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Chasing our tails? - Rebound effects from improved energy efficiency

Seminar at the School of Earth and Environment, University of Leeds, 16th Nov 2011

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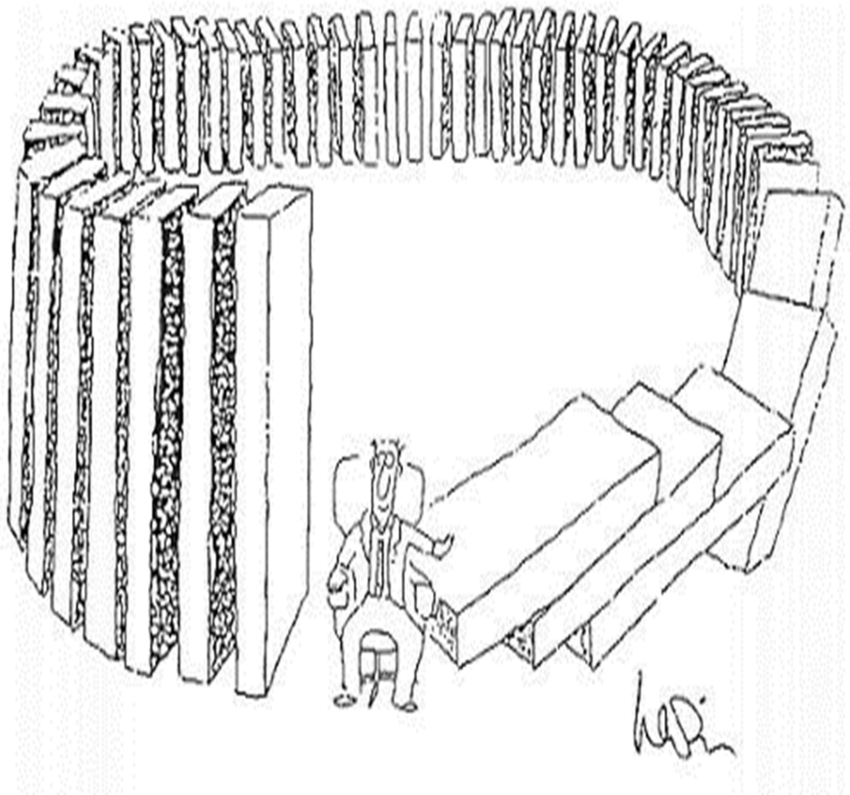
Sustainable Lifestyles Research Group

Topics

- Defining and measuring rebound effects
- Rebound effects for consumers
- Rebound effects for producers
- Jevons Paradox
- Summary and implications



Defining and measuring rebound effects

Rebound effects - consumers

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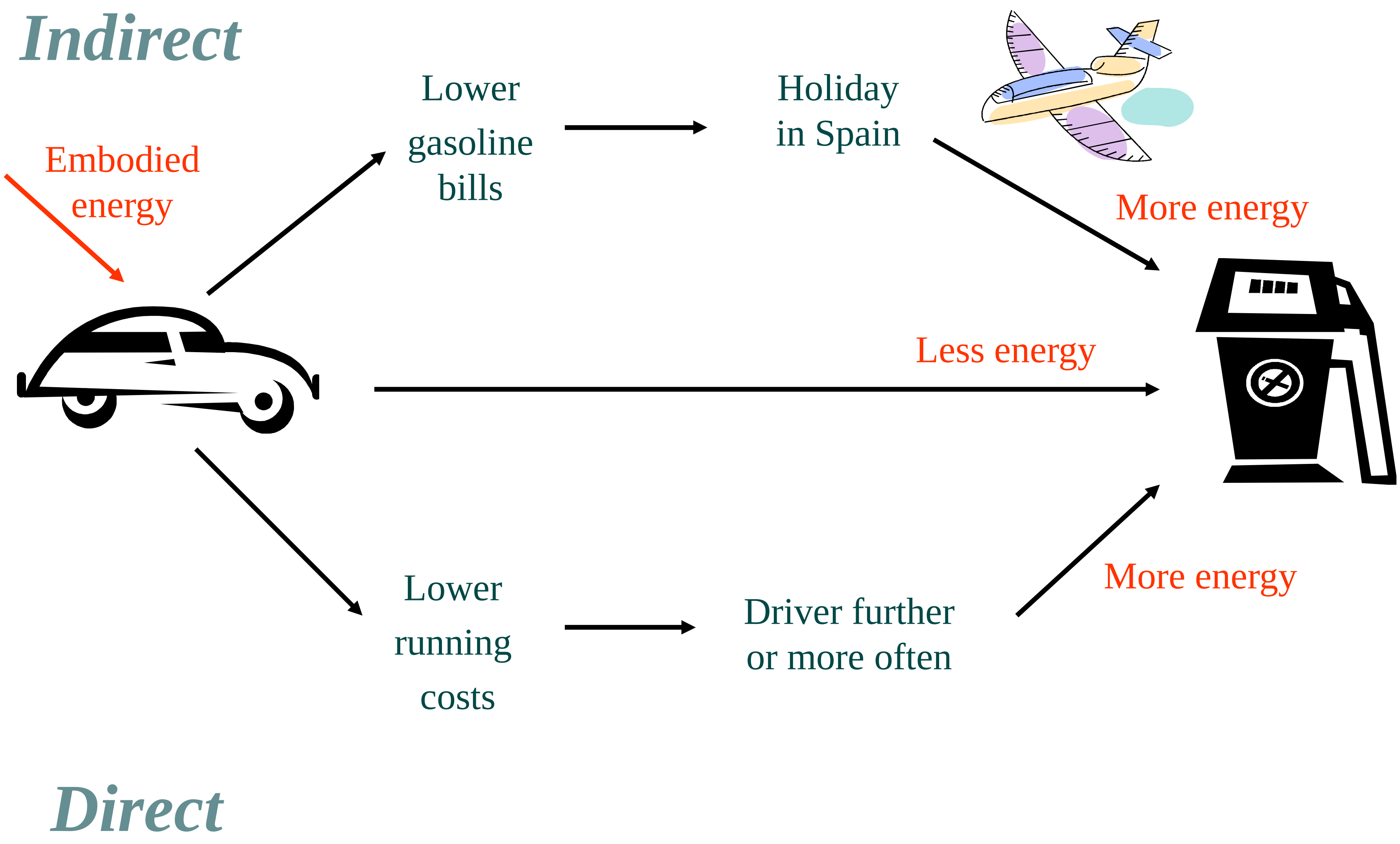

Reinforcing rebound effects!

Rebound effects - producers

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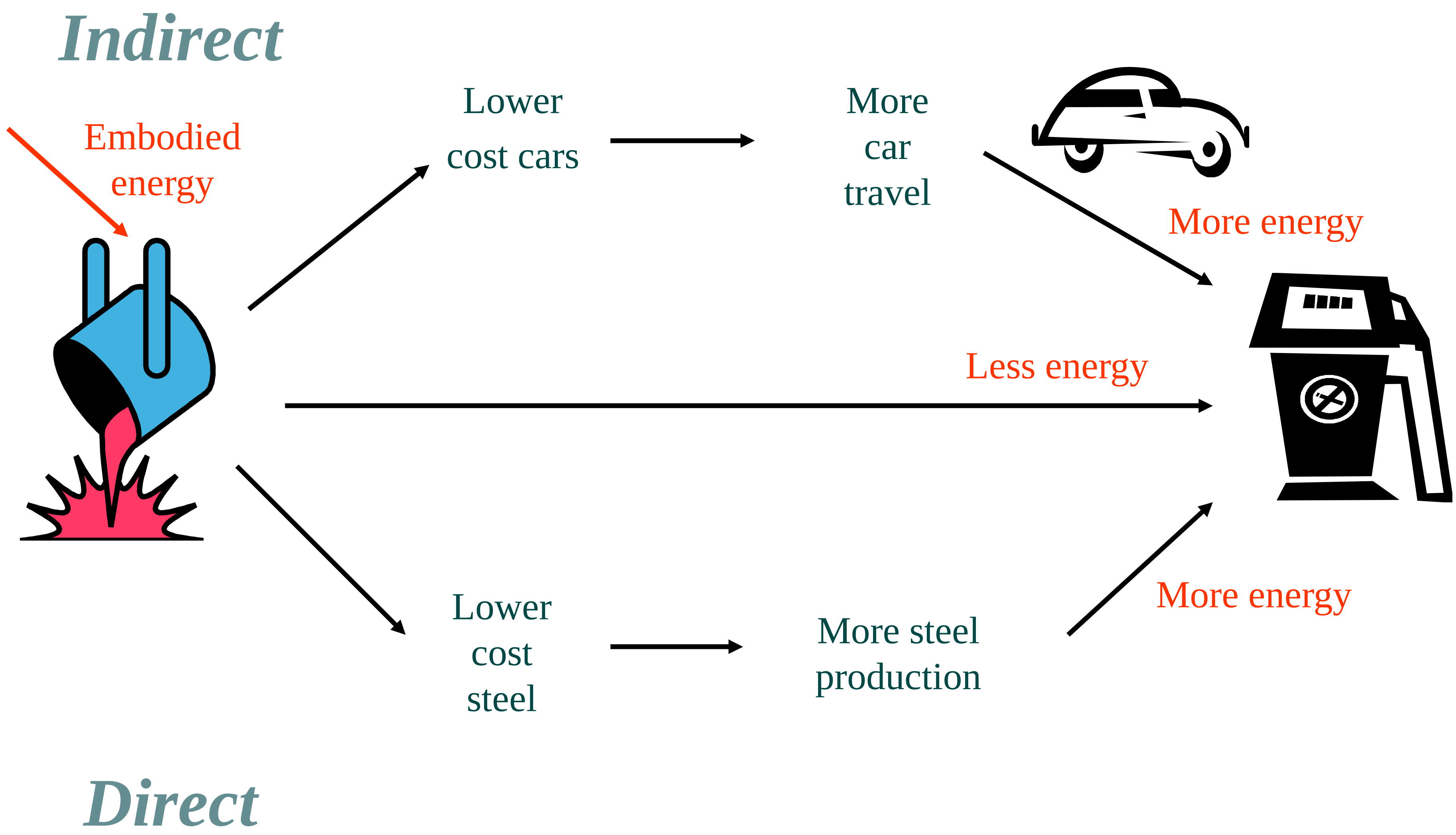

Economy-wide rebound effect

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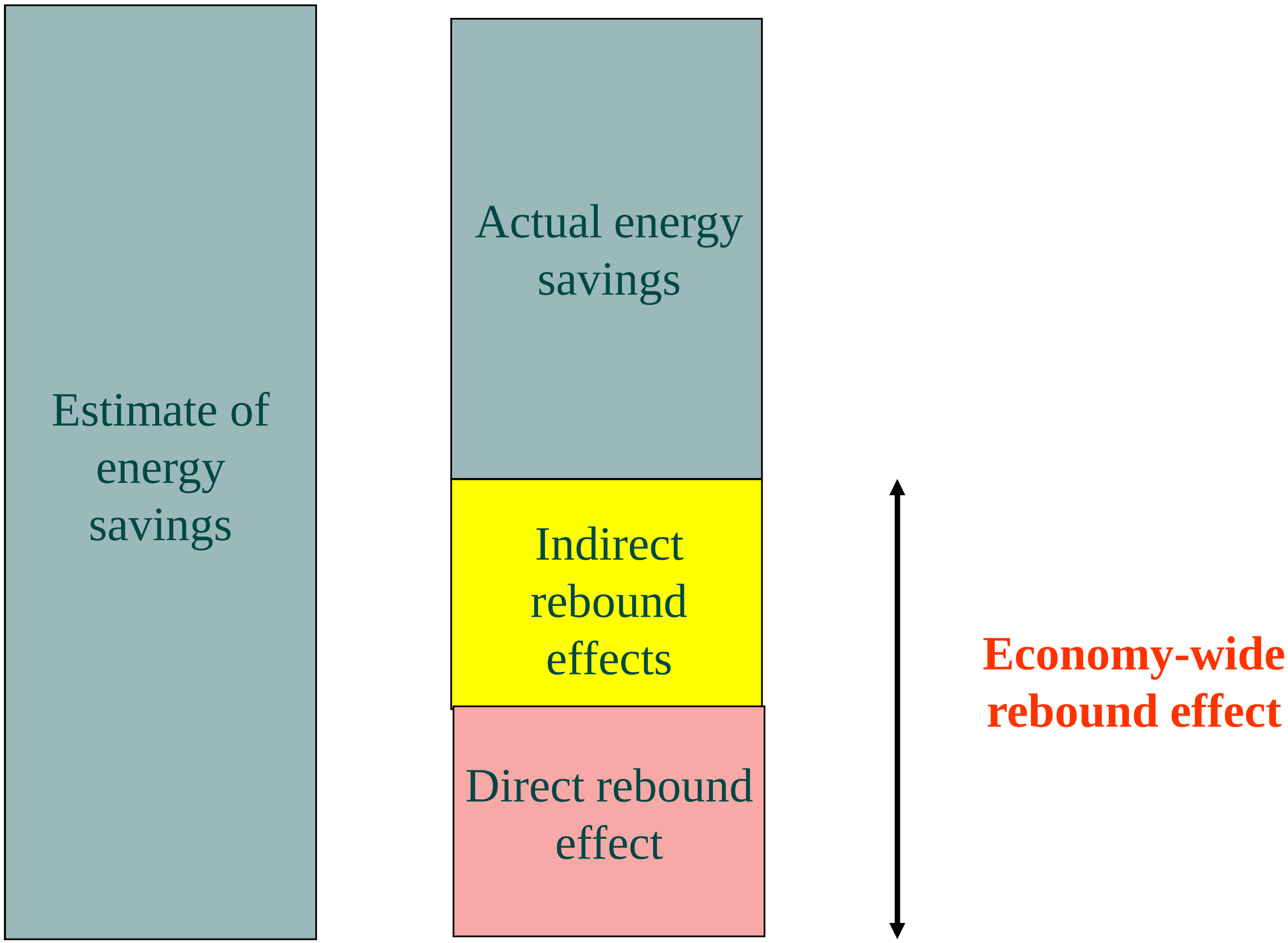

A polarised debate

“The concept of a nontrivial rebound effect…..is without basis in either theory or experience. It is, I believe, now widely accepted to be a fallacy whose tedious repetition ill serves rational discourse and sound public policy” (Lovins, 1988)

“With fixed real energy prices, energy efficiency gains will increase energy consumption above what it would be without these gains)” (Saunders, 1992)

Quantification hampered by inadequate data, uncertain causal relationships, endogenous variables and complex, long-term dynamics

Existing evidence base only captures a subset of effects in a limited number of countries/sectors over limited periods of time

Defining an energy efficiency improvement

- Energy efficiency may be measured in a variety of ways for a variety of system boundaries
- Sources and consequences of changes and hence rebound effects will vary with the measure chosen
- *Example*: If energy efficiency policy reduced the US energy/GDP ratio by 30%, GDP would need to grow by 55% to offset the energy savings. But rebound effects may prevent the energy intensity reduction

Isolating an energy efficiency improvement

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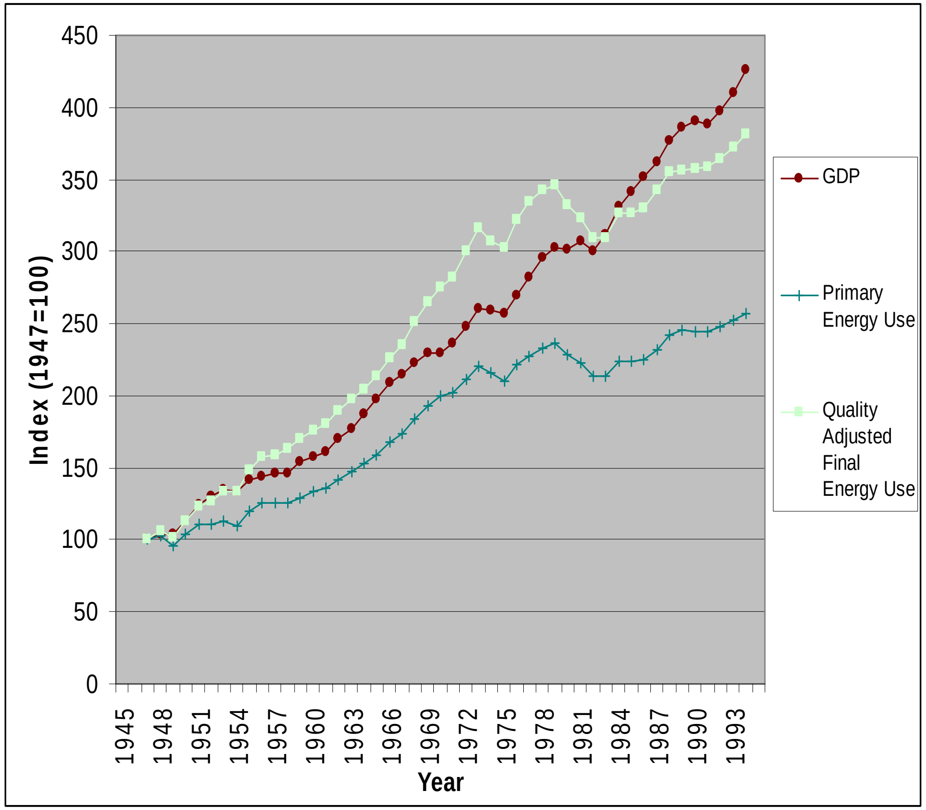
- Energy efficiency improvements rarely occur in isolation – new technologies provide multiple benefits
- Rebound effects need not be small just because the share of energy in total costs is small – and win-win improvements will have bigger rebound effects
- *Example*: Mean payback for 52 energy efficiency projects fell from 4.2 to 1.9 years when non-energy benefits taken into account
- *Example*: green commercial buildings improved labour productivity by 16% (labour costs ~25*energy costs)

Measuring aggregate energy efficiency improvements

- Aggregate measures of represent the net result of multiple variables
- Measuring energy consumption on the basis of thermal content amounts to summing apples and oranges – and will be misleading
- Economic phenomena require economic measures
- Estimated rebound effects will differ if we use carbon or GHGs



Rebound effects for consumers

Evidence for direct rebound effects for households

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- ***Quasi experimental studies*** – before & after measurements of energy or energy service consumption following efficiency improvements
- ***Econometric analysis of secondary data*** - estimates of efficiency or price elasticities for household energy service demand or energy demand
- Scope limited by data availability: largely confined to personal transport, space heating and space cooling in OECD households
  - Convergence in results, despite varying regions, time periods, data types, econometric specifications and measures
  - Many studies rely upon estimates of price elasticities and could be upwardly biased
- Own price elasticity of energy demand provides an upper bound for the direct rebound effect – and is usually less than unity

Estimates of direct rebound effects for households

Source: Sorrell (2007)

Service	Range of estimates	Best guess	No. of studies	Confidence
Car transport	3 - 87%	**10-30%**	17	High
Space heating	1 - 60%	**10 – 30%**	9	Medium
Space cooling	1 – 26%	**1 – 26%**	2	Low
Other	0 – 39%	**<20%**	3	Low

May decline in future as demand saturates and incomes increase

Higher in developing countries

Marginal consumers and key variables ignored

Long term transformational effects not captured

Evidence for direct + indirect rebound effects for households

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- ***Environmentally extended I-O models*** **-** energy/carbon/GHG intensities of commodity groups
- ***Systems of consumer demand equations*** - expenditure, own-price and cross-price elasticities for those commodity groups
- Cheaper energy services may lead to increased or reduced demand for <u>multiple</u> commodities with widely varying intensities
- Key methodological issues:
  - Level of commodity disaggregation
  - National versus multiregional I-O model
  - Cross-sectional versus time-series data on household expenditure (income effects *versus* income + substitution effects)
  - Commodities versus energy services

Estimates of direct + indirect rebound effects for households

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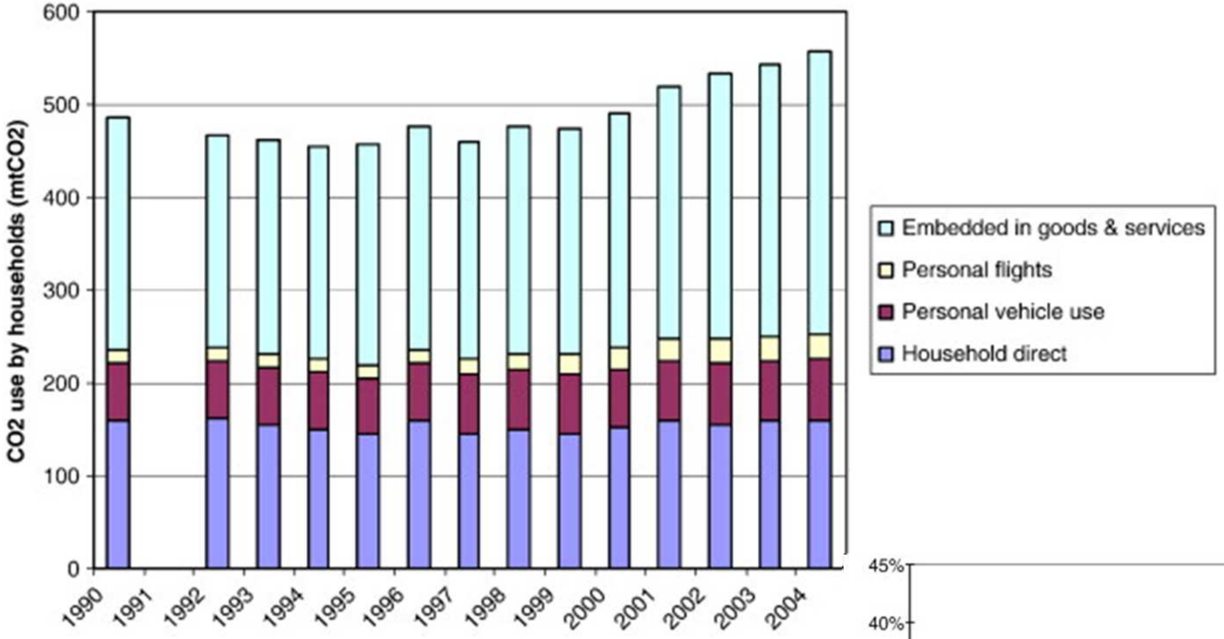
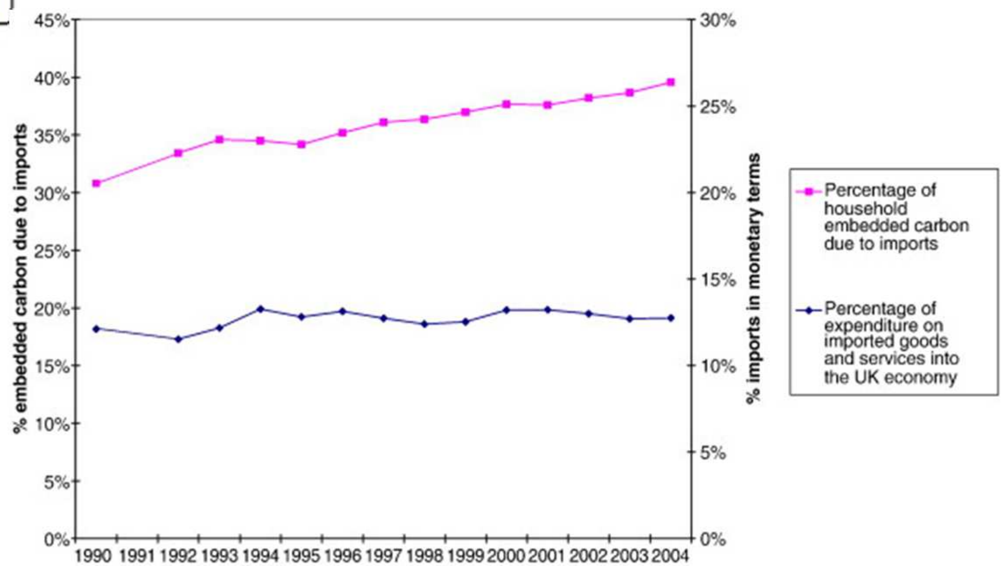
Author	No. categories	Effects captured	Efficiency or sufficiency	Area of consumption	Rebound effects
Lenzen & Day (2002)	?	Income	Efficiency & Sufficiency	Food; heating	**45-123% (GHGs)**
Alfreddson (2004)	300 (18)	Income	Sufficiency	Food; travel; utilities	**7-300% (carbon)**
Brannlund (2007)	13	Income & substitution	Efficiency	Transport; utilities	**120-175% (carbon)**
Mizobuchi (2008)	13	Income & substitution	Efficiency	Transport; utilities	**12-38% (energy)**
Kratena (2010)	6	Income & substitution	Efficiency	Transport; heating; electricity	**37-86% (energy)**
Chitnis *et al* (2011)	16	Income	Sufficiency	Transport, heating, food	**7-51% (GHGs)**
Thomas (2011)	74	Income	Efficiency	Transport, electricity	**7-25% (GHGs)**
Murray (2011)	36	Income	Efficiency & sufficiency	Transport, lighting	**5 – 40% (GHGs)**

The importance of indirect energy use and emissions



Direct carbon emissions from UK households steady, but indirect and total emissions rising

Indirect emissions due to imported goods rising faster



Source: Druckman & Jackson (2009)

The importance of indirect energy use and emissions

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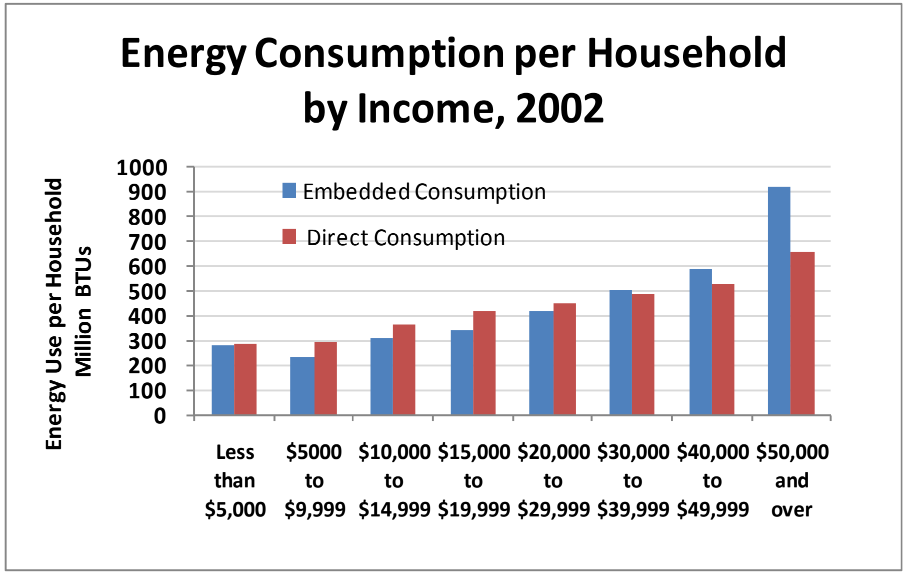
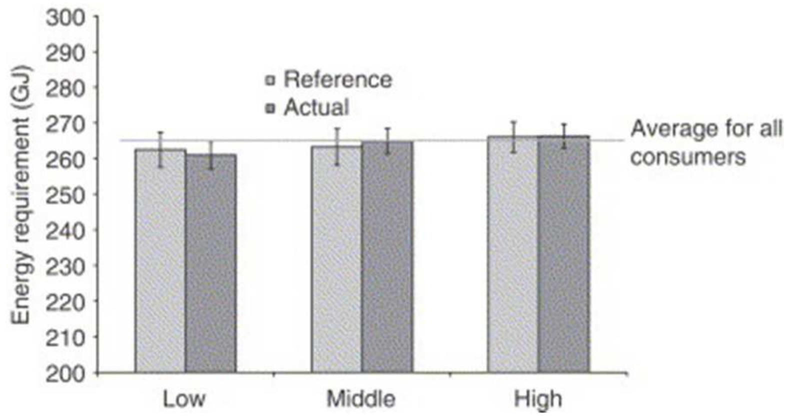


Source: Saunders (2010)

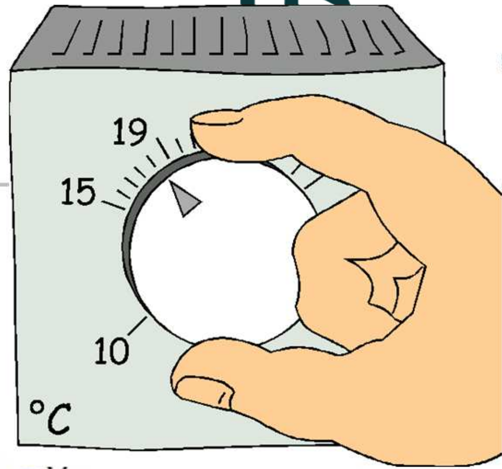
Most countries exhibit a strong correlation between total energy use/carbon emissions and household income – with indirect use of greater importance for higher income groups and over time

Wide variation in total energy use/emissions between socio-economic groups, but little evidence for significance of values and awareness, once socio-economic situation is allowed for



Source: Vringer *et al* (2007)

Simple ‘sufficiency actions’ – GHG savings for average household



Household heating: reduce thermostat by 1^{o}C (10%)

Food: reduce food waste by one third (33%)

Transport: replace car journeys <2miles by walking/cycling (23%).

Estimated rebound effects

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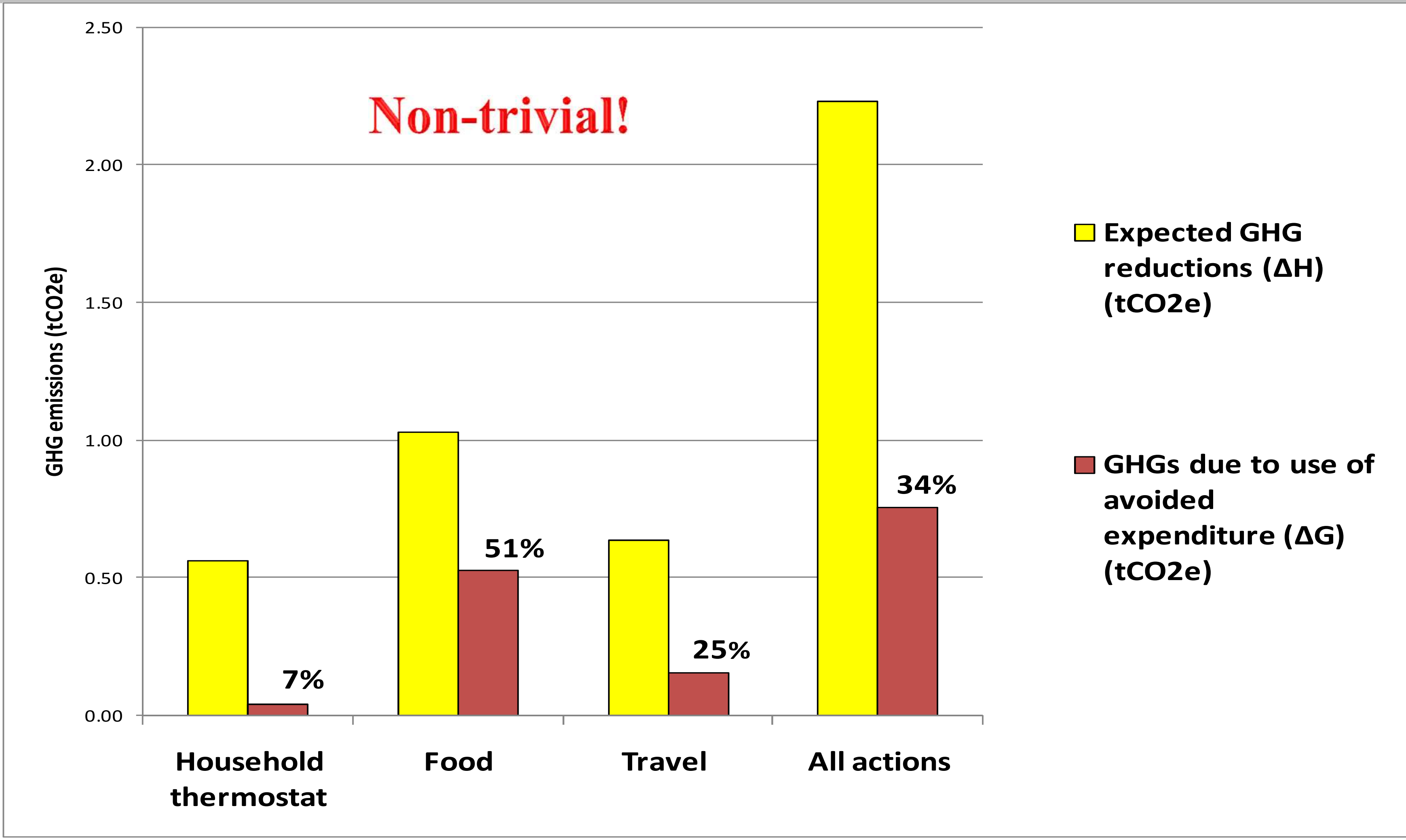
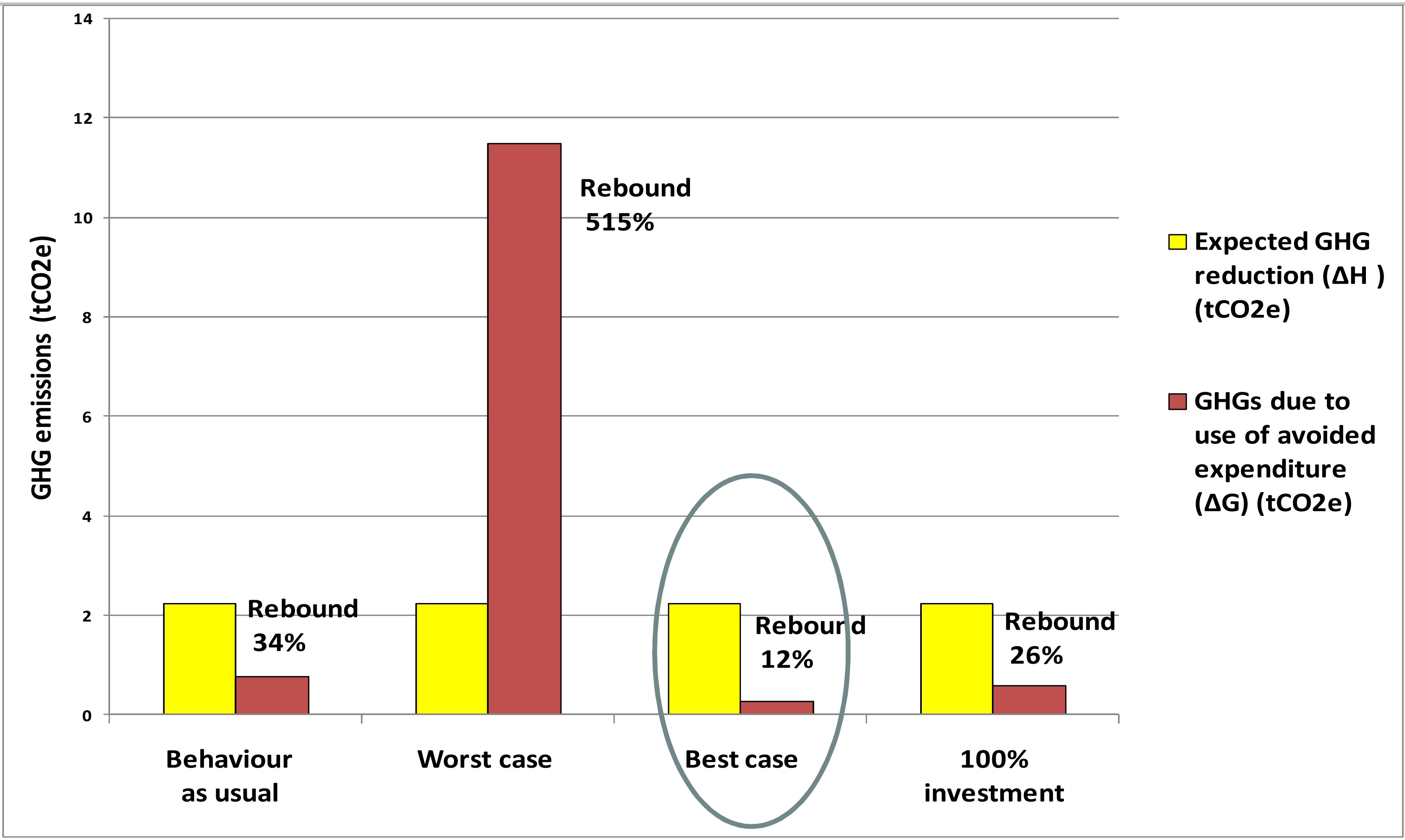


Varying the re-spend from the combined actions



Simple efficiency actions
– GHG savings for average[1] UK household

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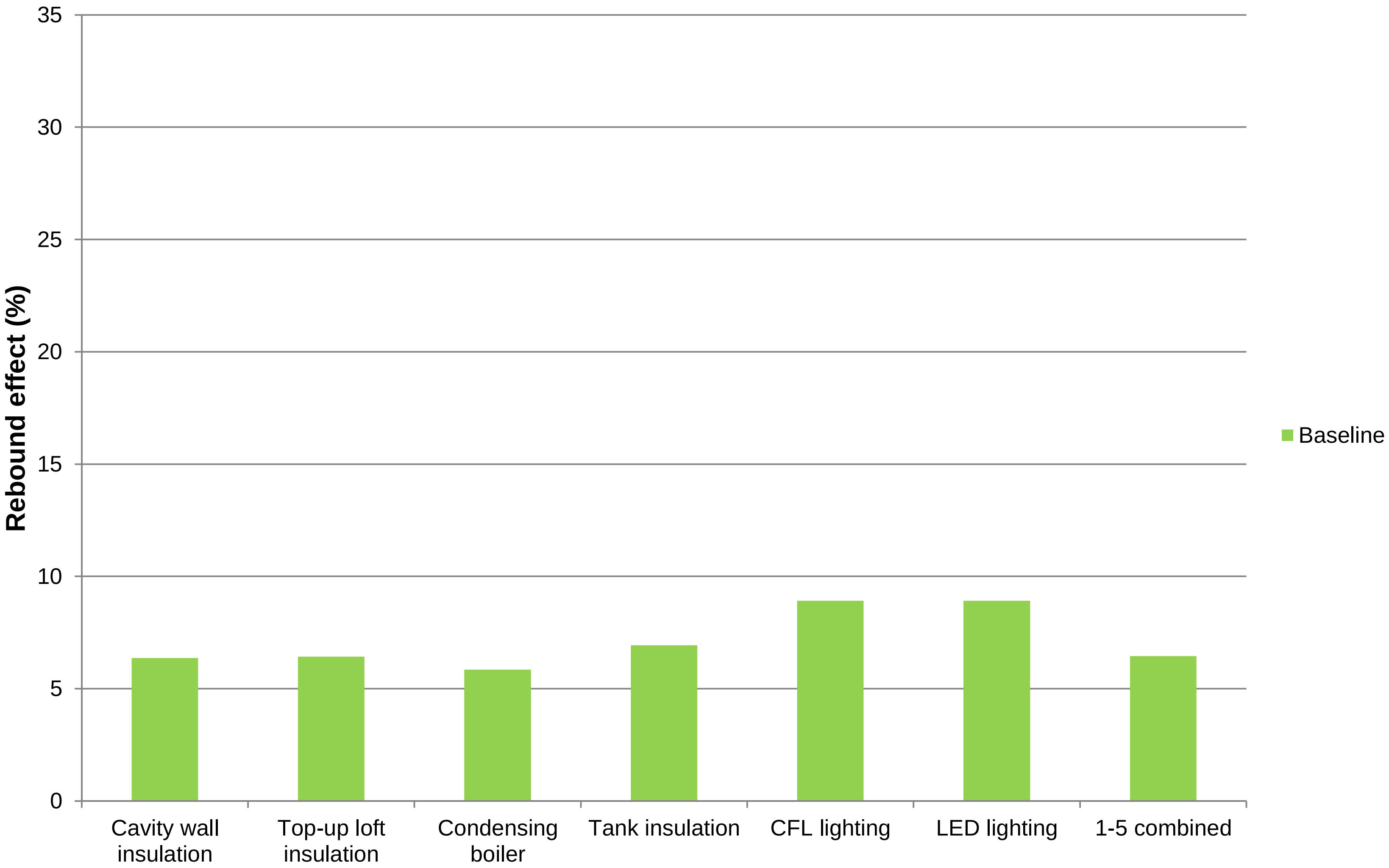
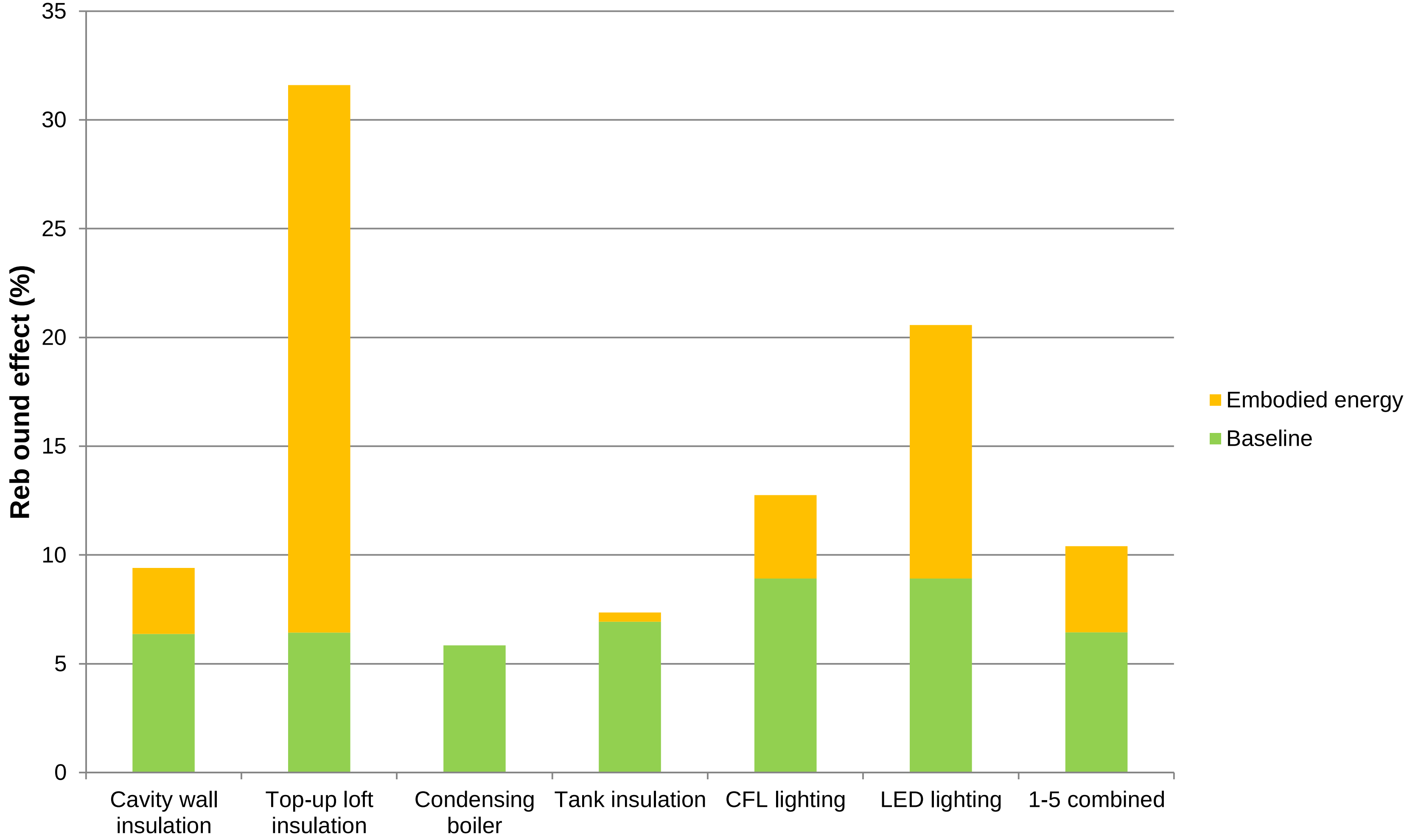
1.	Cavity wall insulation	5.9%
2.	Top-up loft insulation	1.5%
3.	Condensing boiler	5.9%
4.	Tank insulation	1.7%
5.	CFL lighting	1.2%
6.	LED lighting	1.3%
7.	1-5 combined	15.6%

[1] GHG savings for eligible households divided by total number of UK households

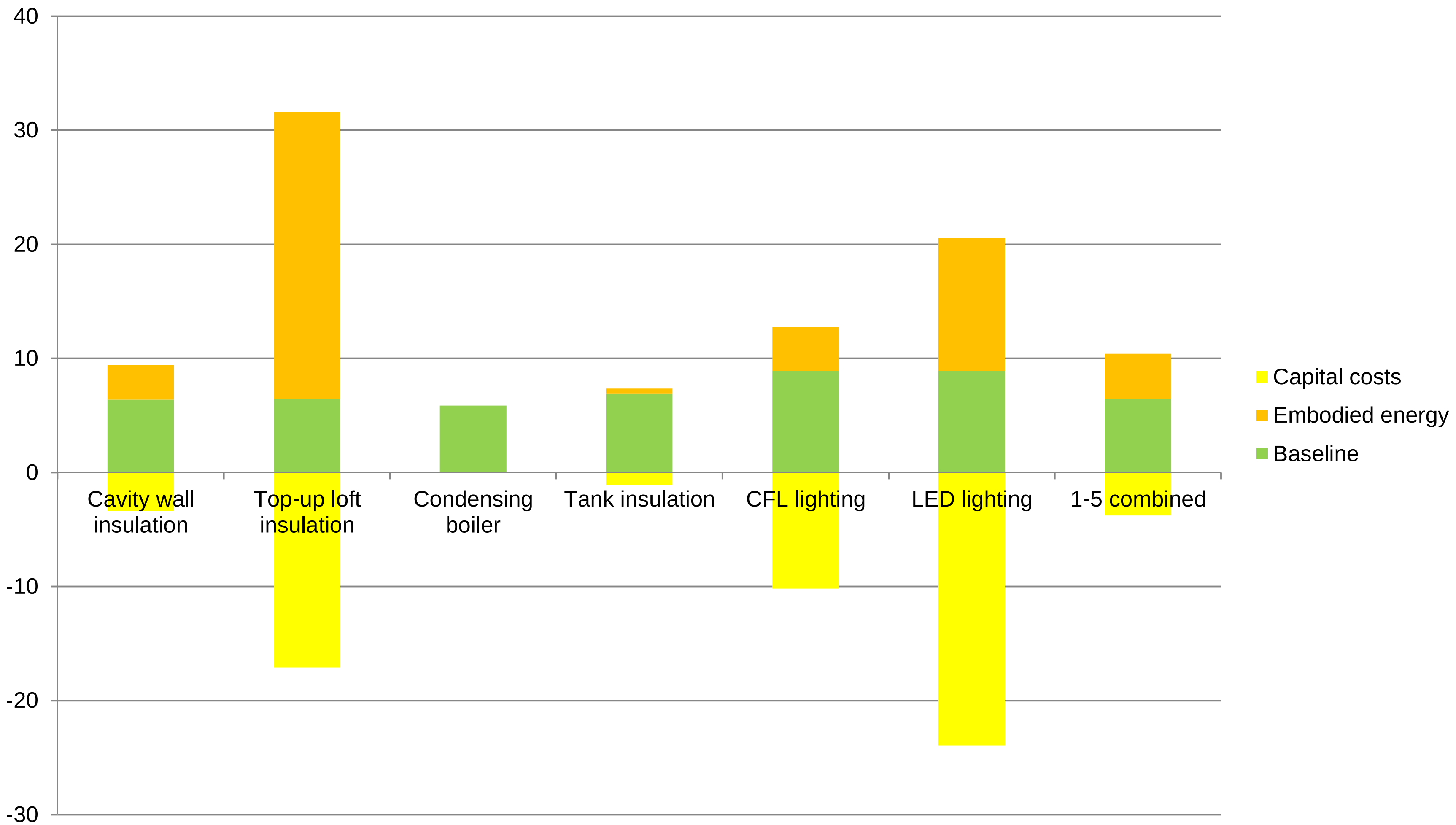
Baseline – no capital costs, no embodied energy, 5-year average



Baseline + embodied energy



Baseline + embodied energy + full capital costs



Baseline + embodied energy + subsidised capital costs

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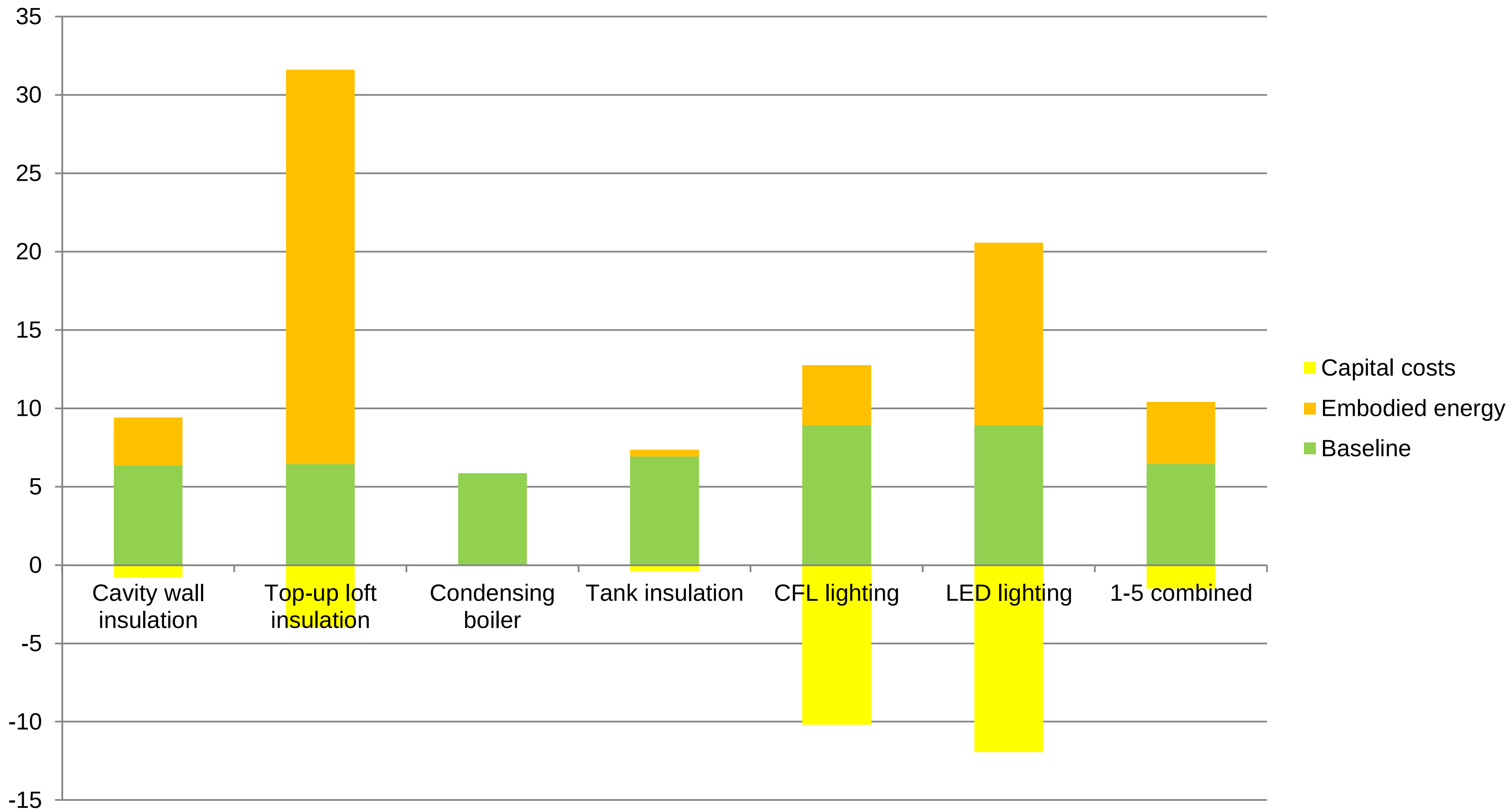

10 years versus 5 years

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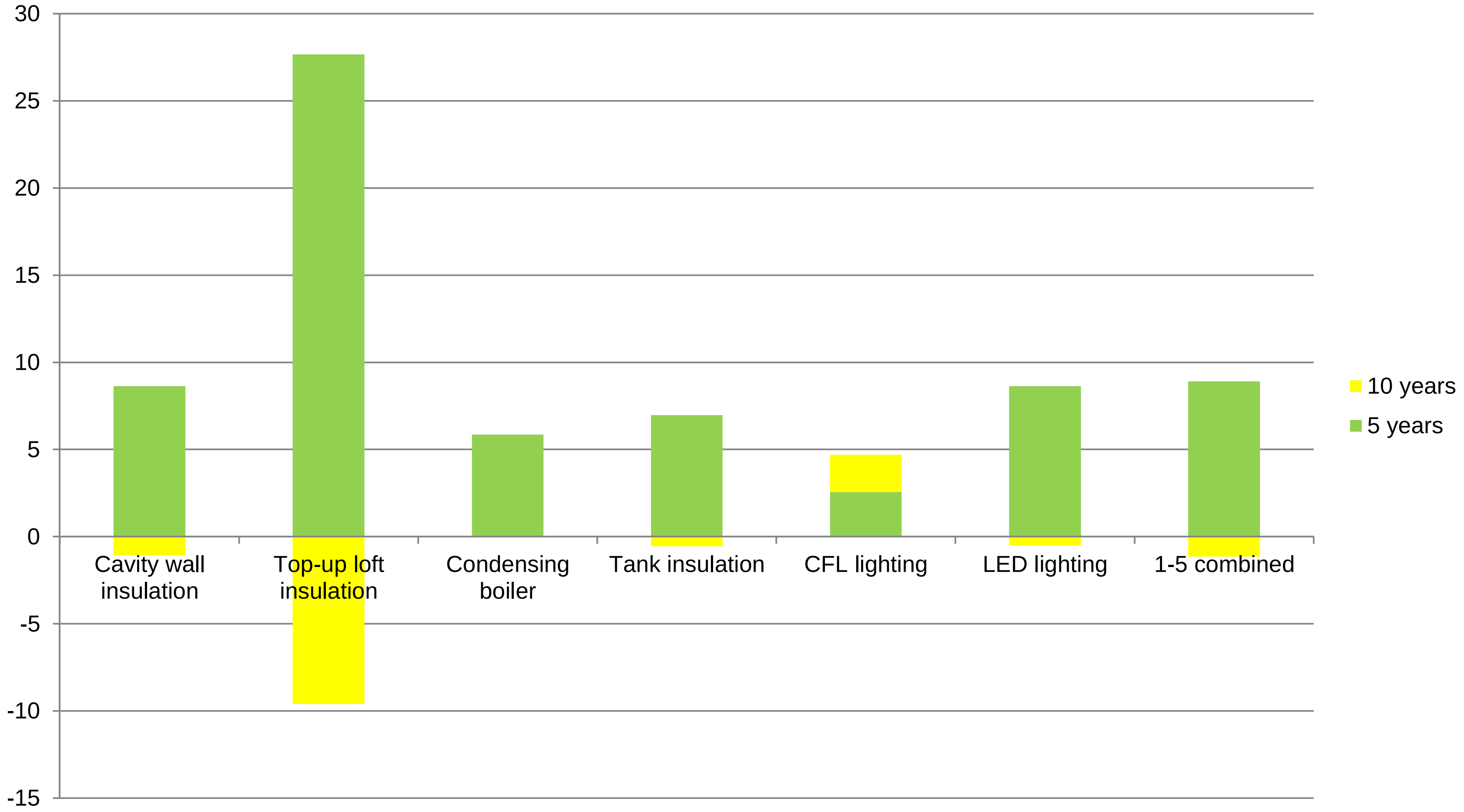

Planned work

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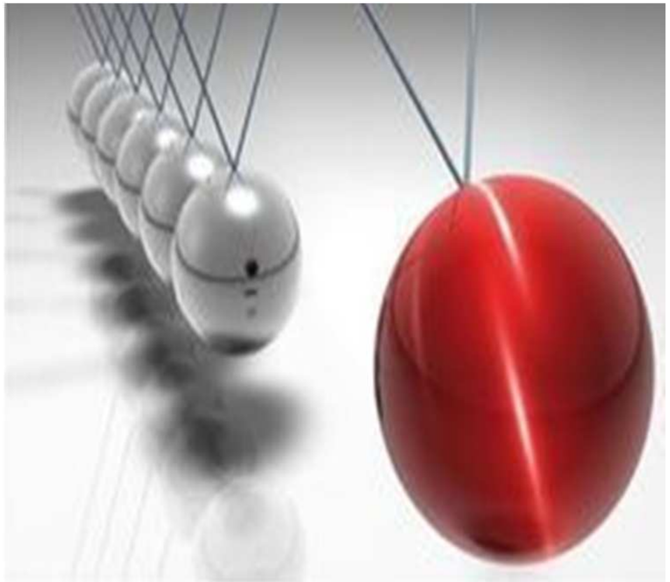
Variation of rebound effects by income group

- Estimate Engel curves for up to 40 commodities using data from UK Living Costs and Food Survey



Capture of income and substitution effects

- Estimate Linear Almost Ideal Demand system using ONS expenditure data for UK households

Conclusions on rebound effects for consumers

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- Evidence base reasonable for direct effects but sparse for combined effects
- Direct effects <30% for transport and heating, smaller for most other energy services but larger for low income groups and developing countries
- Combined effects variable with complex determinants - estimates range from 5 to 200%, but lower values more plausible
- Not capturing economy-wide, long-term and transformational effects

Rebound effects for producers

Rebound effects for producers

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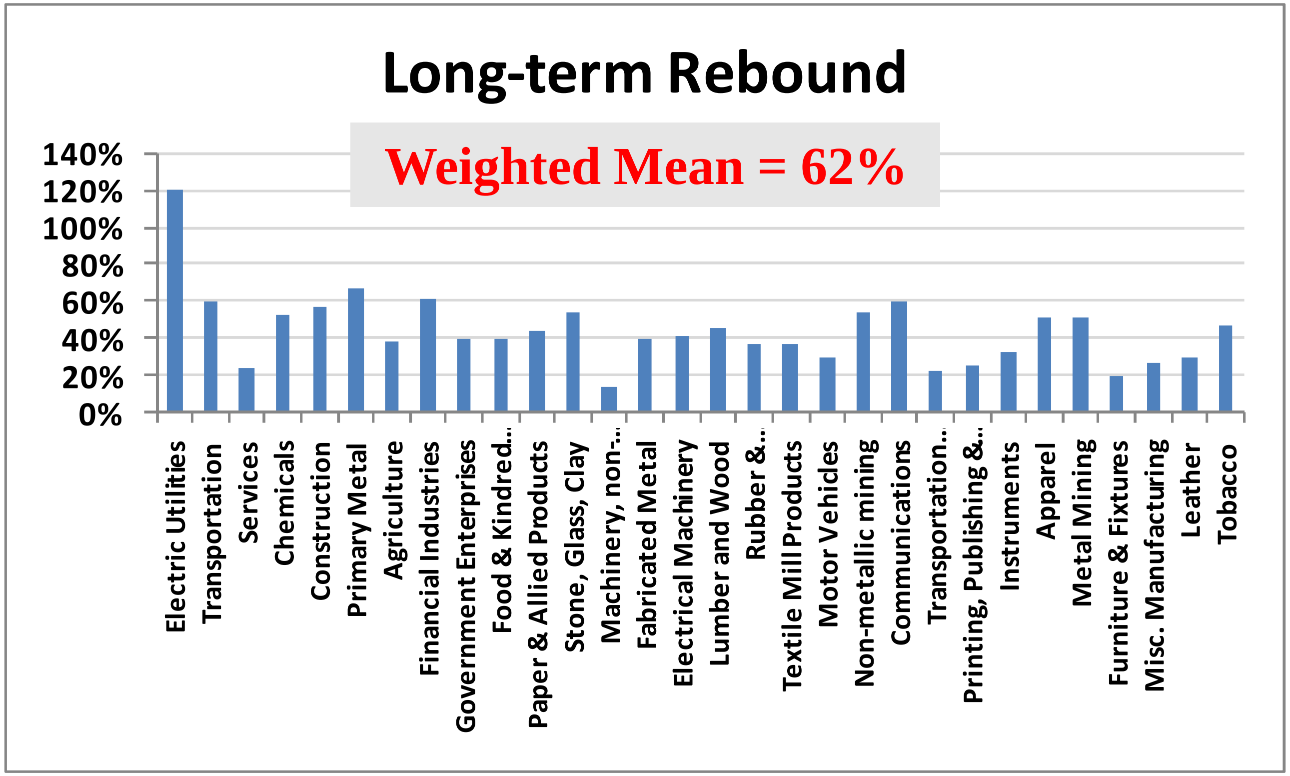
- *Substitution effect*: energy services become cheaper relative to other inputs
- *Output effect*: lowers production costs and therefore price of output encouraging increased demand
- *Productivity effect*: productivity improvements lead to increased incomes, consumption and economic growth
- *Composition effect:* economy shifts towards activities where impact of efficiency improvement is greatest

Econometric estimates of direct rebound effects for US producers

Estimation of KLEM translog cost functions for 30 US industry sectors over period 1960-2000, including technology gain parameters and allowing for capital stock turnover



Source: Saunders, 2011

Macro-economic modelling estimates of economy-wide rebound effects

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Only a handful of studies, focusing upon different regions and different types and sizes of energy efficiency improvement

- 8 CGE studies of economy-wide effects. Smallest result **~37%** and four **>100%**
- Macro-econometric model of global economy to 2030 found **~52%** for from 'no-regrets' policies summarised in IPCC AR4

Results sensitive to uncertain assumptions

- e.g. varying elasticity of substitution between energy and other inputs from 0.1 to 0.7 increased rebound effect from 7% to 60%

Results sensitive to multiple variables

- Energy intensity of sector, openness to trade, capital and labour market adjustments etc.
- Negative multiplier effects in energy sector

Conclusions on rebound effects for producers

- Effect varies widely with the nature and location of the energy efficiency improvement
- Problems with methodologies, sensitivity to uncertain assumptions and little systematic investigation
- Estimates consistently indicate <u>large</u> effects (> 50%) despite focusing upon ‘pure’ efficiency improvements that neglect associated benefits

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Jevons Paradox

Steam engines in the 19th century

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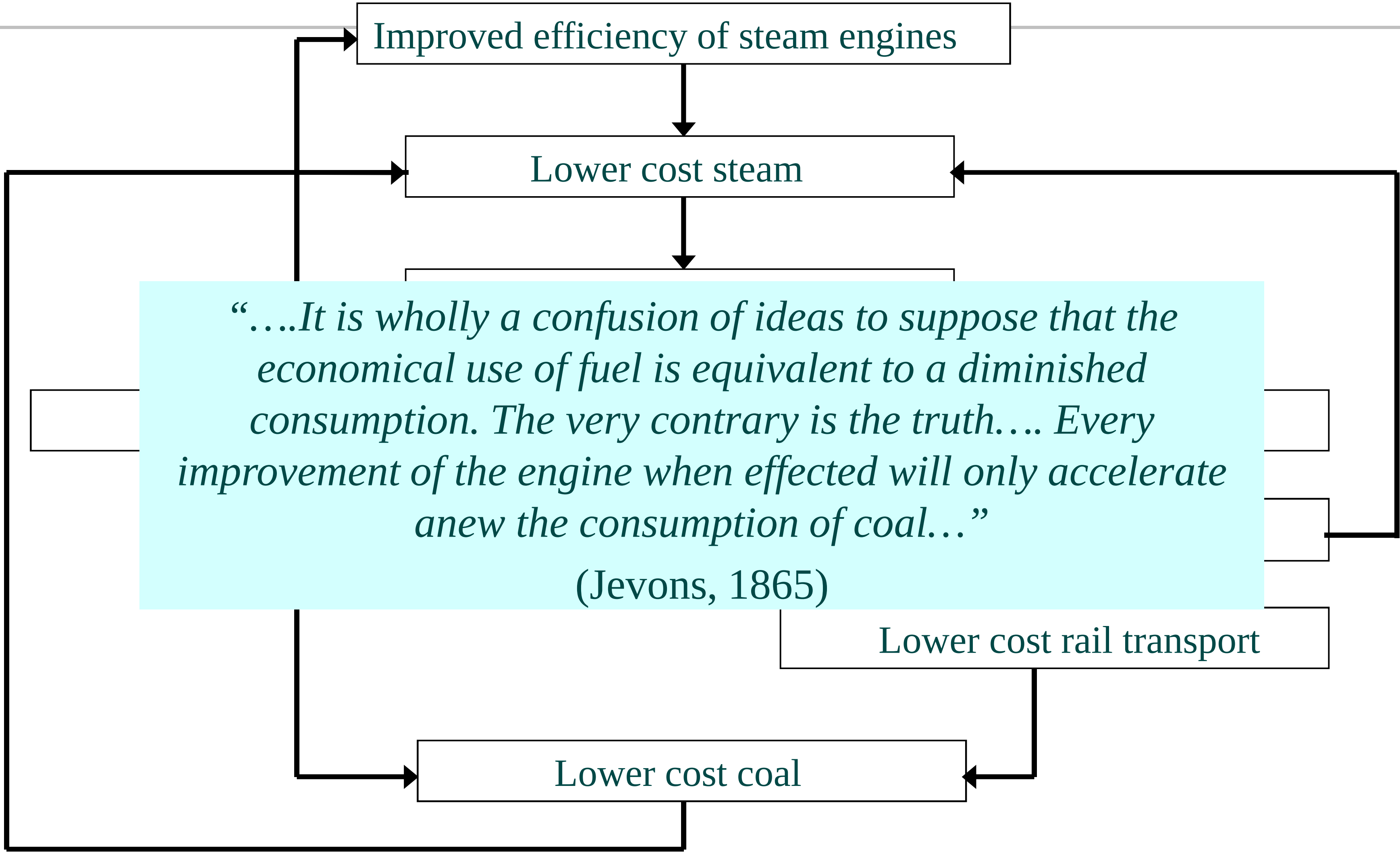

"….It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth…. Every improvement of the engine when effected will only accelerate anew the consumption of coal…"

(Jevons, 1865)

General purpose technologies

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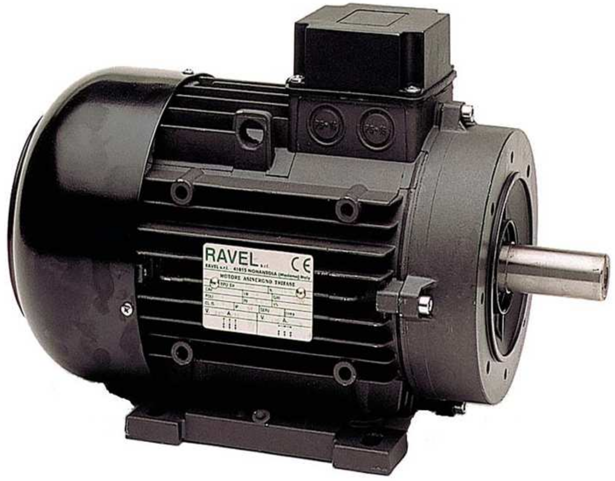
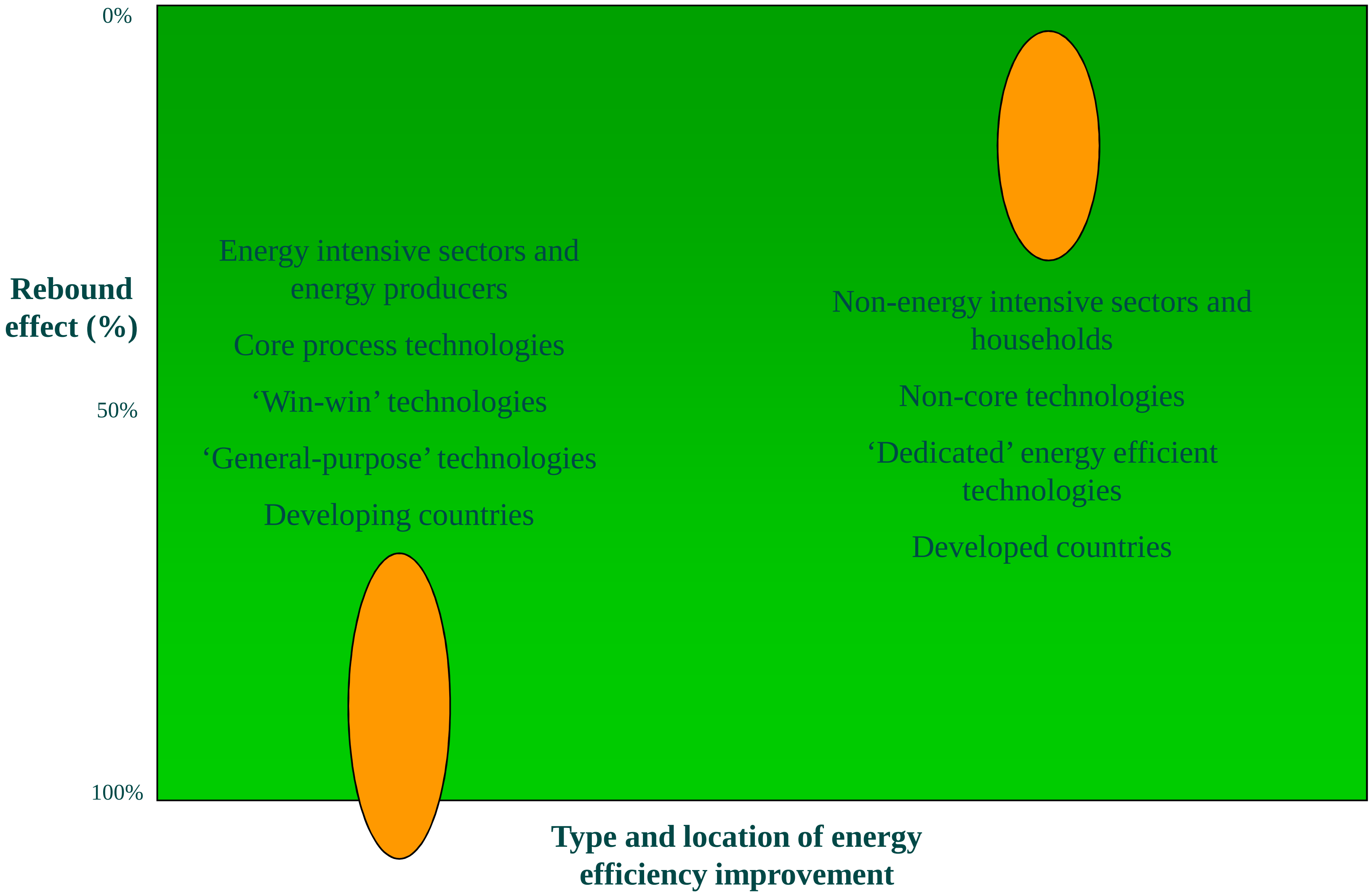
- *Potential* for substantial improvement
- *Pervasive* across a range of uses, sectors, products and processes
- *Complementarities* with existing or potential new technologies
- *Diffusion* characterised by increasing returns, widespread stimulus to innovation and long-term productivity growth



Variability of rebound effects



Long term rebound - indices of key lighting variables in the UK 1300-2000

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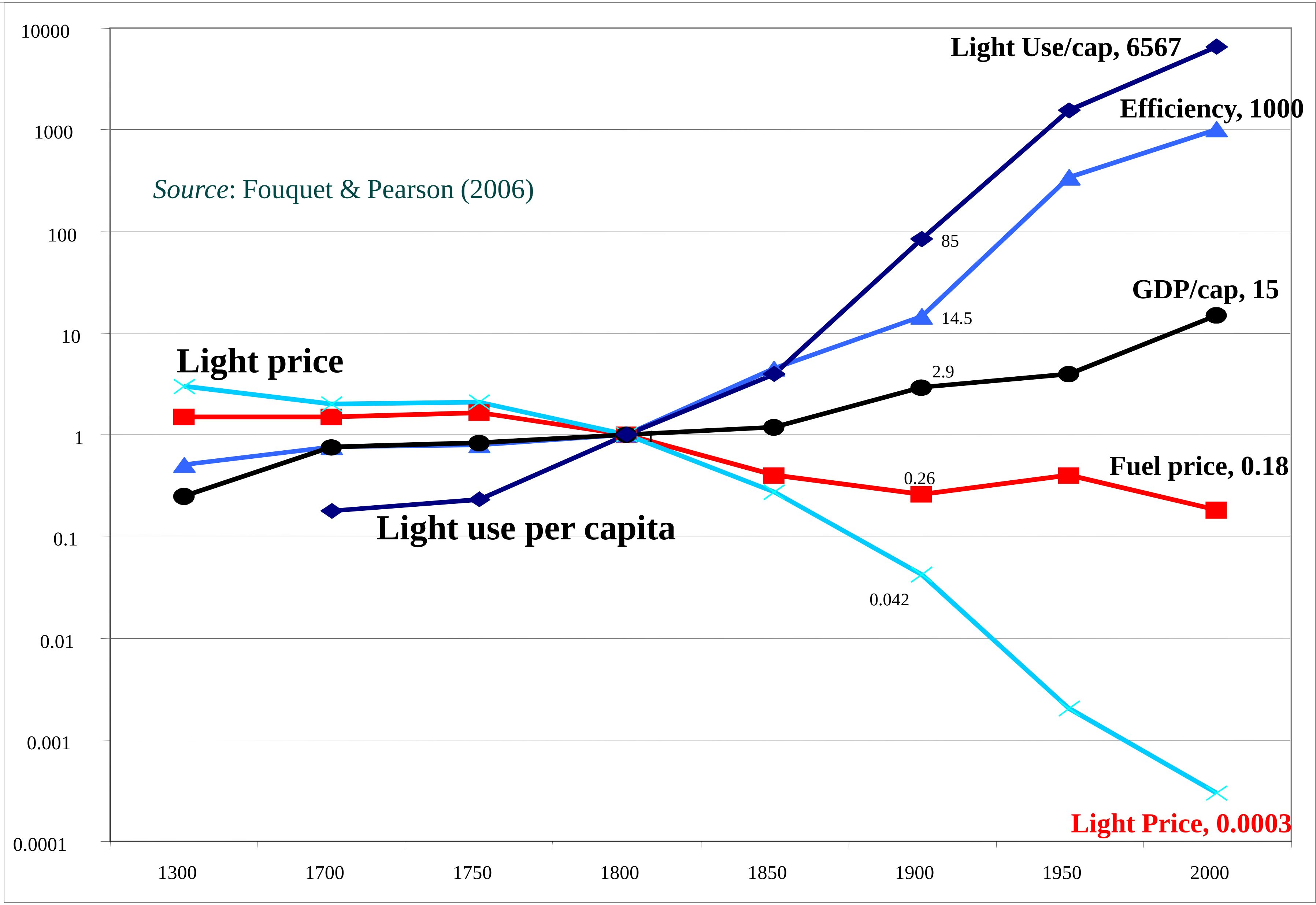

The world's appetite for light

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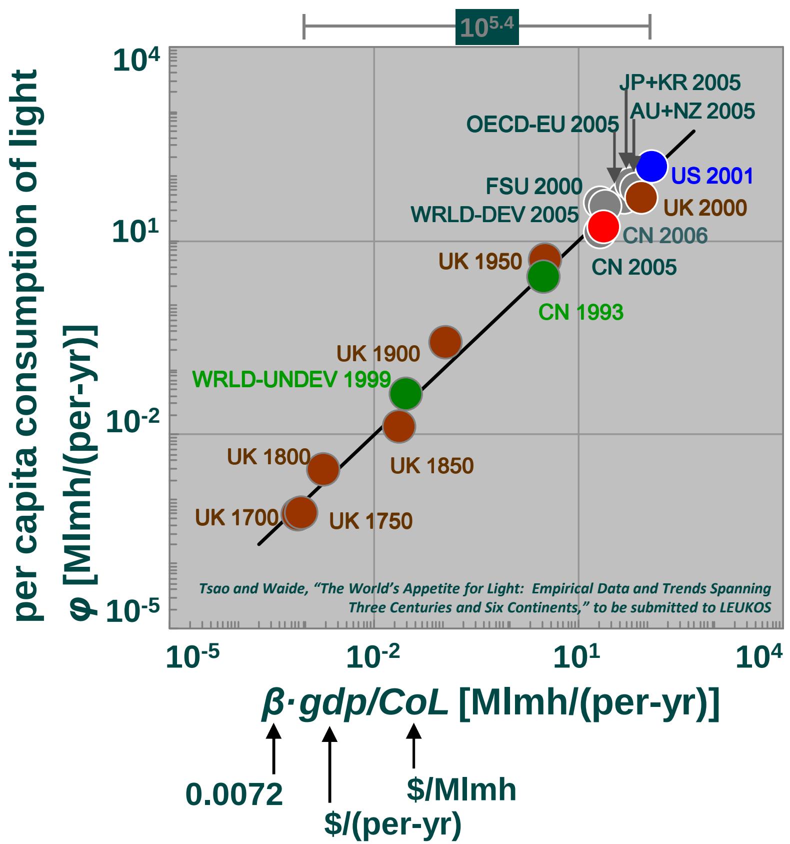
- Global analysis over three centuries
- Per capita consumption of light increased by 1.01% for every 1% reduction in the cost of light
- Energy ''savings' from improved lighting efficiency almost exactly cancelled out by increased light consumption
- Little sign of saturation in lighting consumption in developed countries
- Considerable potential for growth in consumption of both lighting and energy for lighting

Consumption

0.72% = US\$440B / US\$60T

6.5% = 1 TW_c / 16 TW_c



Source: Tsao et al (2010)

Underlying debates

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	Orthodox perspective	Ecological perspective
Source of productivity improvements	Technical change and improvements in labour quality	Increasing availability of high-quality energy, both directly and embodied in capital equipment and technology
Marginal productivity of energy inputs	Proportional to share of energy in the value of output	Greater than the share of energy in the value of output
Input substitution in production	Considerable scope for substituting capital for energy	Limited scope for substituting capital for energy
Decoupling of energy consumption from GDP	Has already occurred with considerable scope for further decoupling	Strong link exists and will continue to exist between quality adjusted energy use and economic output
Implied rebound effects	Small	Large

Len Brookes and ecological economics

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- **"..it is energy that drives modern economic systems rather than such systems creating a demand for energy" (Brookes, 1984)**
- Improvements in energy productivity are typically associated with proportionately greater improvements in total factor productivity. Latter raises output and increases demand for all inputs.
- The resulting increase in demand for energy inputs more than offsets the reduction in energy use per unit of output – so energy efficiency **improves** while energy consumption **increases**

Conclusions on Jevons Paradox

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- Theoretical arguments are stylised and often rely upon questionable assumptions
- Cited empirical evidence is indirect selective and frequently ambiguous
- Backfire not demonstrated to be a universal outcome of energy efficiency improvements
- Arguments and evidence should nevertheless be taken seriously
- Key issue is the contribution of increasing energy services to productivity improvements and economic growth

Conclusions and policy implications

Conclusions

- Rebound effects can be quantified and appear to be substantial
- Estimated size of rebound effects seems to increase with the scope and boundary of the analysis
- Contribution of efficiency improvements to carbon mitigation continues to be overestimated
  - Uncomfortable implications for policy – can energy/carbon pricing mitigate this effect?

Suggested policy responses

- Allow for rebound in policy appraisals
- Introduce progressive efficiency standards
- Impose increasingly stringent carbon taxes or emission caps
- Seek comprehensive, global climate agreement to prevent all forms of carbon leakage...