Oxera

Measuring supply security in electricity markets

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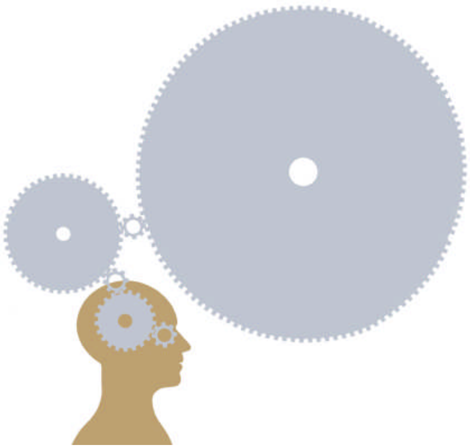
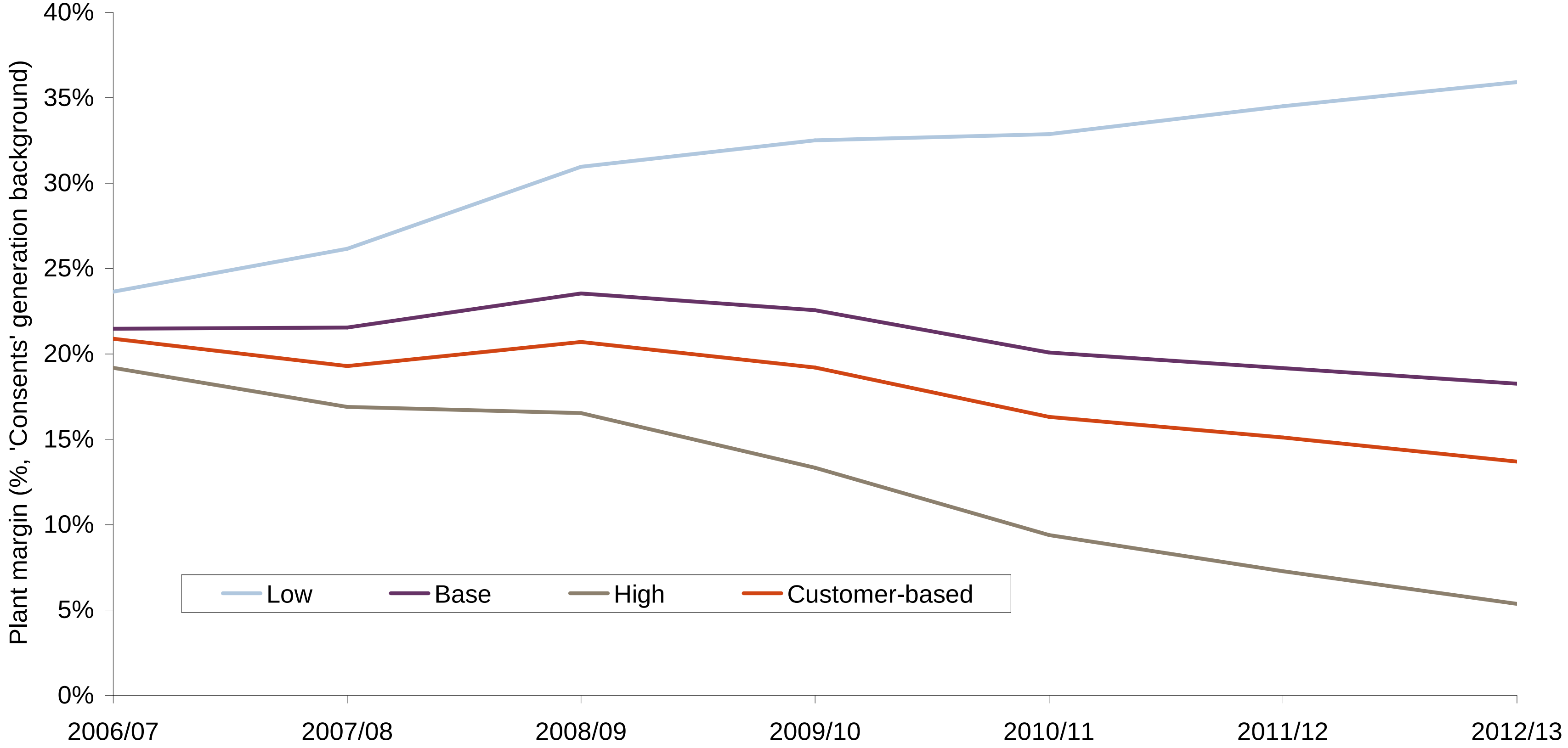


Overview

- plant margins as measures of supply security
- modelling the probability of outages
- outlook for winter 2007
- modelling applications
  - impact of different plant margins
  - impact of different generation mixes
  - incremental impact of investment in generation capacity
- implications for 'optimal' plant margins and supply security

Plant margins



Source: National Grid (2006), 'GB Seven Year Statement', May.
Available at http://www.nationalgrid.com/uk/Electricity/SYS/.

Do (electricity) plant margins adequately measure supply security?

- at best a proxy measure
  - does not account for variations in demand and supply
  - changes in generation/fuel mix and infrastructure are likely to make inter-temporal comparisons difficult
- in practice, outages are also dependent on the security ‘quality’ of alternative generation technologies
  - technical failure rates of different plant
  - incremental size of plant, and size/location of generating ‘fleet’
  - commodity/fuel availability
  - availability of other complementary assets (eg, pipeline and network infrastructure, system balancing capability)

Oxera's approach

- alternative security metric based on the *expected* level of outages
  - in theory, other moments of outage distributions could be incorporated into the definition of 'security' depending on preferences
- greater emphasis on 'bottom-up' modelling of the energy *system*
  - dependent on knowledge of the reliability of both individual components of the system, and their interrelationships
- captures key relationships in the electricity supply chain
  - series relationships increase (eg, excessive reliance on a single source or fuel)
  - parallel relationships increase redundancy, and hence security (ie, diversification of fuels/sources)

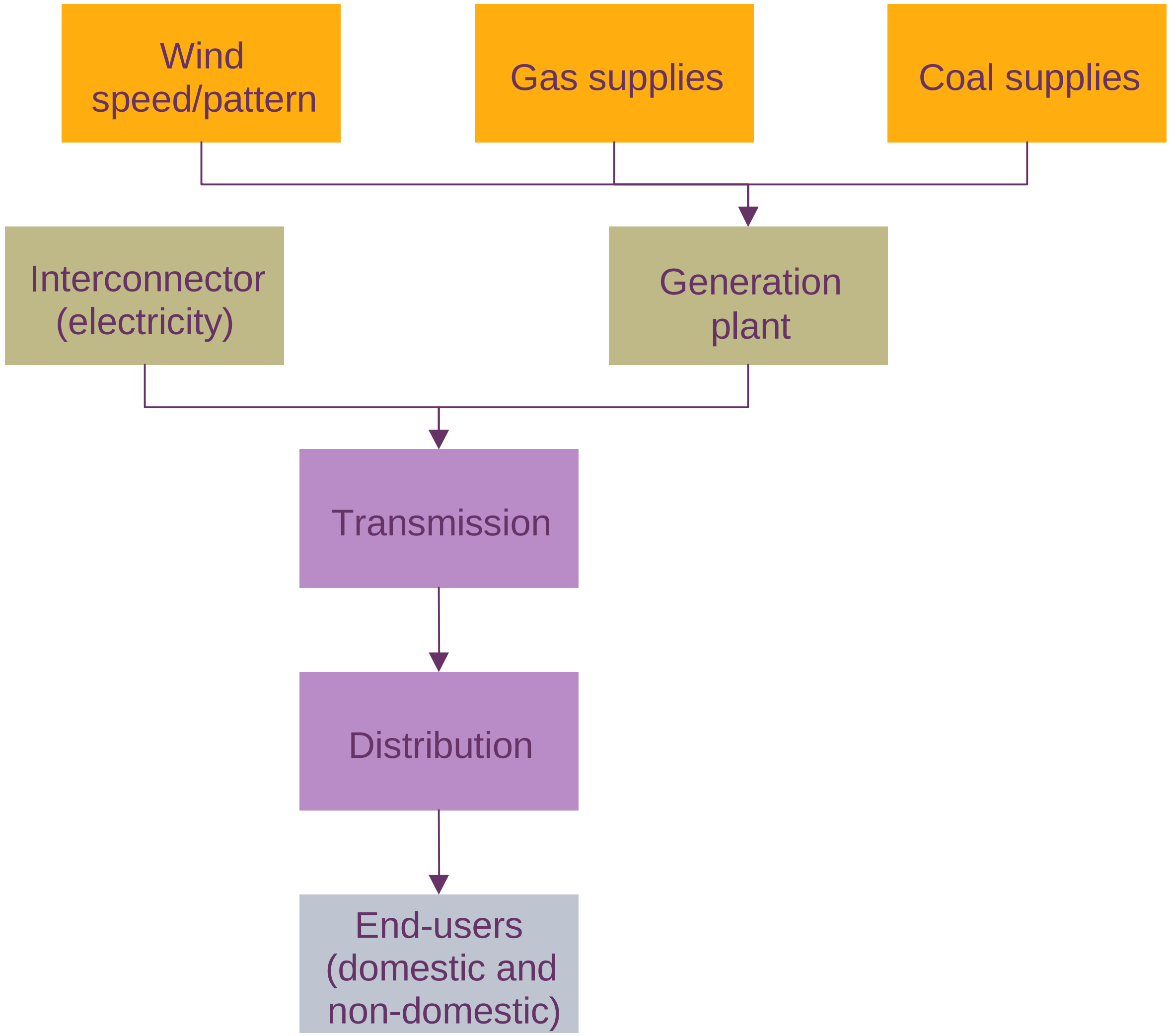
Stylised representation of the energy system

Fuel availability

Generation capacity

Electricity network infrastructure

Consumption

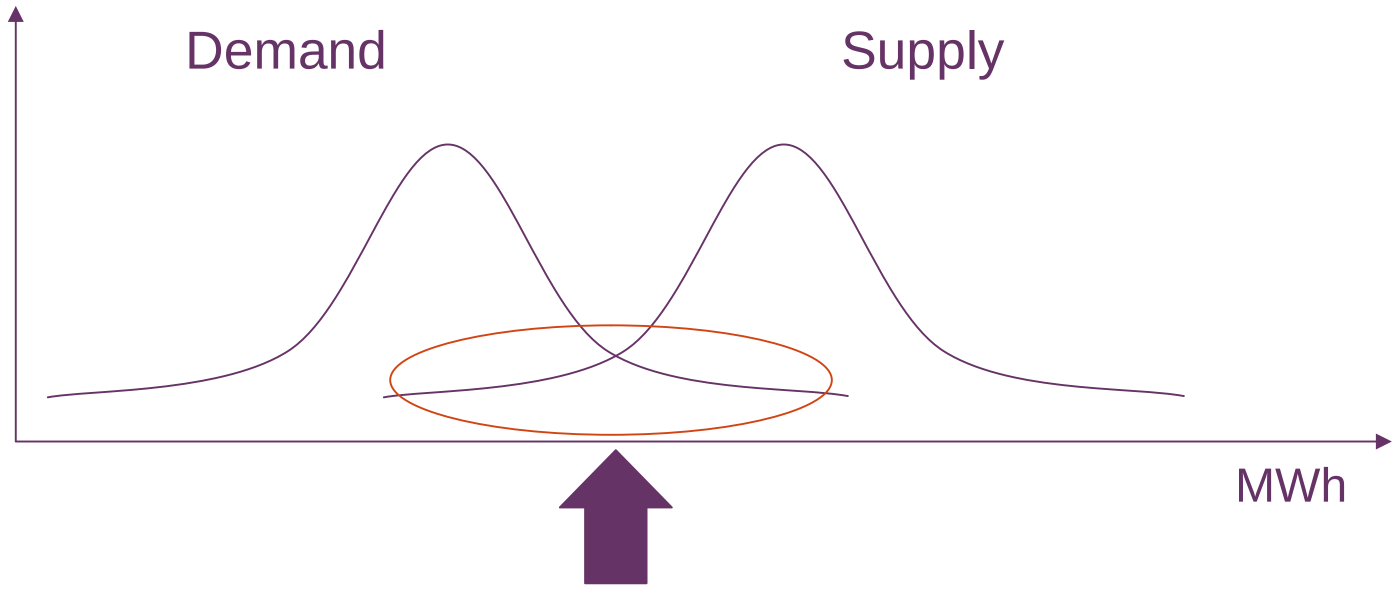


Modelling supply-side disruptions

- fuel availability
  - long-term gas security model—simulation of impact of geopolitical risk factors and unplanned disruptions to UKCS, NCS, and LNG sources to 2012
  - wind availability at peak—simulation based on 20-year Met Office data
- generation capacity
  - planned outages—effective capacity reduced to 90% over year
  - unplanned outages—forced outage rates for different generation plants taken from UMIST (1999)
- electricity network infrastructure
  - risk factors based on CIGRE surveys of international performance benchmarks

Sources: LeReverend, B.K. and Towstego, R.P. (1992), 'Update on the Disturbance Performance of Bulk Electricity Systems', *Electra*, **143**, August, pp. 86–100; UMIST (1999), 'Computation of the Value of Security: Final Report', Rios, M., Kirschen, D., and Allen, R., Manchester Centre for Electrical Energy, November.

Analysing the probability of outages

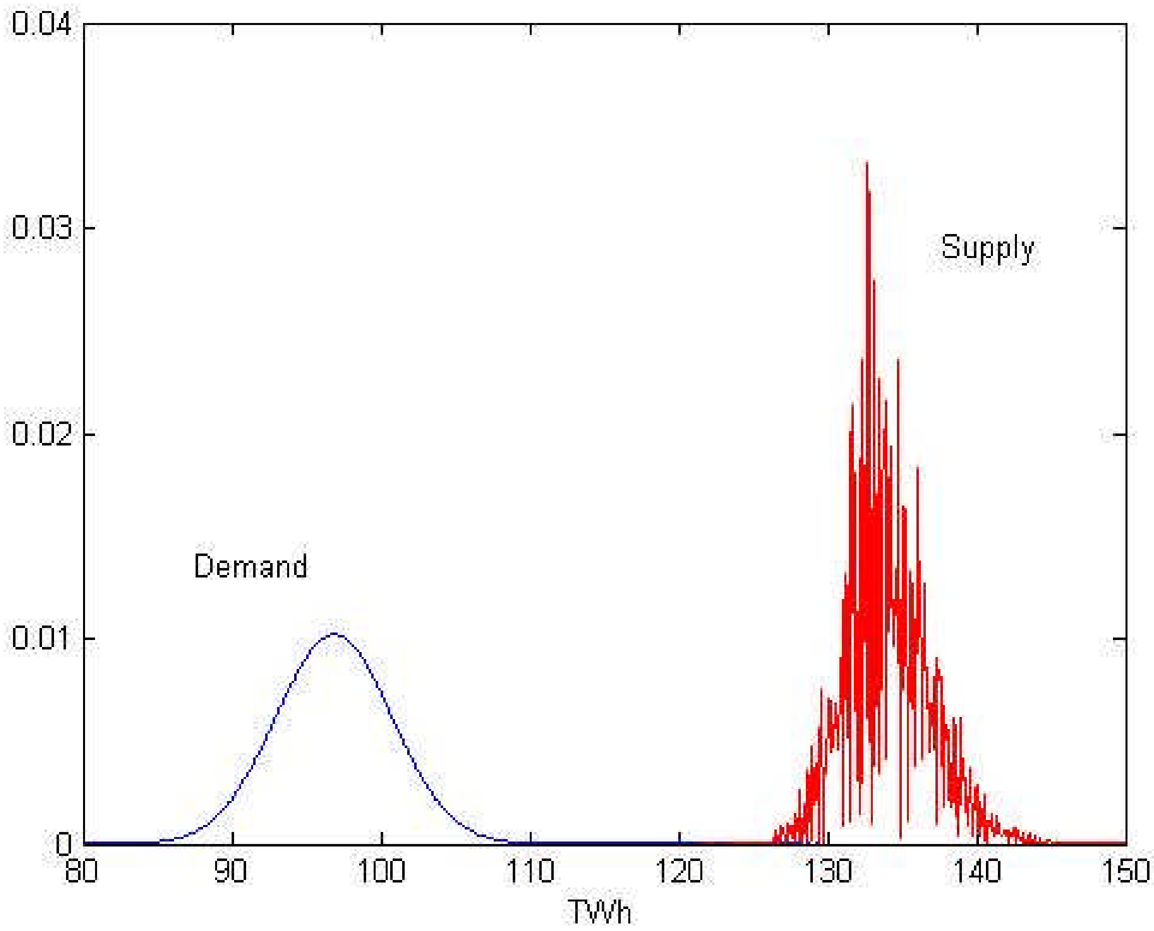


Supply security = probability weighted outages

- **Demand distribution derived from:**
  - historical information
  - statistical analysis
  - growth forecasts

- **Supply distribution derived from:**
  - planned outages
  - estimates of forced outage rates
  - fuel risk factors (especially gas)

Supply and demand in Q1 2007



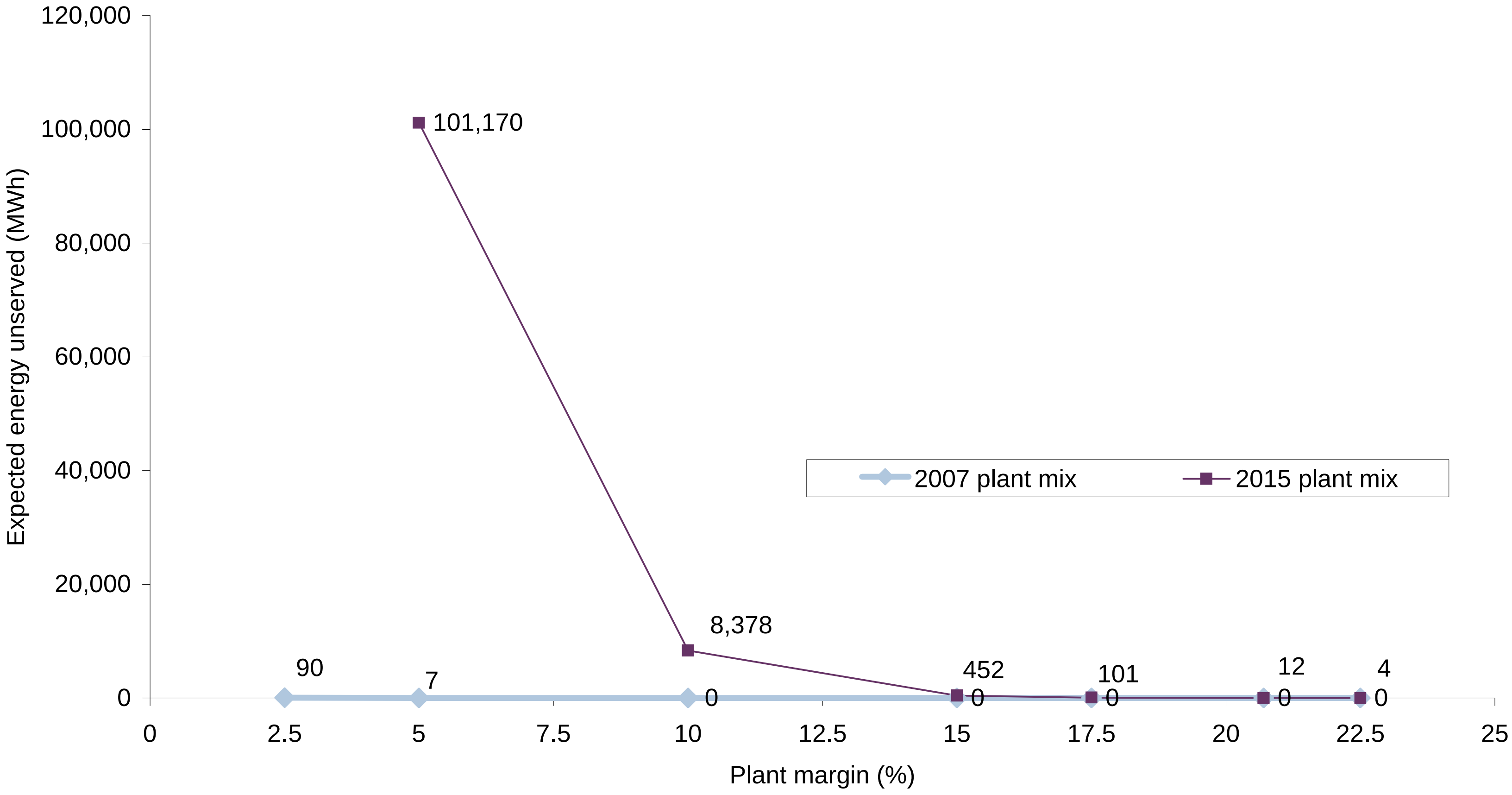
Source: Oxera.

Impact of different plant margins and generation mixes (I)

Plant margin (%)	2007 plant mix			2015 plant mix		
	Expected unserved energy (MWh)	Probability of outages		Expected unserved energy (MWh)	Probability of outages	
		>10 GWh	>100 GWh		>10 GWh	>100 GWh
25	0	1.27E-18	1.17E-18	1	4.95E-07	4.56E-07
22.5	0	1.49E-16	1.35E-16	4	3.00E-06	2.84E-06
20.7	0	3.39E-15	3.04E-15	12	9.43E-06	8.90E-06
17.5	0	7.22E-13	6.49E-13	101	6.81E-05	6.47E-05
15	0	2.99E-11	2.71E-11	452	2.93E-04	2.79E-04
10	0	2.23E-08	2.03E-08	8,378	4.95E-03	4.73E-03
5	7	6.77E-06	6.30E-06	101,170	4.60E-02	4.46E-02

Source: Oxera.

Impact of different plant margins and generation mixes (II)



Source: Oxera.

Implications of the analysis (Q1 2007)

- limited overlap between supply and demand, resulting in no expected unserved energy in Q1 2007
  - primarily due to the capacity margin (20.7%), and a relatively low volume of wind generation (1.5%)
- probabilities of individual security ‘events’ is low
  - ie, less than 1 in 100 years for an event the size of the 2003 London black-out (as a result of generation failure)
- may imply that Q1 2007 ‘optimal’ plant margins could be lower than at present …
- … but this finding is sensitive to the assumed fuel mix

New generation investment

- what is the impact of an additional 500MW?
  - approximately 1% increase in capacity margin
- expect different impacts for different generation/fuel types
  - exposure to fuel risk differs
  - reliability of operation differs
- security impact measured in terms of reduction in unserved energy …
- … but these must be set against capital costs

Impact of new generation investment (based on Q1 2005)

	Expected unserved energy (MWh)	Incremental security benefit (MWh)	Probability of outages	
			>10GWh	>100GWh
Base (7.5% plant margin)	249		2.10E-04	1.96E-04
Base +500MW nuclear	103	146	9.04E-05	8.46E-05
Base +500MW gas	117	132	1.02E-04	9.48E-05
Base +500MW coal	103	146	9.01E-05	8.43E-05
Base +500MW wind	162	87	1.38E-04	1.29E-04

Source: Oxera.

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Valuation of supply security benefits

$$NPV = \sum_{t=1}^{n} \frac{B_t \cdot VoLL}{(1+r)^{t-1}}$$

- based on net present value (NPV) of opportunity costs of forgone energy supplies (B_t)
- use estimate of ‘value of lost load’ (VoLL)
  - range estimate: 5 (low) to 30 (central) £/kWh
- other necessary assumptions
  - discount rate (r): 3.5% (public sector) to 10% (real, post-tax)
  - generation asset life (t): 20 (wind), 25 (coal, gas), or 40 (nuclear) years
  - assumes benefits (B_t) and VoLL are constant, even as plant margin and generation mix change

VoLL: factors affecting opportunity cost of unserved energy

Factor	Issue	Empirical evidence (% of end-user bills)
Seasonality	How much higher is the cost in winter compared with that in summer?	16% for residential (Wood et al., 2000)
Advance warning	By how much does pre-notification of one to two hours reduce outage cost?	Little difference between winter and summer for commercial and industrial customers (Wood et al., 2000)
Back-up generation	By how much does the availability of back-up power reduce outage cost?	28% (Trengereid et al., 2003) 36% (Wood et al., 2000, average figure) 35% (Sullivan et al., 1996, for a large commercial firm) 43% (Sullivan et al., 1996, for a large industrial firm)
Frequency	Is it better to have frequent short outages or infrequent long outages?	60% (Subramaniam et al., 1986) 40% (Woo and Gray, 1987)
Adverse timing	What is the worst time to experience a power cut?	Industrial: infrequent long interruptions $\Rightarrow$ less disruptive Residential: frequent short interruptions $\Rightarrow$ less disruptive Commercial: no preference Billinton et al. (1982)

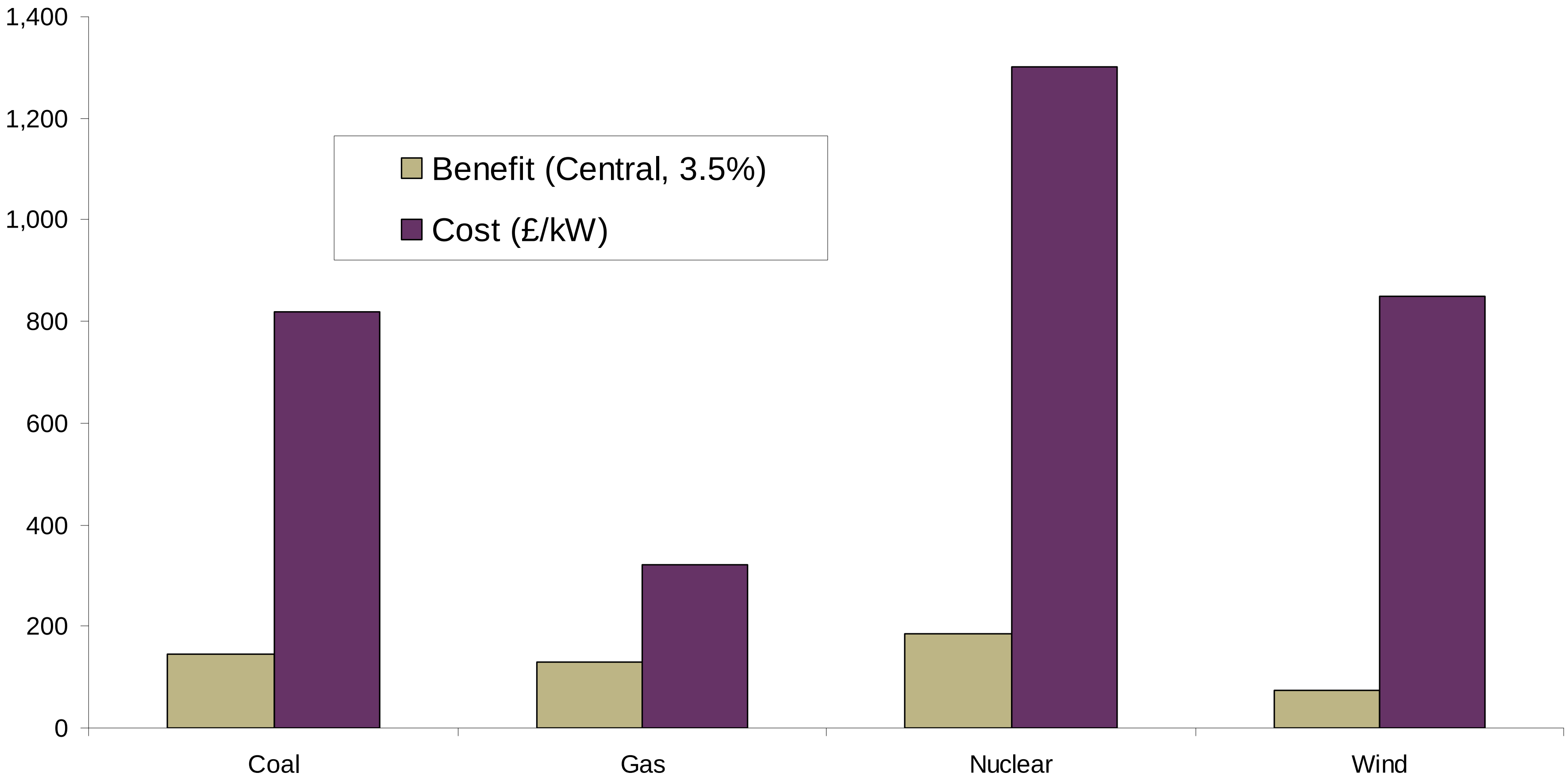
Sources available on request.

Capital cost estimates (£/kW)

Generation type	OECD Low	OECD High	DTI Energy Review	Oxera estimate
Coal	763	1,145	918–1,162	820
Gas	305	610	440	320
Nuclear	763	1,526	1,250	1,300
Wind	763	1,526	795	850

Sources: OECD (2005), 'The Projected Costs of Generating Electricity', 2005 update, Royal Academy of Engineering, Enviros, Oxera; DTI (2006), 'Energy Review Report', July. Available at http://www.dti.gov.uk/energy/review/page31995.html.

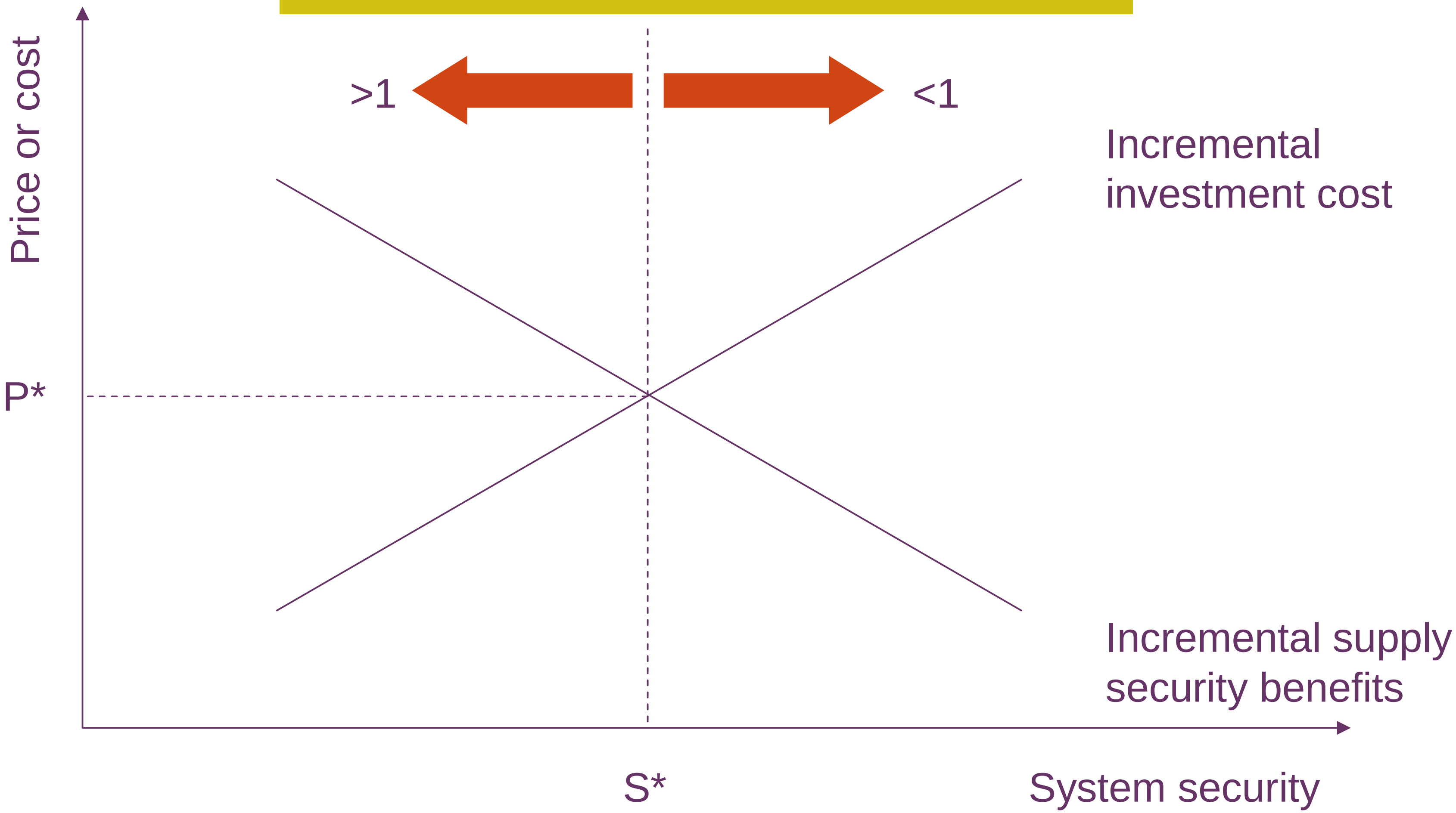
Comparing cost and benefit (Q1 2005, central VoLL, 3.5% discount rate)



Source: Oxera.

Security efficiency factor (SEF)

$$SEF = \frac{\text{NPV of security benefit}}{\text{incremental investment cost}}$$



SEFs
(Q1 2005, central VoLL, 3.5% discount rate)

	2005 generation mix	2015 generation mix
Coal	0.18	203.88
Gas	0.41	467.59
Nuclear	0.14	167.67
Wind	0.09	36.08

Source: Oxera.

Conclusions

- cost–benefit framework can provide useful indications of optimal security positions
  - flexible to changes in emphasis or new information
- margins below the 20% may not be a cause for concern, but depends on the generation/fuel mix
  - however, in a dynamic environment, this is unlikely to remain the case indefinitely
- gas-fired generation may still be the most efficient investment option
  - assumes complementary investments are completed (eg, energy networks, storage)

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