

# Embodied energy LCA assessment of replace / refurbish options for traditional buildings

Mike Berners Lee

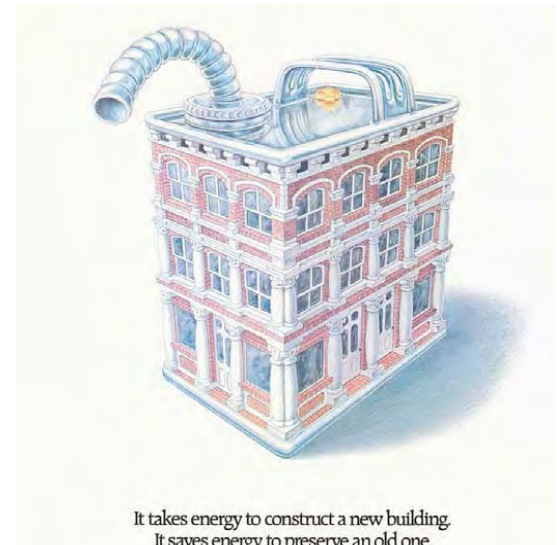
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Small World Consulting for Historic Scotland



# Outline

- Sustainable Buildings
- Process Based Vs Input Output LCA
- Embodied Energy and Existing Buildings
- Scope of Work
- Results and Discussion



# Creating Sustainable Communities



# Aims and Objectives

- The objective of this research was to undertake a comparative assessment of the carbon and energy implications of various refurbishment or replacement options within a traditional rural dwelling.
- The case study chosen was a two bedroom cottage situated in the border region of Scotland.

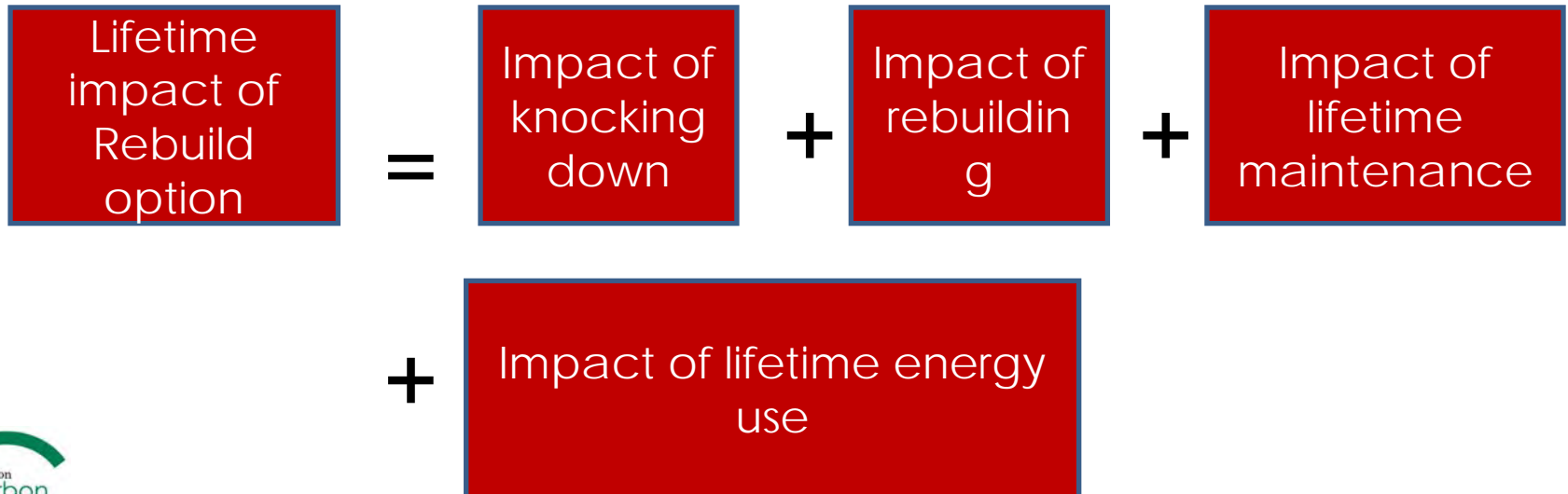
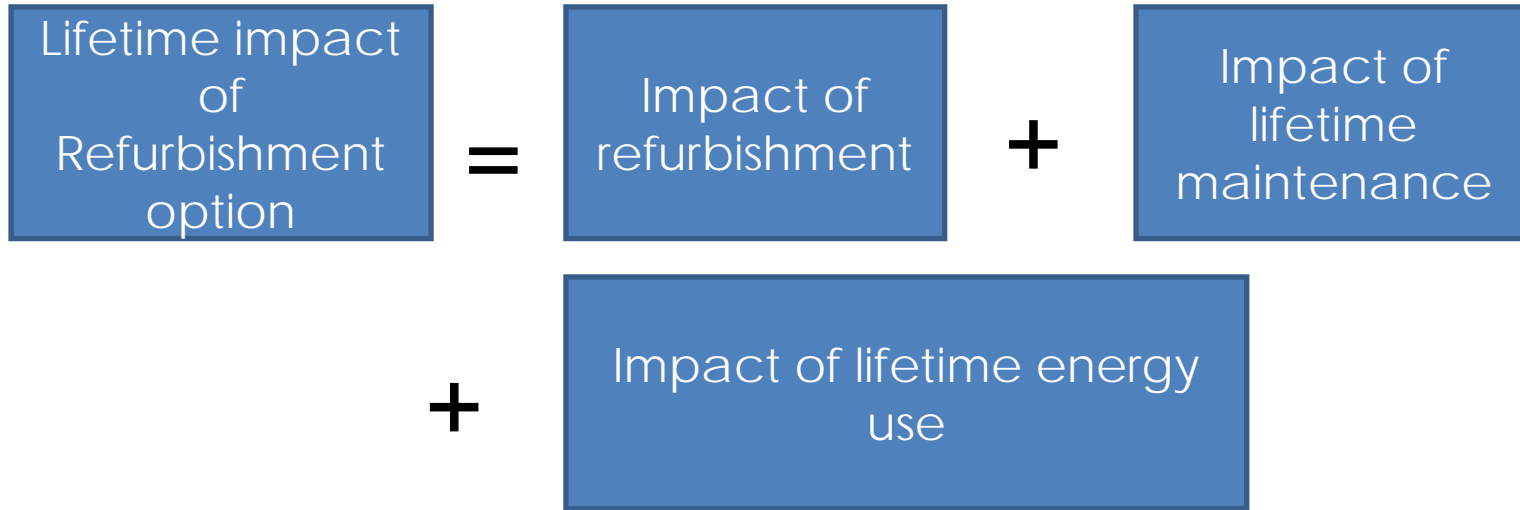


Easter Weens Cottage

# Building Options

Option 1	Baseline	Retaining current building fabric in its current state with no intervention or improvements
Option 2	Upgrade	Undertake a comprehensive upgrade of the building form and fabric but using existing heating and lighting
Option 3	Scottish Building Standards (SBS) 2008 Compliant	Demolish and replace existing building form and fabric to SBS 2008 compliance building of comparable build type
Option 4	Code for Sustainable Homes (CSH) Level 3	Refurbishing building Code for Sustainable Homes Level 3 compliance (form and fabric only)
Option 5	Code for Sustainable Homes (CSH) Level 5	Refurbishing building Code for Sustainable Homes Level 5 compliance (all the above and renewable energy)

# Lifetime impact of options



That sounds great....

BUT...

How are we going to estimate what this is?!?

# Embodied Energy

The energy required to extract, process, manufacture, transport and install building materials...

...and the embodied energy of all the supply chains that feed into these processes.

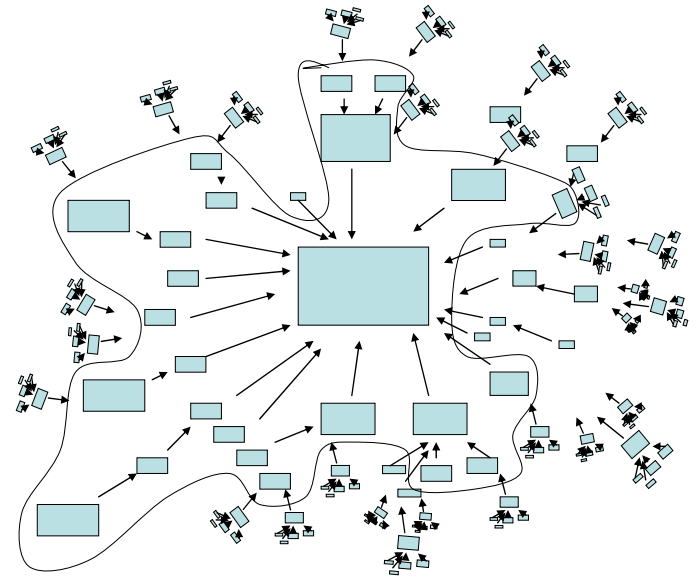
Precise measures are not possible.



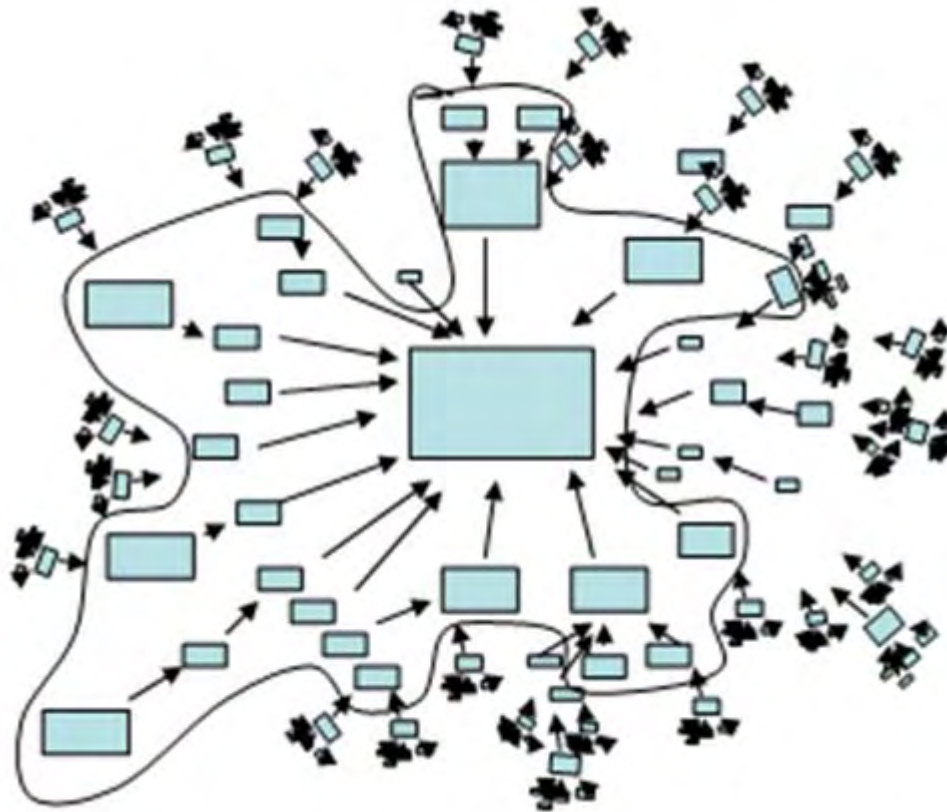
# Life Cycle Assessment Methodologies

Process based Life Cycle Analysis

Input Output Based Life Cycle Analysis

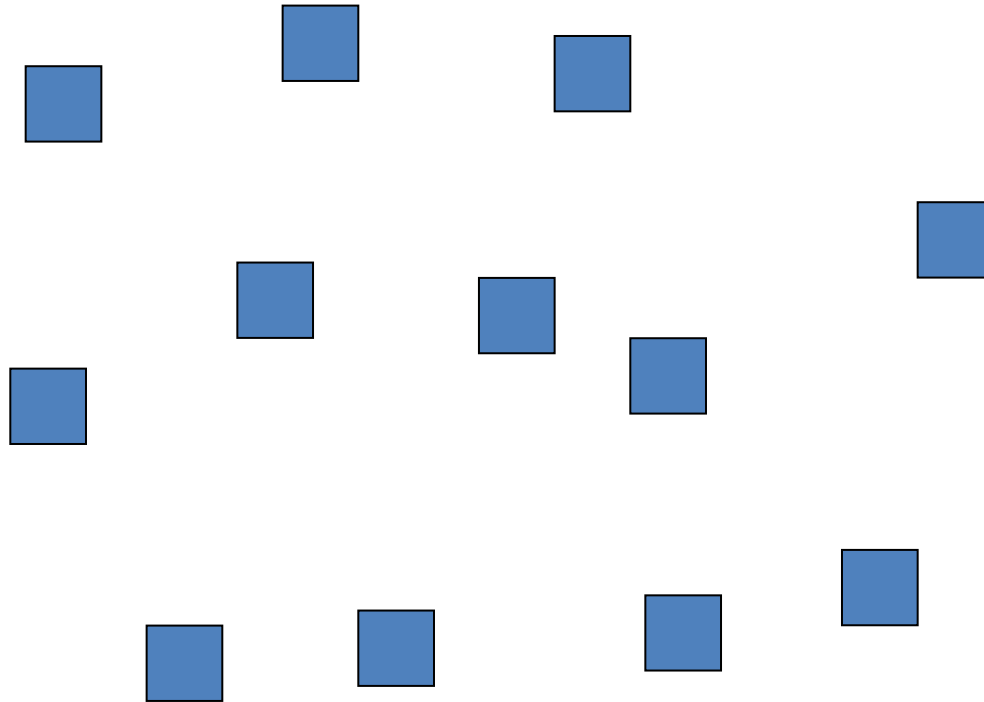


# Process Based Life Cycle Analysis



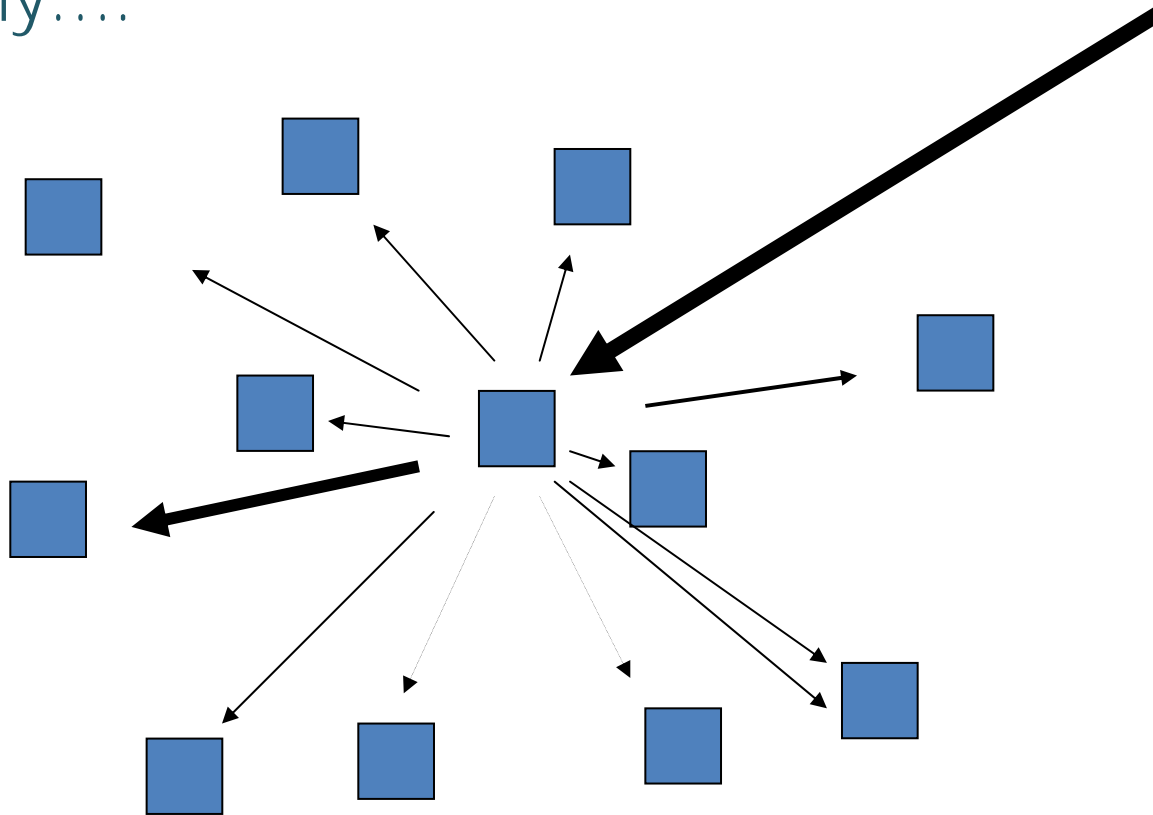
# Input Output Analysis

Looks at the whole economy divided into industry sectors.



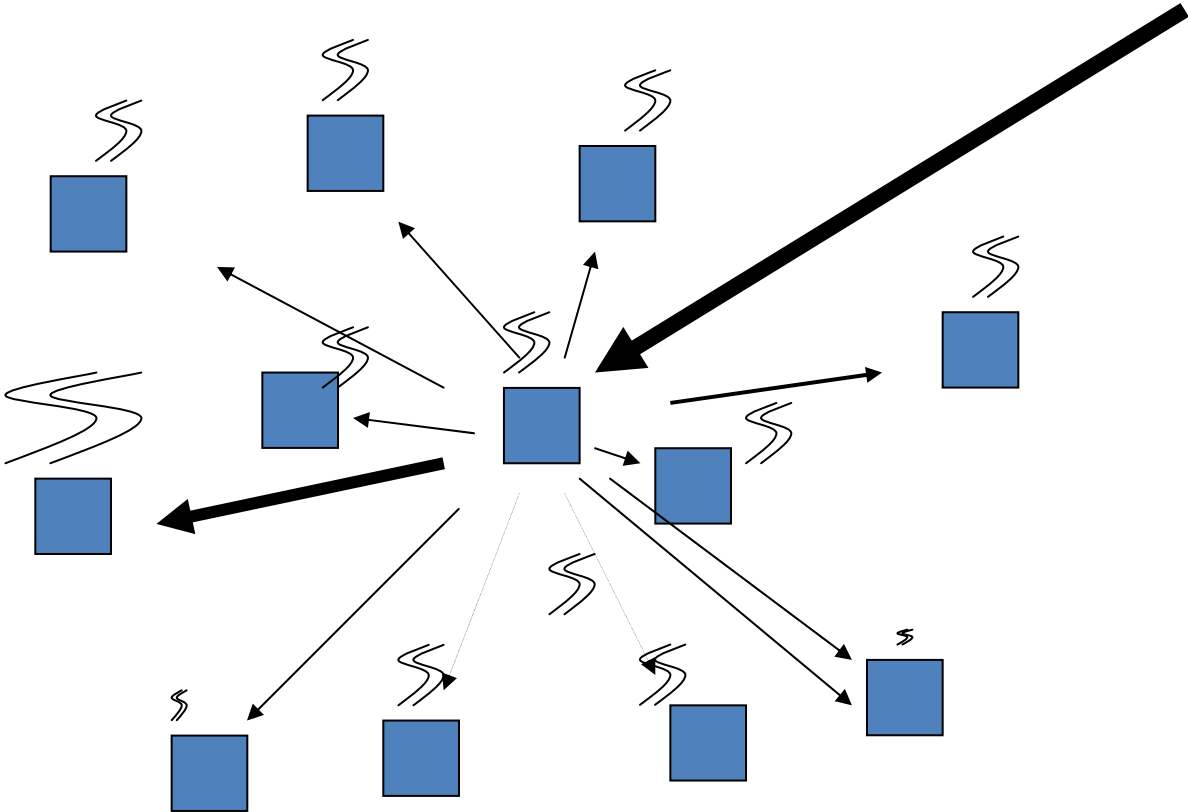
# Input Output Analysis

Demand for products stimulates output across the economy....



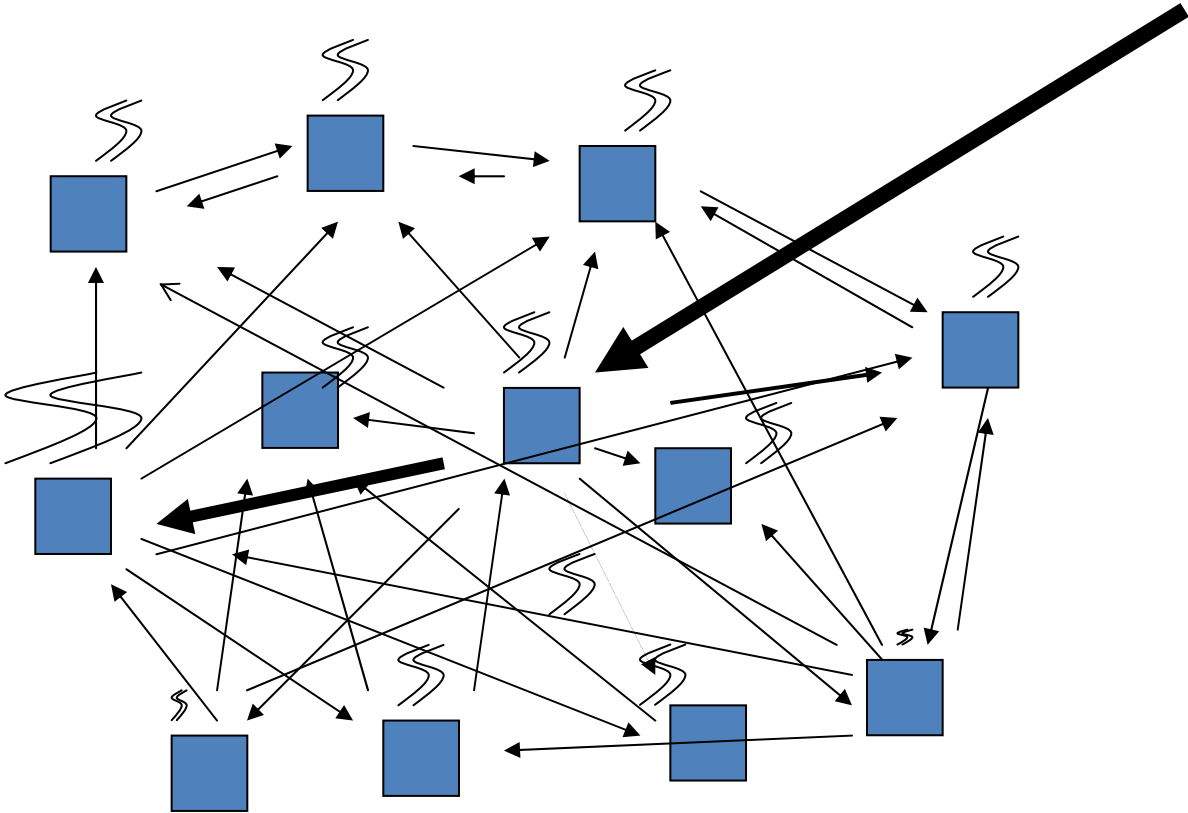
# Input Output Analysis

.... causing both direct and indirect emissions...



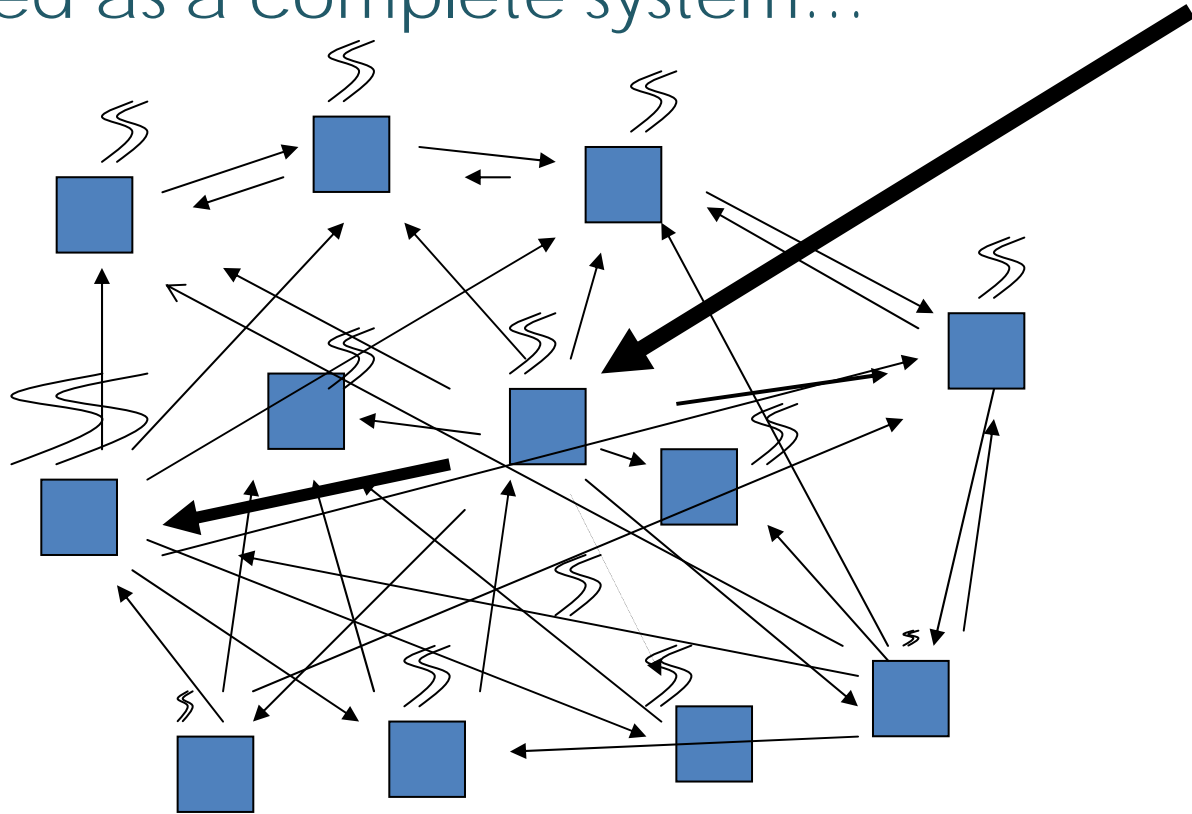
# Input Output Analysis

.... the ripple effects are endless...



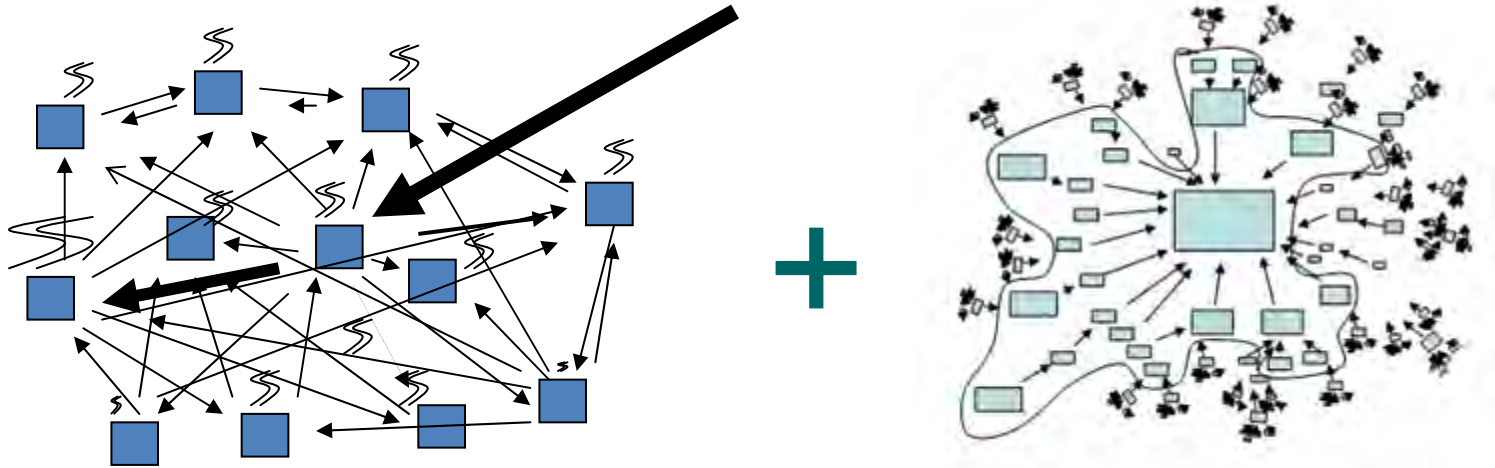
# Input Output Analysis

.... the ripple effects are endless... but can be modelled as a complete system...



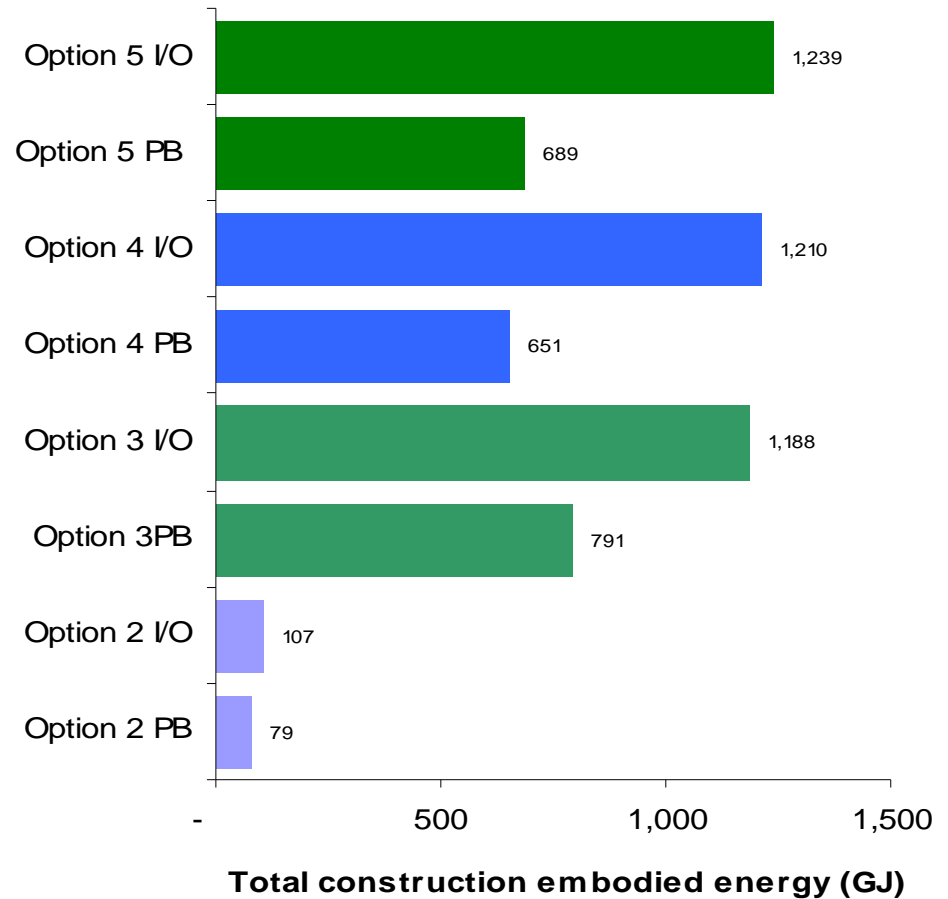
...without systematic underestimation

# A hybrid methodology

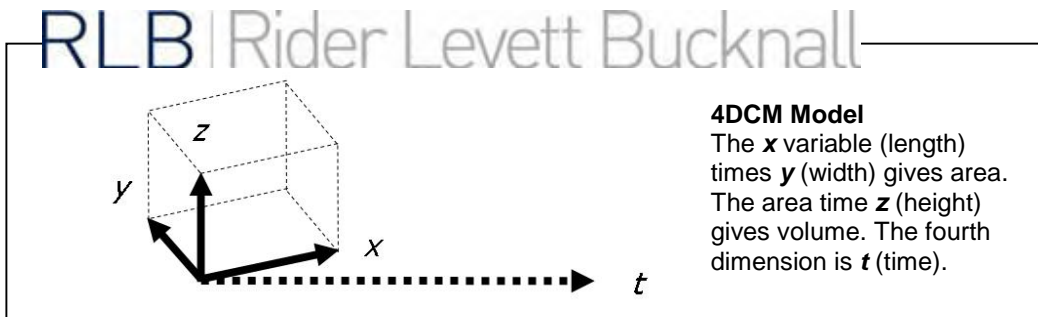


- **Process Based LCA conversion factors** for direct emissions and electricity consumption
- **Input Output Analysis** for a 'first cut' of materials, services and their supply chains
- **Process Based LCA** for bespoke adjustments in key areas.

# Comparison between total construction embodied energy using Process Based and Input Output LCA methodology.



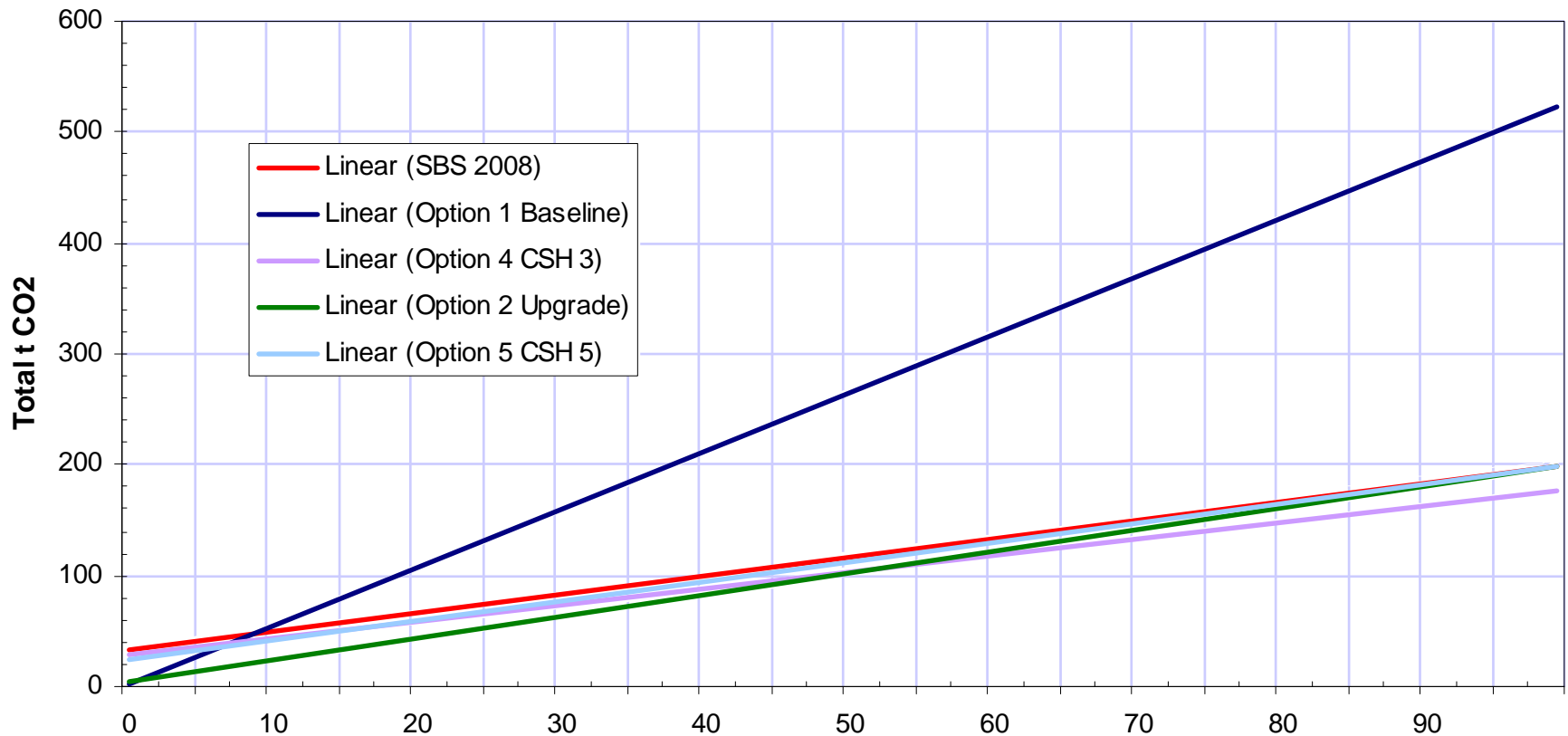
## 4 Dimensional Cost Modelling



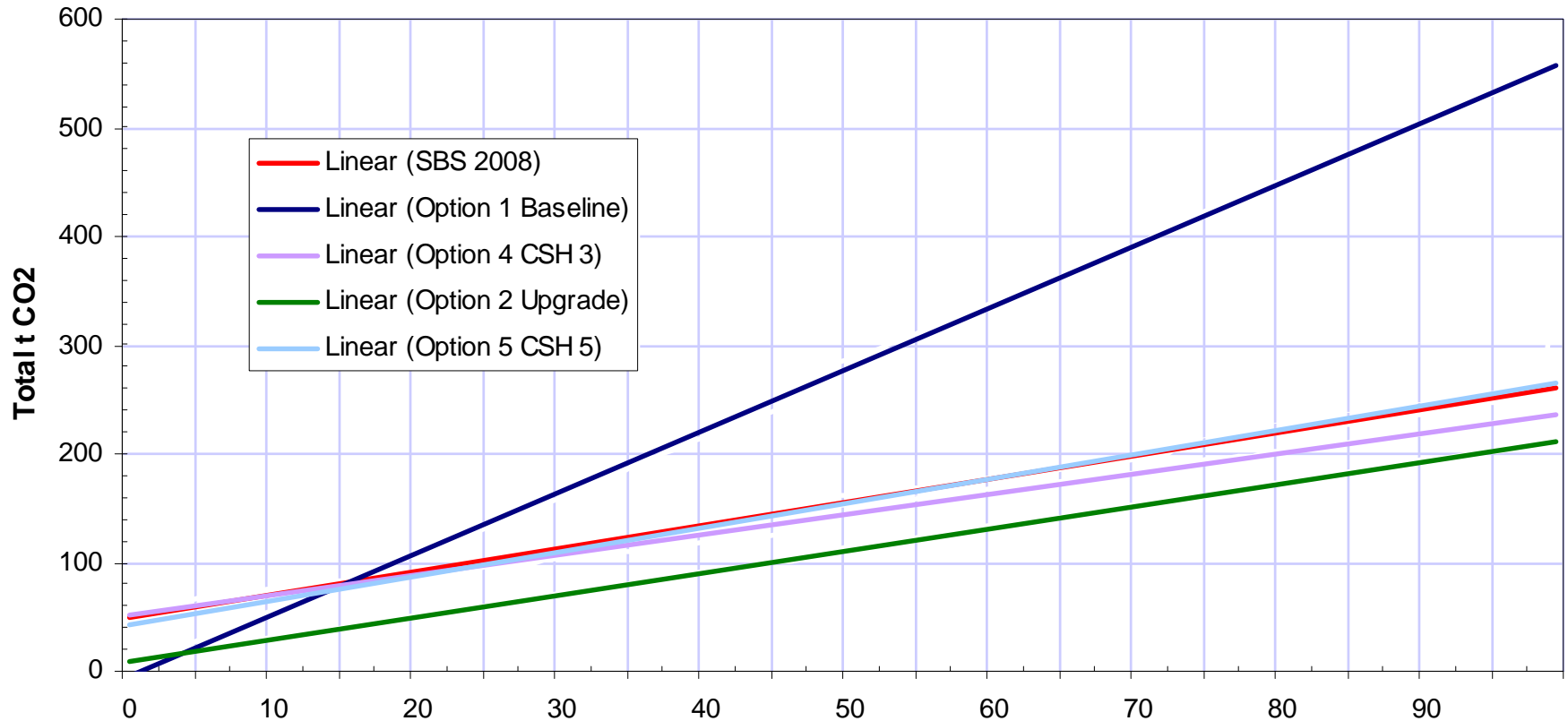
The model was adapted to incorporate the input-output embodied energy methodology developed by Small World Consulting with Lancaster University.

The model was then updated with the latest process based research on embodied energy analysis, including Bath University's ICE database and DEFRA.

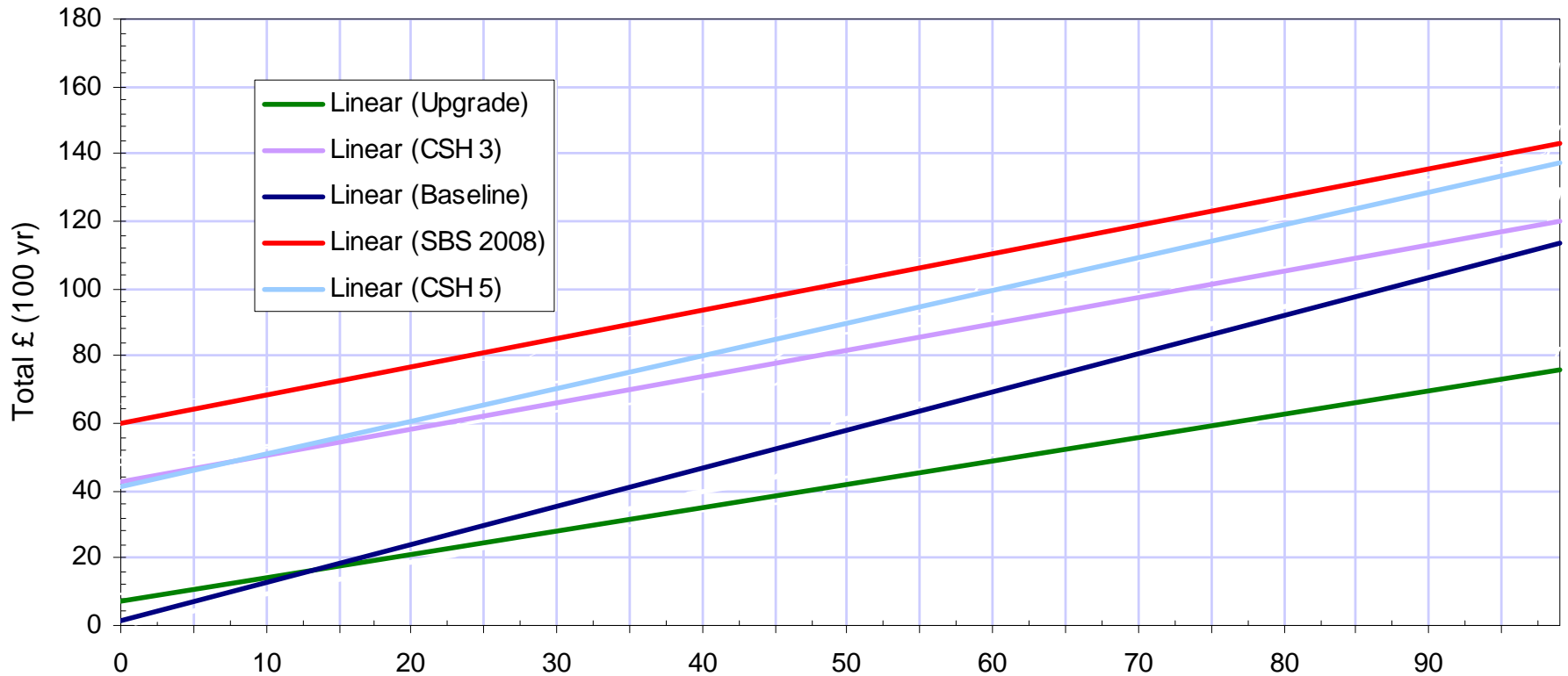
# Total energy consumption (Embodied and Operational) GJ over 100 yrs using PB LCA methodology (linear)



# Total embodied carbon over 100 yrs using Input Output LCA methodology (linear) tCO2

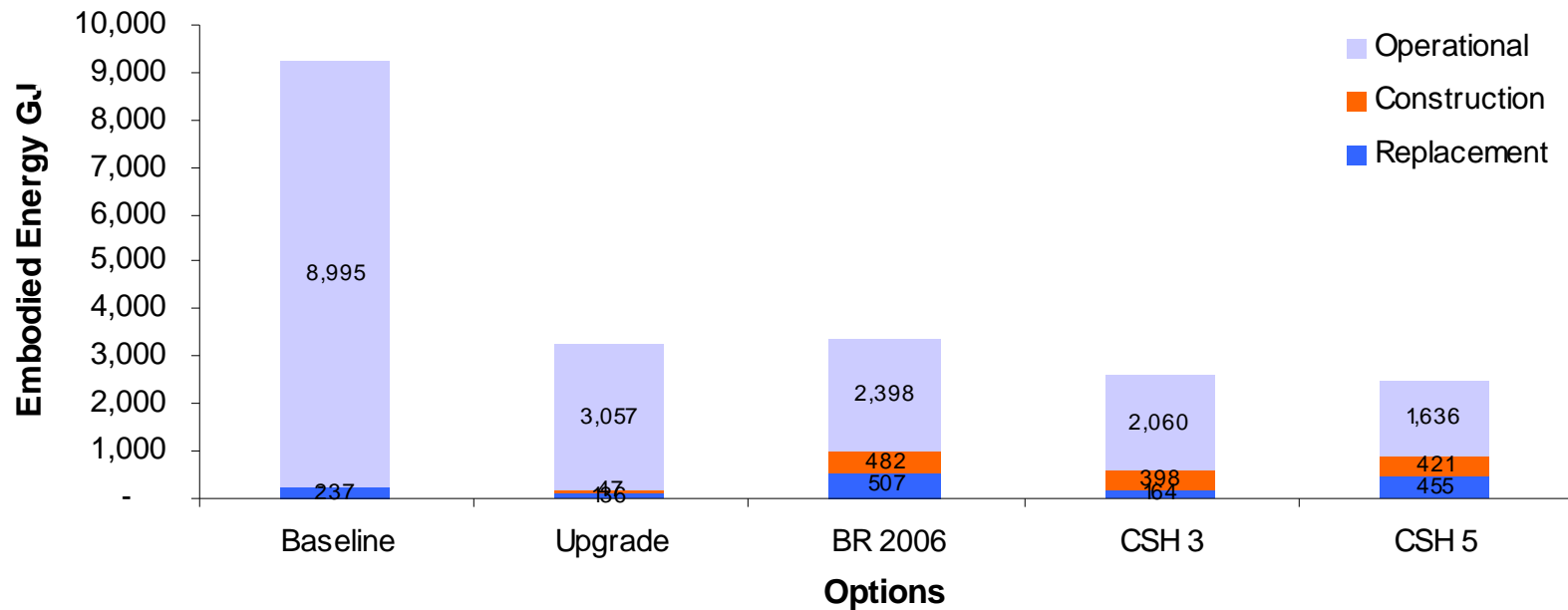


# Total estimated construction, operational and maintenance costs (£) over the lifetime of the building (100 years)



# Results - Summary Embodied Energy for Options 1 – 5 (GJ) (PB LCA Methodology)

## Total Embodied Energy (GJ) 100 yr PB LCA

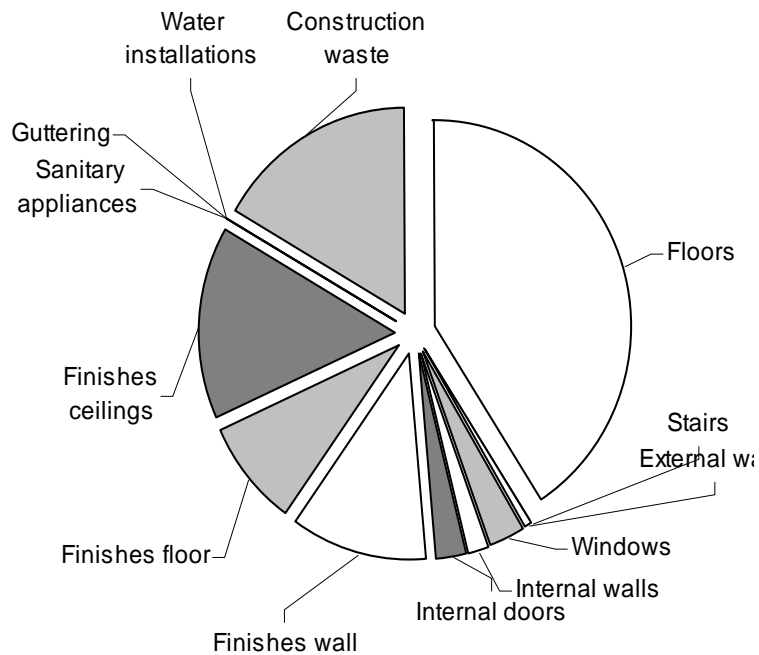


# Embodied and Operation Energy as a % of Total

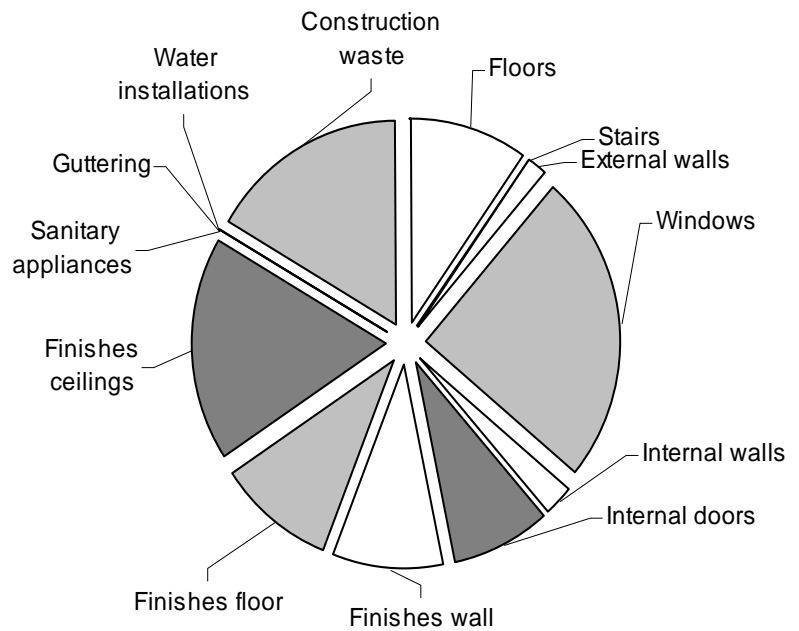
<b>Option</b>	<b>Description</b>	<b>Operational Energy (%) of total energy</b>	<b>Embodied energy (%) of total energy</b>
<b>Option 1</b>	<b>Baseline</b>	97.4	2.6
<b>Option 2</b>	<b>Upgrade</b>	94.3	5.7
<b>Option 3</b>	<b>SBS 2008</b>	70.8	29.2
<b>Option 4</b>	<b>CSH 3</b>	78.6	21.4
<b>Option 5</b>	<b>CSH 5</b>	65.1	34.9

# Distribution of embodied energy in building components for Option 2 (Building Upgrade)

**Process Based LCA**

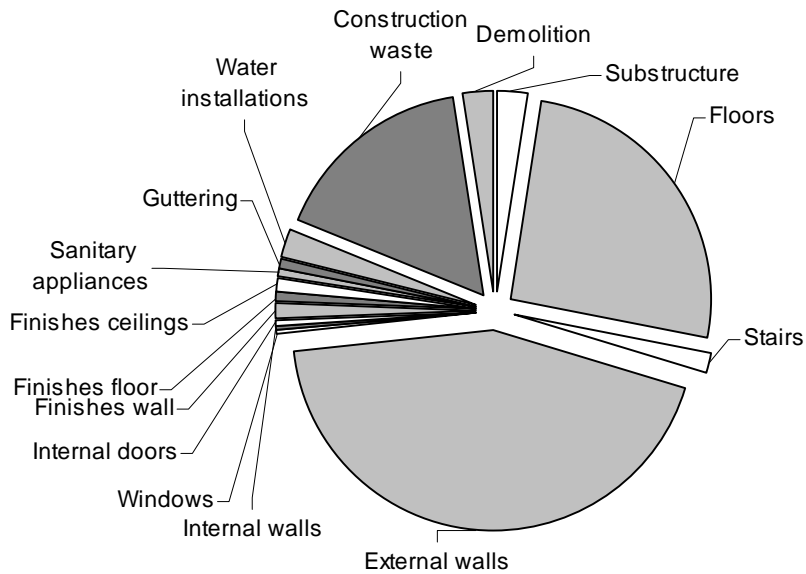


**Input Output LCA**

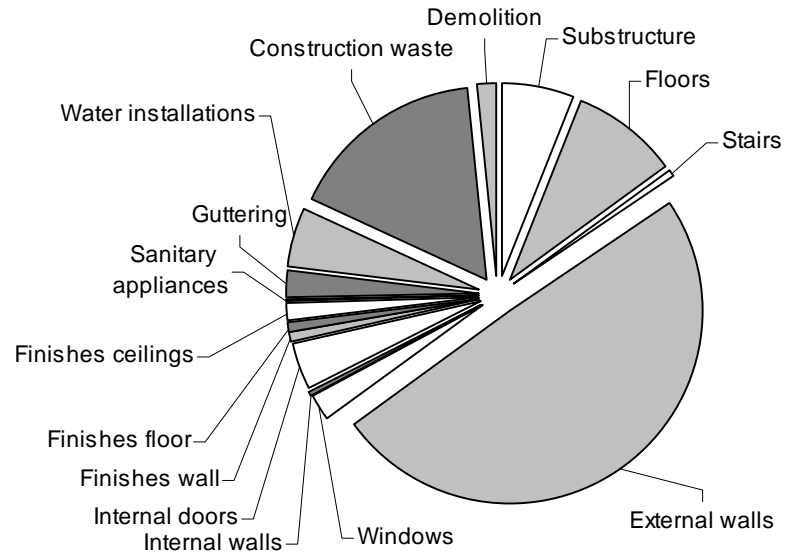


# Distribution of embodied energy in building components for Option 3 (SBS 2008 Compliant)

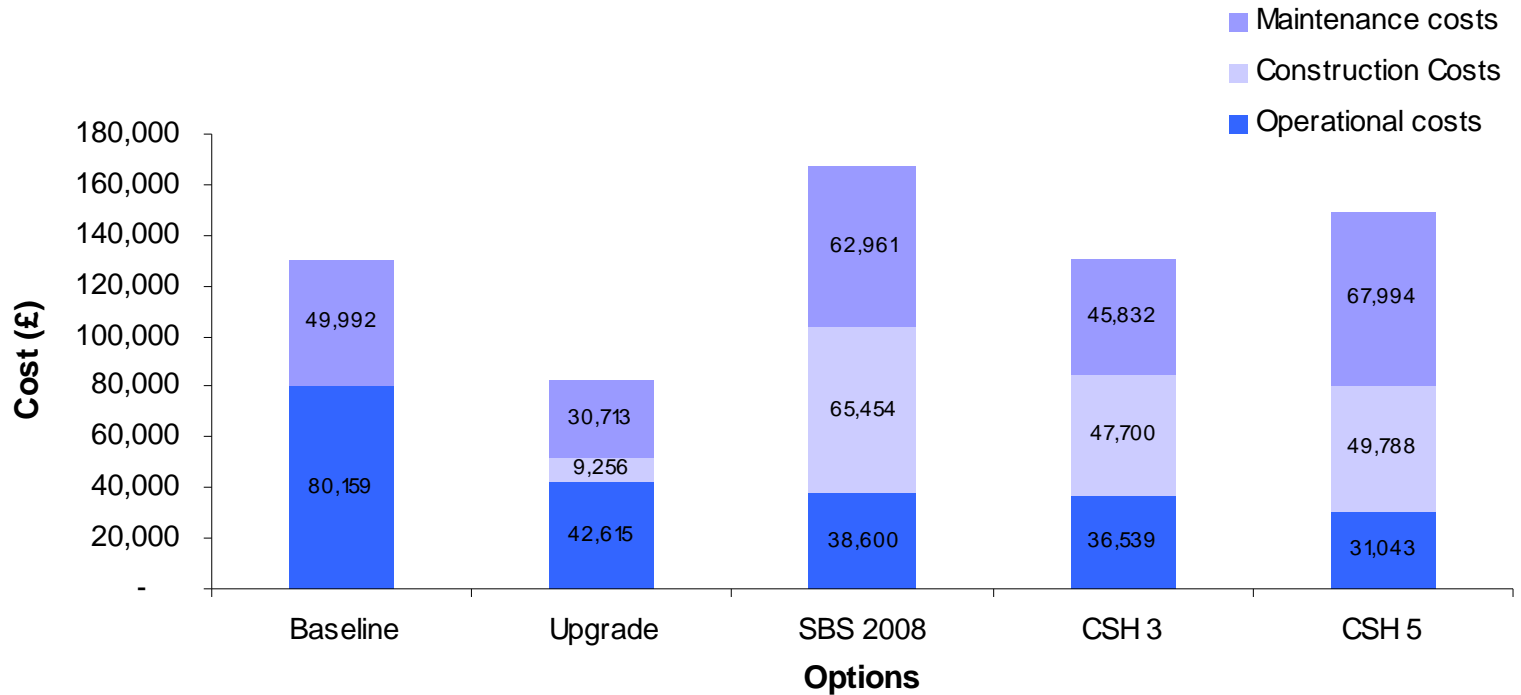
Process Based LCA



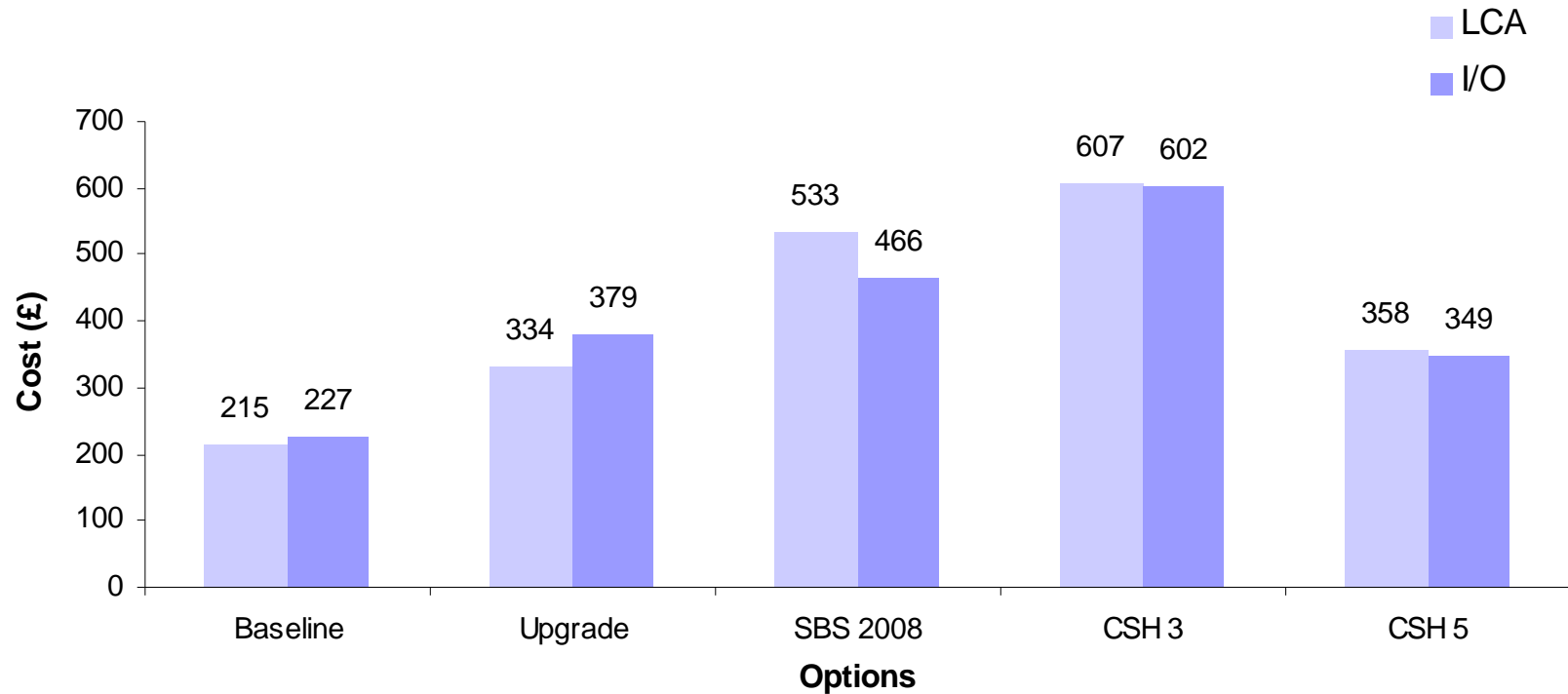
Input Output LCA



# Total estimated construction, operational and maintenance costs using the 4DCM model for each option over 100 yrs

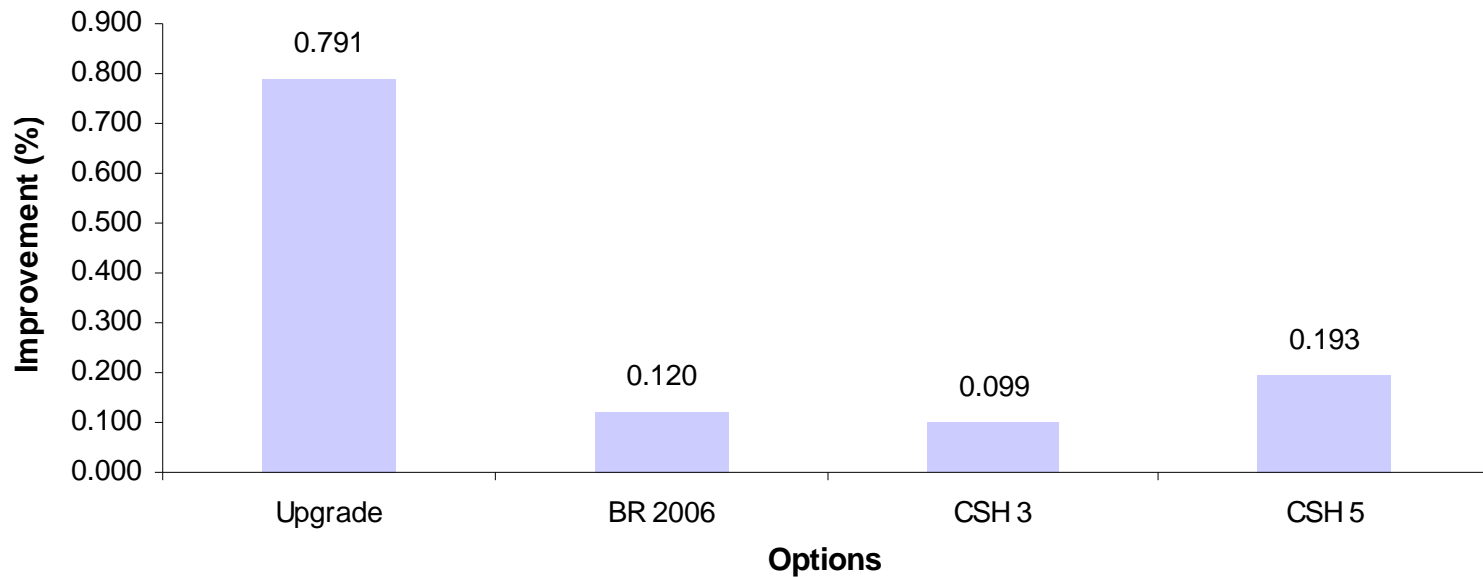


# Cost (£) per tonne of CO2 produced over the building lifetime comparing Process-Based and Input Output LCA results



# Total cost (£) per GJ of energy consumed

**Improvement on baseline operational EE (100 yr) PB LCA as a factor of total cost**



# Conclusions

- LCA process-based assessments of materials and products produce variable results and depend highly on the system boundaries chosen. It is not always clear what is included within the system boundaries making it difficult to achieve consistency within the method.
- It is highly likely that the results obtained on the embodied energy of the window replacement options underestimate the full significance of this life cycle phase.

# Conclusions

- Traditional buildings that are well insulated and with efficient heating and lighting systems have the potential to out perform new buildings over the life of the building (100 yrs) when total embodied energy is included in the equation
- The simplest energy improvements are where the most cost/benefits arise.

# Conclusions

- In terms of building replacement, even when compared to traditional buildings with very poor thermal performance, investing in a replacement building, even a very highly efficient building, is unlikely to recoup the investment over the life (100 yrs) of the building.
- In terms of cost returns on investment, the traditional building refurbishment option has significant cost benefits over the life of the new build, regardless of the energy performance level.

# Thank you for listening



The Crichton Carbon Centre

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