraldton, WA:
80 MW, 48x1.65MW

Albany,WA: 22MW,
12x1.8MW

Alinta, Geraldton, WA:
90 MW, 55x1.65MW

Wind farm response to varying wind conditions



IDV65059

WIND CHANGE FORECAST CHART

ISSUED: 2100 on Thursday 22 April 2004

BUREAU OF METEOROLOGY - VICTORIAN REGIONAL OFFICE
P.O. Box 1636M Melbourne Vic 3001 http://www.bom.gov.au Severe Weather Ph: (03) 9669 4923

COMMENTS:

Northerly wind 15 to 30 km/hr ahead of front. West to southwesterly wind 15 to 25 km/hr west of front initially but wind gradually tending southwesterly and increasing 25 to 35 km/hr.

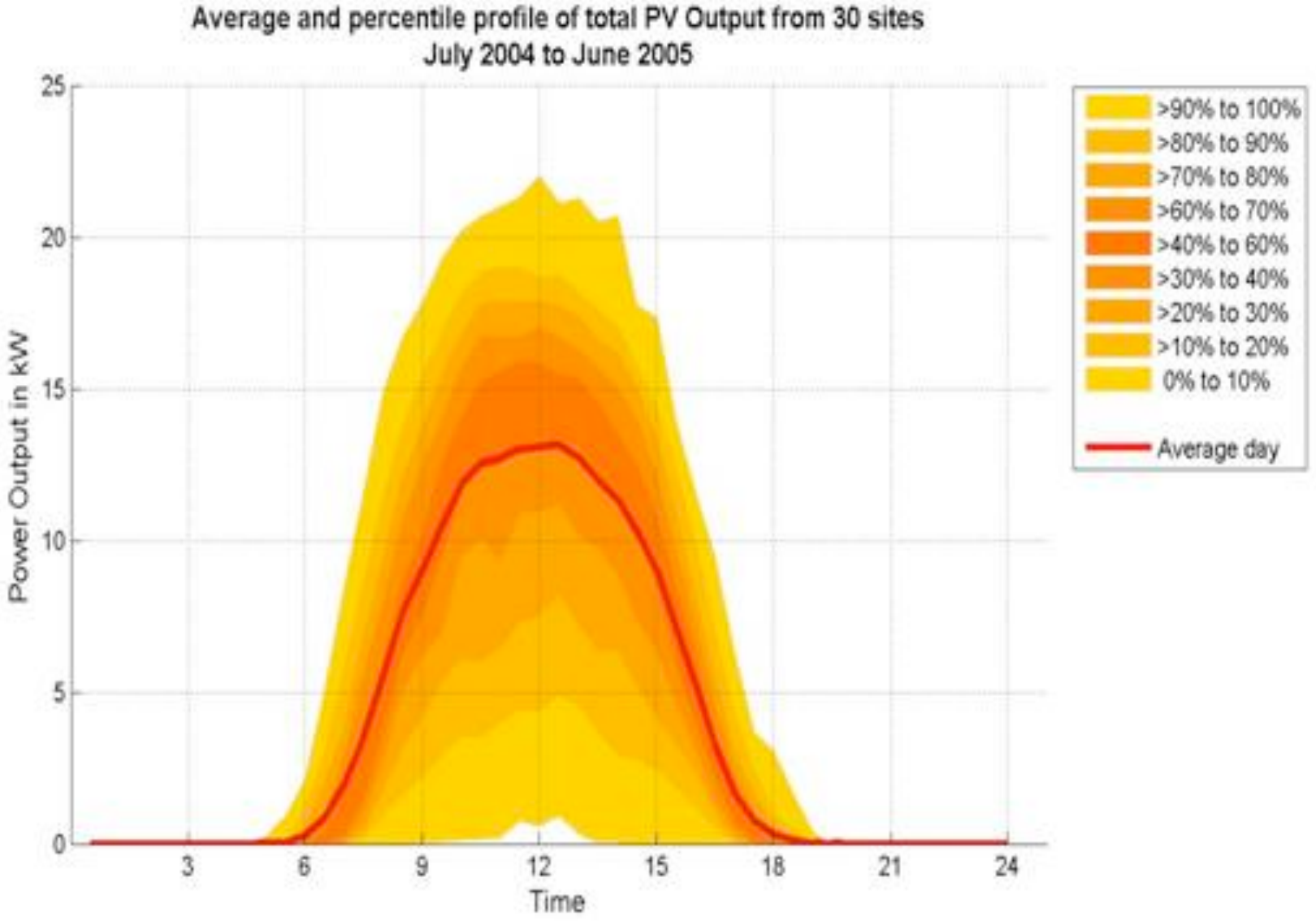
This approach may be valuable for predicting the timing of large changes in summated wind farm output

** Note: Timing of wind changes cannot be forecast with precision and positions are best estimates. **

PV Case Study for NSW Dept of Planning: Newington Solar Village (PV+SWH)

Photo: BP Solar

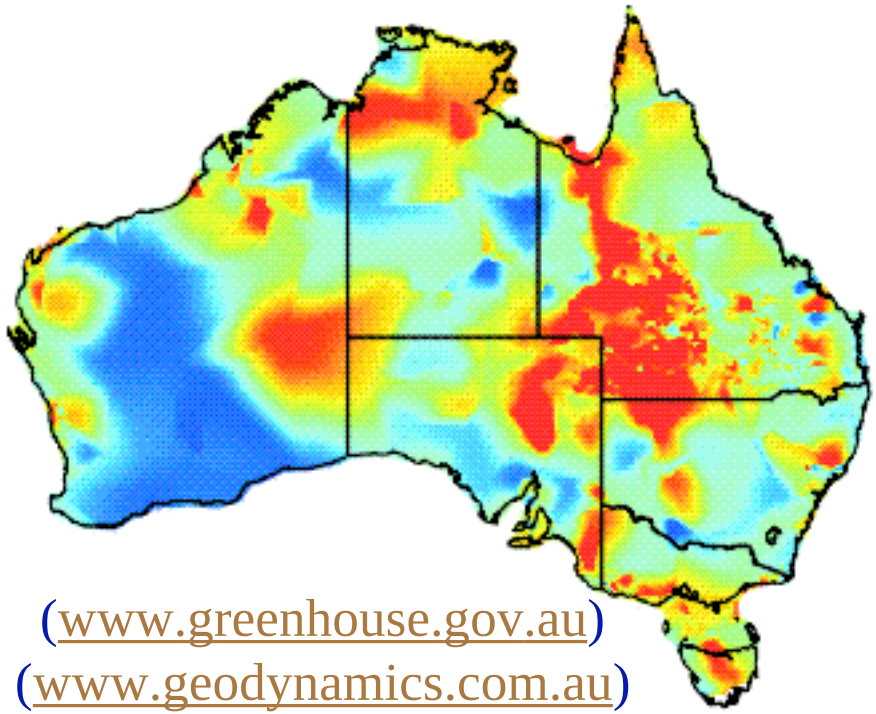
PV output variability (30 houses)



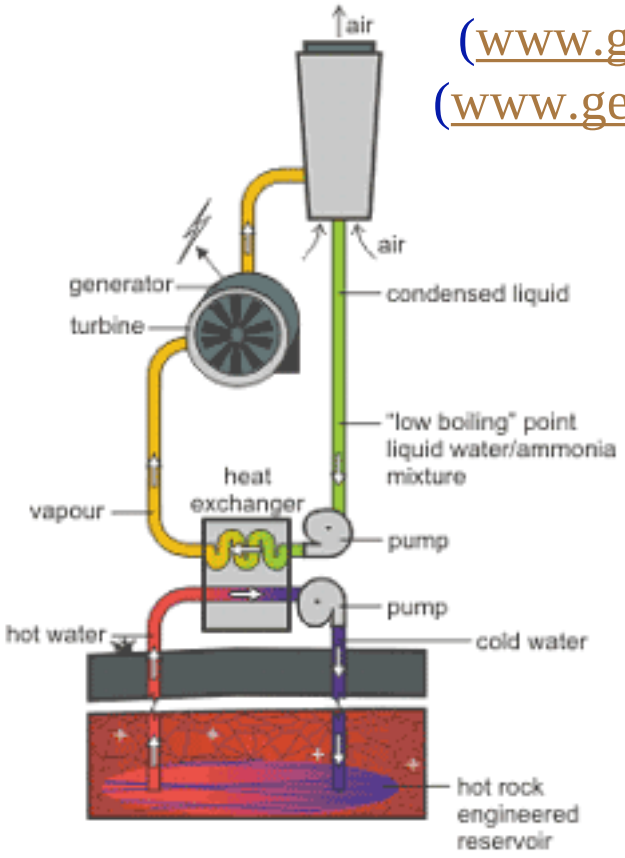
Geothermal energy - radioactive rock

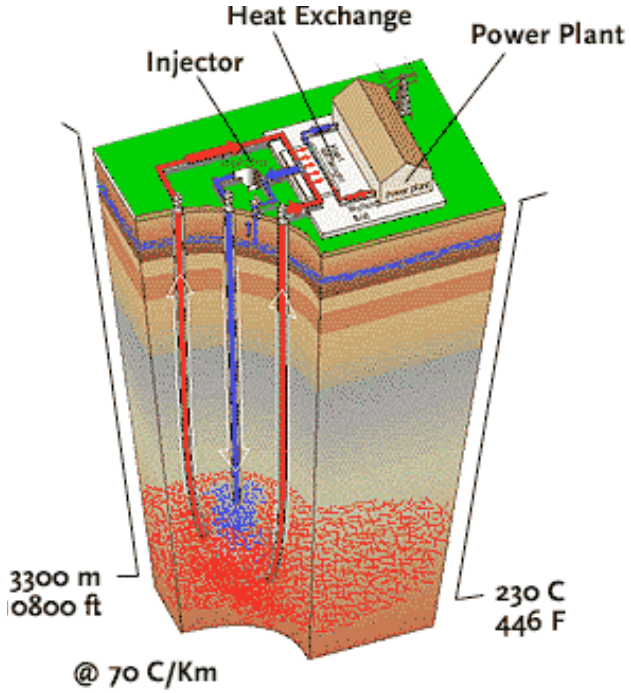
Australia has plentiful radioactive rock at ~3,000m covered by insulating layers:- *safe nuclear energy*

eg: Geodynamics trial at Cooper Basin, SA

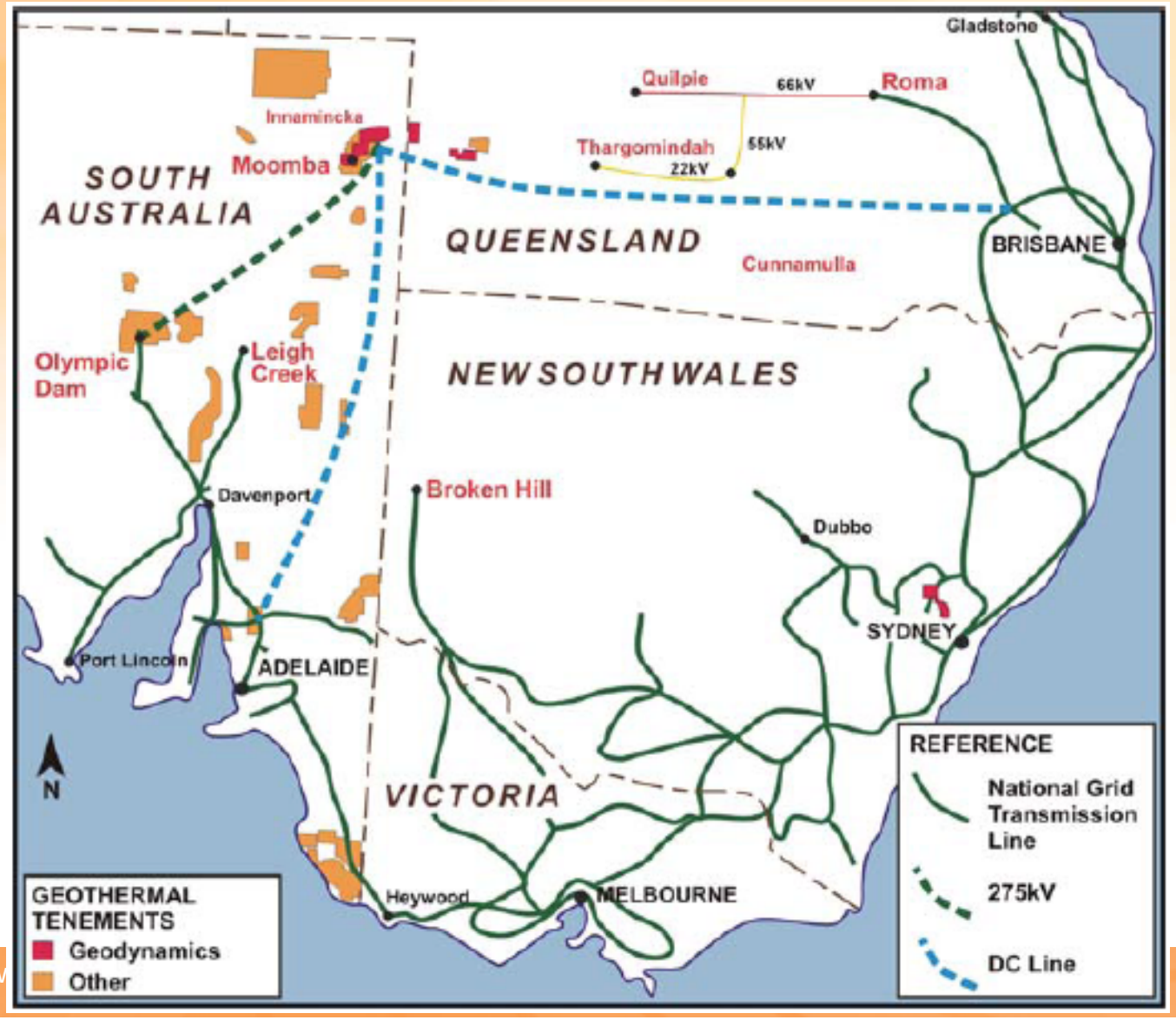


(www.greenhouse.gov.au)
(www.geodynamics.com.au)

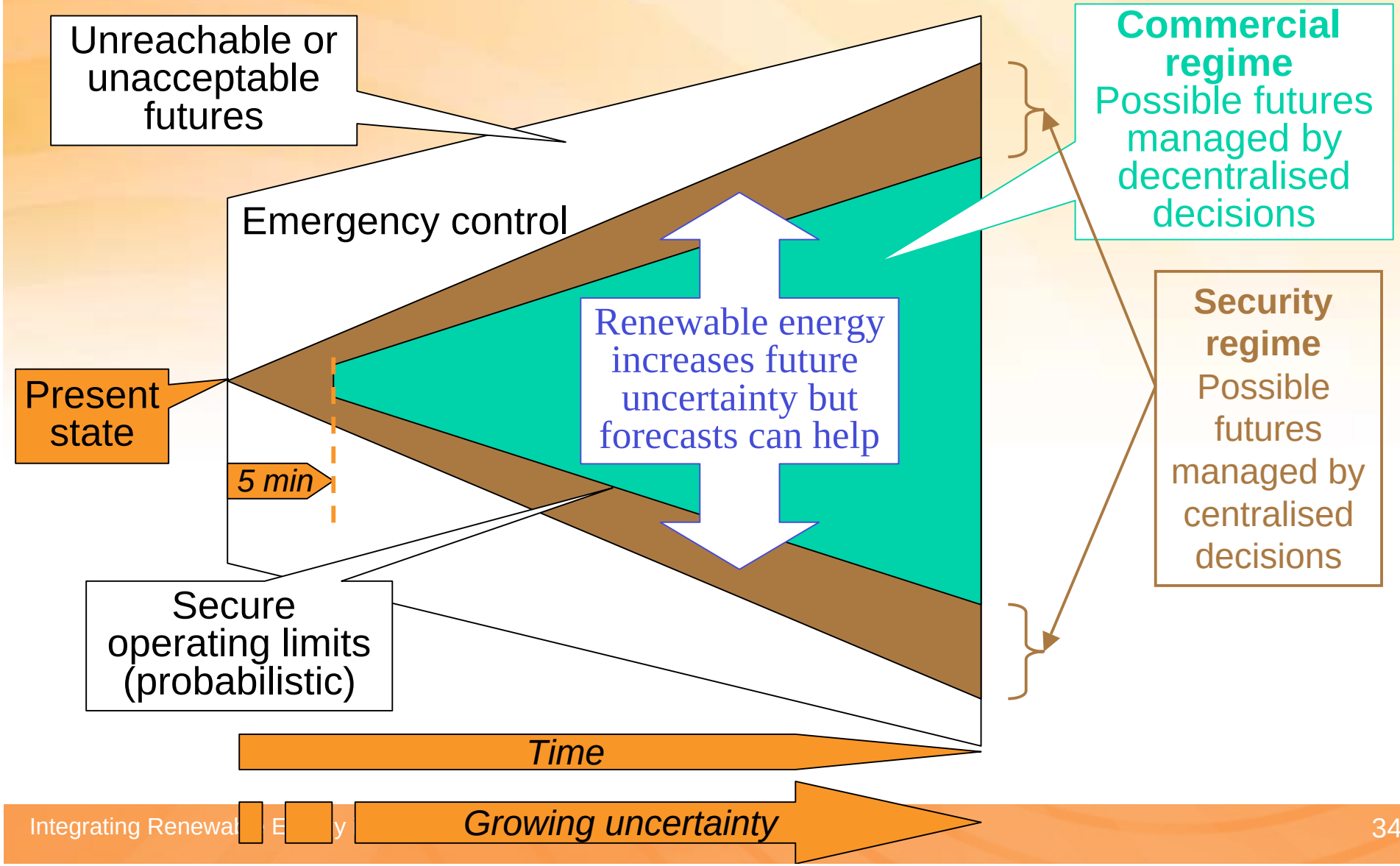




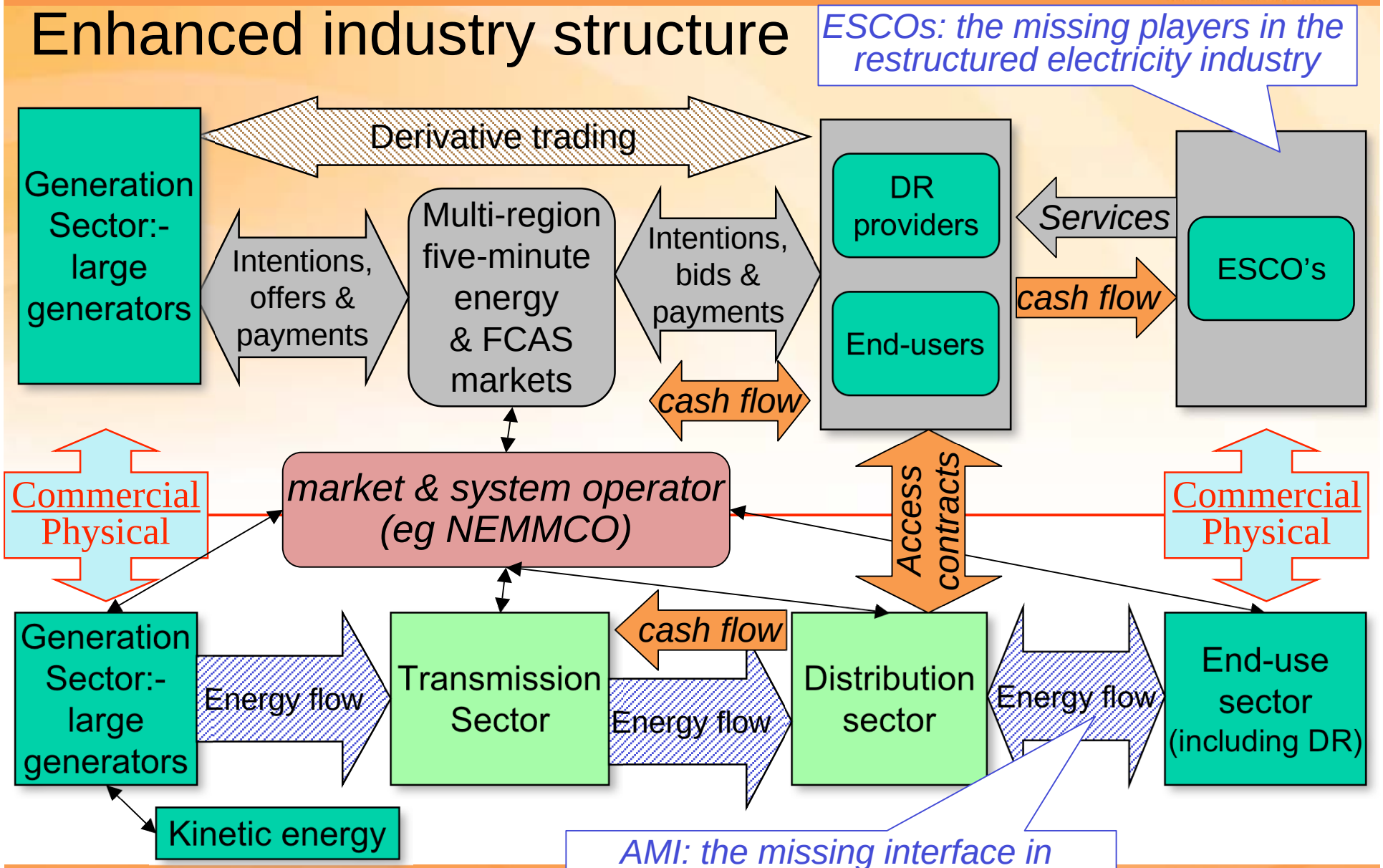
Geothermal energy - grid connection
(Geodynamics, 2006)



Security & commercial regimes (global & local)



Enhanced industry structure



Key electricity industry issues for high-penetration renewable energy #1

- Structural issues:
  - Robust security regime with security-constrained dispatch
  - Efficient commercial regime (operation & investment)
  - Effective regulation of network services
  - Compatible arrangements for gas industry
- Development issues:
  - Innovation in renewable energy technologies
  - Forecasting for security & commercial regimes
  - Active end-user participation (value, timing, efficiency)
  - Education & training in all relevant areas

Key electricity industry issues for high-penetration renewable energy #2

- Auction-style, security-constrained markets:
  - For spot energy, ancillary services & derivatives
  - Active end-users supported by ESCOs & equity policies
- Efficient network service regime:
  - Augmentation; availability & quality; distributed resources
- Renewable energy forecasting tools for:
  - Security, commercial & governance regimes
- Internalisation of un-costed fossil fuel externalities:
  - Carbon taxes
  - Development & deployment of low emission technologies

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