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Electricity industry restructuring overview:
economic, commercial & regulatory perspectives

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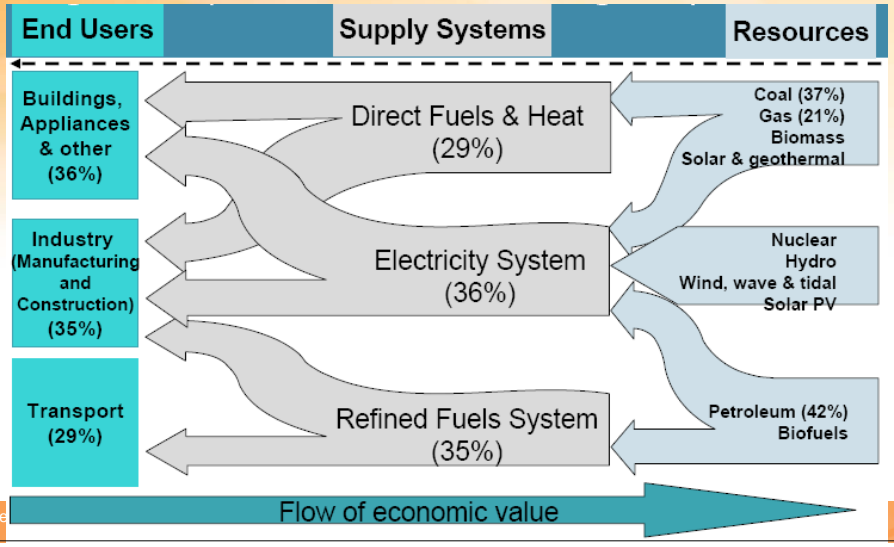
The energy 'socio-technical' system
(physical outcomes of human decisions) (Grubb, 2006)



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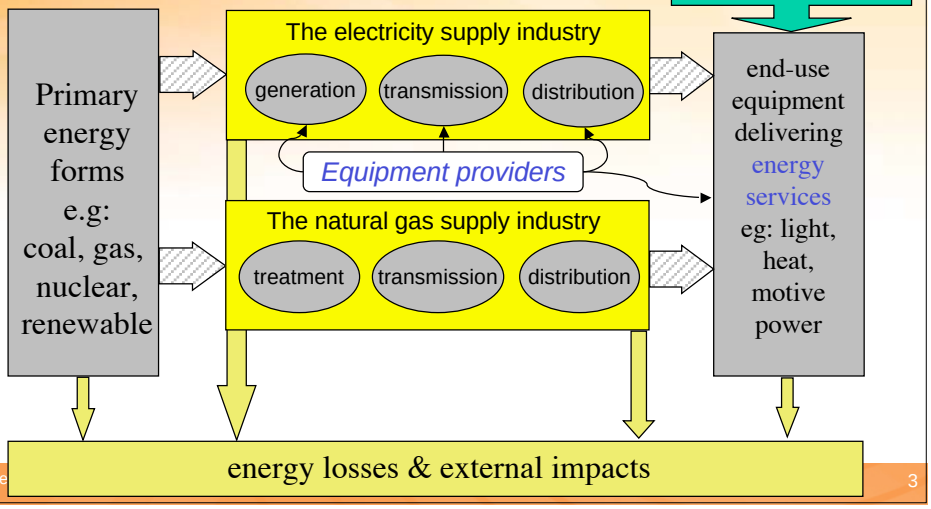
Energy service delivery in the stationary energy sector
(many decision-makers involved)



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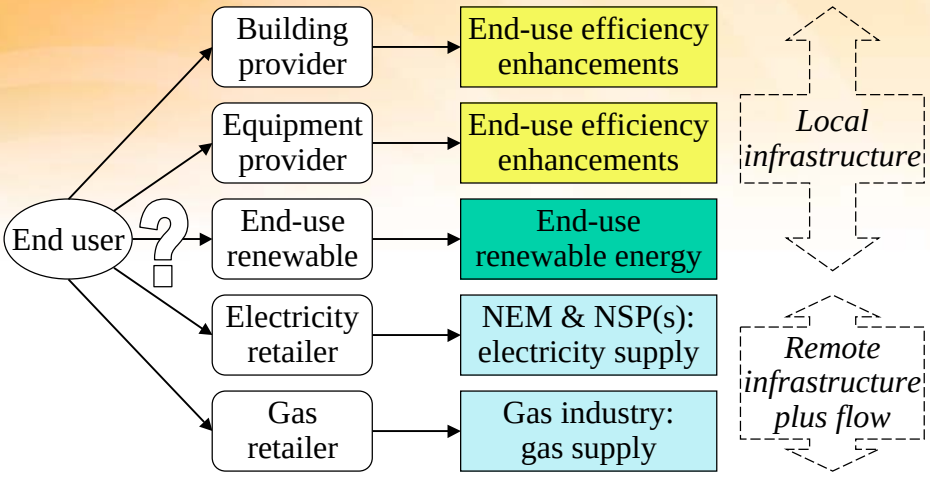
Ideal decision making in the stationary energy sector: *led by the end-user*



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Comparison of car & electricity industries

Cars

- Can be touched seen, & stored, last for years
- Status can be an important issue
- Buyer choice promotes competition:
  - Each consumer can buy a specific car
  - Each manufacturer can control product quality
- Spatial separation of buyer & seller not a serious issue

Bilateral trade works well:

- *Can use normal commercial framework*

Electricity

- Intermediate energy form:- invisible, ephemeral, fungible - a *flow* industry
- An end-user receives a mixed flow of energy from all power stations:
  - An end-user can't choose a power station
  - A power station can't control quality of delivered energy at another location
  - Status derived from end-use applications NOT energy
- Location matters because of network losses & constraints - the key issue is:
  - *Continuity & quality of flow of electrical energy arriving at end-use equipment*

Bilateral trade does NOT work well:

- *Must design & implement an industry framework that works for electricity*

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Infrastructure industries

- A definition of infrastructure:
  - Essential elements forming the basis of a system
- Examples of infrastructure industries:
  - Communications, electricity, gas, water, transport
  - Provide inputs to products or services
  - Often capital intensive with long investment lead times & asset lives
- An infrastructure industry is essential (to a product or service) if:
  - A particular product/service can't be made without it
  - No alternative product/service can be made without it

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"Natural monopoly" industries

- Definition:
  - Most efficient if production undertaken by a single firm to meet demand when price=SRMC
    - Always true for "increasing returns to scale", ie average cost decreases as production increases
- Some infrastructure industries may be both essential & natural monopolies, eg:
  - Electricity transmission and/or distribution networks
- However, electricity generation & end-use are not natural monopolies

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Traditional models for infrastructure industries: *centralised decision-making*

- Britain, Australia, etc:
  - Statutory authorities supervised by a Minister:
    - Usually vertically integrated monopolies
  - Decision making political, "behind closed doors":
    - Politicians negotiate tradeoffs
- USA (in some cases):
  - Regulated private monopolies
  - Politically appointed regulatory boards
  - Formal public hearings

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Five perspectives on accountability of an agency (Hodge et al, 2004, p 200)

Parliamentary control	Accountable to a Minister
Managerialism	External control strategic rather than detailed
Judicial & quasi-judicial review	Formal, reviewable decision-making
Constituency relationships	Public hearings; advisory bodies; ombudsmen
Market processes	Requires meaningful consumer choice

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Electricity industry restructuring objective: *decentralised decision making*

- Improve economic efficiency by facilitating competition & new entry, which assumes:
  - Effective markets & sound legal & policy frameworks
- Enhance accountability to end-users & society through 'customer choice', which assumes:
  - End-users become active participants in the industry
  - End-users are independent agents who make "informed" decisions & efficiently manage the associated risks:
- Implement a market-based approach to social & environmental externalities:
  - Assumes political will to regulate non-monetary impacts
- Release government funds by asset sales:
  - Creates a moral hazard for politicians

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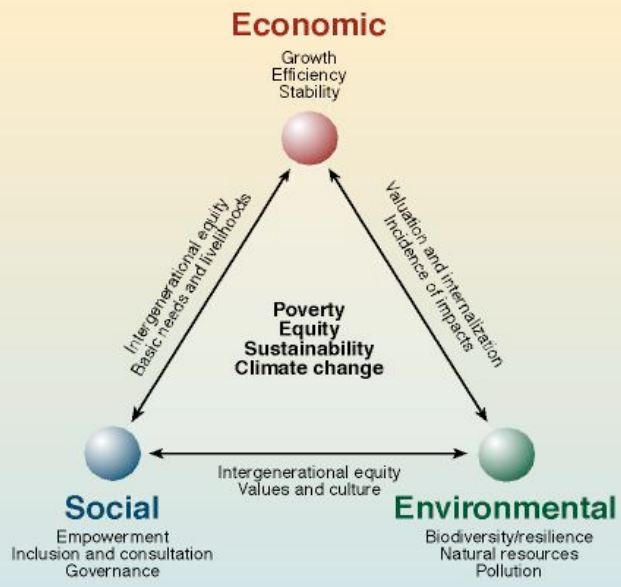
Key elements of sustainable development and interconnections

The broader context of sustainability that electricity industry restructuring should address
(IPCC COP7)

Engineering criteria must also be met: availability & quality of supply



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Economic efficiency objectives

- Allocative efficiency:
  - Appropriate choice between goods & services:
    - For example, electricity versus gas
- Technical or productive efficiency:
  - Cheapest method to produce a good or service:
    - Best available technology & work practices
- Dynamic efficiency (crucial in electricity industry):
  - Support innovation & response to change:
    - R&D & technological change
    - Environmental impacts, social expectations, etc.
  - Efficiently manage both short- & long-term risks

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Other drivers for change in infrastructure industries

- Improving theoretical understanding:
  - Imperfect regulation versus imperfect markets
  - A theory of electricity spot pricing from 1979
- Evolving political context in western world:
  - Emphasis on individual choice/accountability
- Challenging conditions for central planning:
  - Slow & uncertain growth in demand
  - Technological progress creating new options:
    - Eg metering, communications & demand-side options
  - Growing climate change concerns

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Microeconomic reform

- *Objective* - to improve economic efficiency
  - Particularly challenging for infrastructure:
    - Potential for natural monopolies in essential goods & services
- *Means* - reduce barriers to competition, eg:
  - Remove monopoly franchises & introduce competition
  - Break-up large state-owned enterprises
  - Privatise state-owned enterprises
  - Improve strategies for industry regulation
- *Assumptions:*
  - The key public interest issue is economic efficiency
  - The best mechanism is competition
  - Participants act as profit-maximising economic agents
  - Sound legal framework in which restructuring can occur

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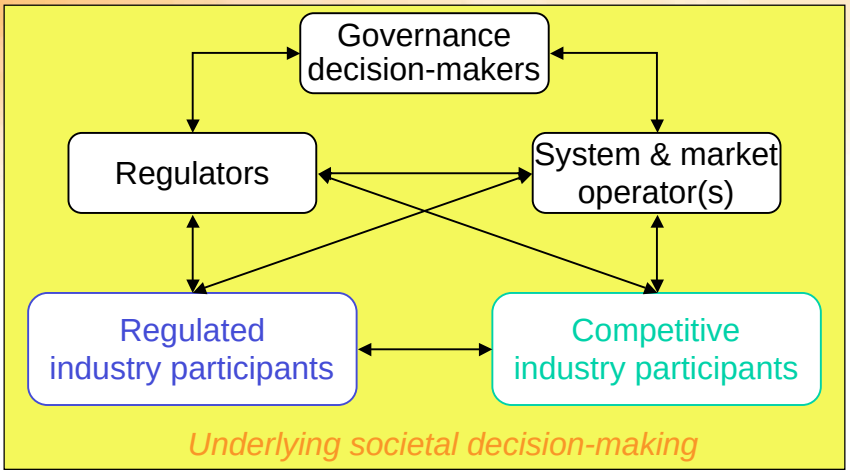
Decision-making framework for a restructured electricity industry



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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	▪ 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

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Comparison of decision-making styles

- Engineering decision making *(security & technical regimes):*
  - Assumes participants act in "good faith"
  - Data is best estimate of actual phenomena
  - Decision-making criterion is the "public good"
- Commercial decision-making *(commercial regime, governance regime?):*
  - Assumes participants act to maximise their own outcomes
  - Data is probably biased towards their self interest
  - Decision-making criterion is the "private good"

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The role of markets in decision making

- A market is a form of coordinated decentralised decision making:
  - Participants aim to maximise their commercial outcomes
  - Require well-specified tradeable goods or services & cause participants to "reveal their preferences"
- Electricity industries need formal market design:
  - Difficult to define tradeable goods/services due to special characteristics of electricity & hence difficult to achieve clear contractual obligations
  - Difficult to achieve adequate levels of competition:
    - Potential for market power in primary energy &/or generation
    - Yet to achieve active end-user participation

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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 (commercial) risk allocation to:
  - Generators, retailers & end-users
  - Need unambiguous contractual obligations for all participants
- *Difficulties arise because decisions & risks interact:*
  - *Difficult to make decision-makers accountable for their decisions*

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Evolution of competition policy in Australia

- Development of COAG process in late 80's
  - Formal interface between federal & state governments may foster rational policy development
- National Competition Policy,1993 Hilmer Rpt:
  - Facilitate competition where effective & pro-competitive regulation where not
  - Treat public & private firms equally
  - Apply universal & uniform market rules of conduct
    - Specific codes only if shown to be in the public interest
  - Develop access regimes for essential facilities

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Evolution of competition policy in Australia: Competition Reform Act, 1995

- Amended Trade Practices Act, encompassed Prices Surveillance Act
- Established Australian Competition & Consumer Commission (ACCC):
  - Neutral, economy-wide, open process
  - Decisions can be appealed to Aust.Competition Tribunal
- Implements the principles of competition policy
  - Assumes primary public interest is in economic efficiency and other objectives are secondary
  - Assumes civil society, equity, etc.

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The electricity industry restructuring process

Issue	Transition	Key challenges
Industry structure	*From* monopoly *To* competing firms *Plus* system operator(s)	Cultural change; Adequate competition; legal framework *Accountability*
Commercial framework	*From* cost recovery *To* market prices	Market power; legal framework Market design fidelity; *Accountability*
Industry regulation	*From* Rate of Return *To* Incentive Regulation	Multiple objectives; Measuring outcomes; *Accountability*
Sustainability	*From* direct cost *To* full costs	Variable RE energy flows End-user participation; *Accountability*

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Key issues in the design of a fully restructured electricity industry

- Particular characteristics of electrical energy:
  - A *flow* industry with short-term uncertainty in, & shared responsibility for, location-specific *availability & quality*
- Inherent market incompleteness & inefficiency:
  - Temporal & locational averaging; important externalities
  - Imbalance between large & small participants; gaming
  - Long-term risks due to asset longevity & capital intensity
  - Large environmental externalities
- Inevitable residual *centralised decision making* by:
  - Policy makers, Regulators, System operators, Network Service Providers
- Unavoidable interaction between:
  - Cooperative (*centralised*) decision making and
  - Competitive (*decentralised*) decision making

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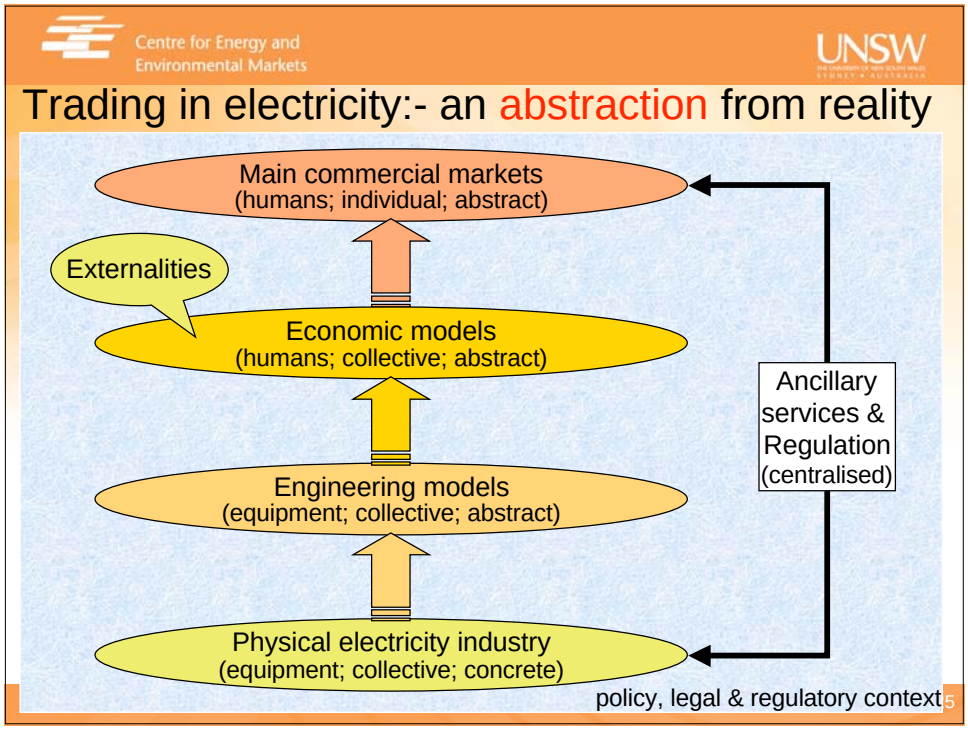
Models of the electricity industry

- Physical reality, e.g. for electricity:
  - Instantaneous voltages, currents & power flows
- Engineering models (a typical example):
  - Balanced 3 phase sinusoidal voltages & currents
- Main commercial models (typical examples):
  - Spot & forward markets; network access regime:
    - *Designed to elicit economically efficient behaviour*
- Ancillary services to manage mismatches:
  - Between main commercial models & physical reality
- Policy & regulatory framework for the industry:
  - Societal objectives & behavioural norms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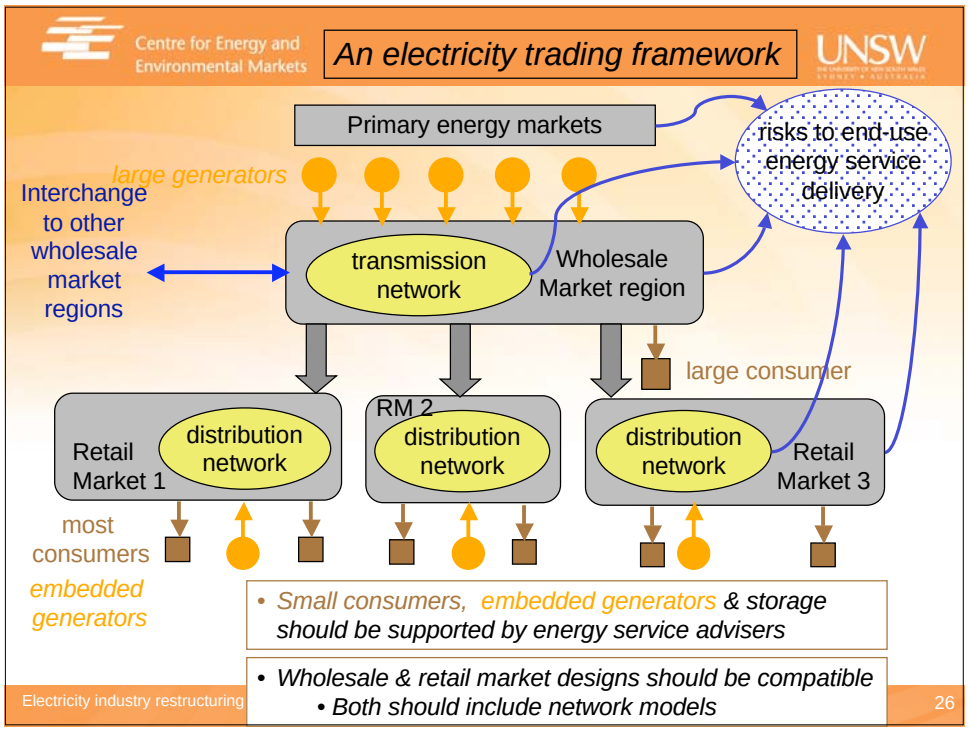
Trading in electricity:- an abstraction from reality
Main commercial markets
(humans; individual; abstract)
Externalities
Economic models
(humans; collective; abstract)
Engineering models
(equipment; collective; abstract)
Physical electricity industry
(equipment; collective; concrete)
Ancillary services & Regulation
(centralised)
policy, legal & regulatory context
5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An electricity trading framework
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Primary energy markets
risks to end-use energy service delivery
large generators
Interchange to other wholesale market regions
transmission network
Wholesale Market region
large consumer
Retail Market 1
distribution network
RM 2
distribution network
distribution network
Retail Market 3
most consumers
embedded generators
• Small consumers, embedded generators & storage should be supported by energy service advisers
• Wholesale & retail market designs should be compatible
• Both should include network models
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Advanced Metering Infrastructure (AMI)

- Metering:
  - Interval metering should be provided for all participants:
    - Record energy flow level (30 minute energy), quality & availability
    - Provide data read-out for participant & market operator
  - Profiling could be used to calculate default CFD volumes
- Communication between market/system operator, participants & network service providers:
  - Locational spot prices for 30-minute average energy flow & for network access
  - Participant 30-min. ave. P, Q, V, availability
  - Feeder P&Q flows & voltage profiles (for quality & security management & price setting)

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Some insights from electricity pricing theory #1: temporal issues in pricing

- A single owner of an electricity industry:
  - Could maximise Industry Benefits of Trade (IBOT):
    - if *all* supply costs *& all demand side benefits* were known
- Optimal prices in a decentralised industry:
  - That set of prices that achieves the same IBOT:
    - The incremental cost *or loss of benefit* of delivering an additional flow of energy *at a particular location at a particular time*
  - Similar to usual SRMC definition if no inter-temporal links:
    - Location-specific; time-specific; may be set by loss of benefit (value)
  - Otherwise a set of prices that reflect *future decision options*:
    - Based on best available model of future price behaviour, *including impacts of a specific decision on future prices*

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Some insights from electricity pricing theory #2: spatial issues in pricing

- A single owner of an electricity industry:
  - Could maximise IBOT taking into account:
    - Network losses & flow constraints
    - Security: probability & consequence of outages
- Optimal pricing policy in a decentralised industry:
  - Location-specific & time-specific spot prices based on:
    - Local supply/demand balance
    - Network arbitrage subject to losses & flow constraints
  - Location- & time-specific derivative prices based on:
    - Plausible scenarios of future generation & demand
    - Plausible scenarios of future network losses & flow constraints
    - Plausible effects of future decisions

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Single owner (centralised decisions): *An engineering optimisation problem*

- Given:
  - An inventory of existing & potential future generation, network & demand side electrical equipment:
  - Technical parameters, operating & capital costs, industry benefits, operating constraints
  - Uncertainties in performance, costs & benefits
  - Ability to control all generation, network & end-use equipment
- Calculate a strategy to maximise IBOT:
  - Solve a stochastic non-linear dynamic optimisation problem for operating & investment decisions in generation, network and demand side equipment

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Many owners (decentralised decisions): *An economic optimisation problem*

- A set of location-specific spot markets:
  - Each in energy flow (that meets QOS criteria) at local spot price in successive short spot market intervals
- A set of location-specific derivative markets:
  - Related to future spot price expectations at that location:
    - Predict aspects of future spot market behaviour
    - Permit reallocation of risks
- A set of often location-specific ancillary services:
  - Resources that maintain availability & quality of supply:
    - Some systemic, some location-specific
- Regulatory monitoring of strategic behaviour

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Electricity market models

- Gross pool (eg NEM):
  - All “physical” energy flow arranged in (nodal) spot market
  - Temporal & location risk managed jointly:
    - Ancillary services, spot & derivative markets,
    - PASA, SOO, ANTS
- Net pool (eg UK NETA):
  - Long term & location risk managed bilaterally:
    - Network not modelled in trading arrangements
    - Resource adequacy managed partly as a bilateral issue
  - Imbalance flow traded in “balancing market”
  - Short-term operational risk managed collectively:
    - System operator typically given 1 day’s notice of bilateral trades

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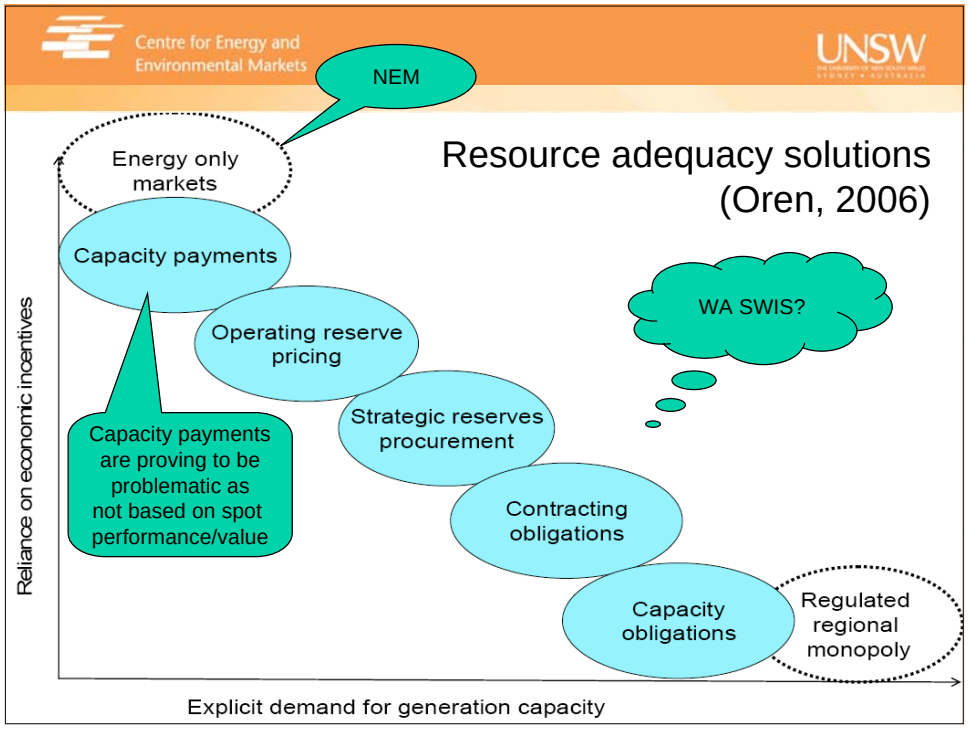
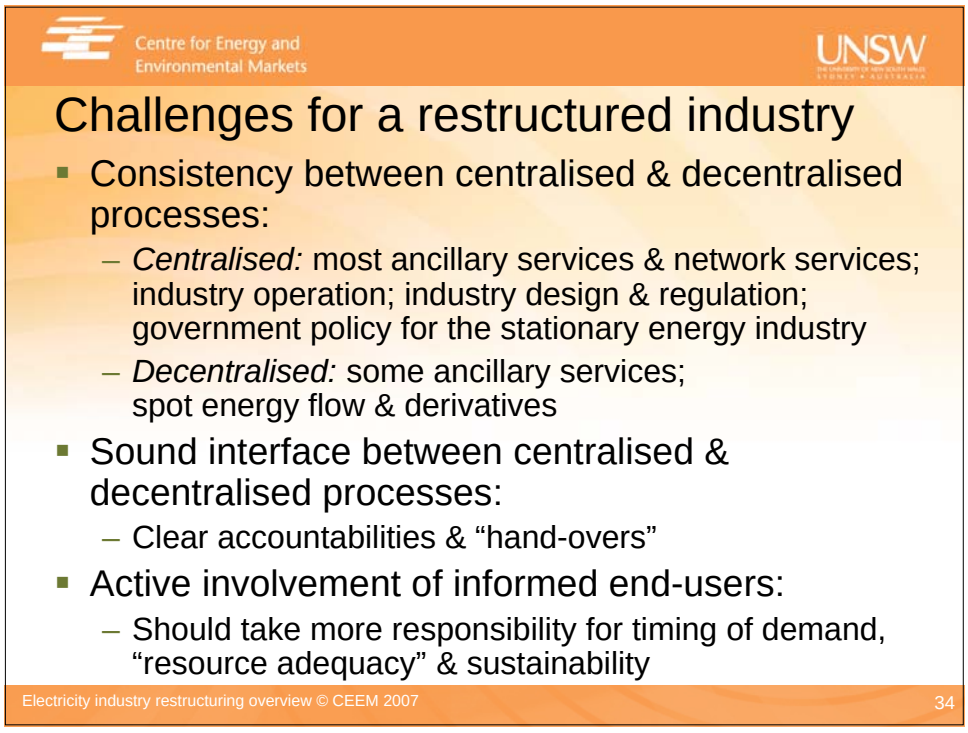


Resource adequacy solutions (Oren, 2006)



Challenges for a restructured industry

- Consistency between centralised & decentralised processes:
  - *Centralised:* most ancillary services & network services; industry operation; industry design & regulation; government policy for the stationary energy industry
  - *Decentralised:* some ancillary services; spot energy flow & derivatives
- Sound interface between centralised & decentralised processes:
  - Clear accountabilities & “hand-overs”
- Active involvement of informed end-users:
  - Should take more responsibility for timing of demand, “resource adequacy” & sustainability

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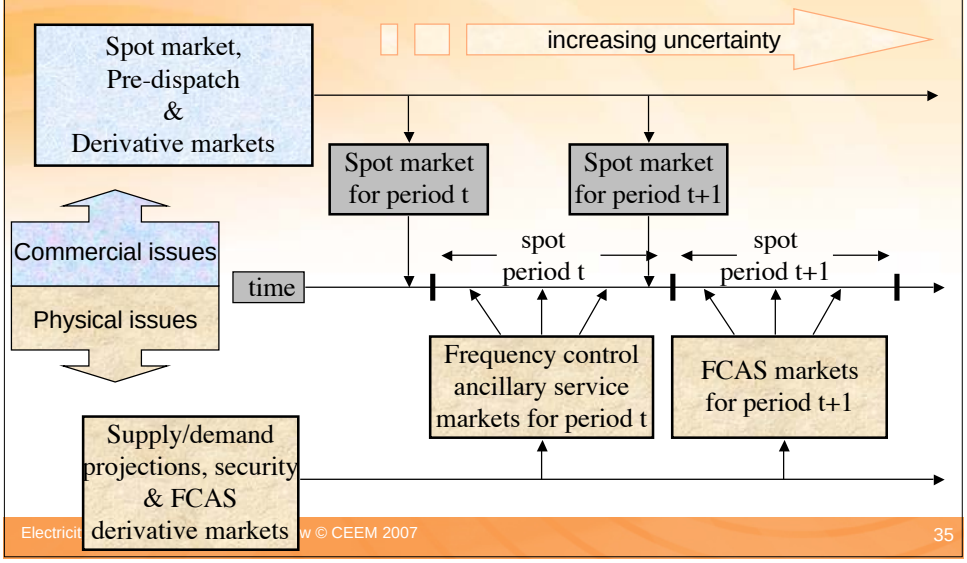
Managing supply-demand balance in NEM



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Uncertainty & risk in electricity trading

Time scale	Issues	Mechanisms
< 30 minutes	▪ Uncertain energy flow ▪ Contingencies	▪ Ancillary services *(frequency & voltage)*
30 minutes to several days	▪ Uncertain energy flow ▪ Inter-temporal links, eg. *unit commitment*	▪ Ex-ante spot market ▪ Short-term derivatives ▪ Security constraints
Weeks to years: *operation*	▪ Inter-temporal links, eg. fuel, maintenance	▪ Long-term derivatives ▪ Security management
Years to decades: *investment*	▪ Resource mix ▪ Externalities ▪ Policy uncertainty	▪ Long-term derivatives ▪ Security management ▪ Policy settings

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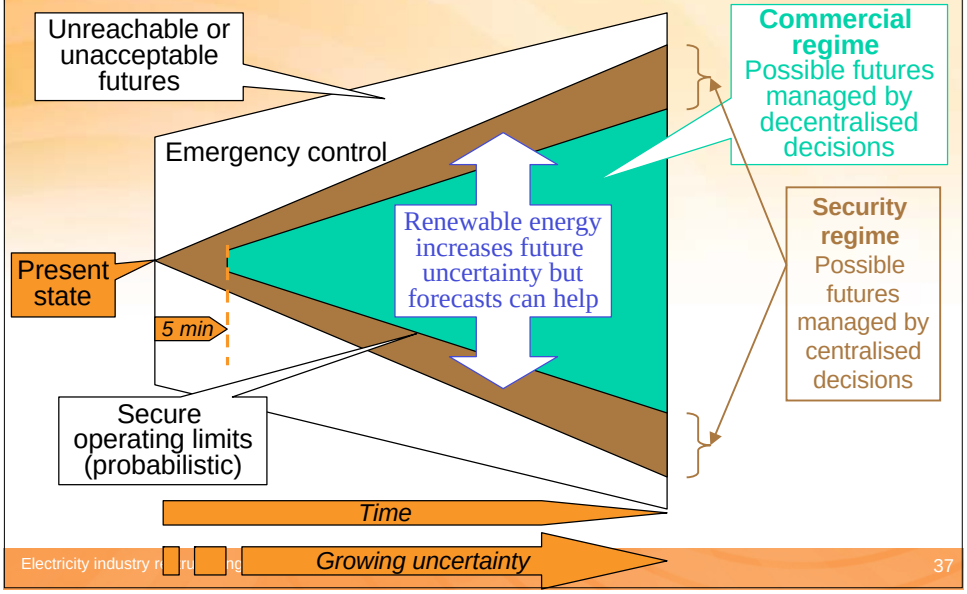
Security & commercial regimes (global & local)



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Ideal spot market trading of energy flow

- Use shortest spot market interval consistent with commercial decision making, e.g:
  - Half-hour trading intervals
- Specify locations at which trading occurs:
  - Use multiple locations to partly incorporate network losses & flow constraints
- Active generator & end-user participation:
  - Symmetrical bidding & market clearing price:
    - Express willingness to operate at a certain flow level
    - Demand & supply side options fully equivalent
  - Allow participants to express voltage quality preferences:
    - Minimise reliance on technical ancillary services

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Possible implementation

- Ancillary service, spot energy & derivative markets:
  - Generators, end-users, network service providers
  - Retailers become agents for small end-users
- Regulated network services:
  - Network access contracts:
    - Spot & derivative tariff structure with default derivative contracts for small end-users

Enhanced NEM structure with active end-user participation

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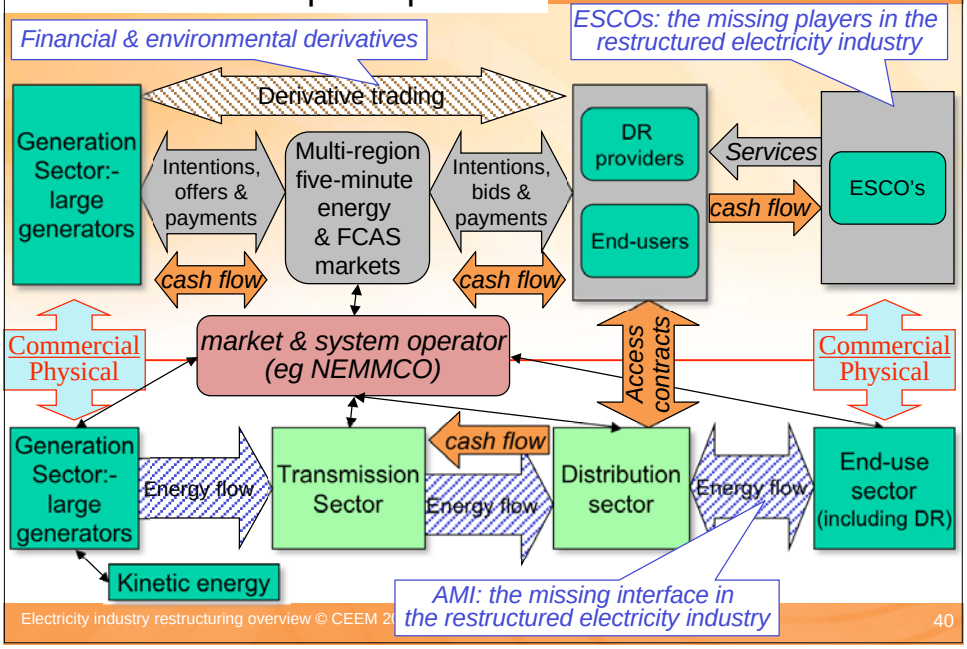

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Conclusions on electricity industry restructuring

- A "designer" process:
  - Industry-specific laws, codes, markets
  - A "social experiment" with risks & ethical issues
- Mix of technical, economic & policy issues:
  - Physical behaviour is continuous & cooperative
  - Commercial behaviour is individual & competitive
  - Hard to achieve a sound balance between the two
- Restructuring is still a learning situation:
  - Must solve commercial, technical, legal, regulatory & institutional challenges (each aspect must function well)
  - Potential to extend competition to most network services

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