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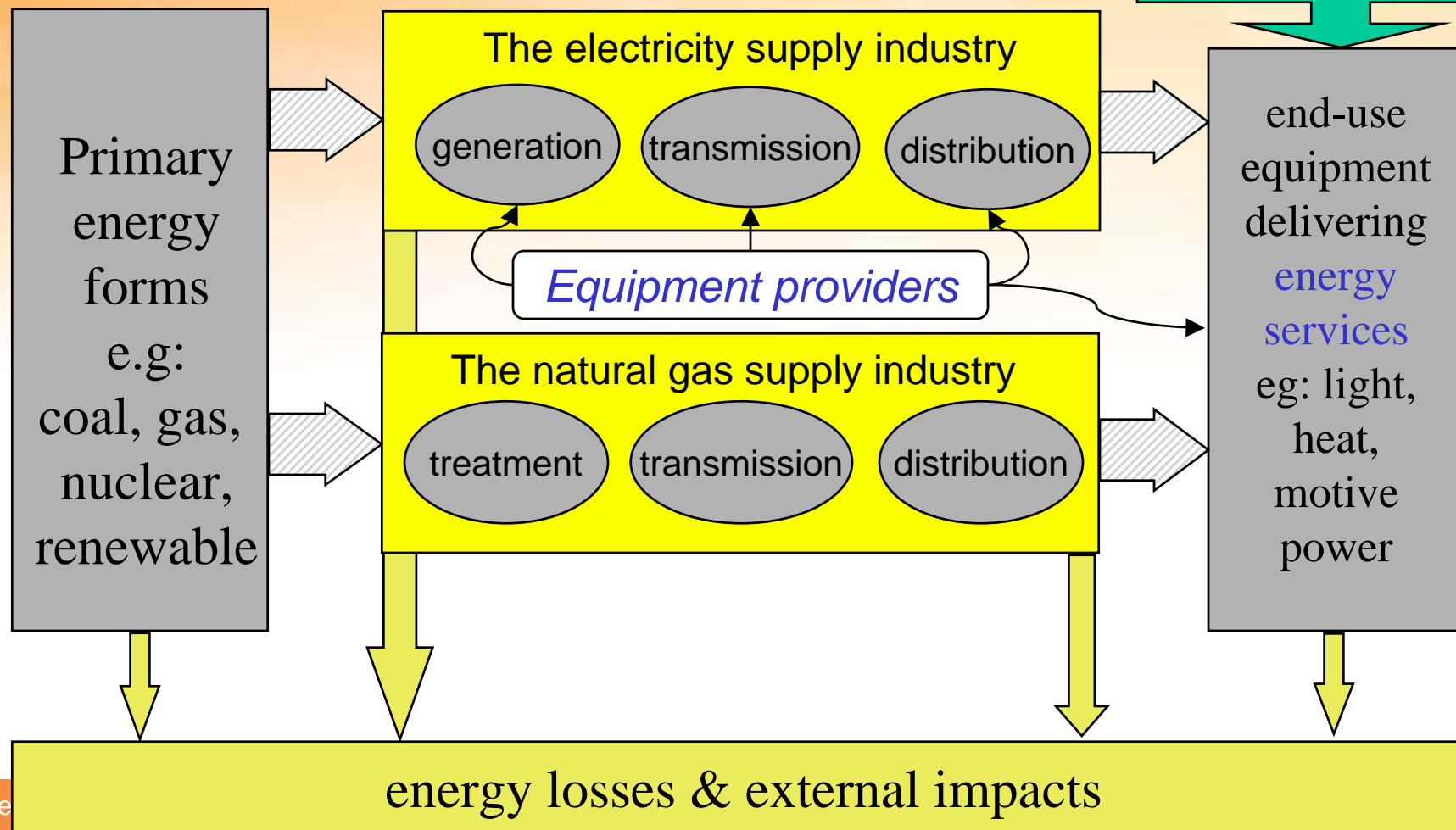
# Electricity industry restructuring overview: economic, commercial & regulatory perspectives

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# Energy service delivery in the stationary energy sector

Energy service companies focus on end-use options, eg: efficiency, CHP, solar





# Comparison of car & electricity industries

## Cars

- Can be touched seen, & stored, last for years
- Consumer 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 consumer receives a mixed flow of energy from all power stations:**
  - **A consumer can't choose a power station**
  - **Power station can't control quality of delivered energy**
- **Location matters because of network losses & constraints**

*Bilateral trade does NOT work well:*

- *Must design & implement a trading regime that works for electricity*



# 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 asset lives
- An infrastructure industry is only essential if:
  - A particular product or service cannot be produced without it
  - No alternative product or service can be made without it



# “Natural monopoly” industries

- Definition:
  - Most efficient if production undertaken by a single firm to meet demand when  $\text{price} = \text{SRMC}$ 
    - 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 distribution networks
  - However, the demand side of the electricity industry is not a natural monopoly



# 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



## 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



# Electricity industry restructuring objective: *decentralised decision making*

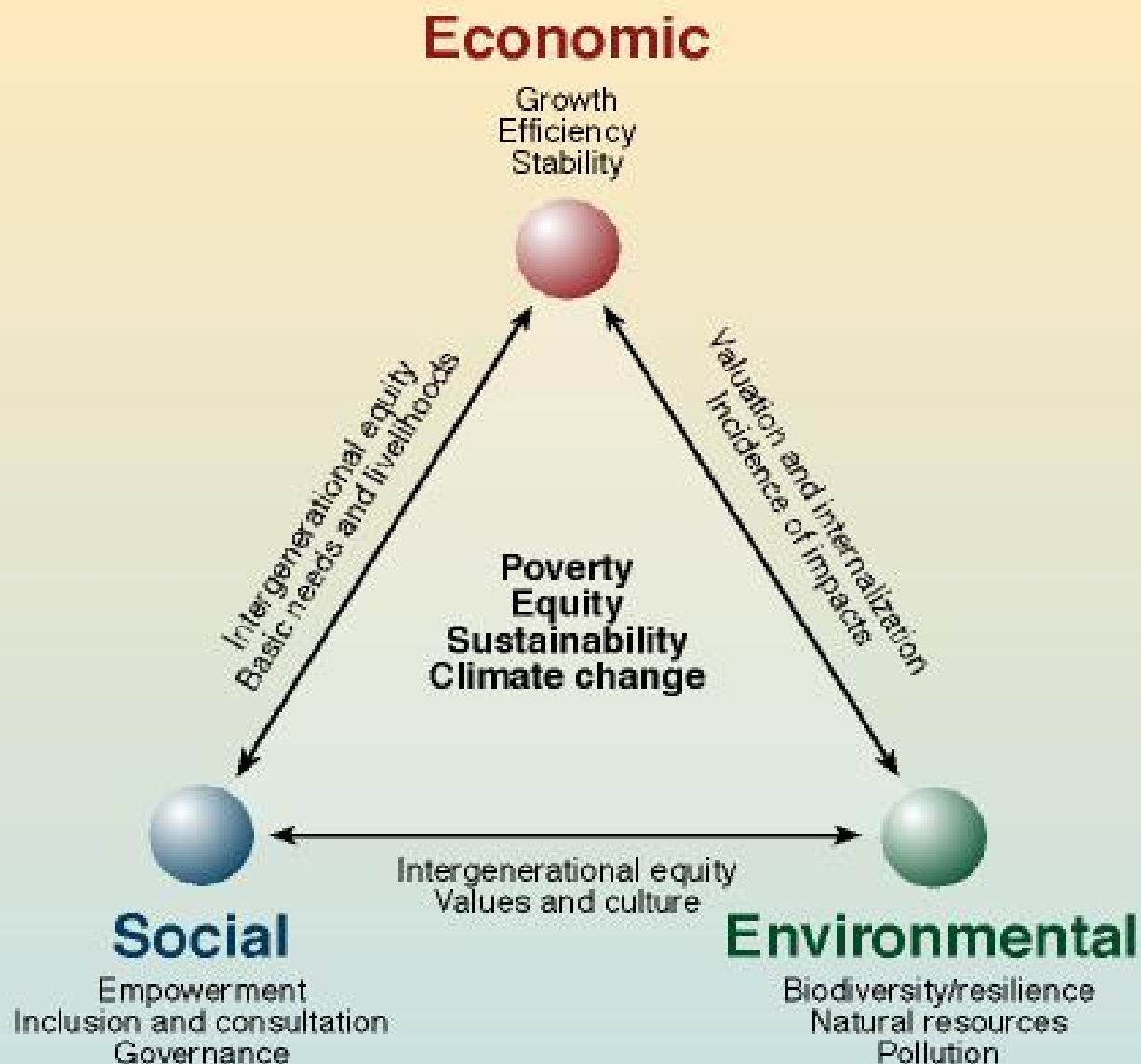
- Improve economic efficiency by facilitating competition & new entry, which assumes:
  - Effective markets & sound legal & policy frameworks
- Enhance accountability to end-users & society through ‘customer choice’, which assumes:
  - End-users become active participants in the industry
  - End-users 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



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

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

## Key elements of sustainable development and interconnections





# 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:
  - Support innovation & response to change:
    - R&D & technological change
    - Environmental impacts, social expectations, etc.
  - Very important in a capital intensive industry



## 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



# 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
  - Privatised 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



# Evolution of competition policy in Australia

- Development of COAG process in late 80's
  - Formal interface between federal & state gov'ts 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



# 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 public interest is in economic efficiency subject to other specified social objectives



# The electricity industry restructuring process

Issue	Transition	Key challenges
Industry structure	<i>From</i> monopoly <i>To</i> competing firms <i>Plus</i> system operator(s)	Cultural change; Adequate competition; <i>Accountability</i>
Commercial framework	<i>From</i> cost recovery <i>To</i> market prices	Market power; Market design fidelity; <i>Accountability</i>
Industry regulation	<i>From</i> rate of return <i>To</i> Incentive Reg'n	Multiple objectives; Measuring outcomes; <i>Accountability</i>
Sustainability	<i>From</i> direct cost <i>To</i> full costs	Variable RE energy flows End-user participation; <i>Accountability</i>



# 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 *central decision making* by:
  - System operators, Network Service Providers, Regulators
- Unavoidable interaction between:
  - Cooperative (*centralised*) decision making and
  - Competitive (*decentralised*) decision making

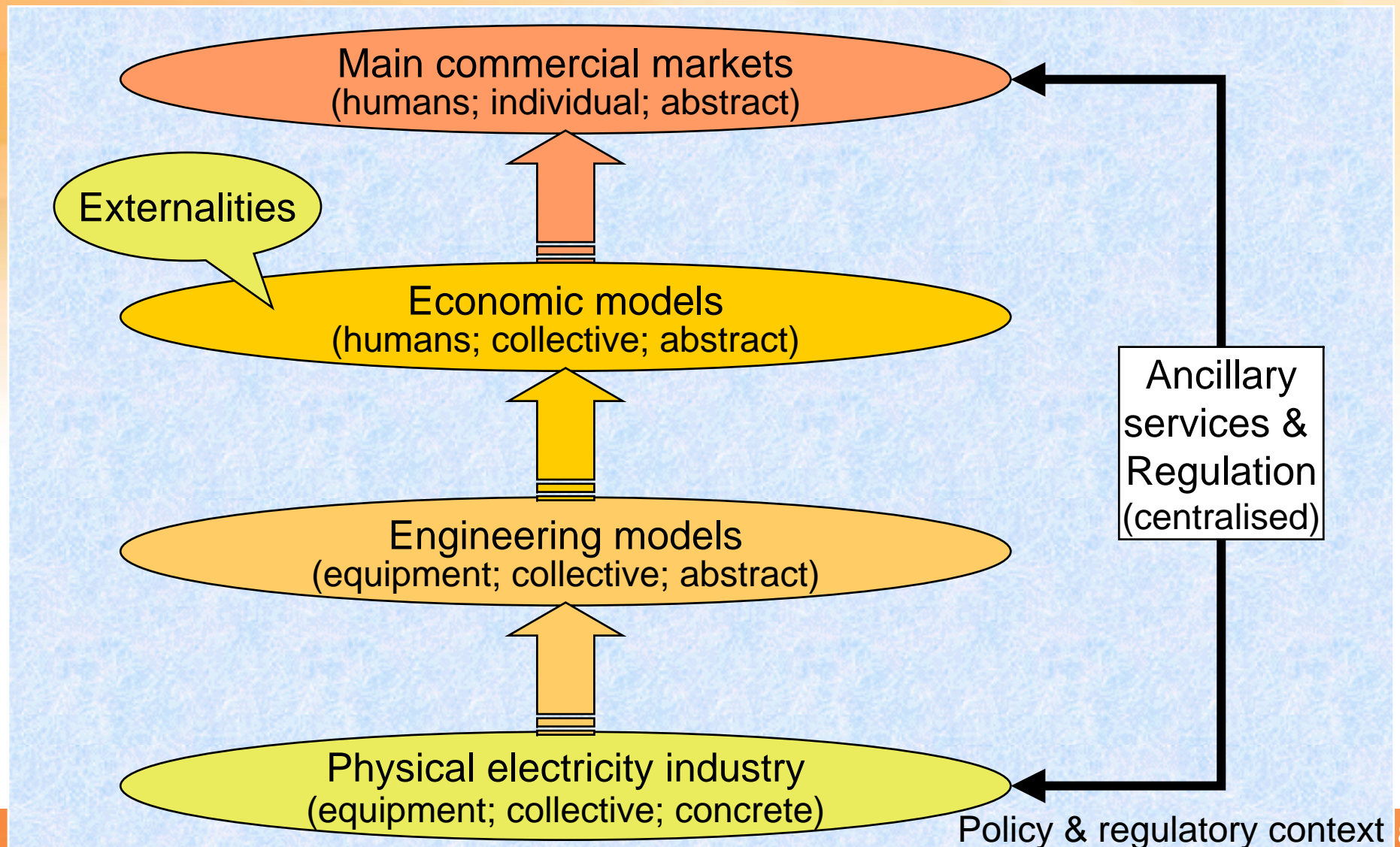


# Models of the electricity industry

- 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

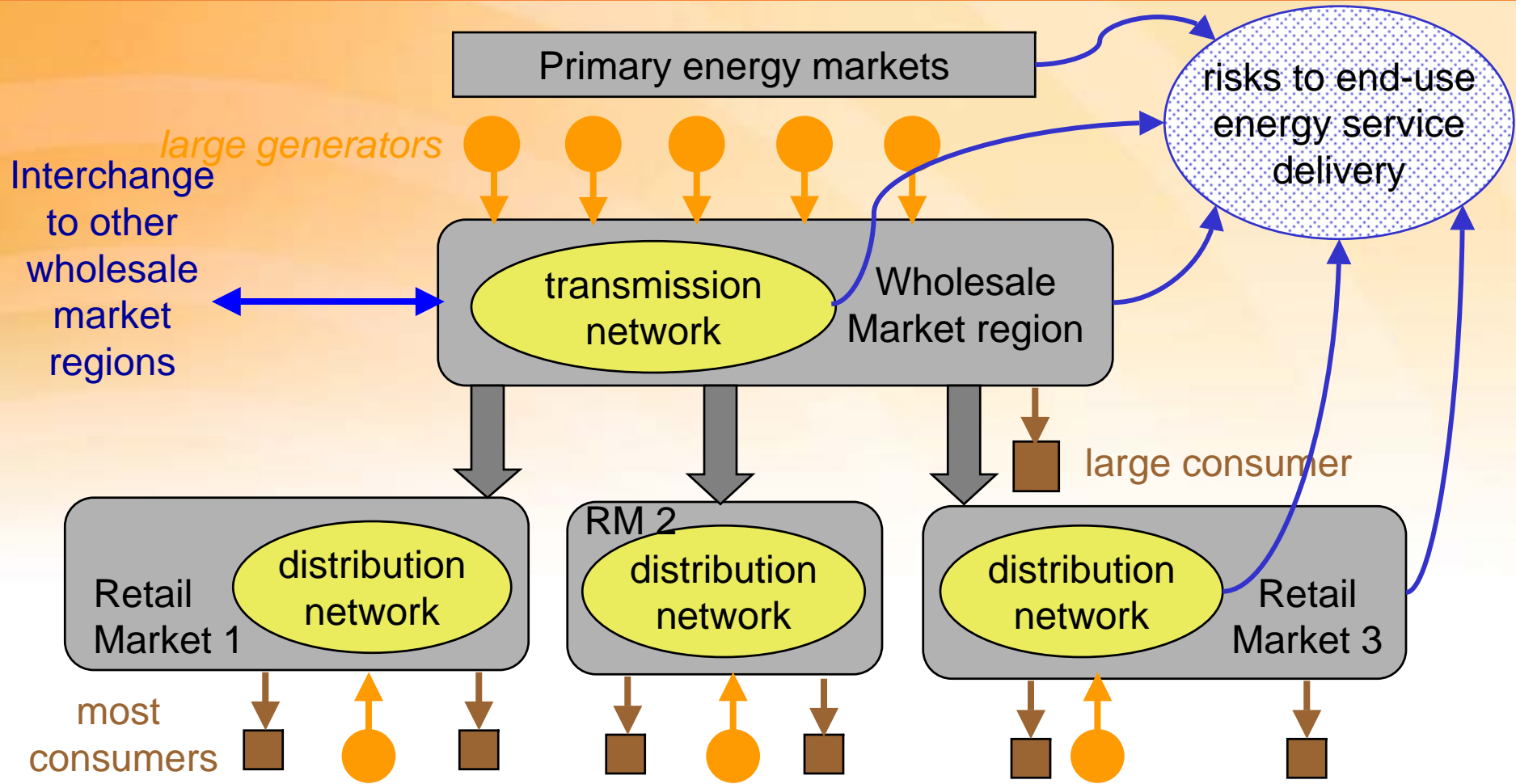


# Trading in electricity:- an **abstraction** from reality





# An electricity trading framework



*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*



## 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:
  - Those prices that achieve the same IBOT:
    - The incremental cost *or loss of benefit* of delivering an additional unit of energy *at a particular location*
  - Standard SRMC definition if no inter-temporal links
  - Otherwise prices that reflect future decision options:
    - Based on best available model of future price behaviour, *including impacts of a specific decision on future prices*



## 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 prices in a decentralised industry:
  - Location-dependent avoidable spot prices:
    - Local supply/demand balance
    - Network arbitrage subject to losses & flow constraints
  - Location-dependent derivative prices reflecting:
    - Plausible future patterns of generation & demand
    - Plausible future network losses & flow constraints
    - Effects of future decision options



# 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



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

- Locational energy spot market:
  - Energy (that meets QOS criteria) traded at spot price in successive short spot market intervals
- Locational derivative markets:
  - Related to future spot price expectations:
    - Predict aspects of future spot market behaviour
    - Permit reallocation of risks
- Ancillary services:
  - Resources that maintain quality of supply
- Regulatory monitoring of strategic behaviour



# Electricity market models

- Gross pool (eg NEM):
  - Temporal & location risk managed collectively:
    - Ancillary services, spot & derivate 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
  - Short-term operational risk managed collectively:
    - System operator typically given only one day's notice of bilateral trades



# Some UK perspectives on NETA

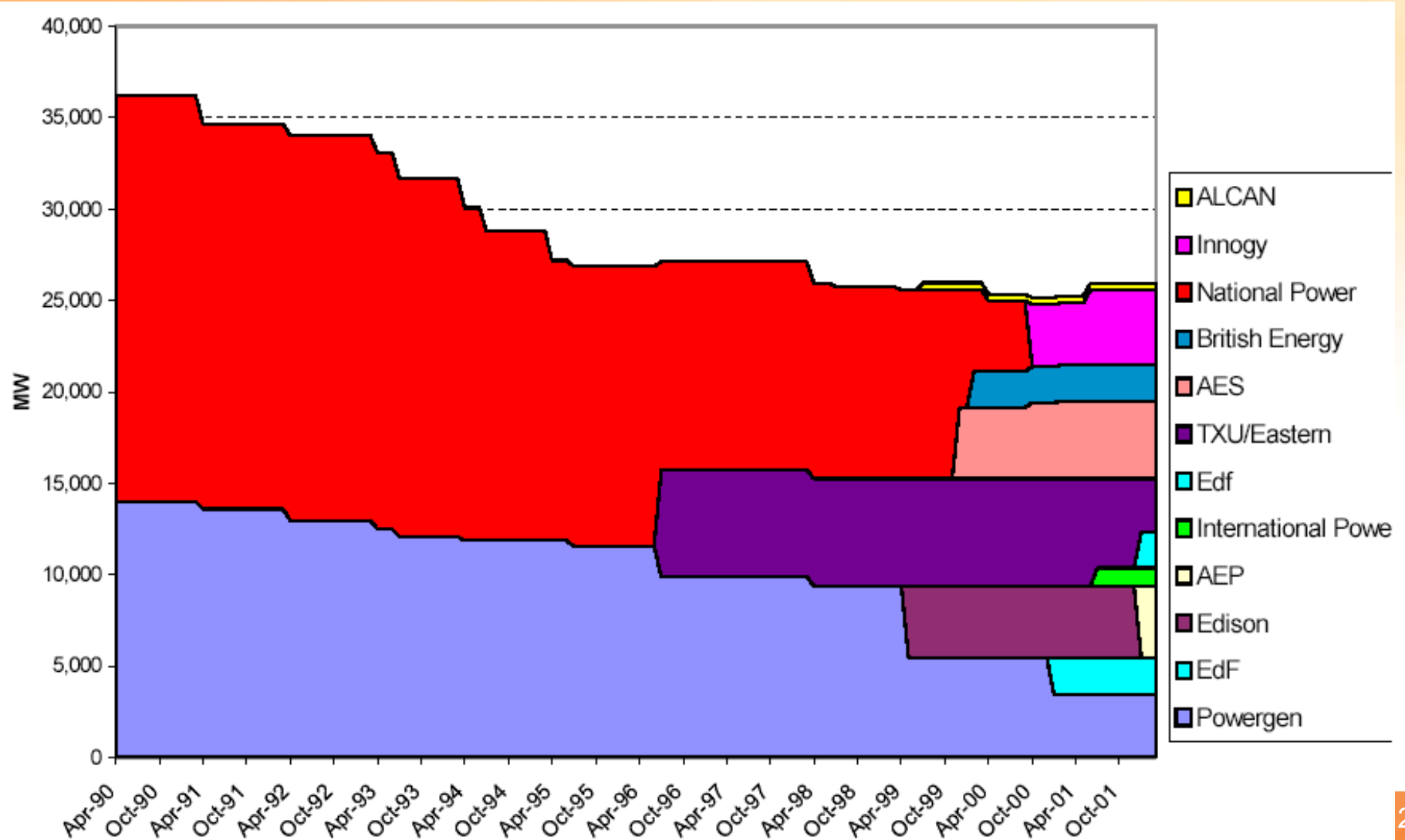
(England & Wales wholesale market 2 years on, Ofgem, 2003)

- Newbery (Cambridge University):
  - Increased competition in fuel & generation may be the key driver on wholesale price reductions
  - NETA very expensive to implement
- Yarrow (Oxford University):
  - How will security of supply be maintained?
  - Demand side more clearly involved
  - Transmission losses & constraints difficult under NETA



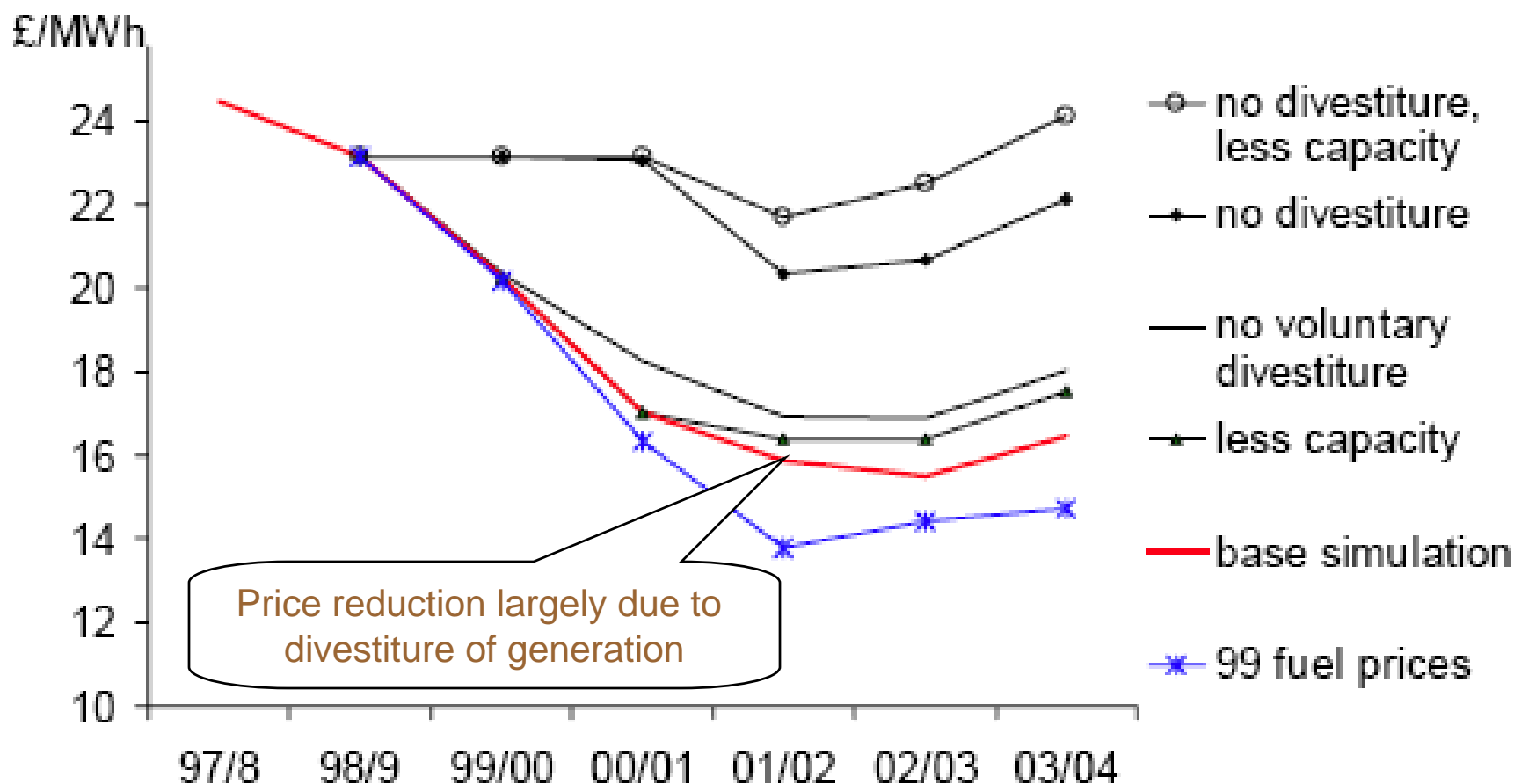
# Ownership of UK coal-fired generation 1990-2001

(D Newbery, England & Wales wholesale market 2 years on, Ofgem, 2003)





## UK electricity price modelling by Evans & Green, 2005: *Divestiture the most important influence on price, not the change in market rules.*





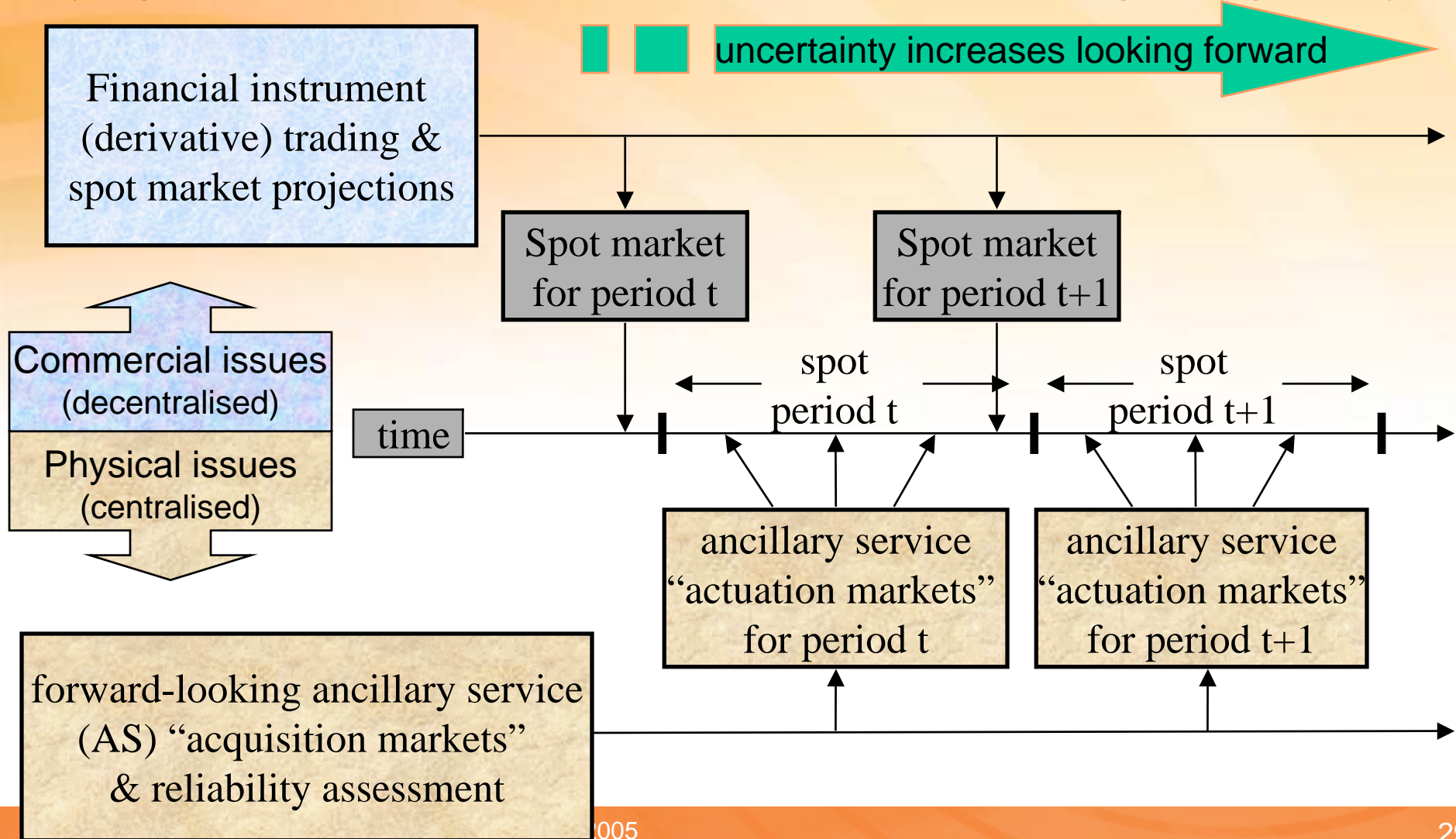
# Challenges for a restructured industry

- Consistency between centralised & decentralised processes:
  - *Centralised*: most ancillary services; industry operation; industry design & regulation; government policy for the stationary energy industry
  - *Decentralised*: some ancillary services; spot & forward markets
- 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



# Timeline for electricity trading

(requires locational detail & active demand-side participation)





# Uncertainty & risk in electricity trading

<b>Time scale</b>	<b>Issues</b>	<b>Mechanisms</b>
< 30 minutes	<ul style="list-style-type: none"><li>• Demand fluctuations</li><li>• Contingencies</li></ul>	<ul style="list-style-type: none"><li>• Ancillary services</li></ul>
30 minutes to several days	<ul style="list-style-type: none"><li>• Demand uncertainty</li><li>• Inter-temporal links, eg<ul style="list-style-type: none"><li>• Unit commitment</li></ul></li></ul>	<ul style="list-style-type: none"><li>• Ex-ante spot market</li><li>• Short term forward market</li></ul>
Weeks to years - <i>operation</i>	<ul style="list-style-type: none"><li>• Inter-temporal links, eg<ul style="list-style-type: none"><li>• Retail tariff setting</li><li>• Hydro scheduling</li></ul></li></ul>	<ul style="list-style-type: none"><li>• Long term forward market</li></ul>
Weeks to years Š <i>investment</i>	<ul style="list-style-type: none"><li>• Optimal investment decisions</li></ul>	<ul style="list-style-type: none"><li>• Long term forward market</li><li>• Policy framework</li></ul>



# Ideal spot market trading of electricity

- Specify quality of supply (QOS) criteria:
  - Assume QOS maintained by Ancillary Services
- 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
    - Demand & supply side options fully equivalent



# Practical implementation

- Wholesale spot & forward market:
  - Large generators, retailers, large consumers
  - Some representation of networks in markets
- Retail spot & forward market:
  - Retailers, consumers, embedded generators:
    - *In future, wholesale & retail markets might merge*
- Ancillary services (wholesale & retail):
  - Hybrid engineering & commercial arrangements
- Residual network services:
  - Regulated access regime, administered network pricing, limited competition in some aspects



# Metering and communication

- Metering:
  - Interval metering should be provided for all participants:
    - Record 30 minute energy, quality & availability
    - Provide data read-out for participant
  - Profiling not an adequate option
- Communication:
  - 30-minute energy prices sent to all participants
  - Feeder power flows monitored continuously
  - Participant 30-minute energy collected at appropriate intervals for billing purposes



# 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 continuous & cooperative
  - Commercial behaviour individual & competitive
- Restructuring is still a learning situation:
  - No complete successes, some disastrous failures, difficult to go back to traditional model
  - Must solve commercial, technical, regulatory & institutional challenges (each aspect must function well)