UNIVERSITY OF CAMBRIDGE | Electricity Policy Research Group

SUPERGEN FLEXNet

The Economics of Energy Demand

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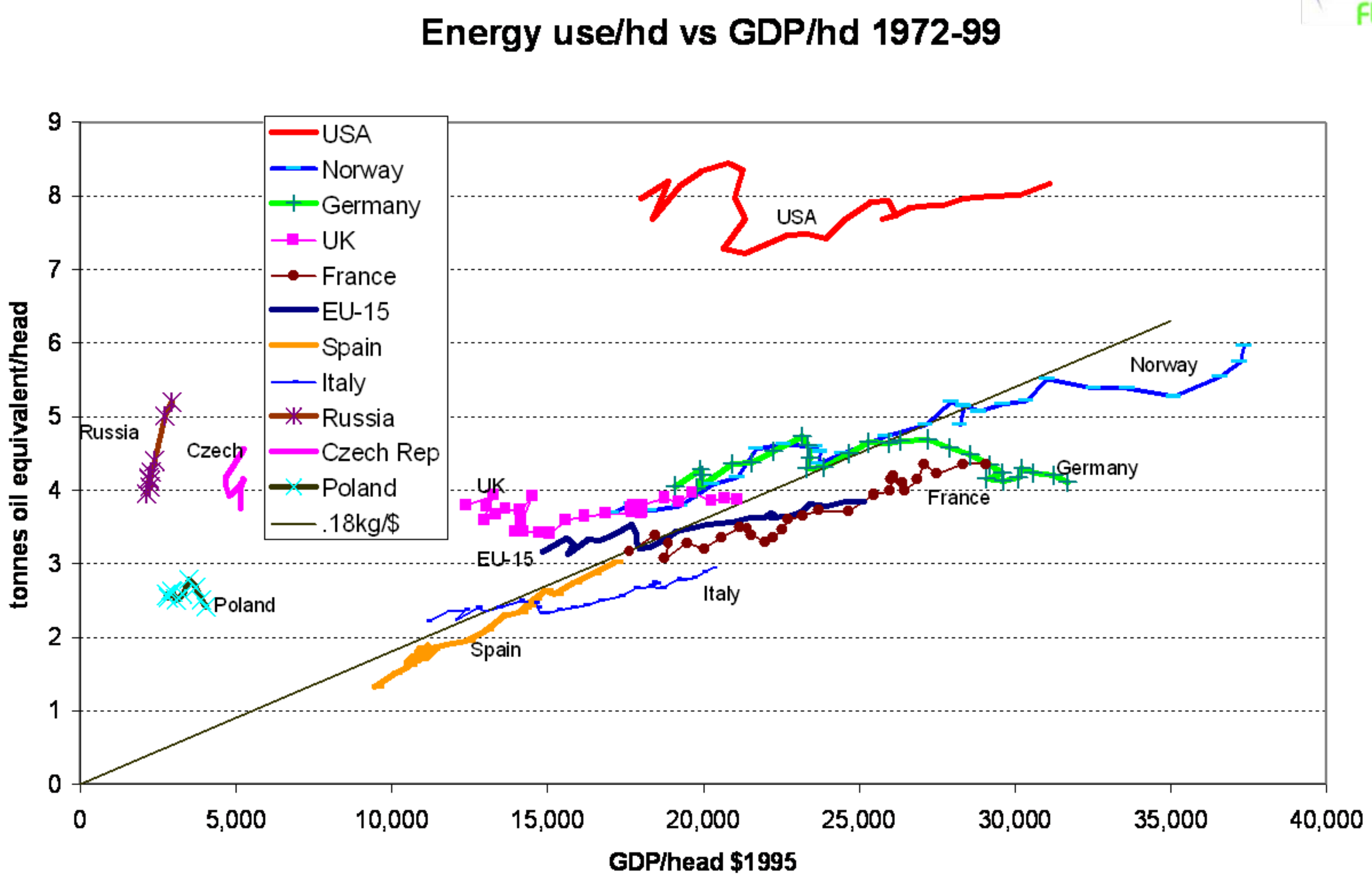
E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Outline

- Macro context of energy demand
- It’s all about income and price
- Factor prices and technology and activity
- Micro context of energy demand
- Shifting demand as important as reduction
- Market opportunities

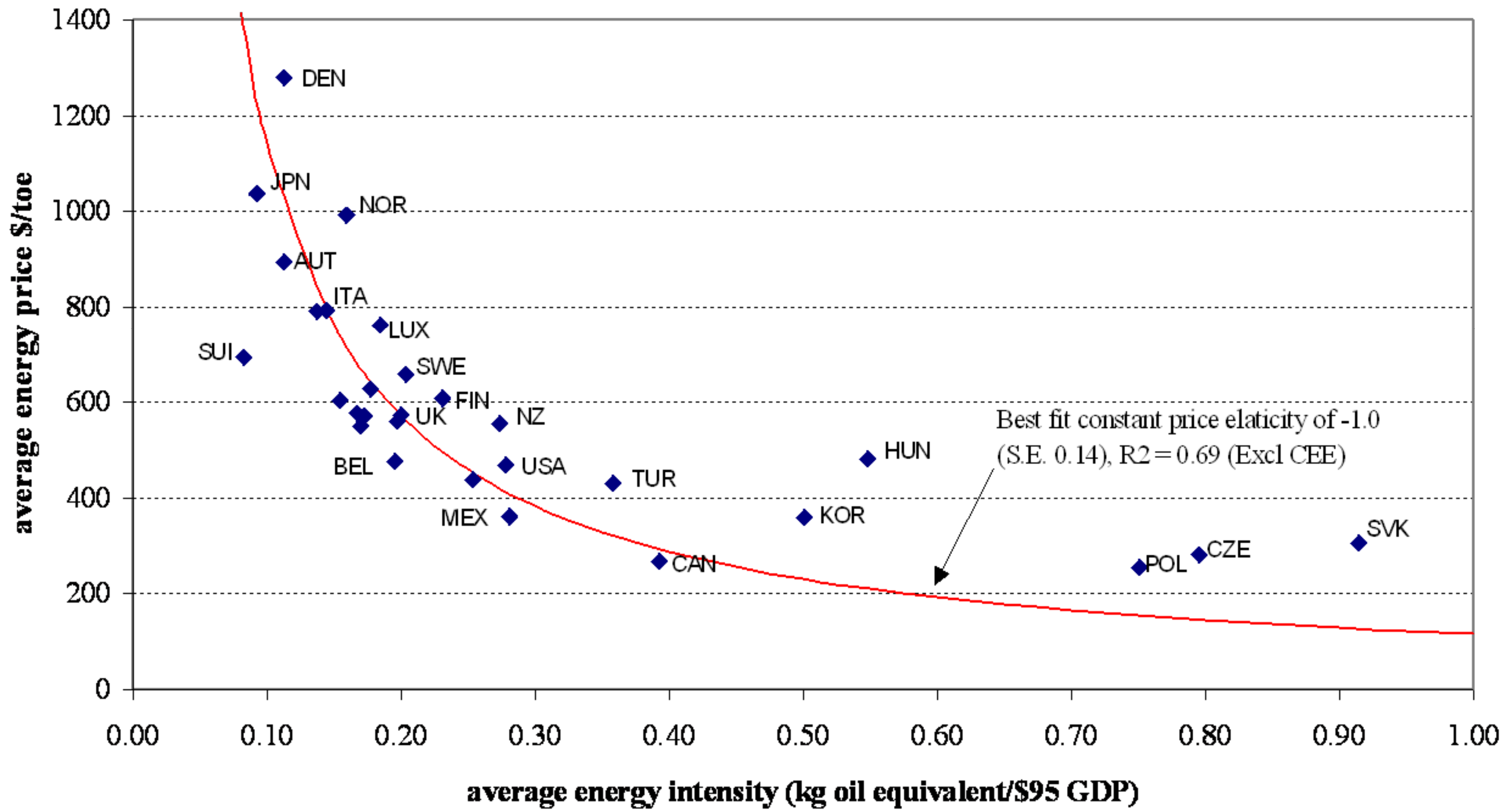
Income as a driver of energy consumption…



Source: Newbery, 2010

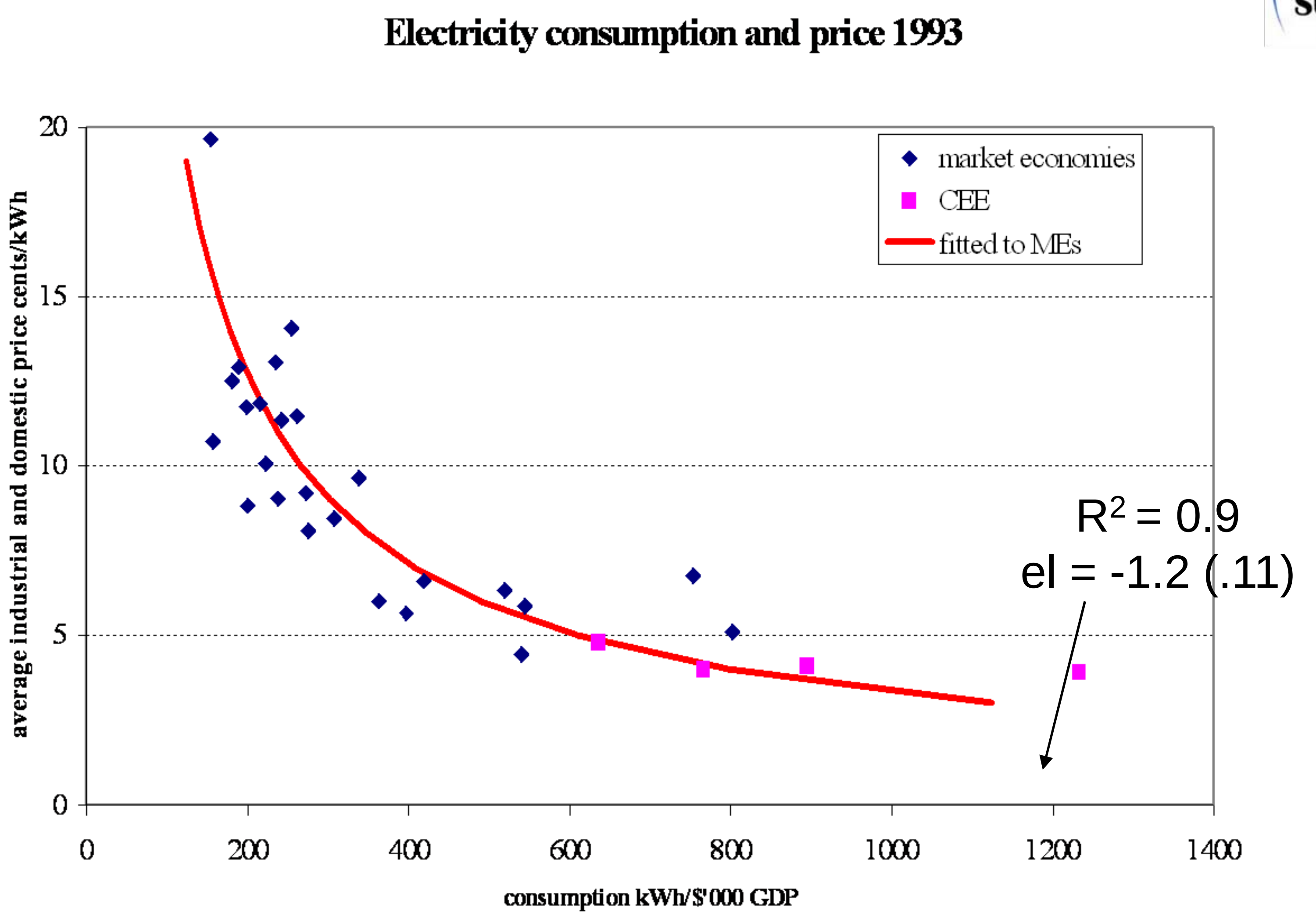
Price as a driver of energy consumption…

Cross-section relation between average energy intensity and average energy price 1993-99



Source: Newbery, 2010

Electricity similar to overall energy….



Source: Newbery, 2010

The role of relative production input prices in long run development…

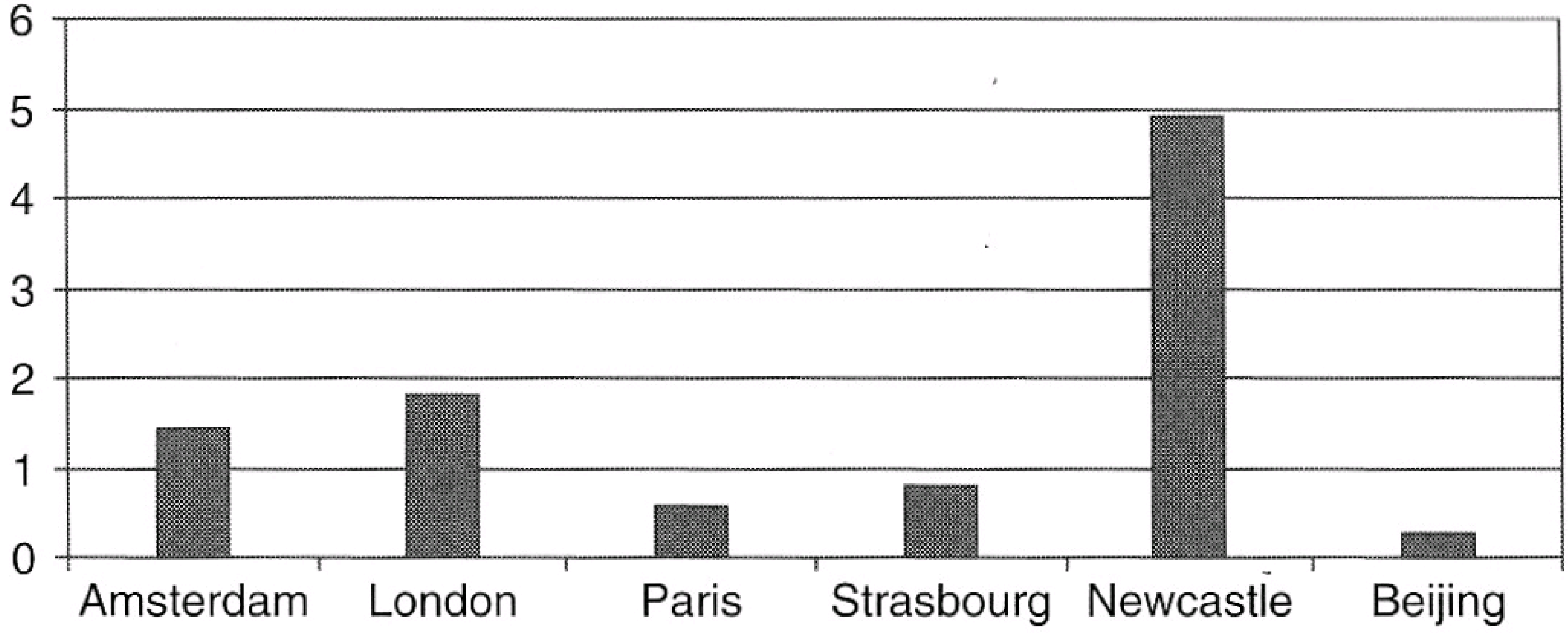
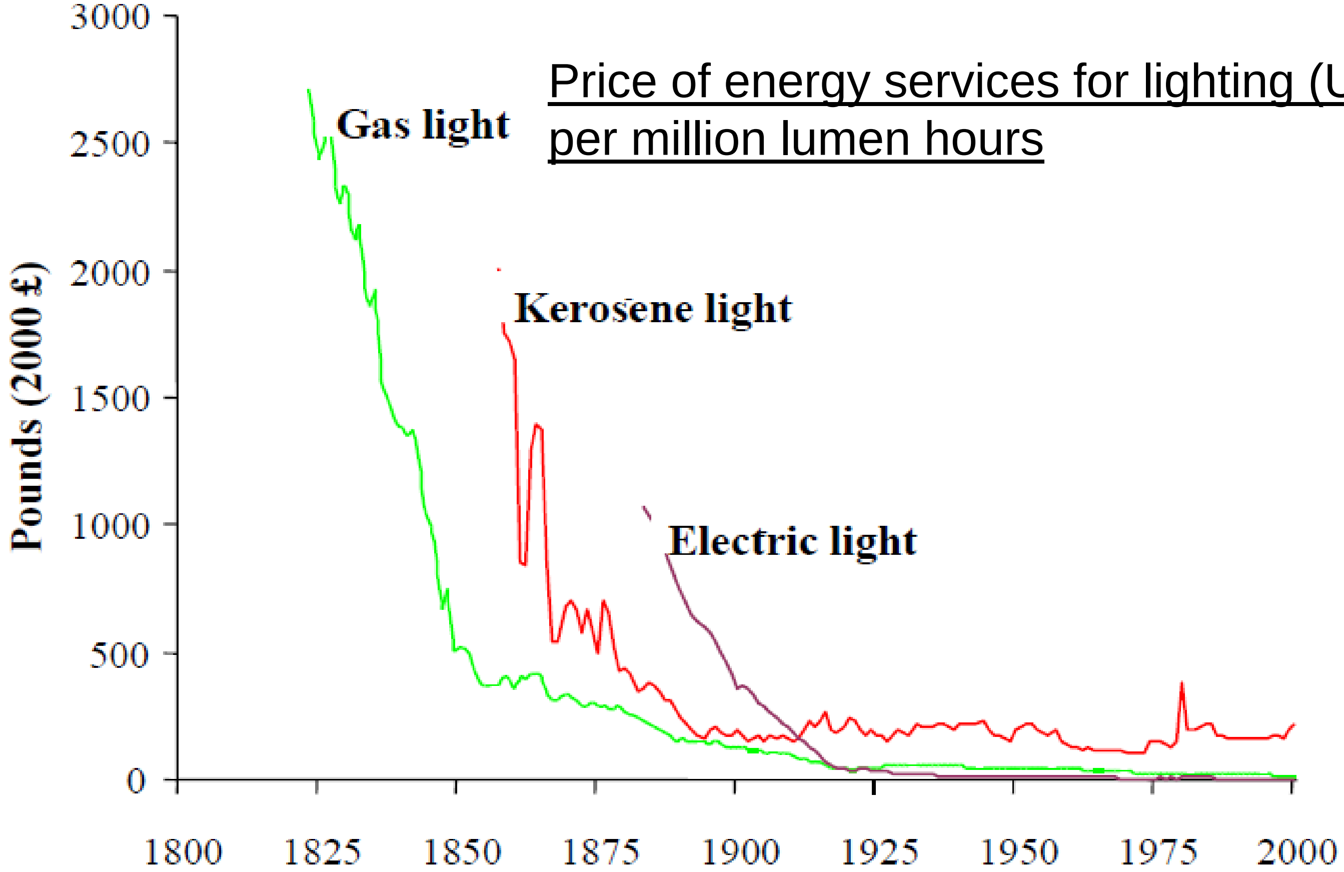


Figure 6.2 Price of labour relative to energy, early 1700s

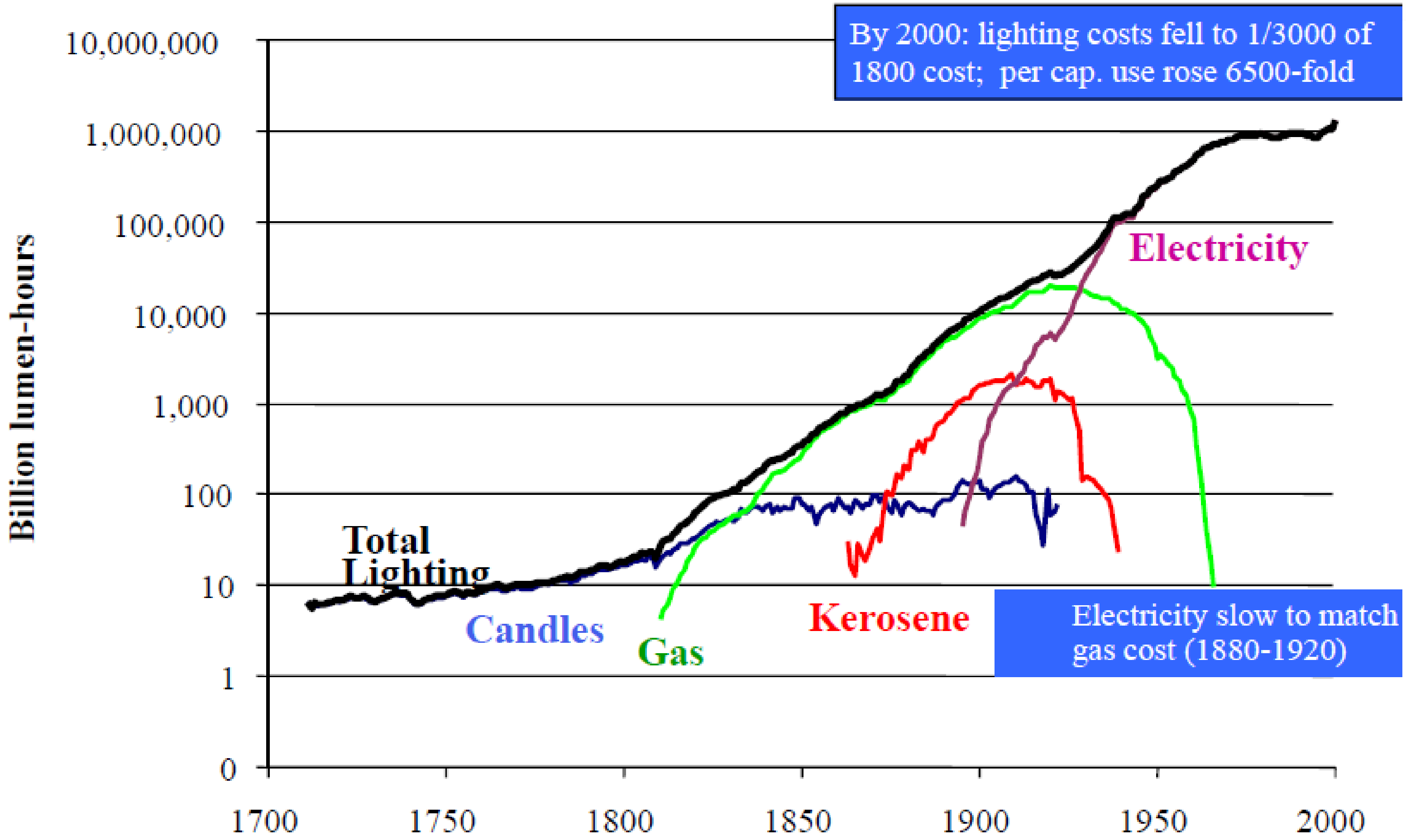
Source: Allen (2009, p.140).

Long run technological change and prices…



Source: Fouquet and Pearson, 2006, p.158.

How falling prices have driven long run demand…



Source: Fouquet and Pearson, 2006, p.171; Billion = 10^9.

Global Drivers of Energy Consumption

Table 7
Factor analyses for the change of energy consumption, 1973–1990

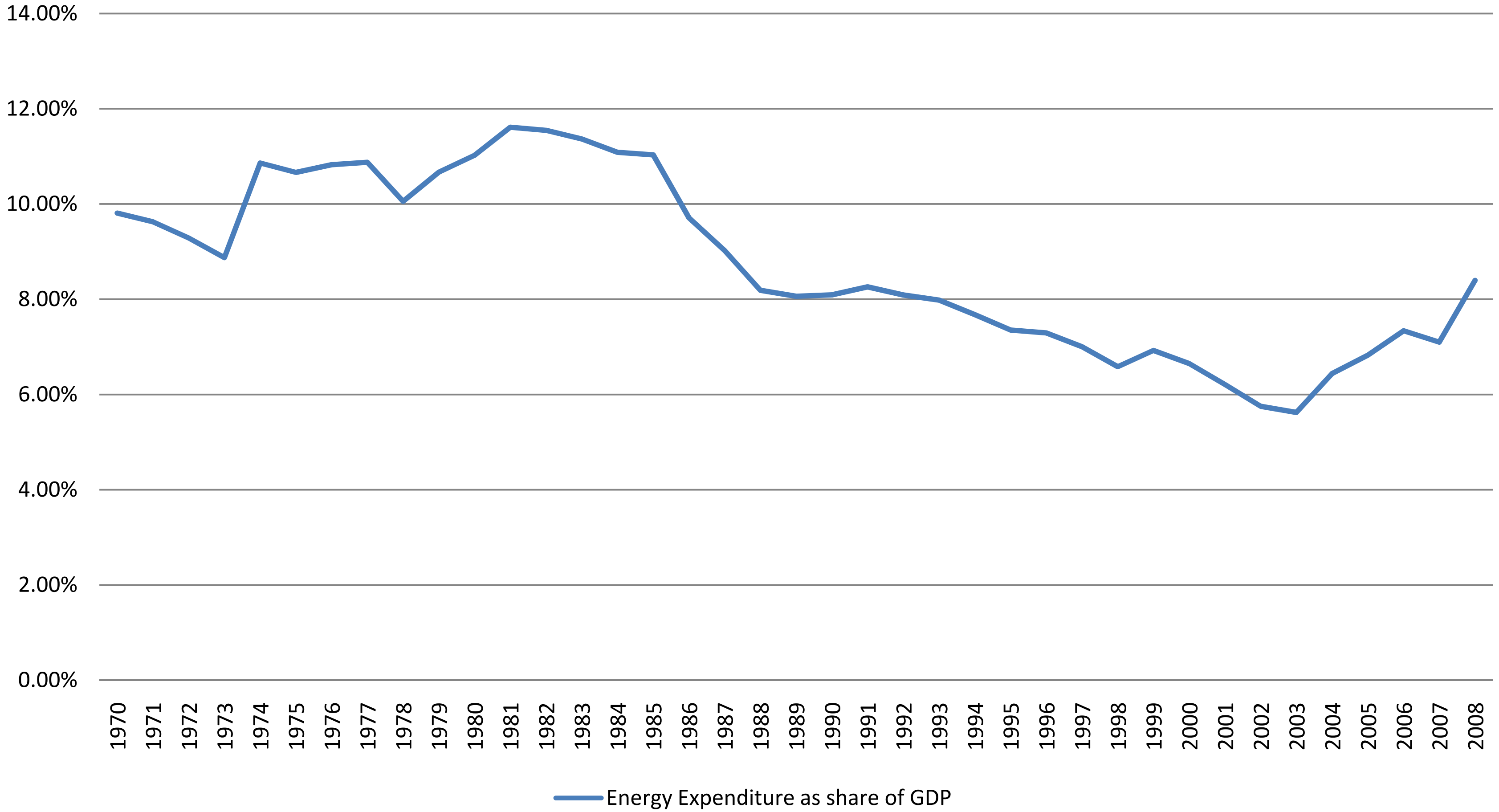
	Contribution by			Total
	Activity effect	Structural effect	Intensity effect	
Developing	322.85 (57.8%)	99.12 (17.7%)	136.56 (24.5%)	558.53 (100.0%)
China	178.65 (63.2%)	243.90 (86.3%)	−139.80 (−49.5%)	282.75 (100.0%)
Developed	1488.21 (693.2%)	−204.35 (−95.2%)	−1069.16 (−498.0%)	214.70 (100.0%)
Eastern Europe, former USSR	503.70 (156.1%)	29.42 (9.1%)	−210.53 (−65.2%)	322.59 (100.0%)
World	2493.41 (180.9%)	168.09 (12.2%)	−1282.93 (−93.1%)	1378.58 (100.0%)

Units: mtoe. Activity = scale; Structure = industry mix; Intensity = technological effect

Source: Sun, 1998, p.98.

Need to worry about embodied energy in world trade…

Energy Expenditure as share of UK GDP



Source: ONS.

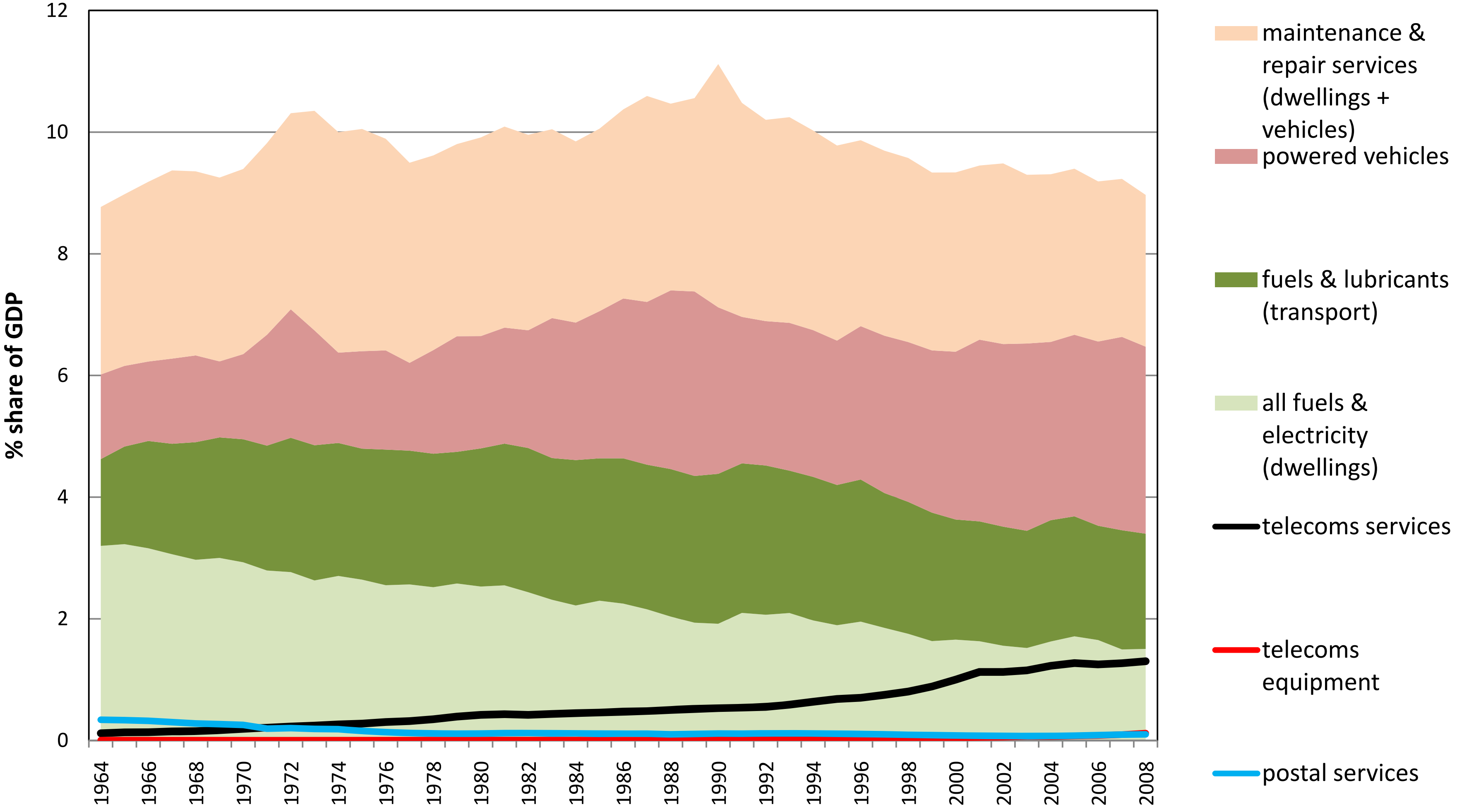
Taxes and transport fuels share large…

- Total energy expenditure in 2008:
- £ 121bn of which:
- £ 17.7bn Gas;
- £ 30.7bn Elec;
- £ 71.6bn petroleum (£57.1bn road transport)

- Energy Taxes in 2008: £24.8bn on oils + VAT receipts + CC Levy (say £30bn in total)

Expenditure on energy services

consumers spending as share of UK GDP



Source: ONS, chained volumes terms, http://www.statistics.gov.uk/STATBASE/Product.asp?vlnk=242

Making networks fit for renewables …

Projections of electricity demand

- Residential & commercial buildings:
  - **without** attempts to reduce emissions: electricity demand could increase by **2.5% p/annum** (p.55)
  - with **application of technologies** (led lighting, & more efficient appliances and air conditioning): electricity demand in 2050 **could be reduced by 35% below baseline level** (IEA, cited by CCC, 2008, p.55)
- Industrial processes:
  - improvements in efficiency could **reduce electricity demand in industrial processes in 2050 by 18% versus the baseline** (p.56)
- Uncertain and depends on price and income.

Source: CCC (2008)

Micro Context

- Nature of energy services: time, place, quantity and quality specific
- Derived / intermediate demand
- Scope for reduction in quantity drivers
- Scope for shifting time of consumption
- Scope for shifting place of consumption

Life time energy costs for durable goods

	Capital Cost £	Lifetime energy cost £	Total cost	Energy cost %
Lightbulb 100W	0.35	18.98	19.33	98.2%
Lightbulb low energy 100W	1	15.53	16.53	94.0%
Gas Boiler	1000	7629.05	8629.05	88.4%
TV	700	540.01	1240.01	43.5%
Fridge	300	159.56	459.56	34.7%
Car (annual)	2500		3500.00	28.6%
Computer	1000	48.84	1048.84	4.7%
Mobile phone (annual)	360	1.42	361.42	0.4%

Key assumptions: electricity: 13p/kWh; gas 3.5p/kWh; 5% discount rate.

- ***Implies energy price a key driver for some demand sources…***
- ***Income/non-energy preferences will be key driver for others…***

- ***A role for energy efficiency standards?***

Who pays for energy?

- Energy poverty and its role in energy demand.
- 20-40% of houses in energy poverty in major regions.
- Demand reduction and energy poverty need to be tackled together.
- Challenge to keep prices up and to tackle energy poverty or fear of energy prices.

The demand for mobility services…

- The role of transport in energy demand
- Implications of electric vehicles for energy demand – quantity, timing and location
- Typical EV stats:
  - 30 kW battery
  - 85% charge / discharge efficiency
  - Maximum storage c.13 kWh
  - Charges at 1.5-3 kW per hour
- Danish Edison project: charging from wind on island of Bornholm.

Barriers to large demand changes

- Financial barriers
  - Linking power, heat and transport
- Hidden costs and co-benefits
  - Metering and user interfaces key
- Split incentives and market failures
  - Role of energy poverty policy crucial
- Organisational and behavioural changes
  - Electric vehicles offer exciting possibilities

Large price rises needed to impact household demand…

Model	Data	Findings	Study
Generalized method-of-moments estimator	large number of Californian households	Own price elasticity (electricity): -0.4 (close to 1 when electric heating)	Reiss and White (2005)
Translog model of households' energy fuel demand	more than 80,000 U.K. households between 1972 and 1983.	Own price elasticities: - 0.75 (electricity) -0.3 (natural gas)	Baker *et al* (1989)
Set of fixed effects models	5,000 U.K. households panel dataset between 1991 and 2007	Income elasticity (energy): 0.05, to 0.061, 0.142 and 0.080 (for income from £9,000 to £20,000; £20,000 to £30,000 and £30,000 to £45,000; above £45,000 respectively).	Jamasb and Meier (2010)
Error-correction model	U.S. annual data from 1949 to 1993	SR and LR own price elasticities (electricity) : -0.25 and 0.5 respectively (much lower than other studies)	Silk and Joutz (1997)
Meta-analysis (4 models estimated)	36 studies (electricity) between 1971 and 2000 (123, 125, 96, 126 estimates of SR price, LR price, SR income and LR income elasticities)	SR price : -2.01 to -0.004, median -0.28 LR price : -2.25 to 0.04, median -0.81 SR income: 0.04 to 3.48, median 0.15 LR income 0.02 to 5.74, median 0.92	Espey and Espey (2004)

Source: Steinbuks (2011)

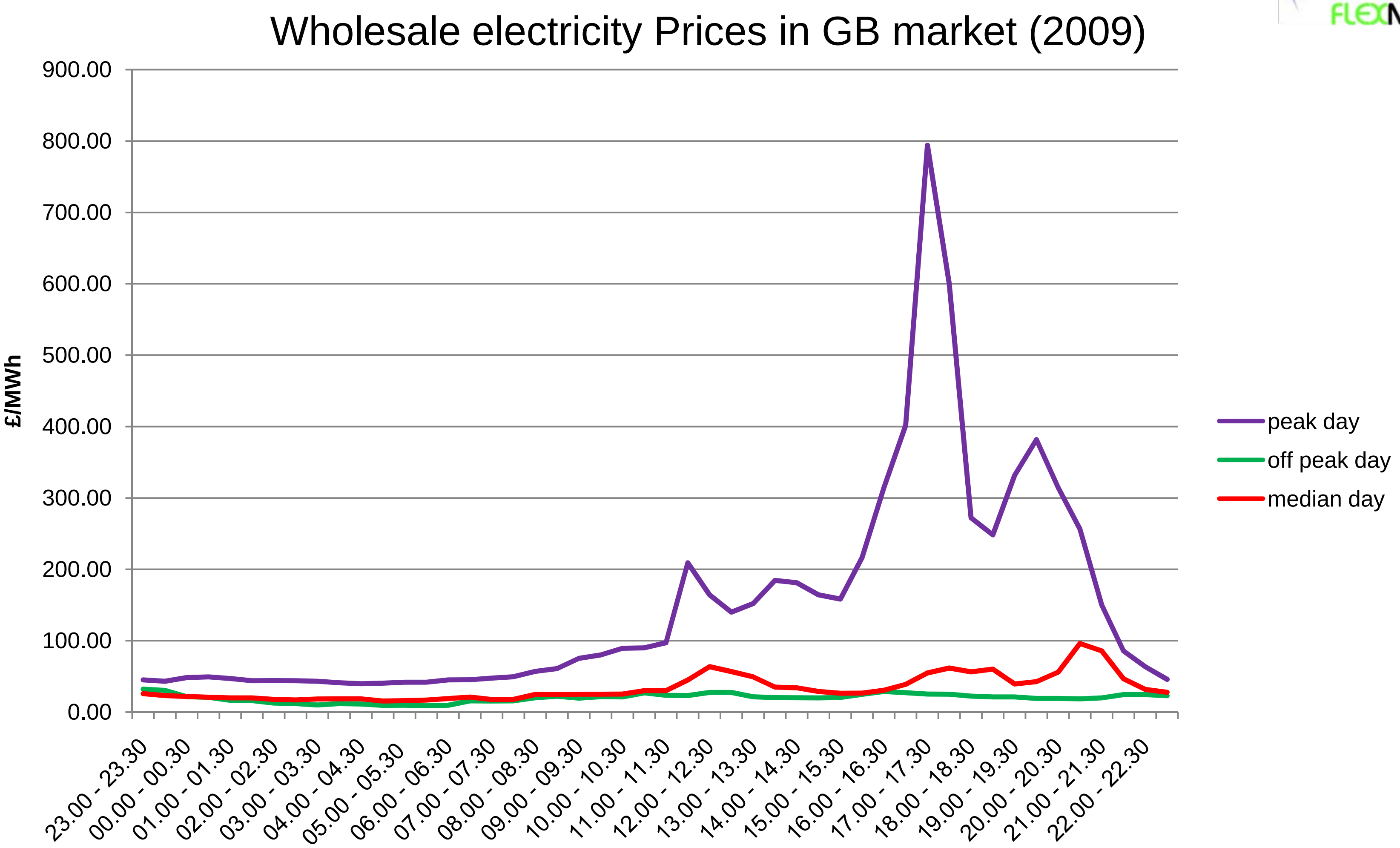
Similar for transport…

Model	Data	Findings	Study
Meta-analysis	Elasticities: 277 LR price, 245 LR income, 363 SR or MR price, and 345 SR or MR income	SR price: 0 to -1.36, median -0.23 LR price: 0 to -2.72, median -0.43 SR income: 0 to 2.91, median 0.39 LR income:0.05 to 2.73, median 0.81	Espey (1998)
Review of literature	Houthakker et al. (1974, Dahl (1979), Wheaton (1982), Dahl and Sterner (1991), Espey (1998), Graham and Glaister (2002	SR price: -0.2 and -0.3 LR price: -0.6 to -0.8 SR income: 0.35 to 0.55 LR income	Steinbuks (2011)

Source: Steinbuks (2011), Espey (1998)

If there is a switch to electric vehicles price elasticity will decline…

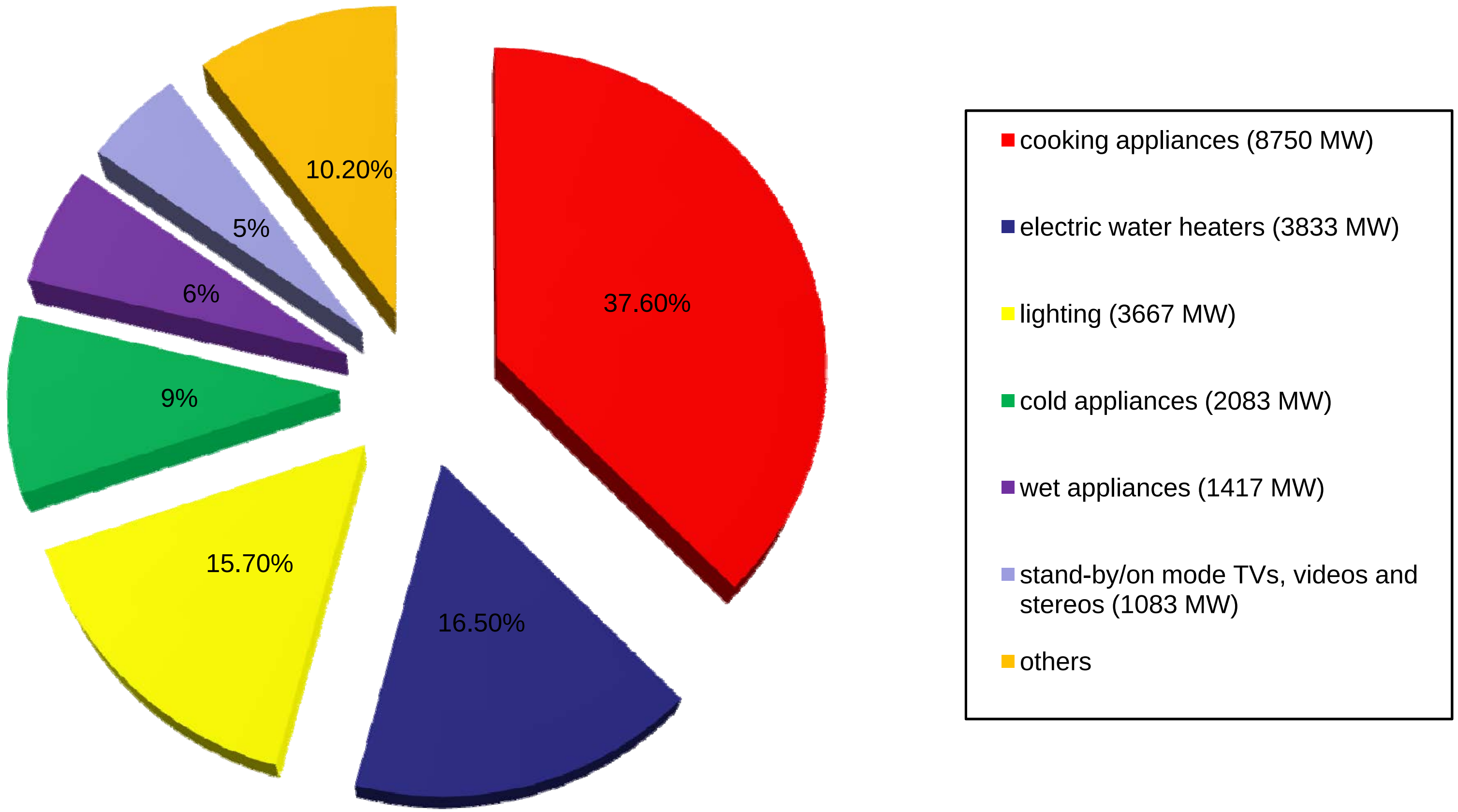
Demand shifting also important…



Source: APX, http://www.apxgroup.com/index.php?id=61

Untapped potential at the household level…

Household peak in the UK (5-6 pm, responsible for 45% of system peak):
breakdown by appliance type, whole UK, typical winter week-day (52016 MW)



Source: adapted from Lampaditou, E. and M. Leach (2005)

Estimating demand shift potential…

- Simulation by Lampaditou and Leach (2005):
- Impacts of **time of use pricing** with water/wet appliances shift :
  - morning peak: **47% decrease** - shift of water heating
  - evening peak: **6% decrease** - shift of wet appliances
  - *consumers' benefits*: **£52/yr** per consumer (using average spot prices of random winter day from UKPX 2005).

- Impact of **direct load control** of major appliances at 5-6 pm (switch off & better cycling) :
  - Switch off washing machine, tumble driers, dish washers & cold appliances: **15% of household peak reduction** (3500 MW)
  - Plus better cycling of water heater: **23%** (5500 MW)

- Also may be opportunities for households to provide virtual spinning reserve (by providing frequency response)…

Smart meters and demand…

Trial	Timeframe	Sample size	Tariffs	DR
California Statewide Pricing Pilot	July 2003 to December 2004	2,500 residential and SMEs	TOU and CPP	**Average critical peak reduction of 13%**
Illinois Community Energy Cooperative	Started in 2003, ongoing	750 initially; 1500 by 2005	RTP	**Up to 15% peak reduction; 4% energy conservation**
Olympic Peninsula Project	Early 2006 to March 2007	112 residential customers	TOU and RTP	**Average peak reduction of 15%**
Ontario Smart Price Pilot	August 2006 to March 2007	373 residential plus control group of 125	TOU, CPP and PTR	**CPP had highest impact on peak reductions (average 8.1%); 6% energy conservation**

Source: Brophy Haney et al. (2011)

Some 'Known Unknowns'

- Scale of the IT challenge
- What outturn response elasticities could be:
  - London Congestion Charge (-0.42 against -0.15 predicted)
- What innovations might come along
  - In heat, in transport…
  - Telecoms suggests expect the unexpected (e.g. growth of SMS)
- Which diversifying entrants will enter
  - Device retailers, supermarkets, oil and gas majors…?
- How consumers will react
  - Ofgem/DECC EDRP trials appear to be disappointing
  - Non-rational behaviour likely
- Likely MC=MR at less than full exploitation of demand response.

Conclusions

- ***The key to demand moderation is price***.
  - Prices must rise (nationally and globally) as technology improves to avoid rebound.
- ***Price signals should be helped by standards.***
  - Prices weak signal for newer sources of demand.
- ***Shifting demand worthwhile*** and may be easier and more valuable than reduction.
  - However new business models required.
- ***Full potential for demand reduction and response will not be realised.***

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