

# **Turning lights into flights? - Estimating rebound effects from sustainable behaviours**

**Centre for Environmental Strategy, University of Surrey, 17<sup>th</sup> July 2012**

**Steve Sorrell (University of Sussex)  
Mona Chitnis, Angela Druckman, Tim Jackson (University of Surrey)  
Steve Firth (University of Loughborough)**

# The team

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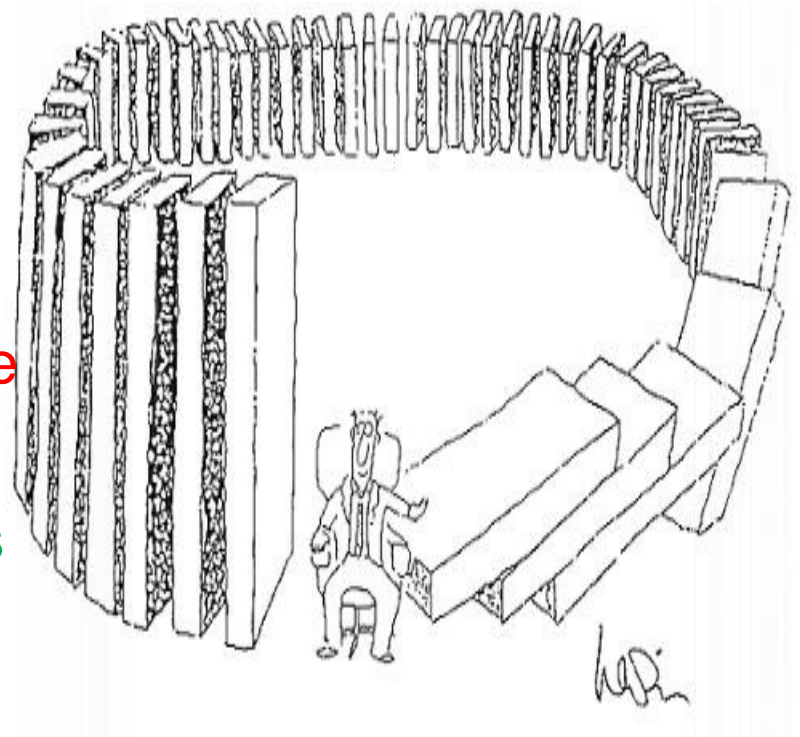
- **Steve Sorrell**  
(University of Sussex)
- **Mona Chitnis, Angela Druckman, Tim Jackson**  
(University of Surrey)
- **Steve Firth**  
(University of Loughborough)



# Plan of presentation

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- Overview
- Rebound from abatement actions
- Rebound from energy efficiency actions
- Rebound variations across income groups
- Discussion and policy implications



# Publications

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## *Missing carbon reductions*

- Druckman, A., M. Chitnis, S. Sorrell and T. Jackson (2011). "Missing carbon reductions? Exploring rebound and backfire effects in UK households " Energy Policy 39: 3572–3581.

## *Turning lights into flights*

- Chitnis, M., S. Sorrell, A. Druckman and S. K. Firth. (2012). "Estimating direct and indirect rebound effects for UK households."  
[http://www.sustainablelifestyles.ac.uk/sites/default/files/projectdocs/estimating\\_direct\\_and\\_indirect\\_rebound.pdf](http://www.sustainablelifestyles.ac.uk/sites/default/files/projectdocs/estimating_direct_and_indirect_rebound.pdf) .

## *Living up to expectations*

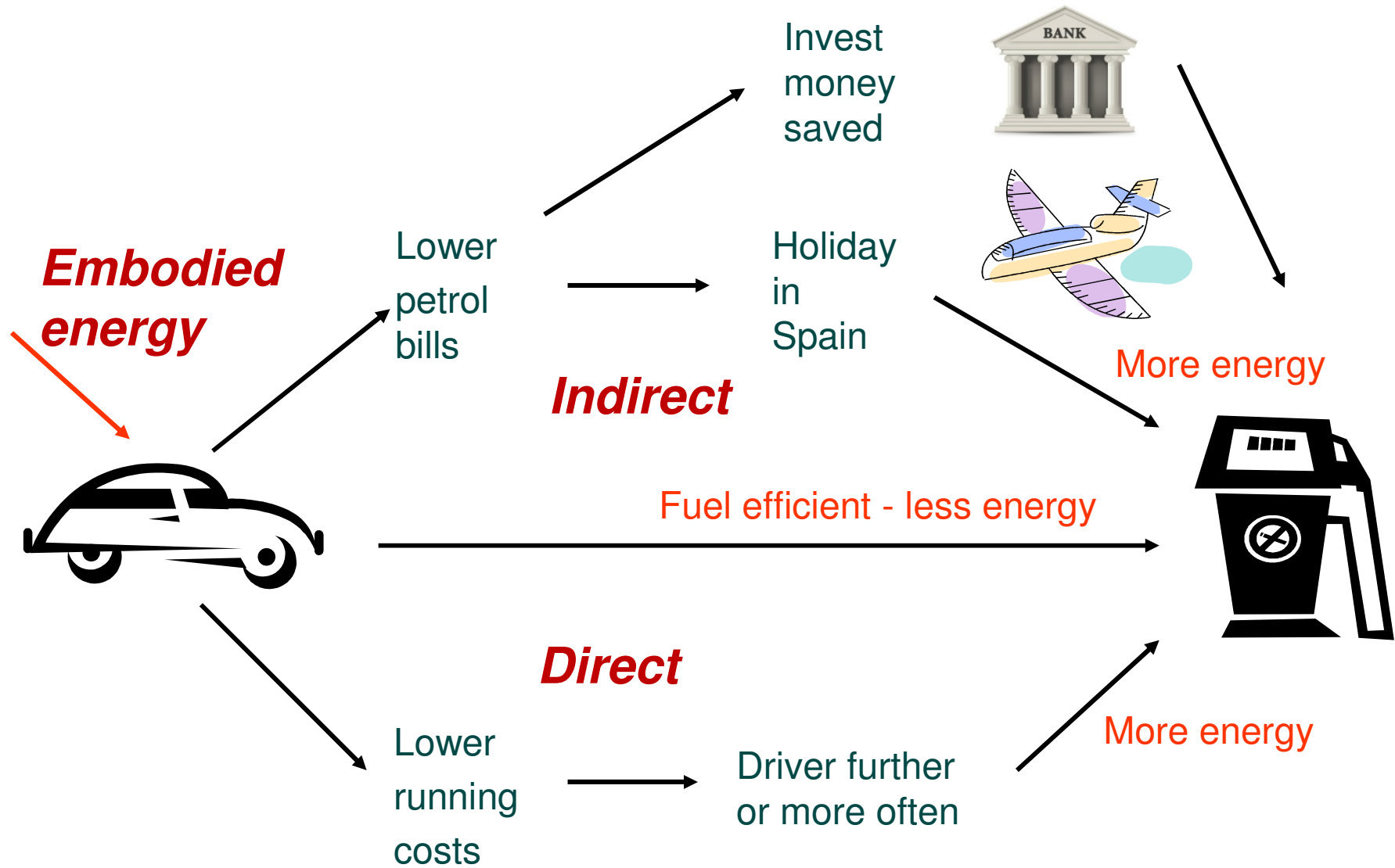
- Watch this space!



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# **Overview – estimating rebound effects for households**

# Rebound effect for households



# How to reinforce rebound effects...

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# Turn lights into flights.



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# Estimating rebound effects

- Rebound effects are challenging to estimate and widely ignored. Limited evidence base largely confined to direct effects for transport and heating
- Very few studies of combined direct + indirect effects for households. None for the UK.
- ‘Rebound’ is a generic term for multiple mechanisms, but most analytical techniques only capture a subset.



Exhibit-1

**The Washington Post**

Are American homes more energy efficient? Not exactly.



**THE NEW YORKER**

**THE EFFICIENCY DILEMMA**

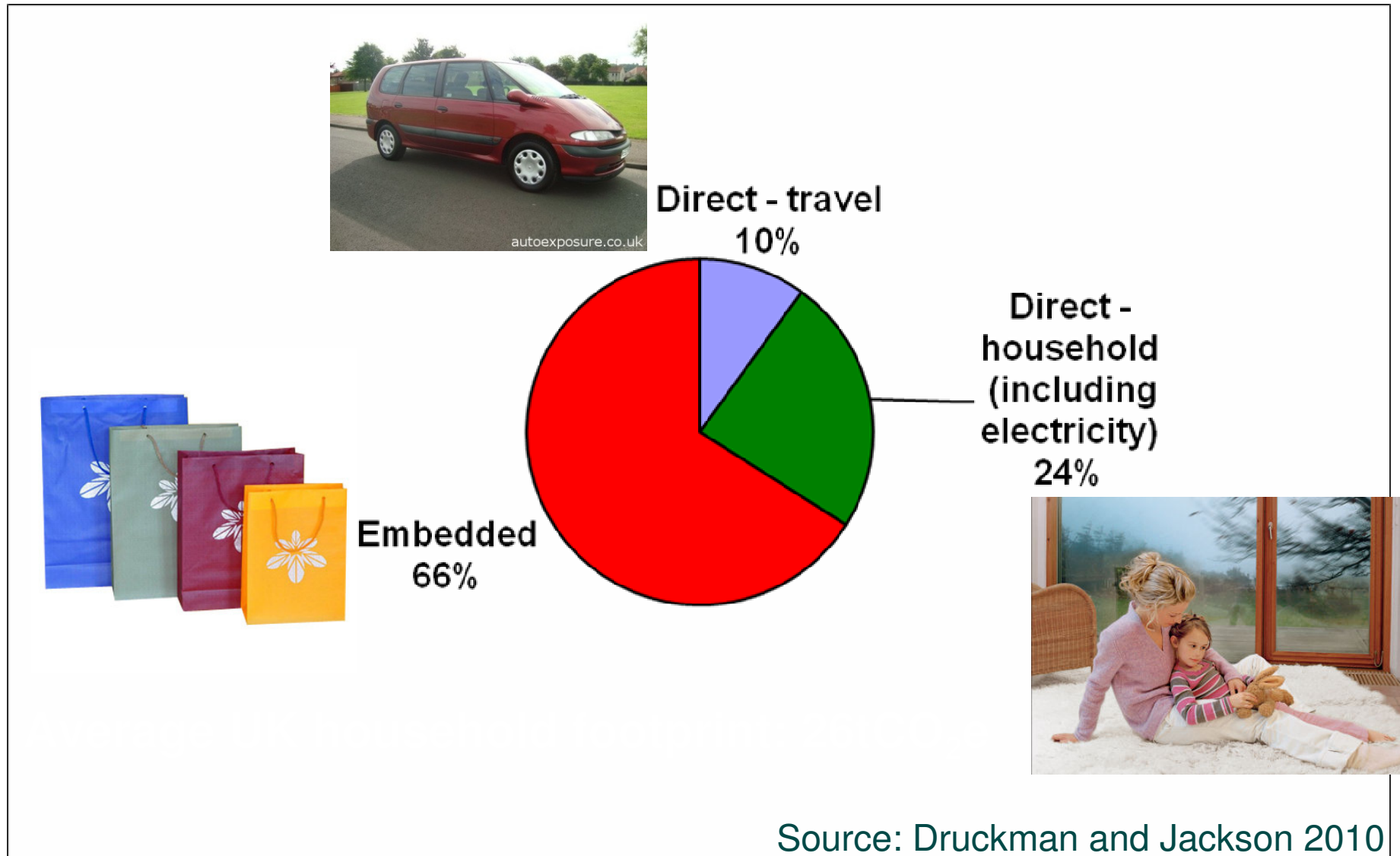
*If our machines use less energy, will we just use them more?*

**The New York Times**

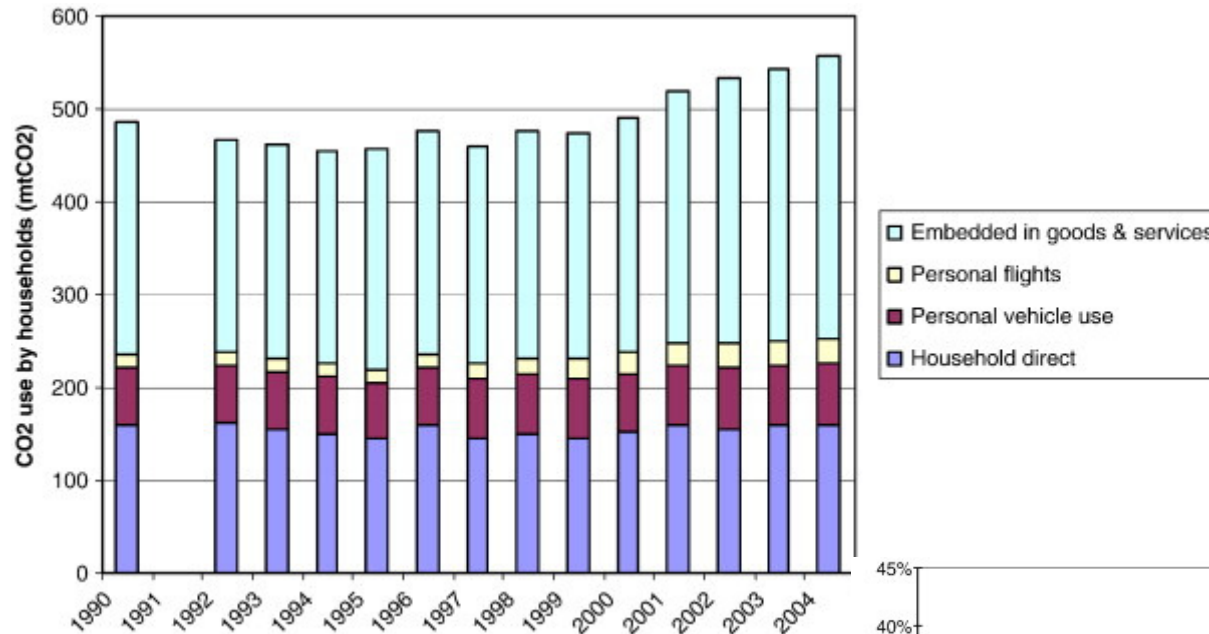
When Energy Efficiency Sullies the Environment



# Types of emissions attributable to households

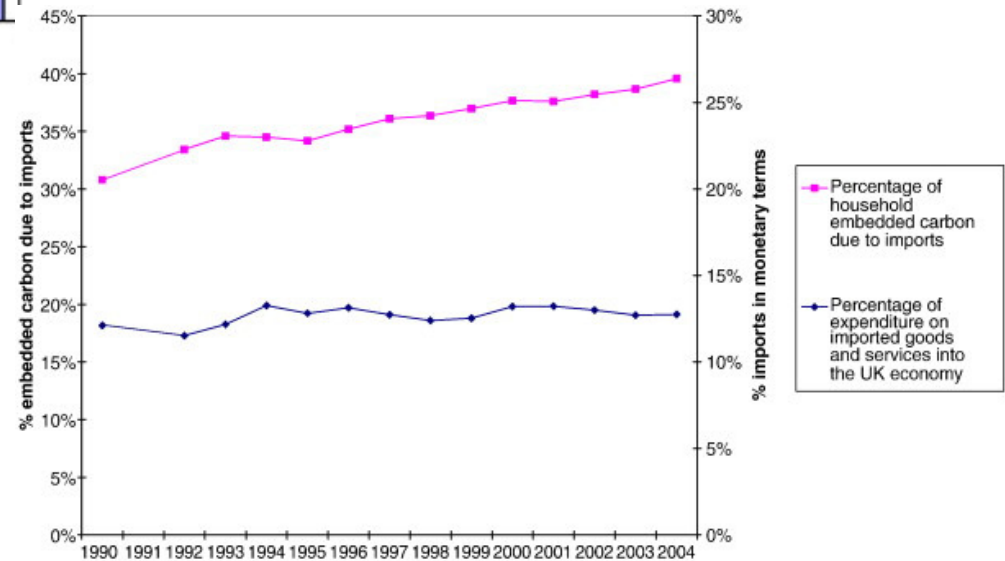


# The importance of indirect/embedodied emissions

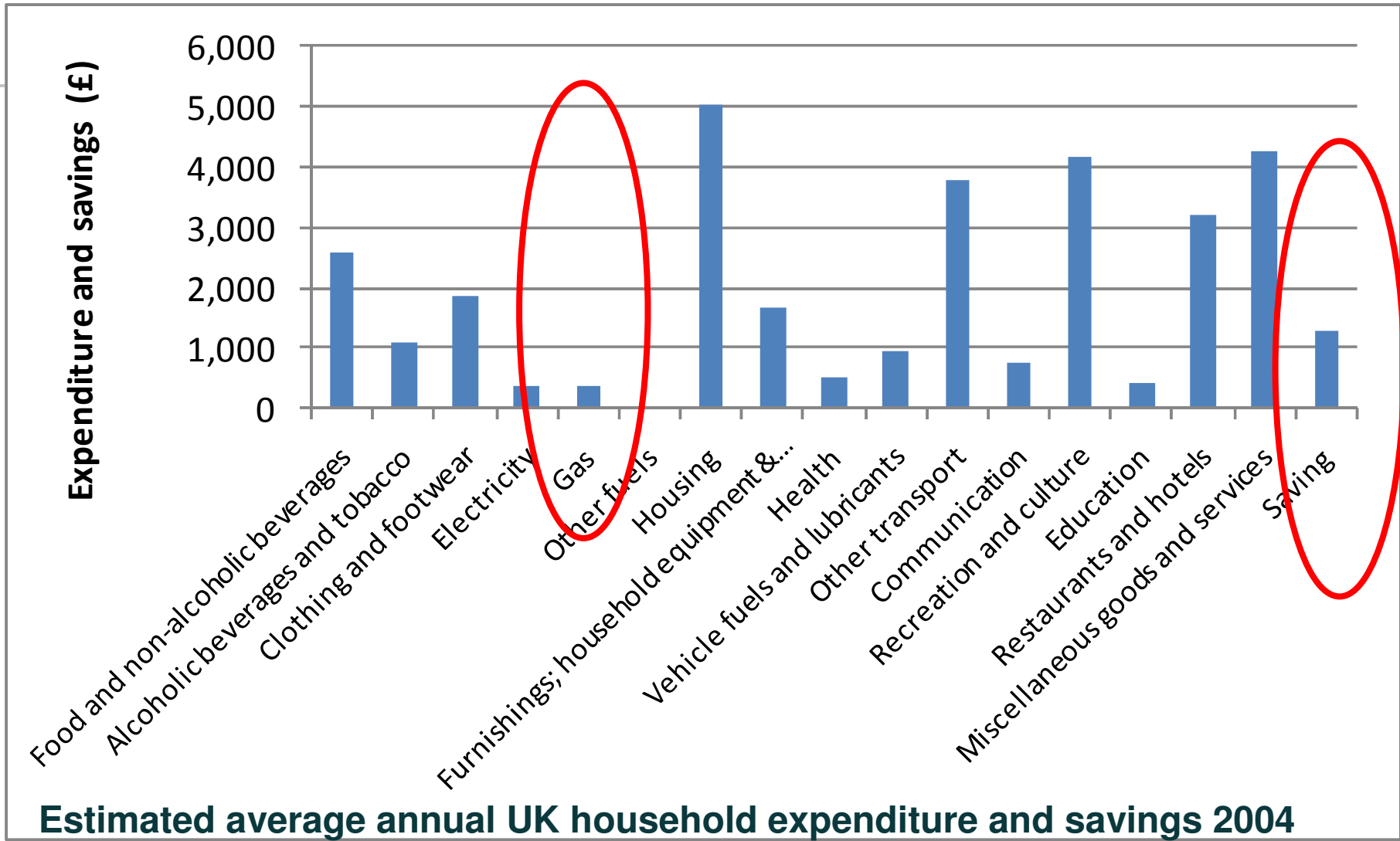


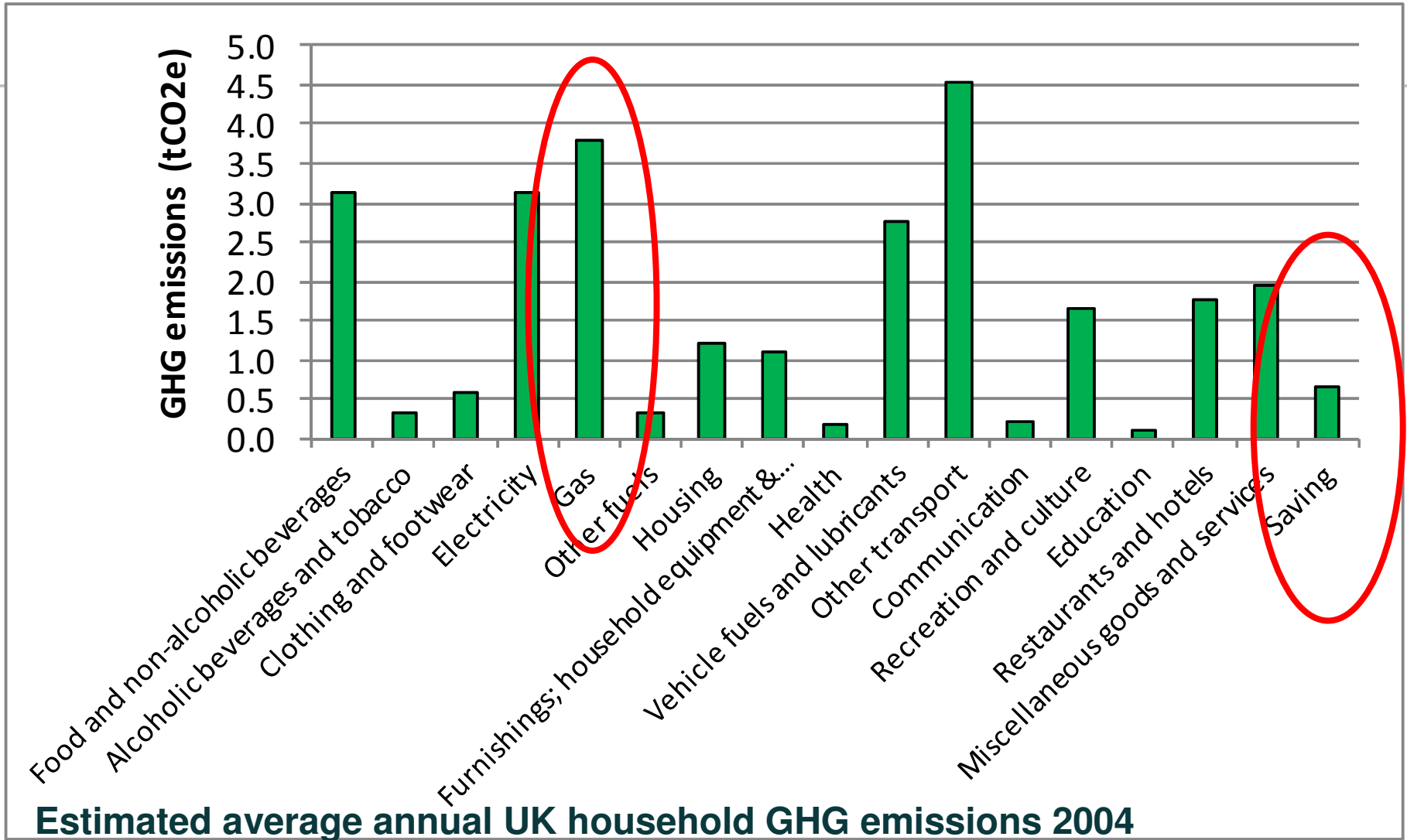
Direct carbon emissions from UK households steady, but embodied and total emissions rising

Embodied emissions due to imported goods rising faster



Source: Druckman & Jackson (2009)

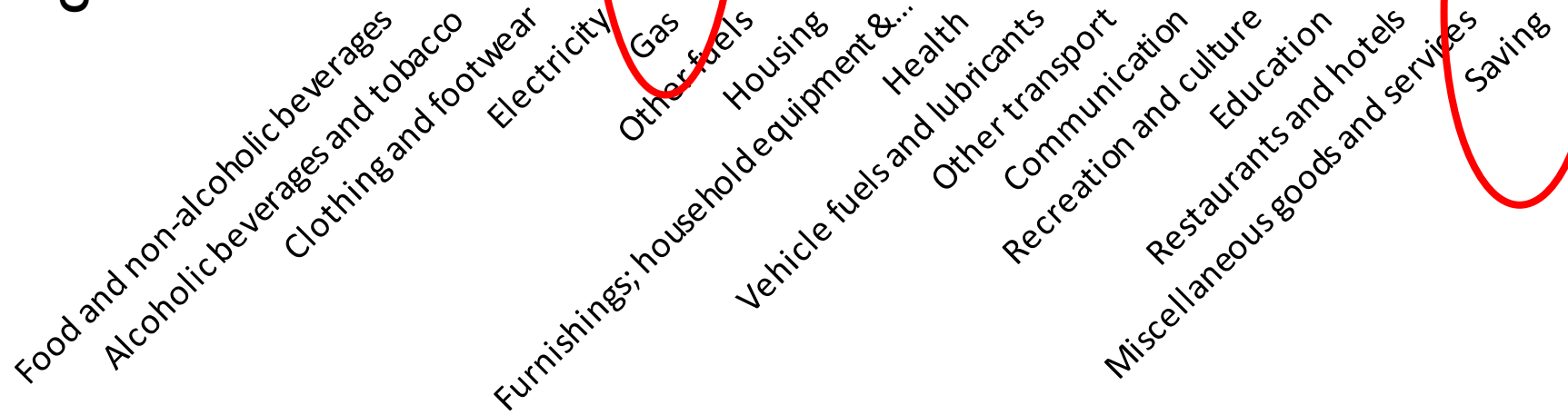




**Total: ~26 tCO<sub>2e</sub>/year**

GHG intensity (tCO<sub>2</sub>e/£)

0.012  
0.010  
0.008  
0.006  
0.004  
0.002  
0.000



**GHG intensities 2004**

# Mapping rebound effects from sustainable behaviours - project aims

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- To explore the combined direct and indirect rebound effects associated with energy efficiency and abatement actions by UK households:
  - Various actions
  - Socio-economic groups
  - Policy implications?



# Methodological choices and limitations

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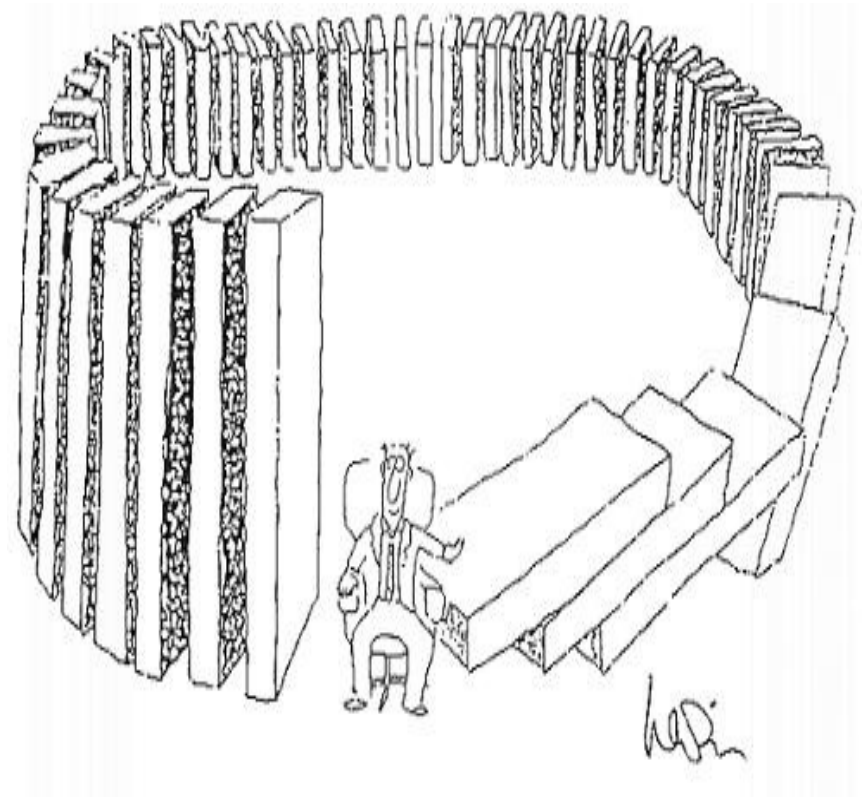
- Study estimates income effect only (excludes substitution effect)
  - Income effect: Cheaper energy service increases 'real' income
  - Substitution effect: Shift in expenditure patterns towards cheaper energy service.
- Excludes wider macro-economic effects
- GHGs only
- Do policy makers take account of embodied energy when setting targets?



# Plan of presentation

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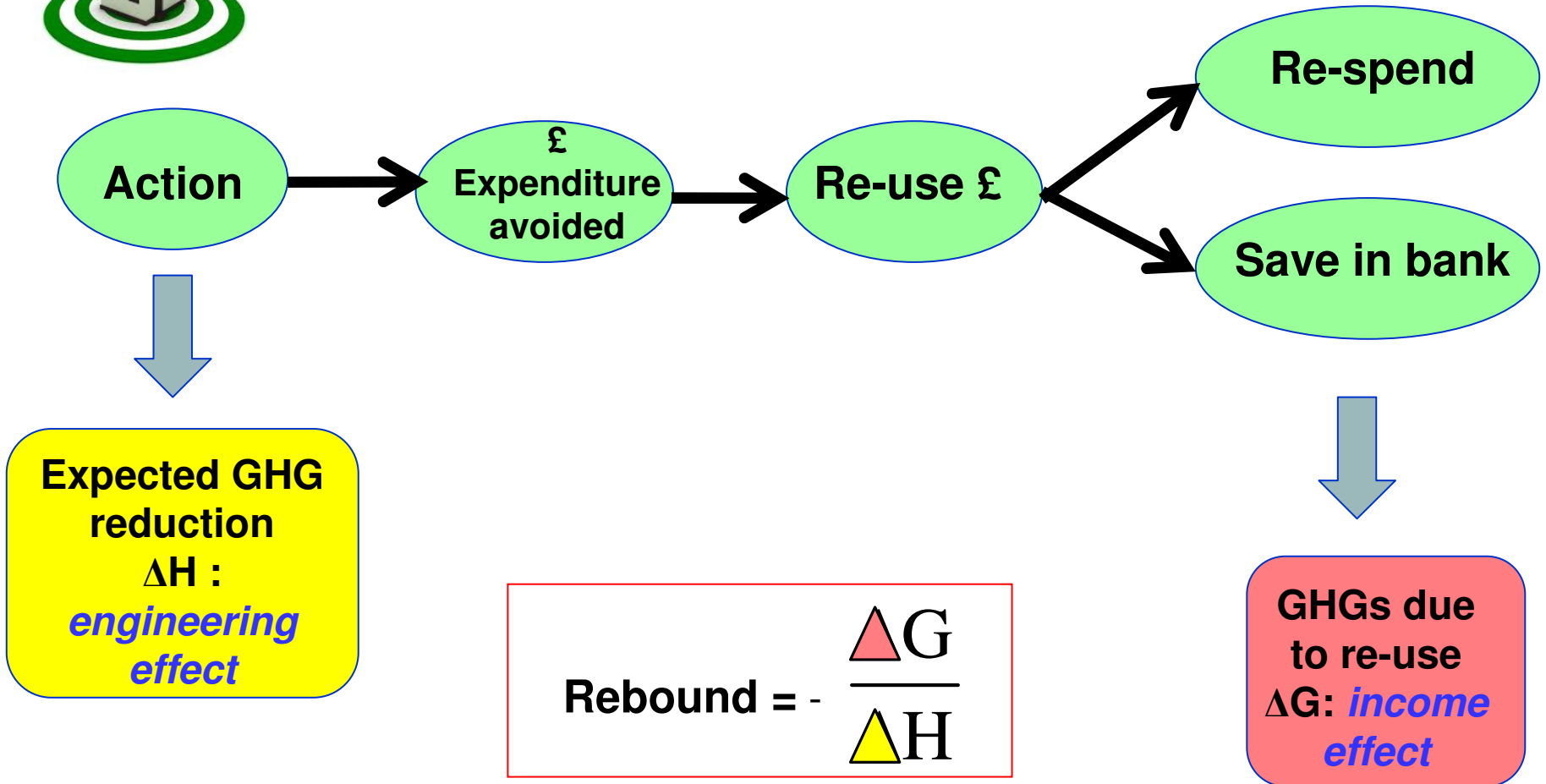




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**Missing carbon reductions  
– rebound from efficiency**

# Rebound effect: GHGs emissions



# Underlying models

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- **ELESA: Econometric Lifestyle Environmental Scenario Analysis model**
  - Econometric modelling tool
  - Estimates UK household expenditure for 16 categories of goods and services using Structural Time Series Model (STSM)
  - Income elasticities for UK average household for 16 categories
  
- **SELMA: Surrey Environmental Lifestyle Mapping Framework**
  - Quasi-Multi-Regional Input-Output model
  - Estimates the GHG intensities of UK household expenditure and savings for 1992-2004



# Expenditure categories used in this study

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1. Food and non-alcoholic beverages
2. Alcoholic beverages, tobacco, narcotics
3. Clothing & footwear
4. Electricity
5. Gas
6. Other fuels
7. Other housing
8. Furnishings, household equipment & routine household maintenance
9. Health
10. Vehicle fuels and lubricants
11. Other transport
12. Communication
13. Recreation and culture
14. Education
15. Restaurants and hotels
16. Miscellaneous goods and services

# Simple 'abatement actions' – GHG savings for average household

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1. **Household heating:**  
reduce thermostat by 1°C



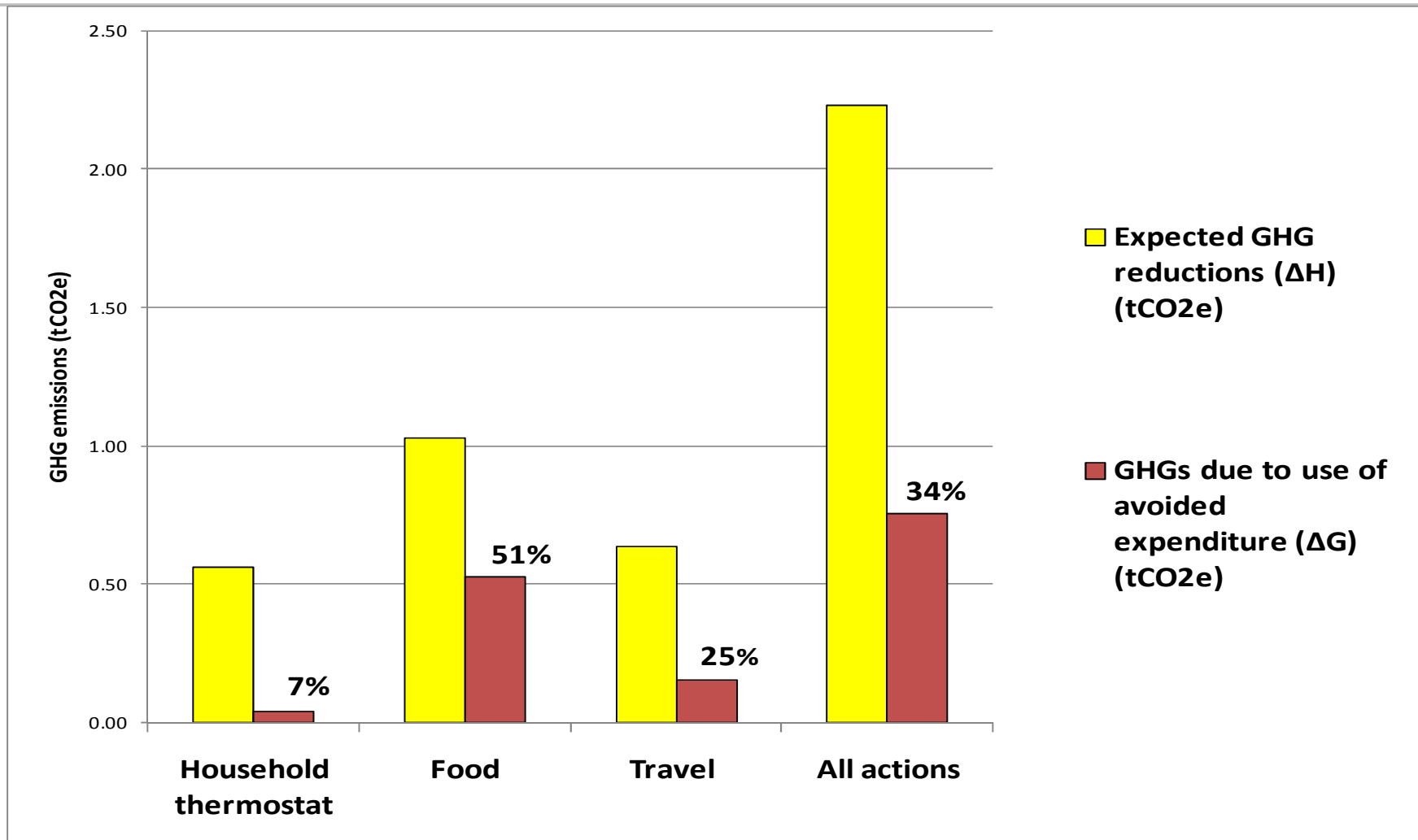
2. **Food:** reduce food waste  
by one third



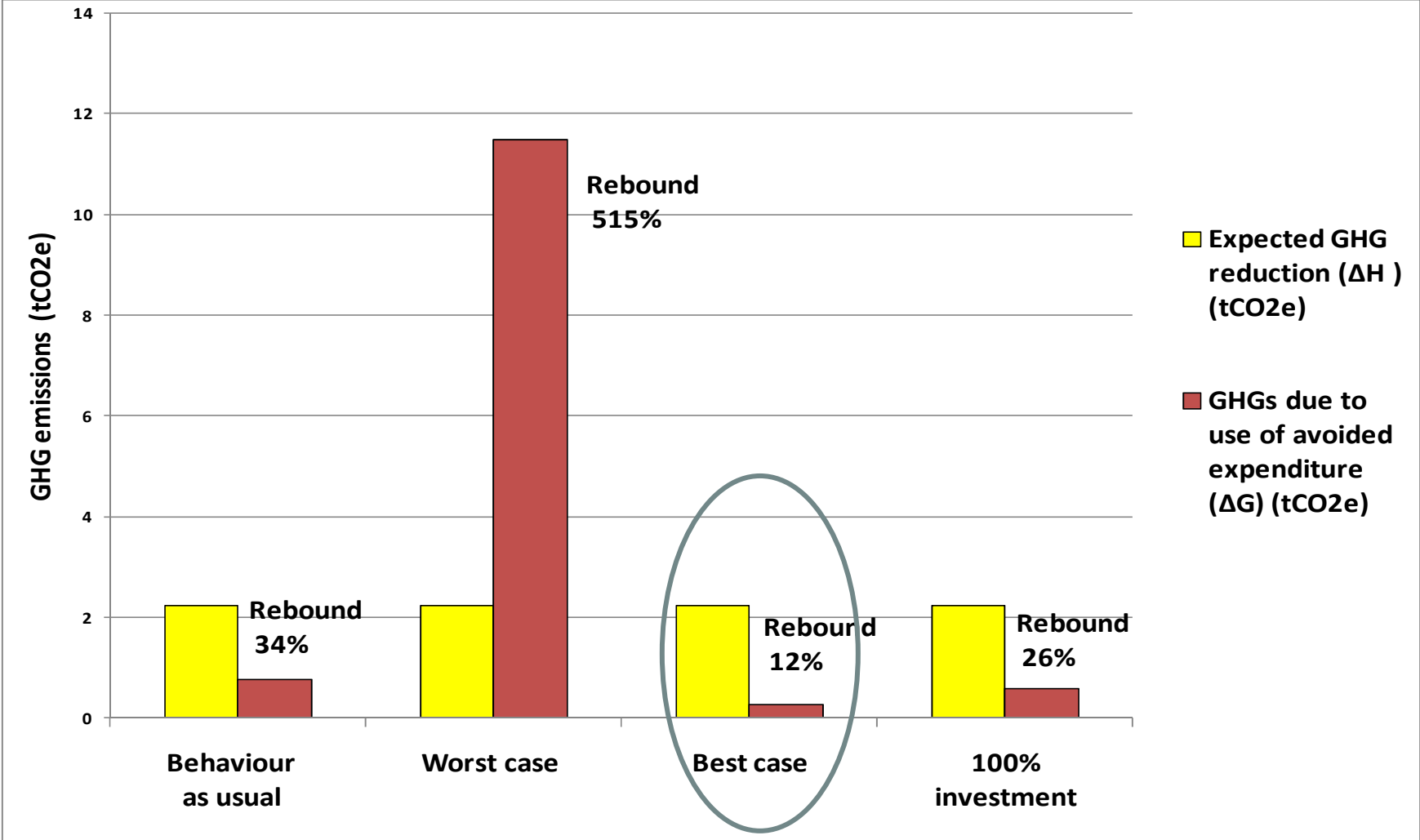
3. **Transport:** replace car  
journeys <2miles by  
walking/cycling



# Estimated rebound effects for UK average household in 2008



# Estimated rebound effects for average UK household in 2008: varying the re-spend from the combined actions



# Missing carbon reductions – key points

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- Rebound effects for these actions are non-trivial
- Minimum rebound of 12% for combined actions
- Magnitude depends upon expenditure share and GHG intensity of ‘abated’ commodity compared to re-spending
- GHG intensity of expenditure on gas is greater than GHG intensity of expenditure on food or transport fuels – leading to lower rebound effect

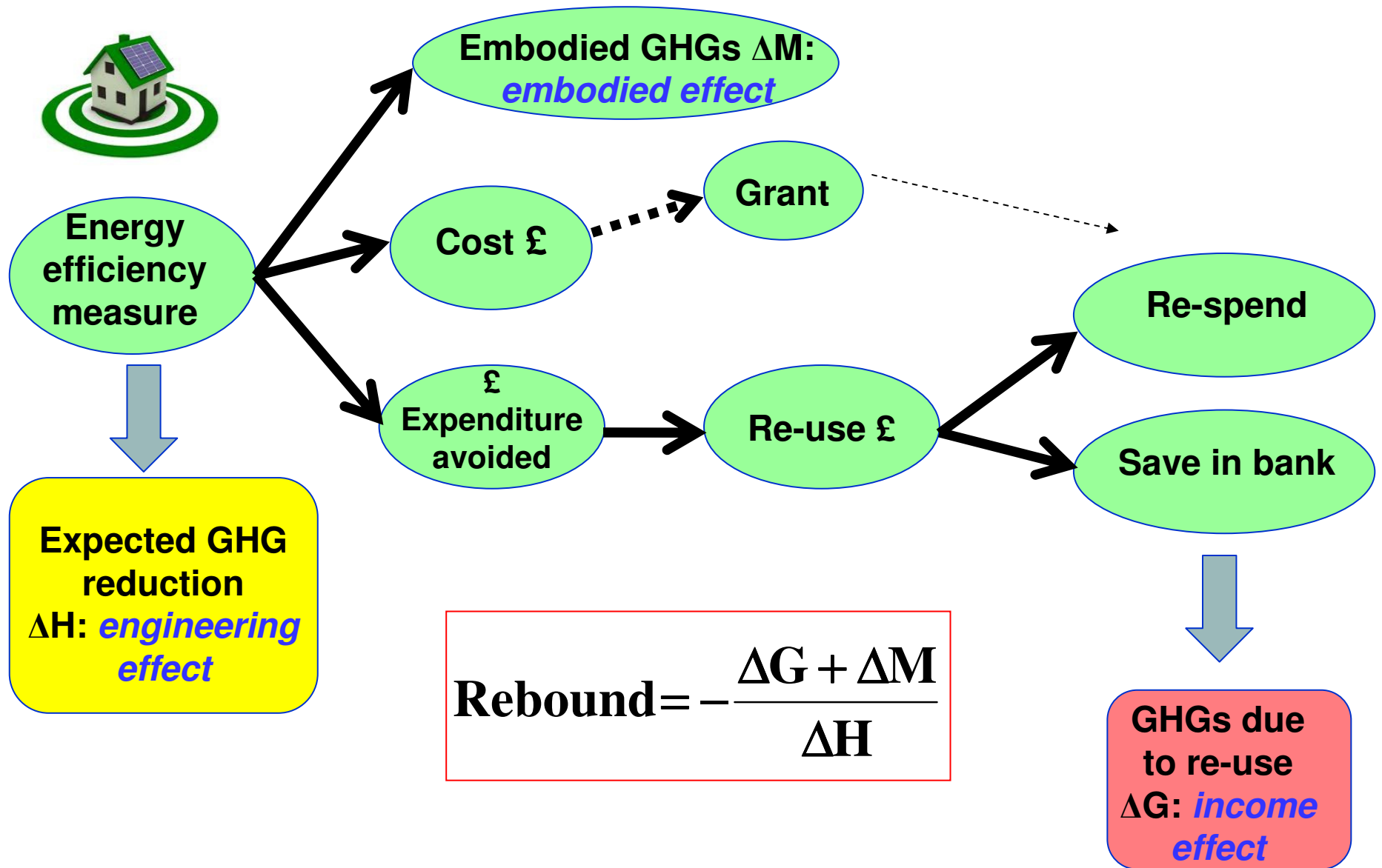




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**Turning lights into fights  
– rebound from energy efficiency  
actions**

# Rebound effect: GHGs emissions



# Underlying models

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## ➤ **CDEM: Community Domestic Energy Model**

- **Developed by Loughborough University (Firth et. al.) to simulate energy use in the English housing stock and to explore options for reducing CO2 emissions.**
- **Used to estimate the expected energy saving by each energy efficiency measure for average UK household**



## ➤ **ELESA**

- **Income elasticities for 16 categories of goods and services**

## ➤ **SELMA**

- **GHG intensities for 16 categories of goods and services and saving (investment)**

# Energy efficiency measures

## – GHG savings for average UK household

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1. Cavity wall insulation

2. Loft top-up insulation

3. Condensing boiler

4. Hot water tank insulation

5. CFL lighting

6. LED lighting

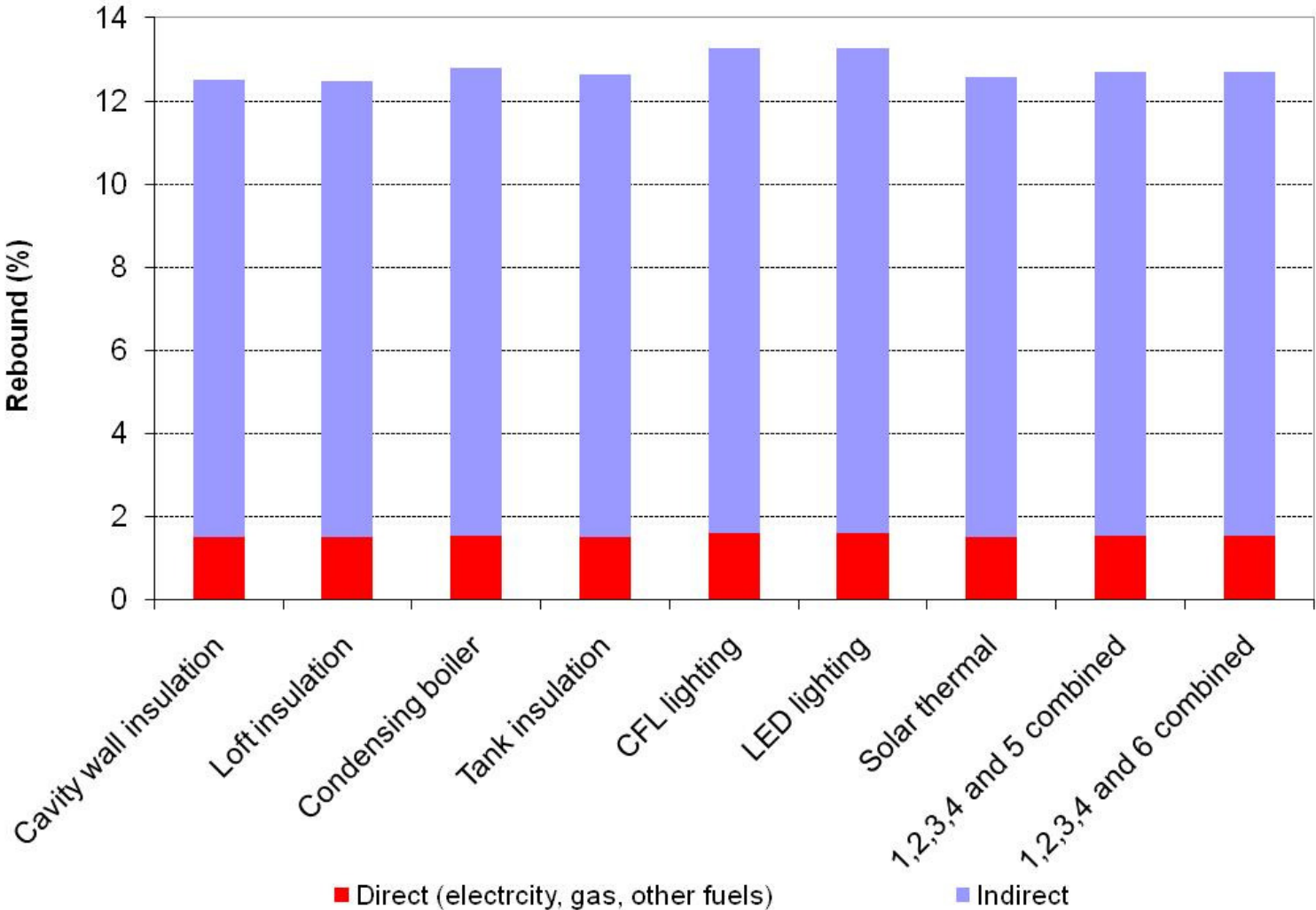
7. Solar thermal

8. 1-5 combined

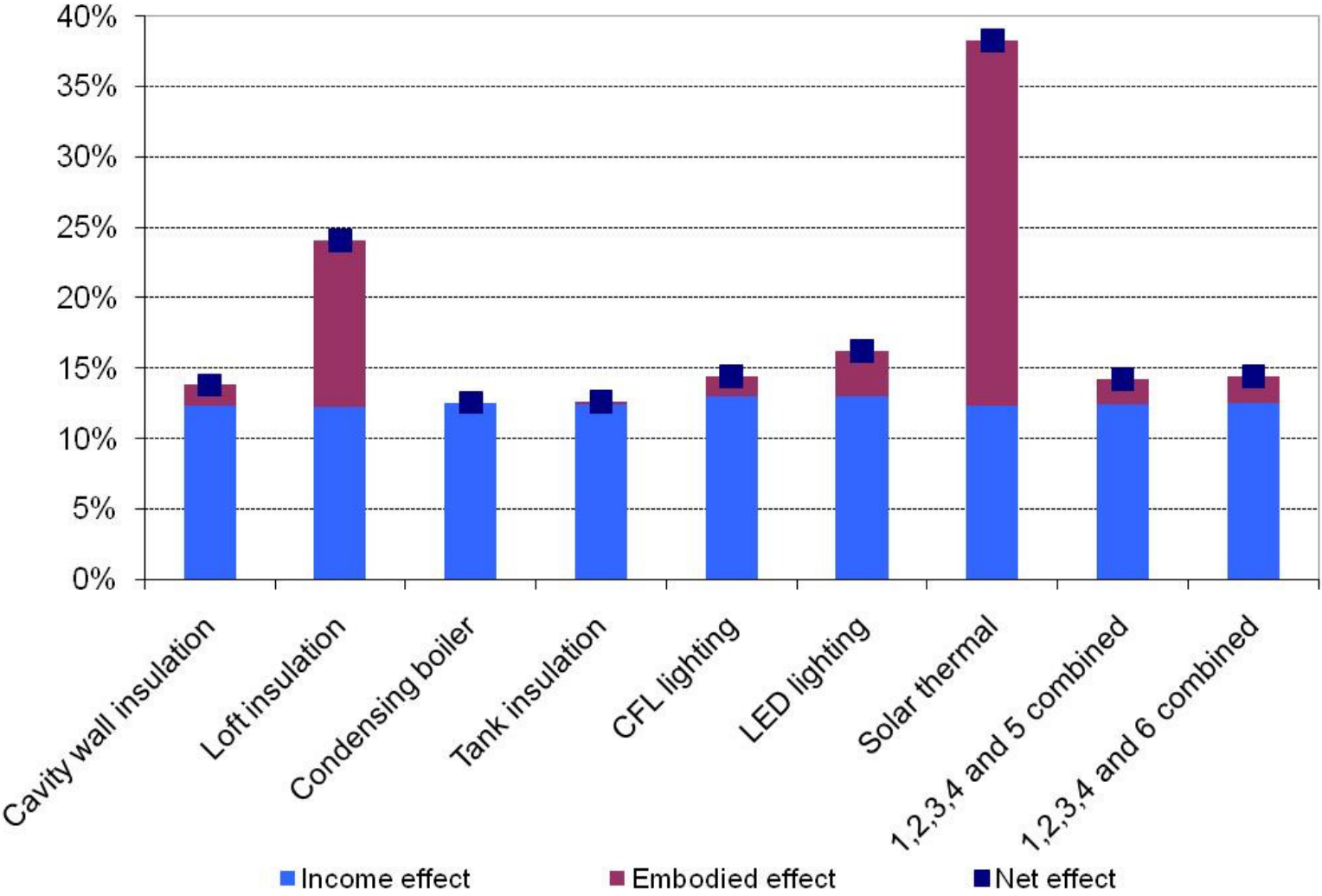
9. 1-4 and 6 combined



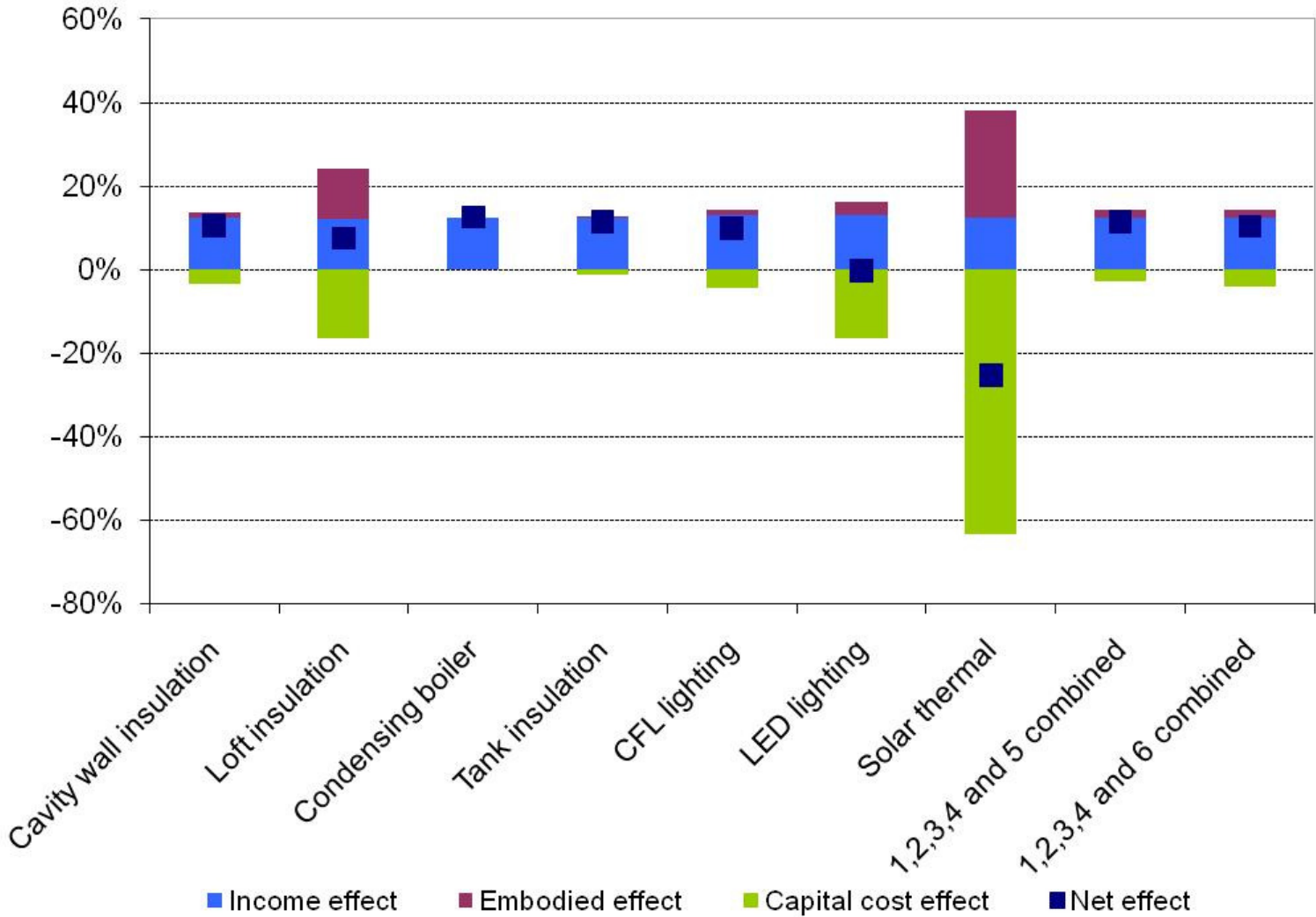
# Estimated rebound effects for average UK household averaged over a ten year period (2009-2018): income effects alone, showing contribution of direct and indirect effects



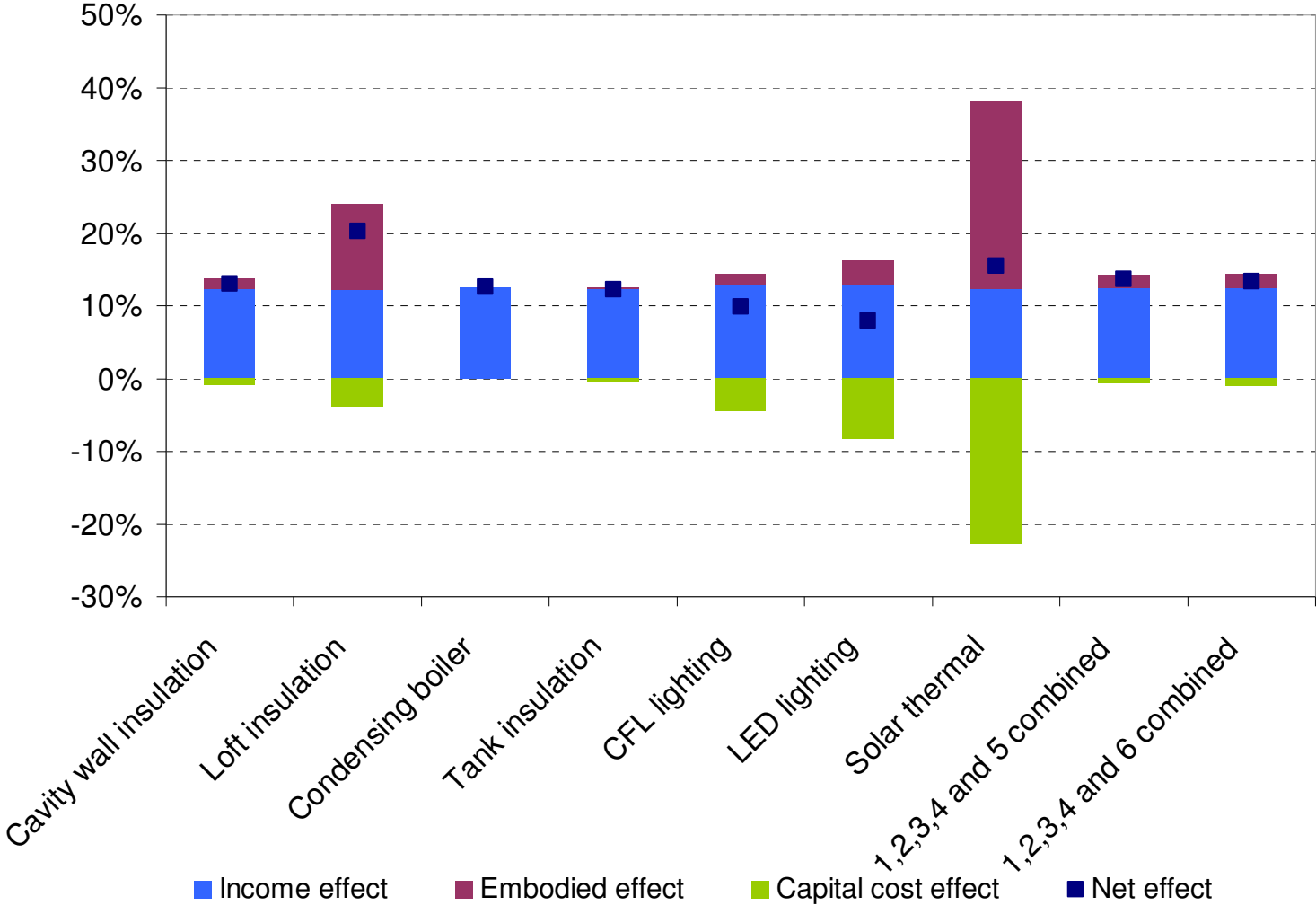
# Estimated rebound effects for average UK household averaged over a ten year period (2009-2018): income and embodied effects, ignoring capital costs



# Estimated rebound effects for average UK household averaged over a ten year period (2009-2018): income and embodied effects, with full capital costs



# Estimated rebound effects for average UK household averaged over a ten year period (2009-2018): income and embodied effects, with subsidised capital costs





# Turning lights into flights – key points

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- Rebound effects in range 5-15% depending upon time periods and assumptions used
- GHG intensity of re-spending much less than that for gas or electricity
- Re-spending effect outweighs embodied GHGs of efficiency measures
- Results insensitive to assumed income elasticities but sensitive to assumed GHG intensity of electricity



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**Living up to expectations**  
**– how does rebound vary across income**  
**groups?**

# Underlying models

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## ➤ Engel curves

- An Engel curve describes how household expenditure on a particular good or service varies with household income.
- The Engel curve for 16 category is estimated using two different functional forms: Working- Leser (WL) and Double Semi-Log (DSL).
- Expenditure elasticities are estimated for 16 categories of goods and services by household income quintiles.

## ➤ CDEM

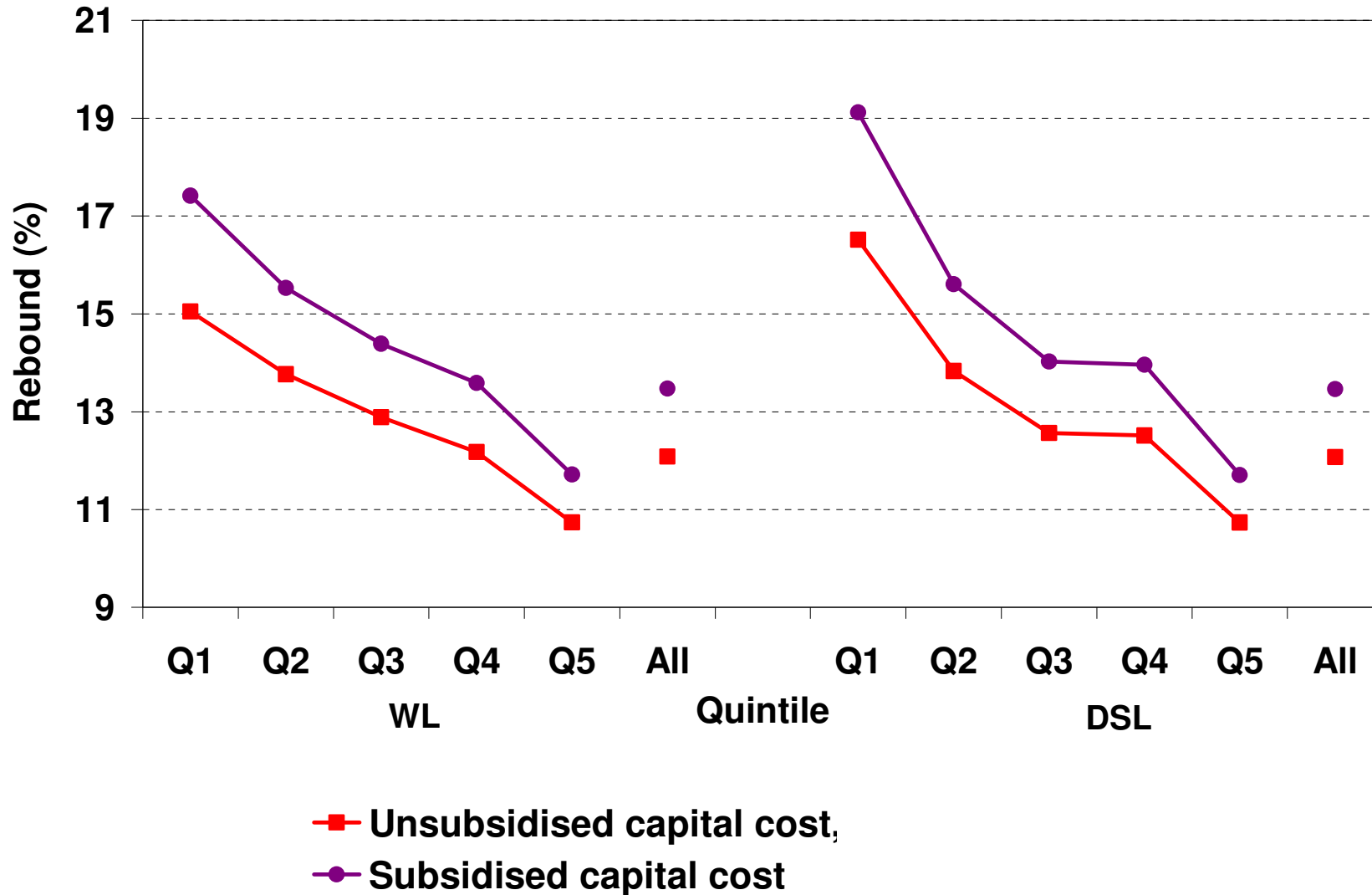
- Used to estimate the expected energy saving by each energy efficiency measure for average UK household

## ➤ SELMA

- GHG intensities for 16 categories of goods and services and saving (investment)

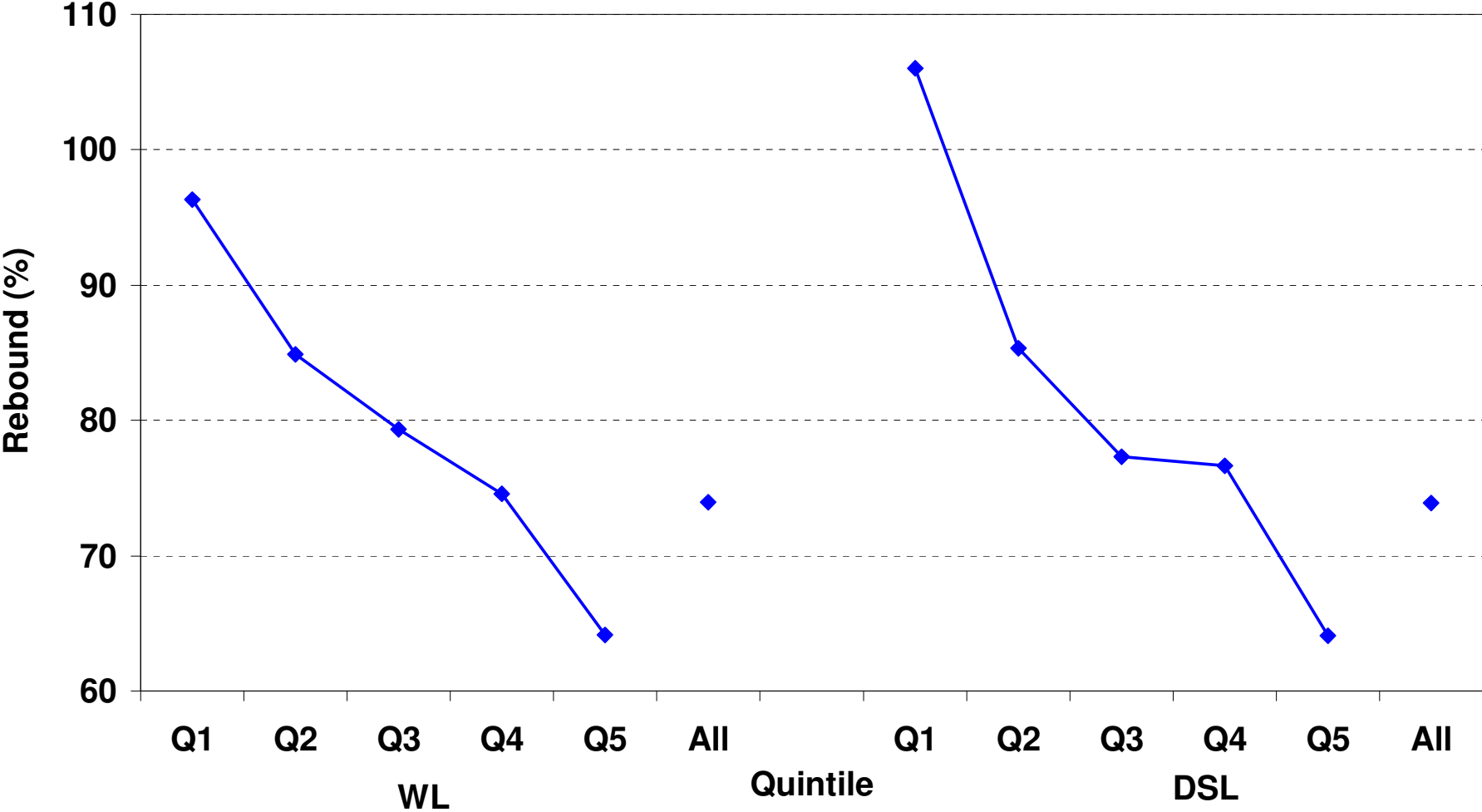
# Estimated rebound effects for UK household income quintiles averaged over a ten year period (2009-2018)

## Hot water tank insulation



# Estimated rebound effects for UK household income quintiles averaged over a ten year period (2009-2018)

## Food waste reduction



# Rebound effect estimation: alternative definition

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- The below definition treats the embodied effect as offsetting some of the engineering effect hence contributing to an increase in the rebound effect.

$$\mathbf{Rebound} = -\frac{\Delta\mathbf{G} + \Delta\mathbf{M}}{\Delta\mathbf{H}}$$

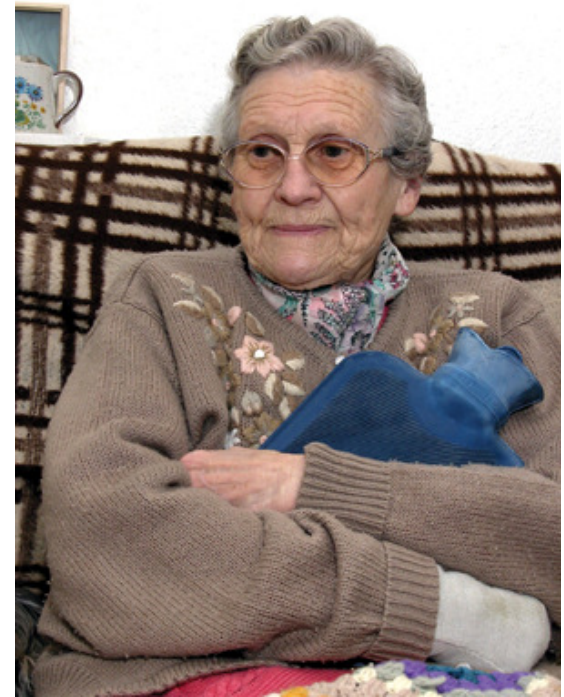
- Some policy-makers might be aware of the embodied energy and take account of it when they set the targets. In these cases the alternative definition of the rebound effect is more appropriate:

$$\mathbf{Rebound}^* = -\frac{\Delta\mathbf{G}}{(\Delta\mathbf{H} - \Delta\mathbf{M})}$$

# Living up to expectations – key points

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- Rebound effects generally larger for lower income groups (with some exceptions) due to higher proportion of expenditure on energy and relatively high income elasticities.
- Other evidence suggests very high direct rebound effects for low income groups – but these are only partly captured by our method.



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## Discussion and implications





# Summary

- Households always re-use saved expenditure.
- Avoid backfire.
- Rebound generally higher for:
  - Lower income groups;
  - Where action in a less carbon intensive category.
- Considerations
  - Welfare;
  - Opportunity costs
- As electricity generation is decarbonised, rebound for electricity measures will increase.



***Extreme backfire***

# Suggested policy responses

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- Policy-makers need to take rebound into account when setting targets.
- Need whole systems perspective that takes account of carbon leakage.
- Shift patterns of expenditure to lower GHG intensive goods and services;
- Encourage 'green' investment.



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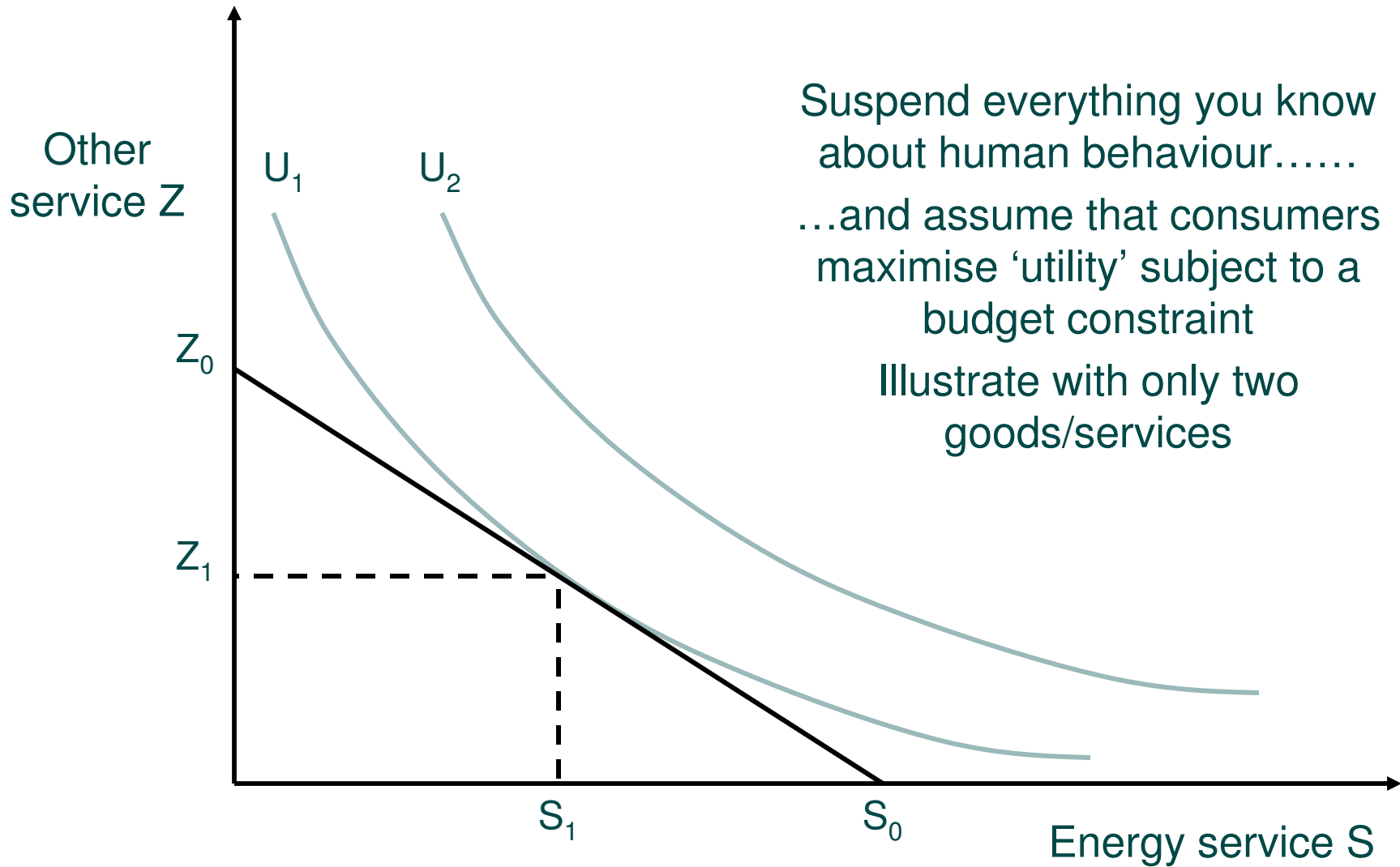
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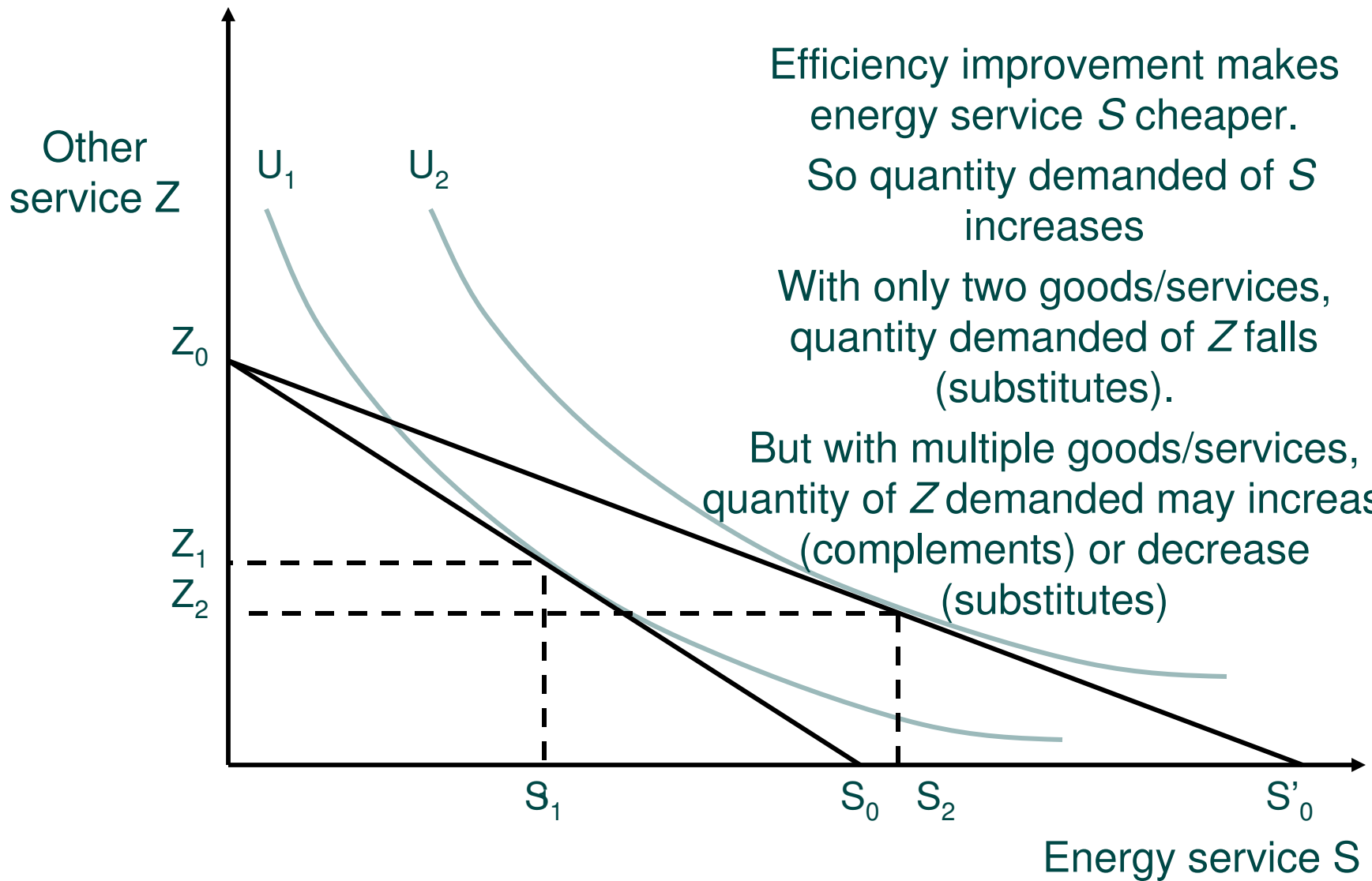
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**Annex –  
income and substitution effects**

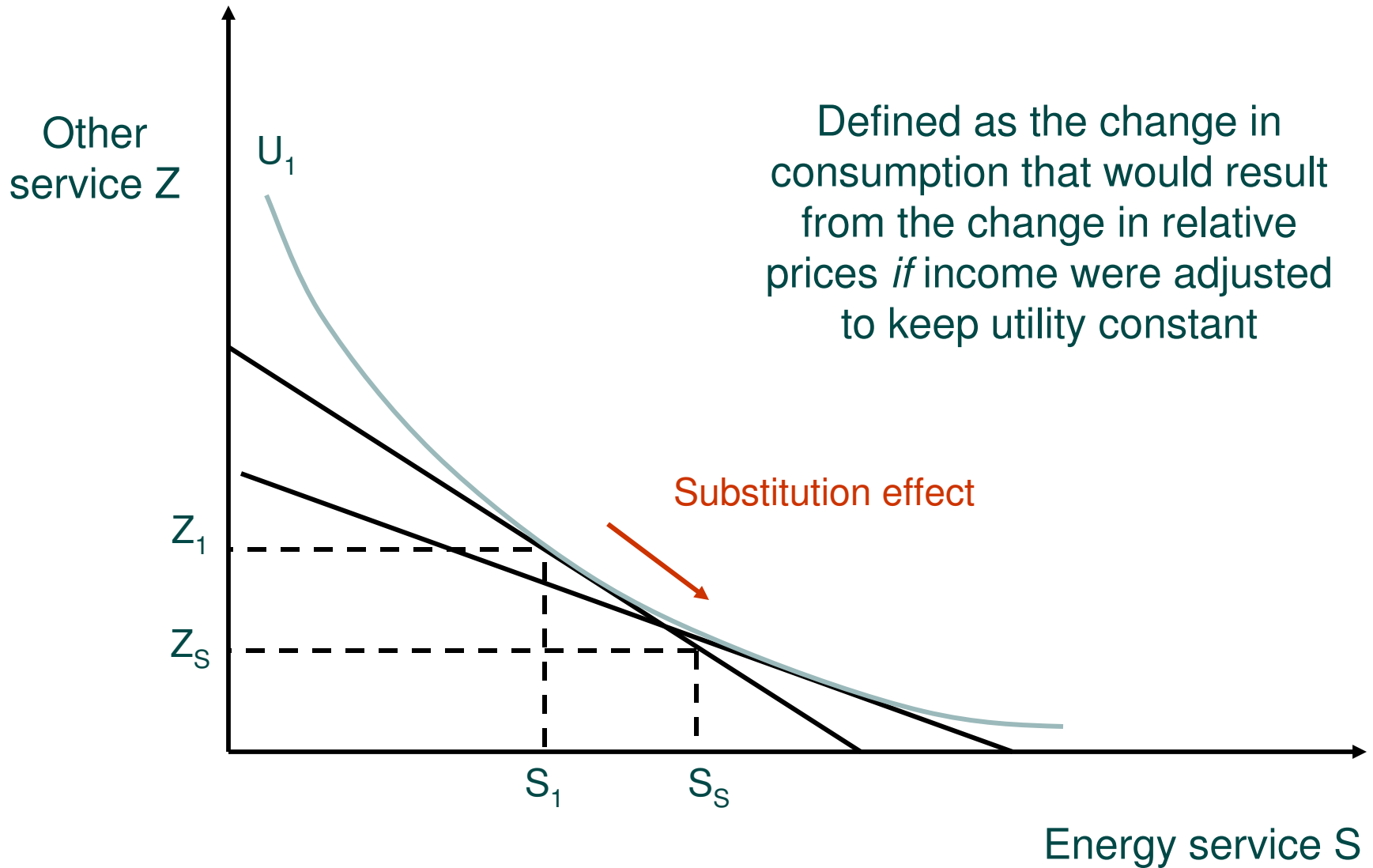
# Conceptualising rebound effects – a neoclassical perspective



# Adjusting to an energy efficiency improvement



# Decomposition - substitution effect



# Decomposition - income effect

