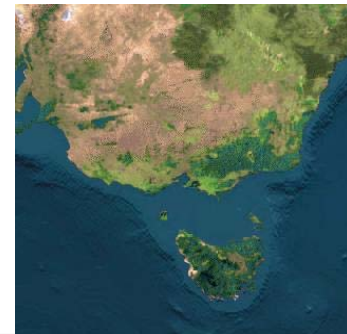


Melbourne Forum, 30th June 2008

Embodied energy in buildings: A review

A/Prof Ralph Horne
Director, Centre for Design, RMIT University,
Trivess Moore
Research Officer, Centre for Design, RMIT University

Acknowledgement: This presentation is produced from a review undertaken for the Building Commission, Victoria



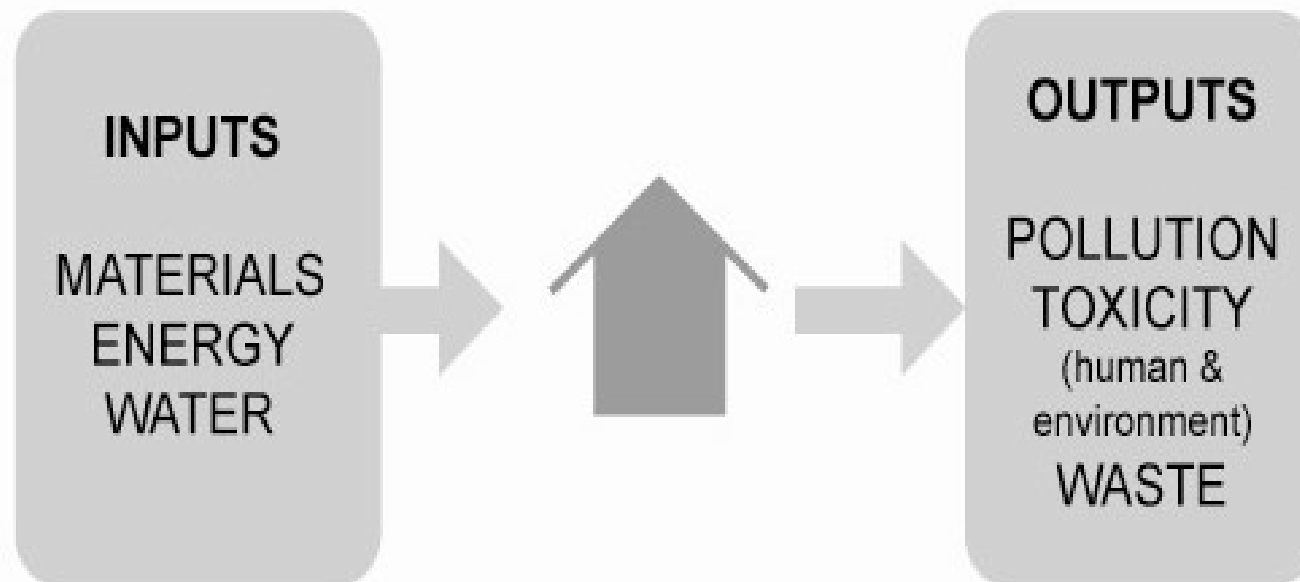
Outline

1. Introduction
2. Definition & framework for embodied energy assessment
3. Existing situation
4. Future scenarios
5. Conclusions and prospects

1. Introduction

- Buildings are estimated to consume 30 - 50% of available raw materials, account for 25 - 40% of final energy consumption and generate about 40% of waste to landfill in OECD countries
- In Australia building stock trend growth is 3.4%, considerably faster than population growth of about 1.5% per year
- Buildings are significant consumers of energy, water and raw materials
- Energy demand and emissions are continuing to rise

Systems approach to building environmental assessment



Stages and key indicators

- Building impacts can be broken down into three life cycle stages:
 - Materials and production
 - Operation
 - End of life
- **Building Energy is also related to GHG emissions**
- The construction industry is responsible for 7% of global CO₂ emissions. Largely due to the production of concrete (approximately 1 kg of CO₂ for each kg of cement produced).

2. Definition & framework

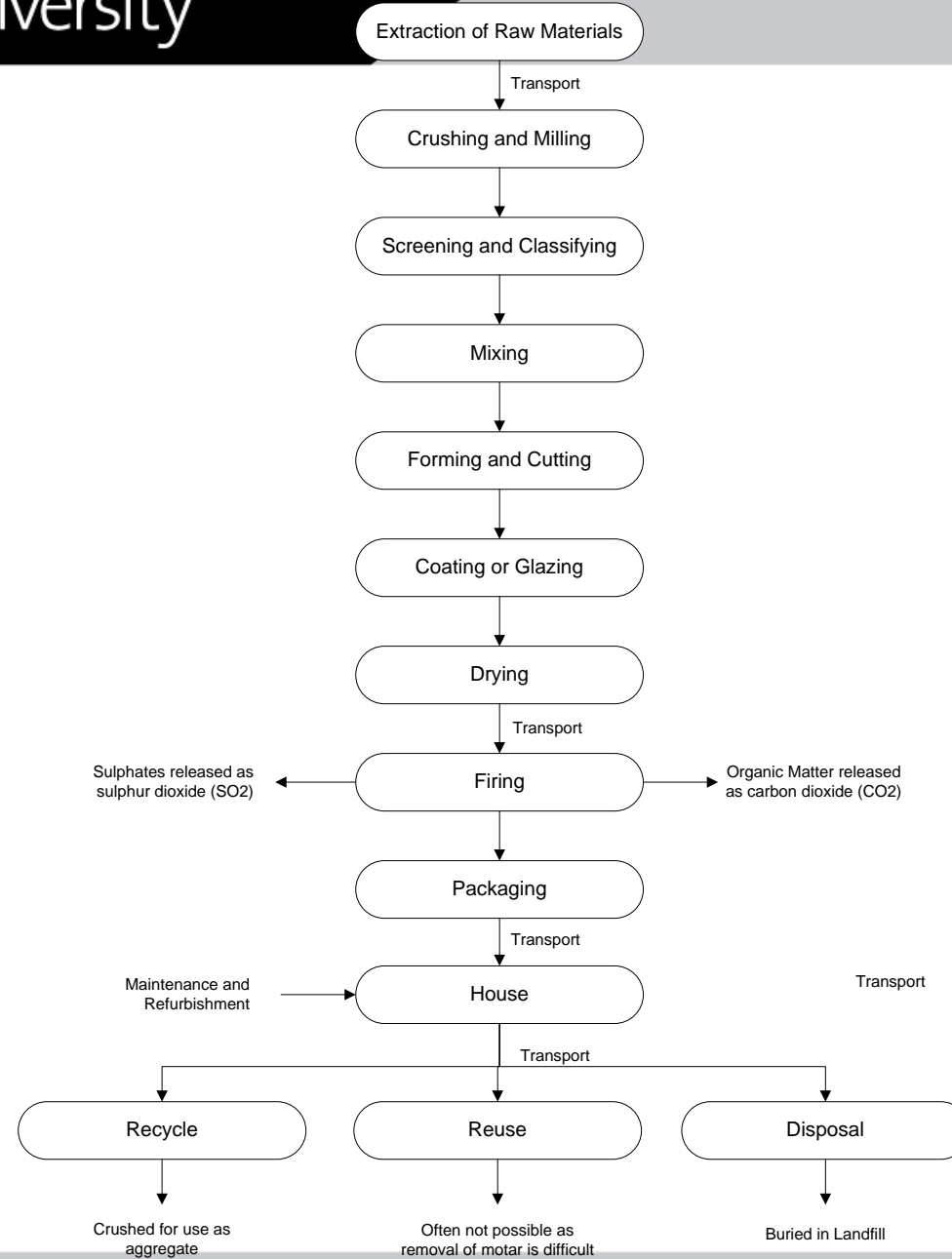
A review of embodied energy (EE) was undertaken looking at studies from Australia (with a Victorian focus) and internationally

Embodied energy is defined as:

‘the energy consumed by all of the processes associated with the production of a building, from the acquisition of natural resources to product delivery, including mining, manufacturing of materials and equipment, transport and administrative functions’ (CSIRO 2008)

LCA

- Life Cycle Assessment (LCA) is a technique for calculating energy, GHG and other impacts of materials, production and processes
- Cradle-to-cradle approach
- Previous buildings research has tended to focus on operational energy (OE) impacts and how to reduce these



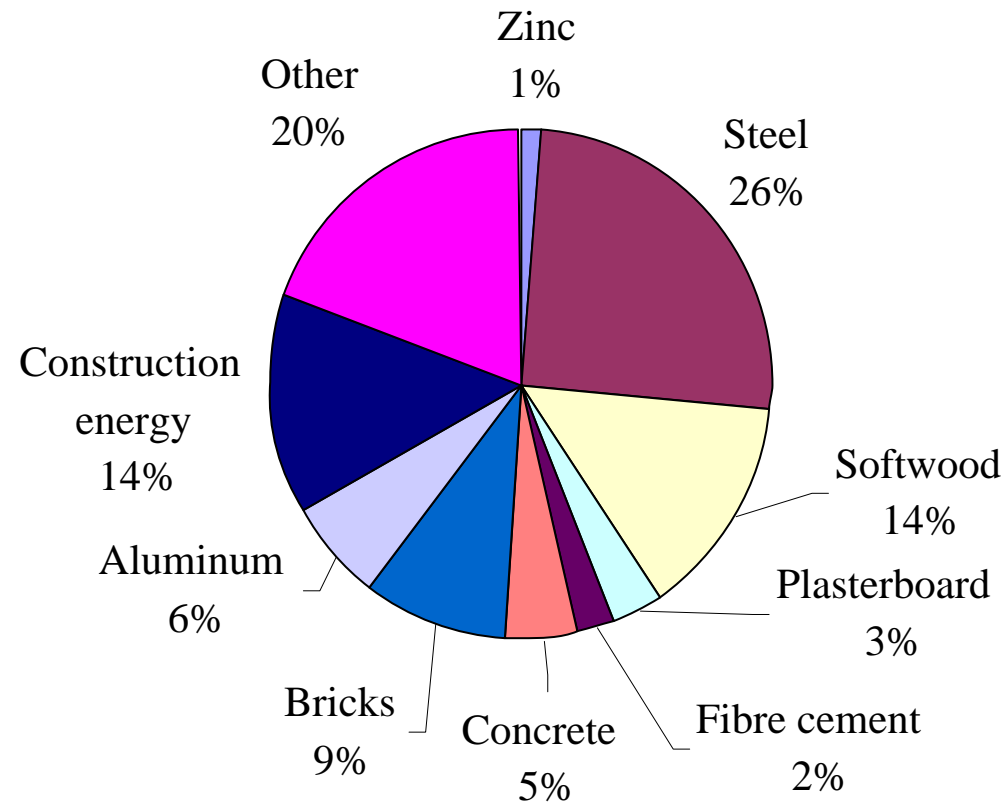
Issues with EE calculations

1. EE calculation methods are not yet standardised
2. Buildings have many variables including context, design, purpose, setting and use
3. Some data being used is over 10 years old
4. Travel distance for materials is often not included but can contribute to impact
5. Data often only assumes a life cycle of 50 years (or less) when in reality it could be 100 years +
.....

Issues with EE calculations (2)

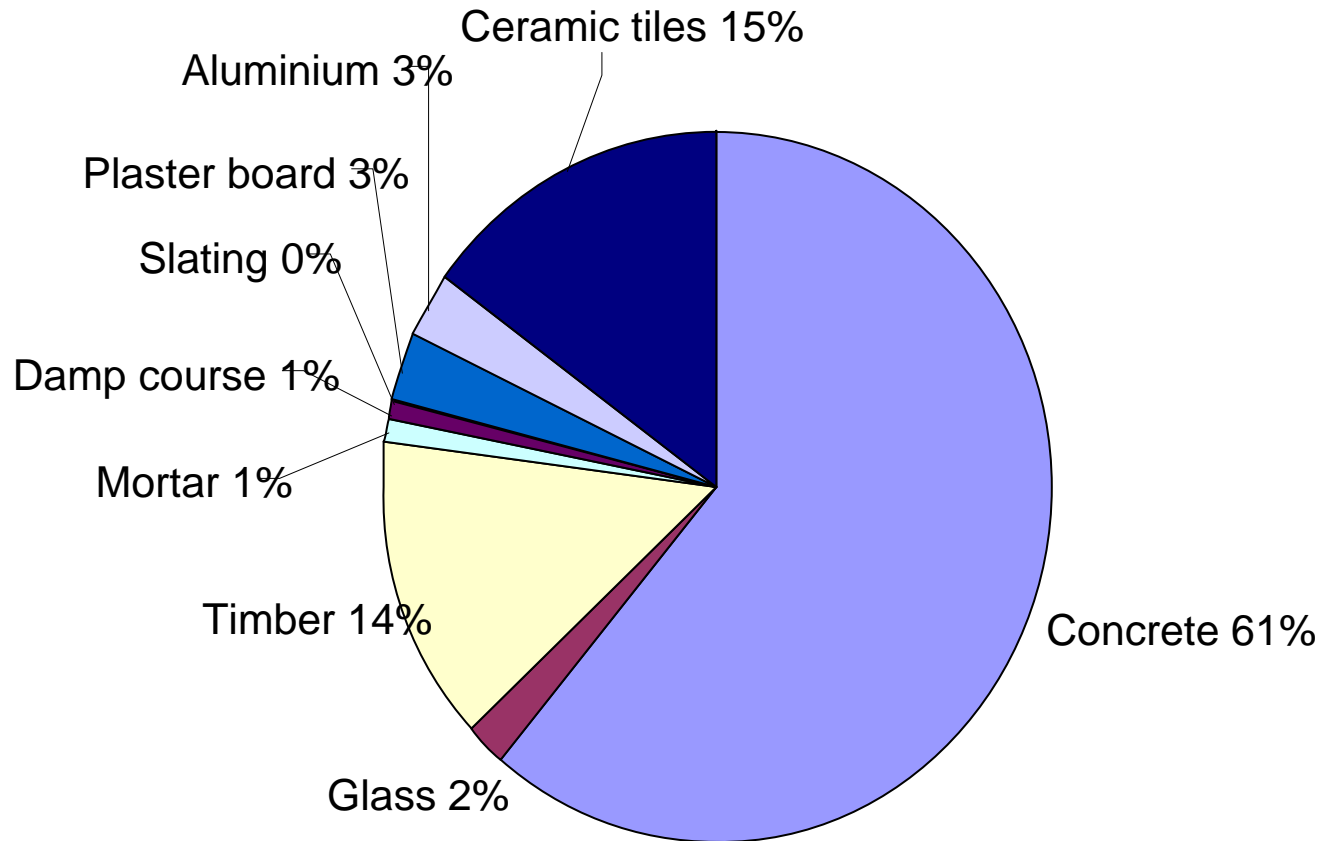
6. Recycling and reuse are often omitted from calculations but some materials can have up to 95% of EE recovered
7. Questionable data from interest groups
8. Maintenance and refurbishment have been found to have significant EE impacts yet are often omitted from calculations
9. Issue of allocation

3. Existing situation



Embodied energy demand by material for all building sectors

for 2005 (Centre for Design, BIS Shrapnel et al. 2006)



Embodied energy distribution in the home (construction materials)

(Asif M, Muneer T et al. 2007)

EE of building materials & assemblies

Material/ assembly	Embodied energy (MJ/m ²)	Material/ assembly	Embodied energy (MJ/m ²)
Kiln dried softwood	3.4	Imported dimension granite	13.9
Kiln dried sawn hardwood	2	Local dimension granite	5.9
Air dried sawn hardwood	0.5	Gypsum plaster	2.9
hardboard	24.2	Plasterboard	4.4
particleboard	8	Fibre cement	4.8
MDF	11.3	Cement	5.6
Plywood	10.4	Insitu Concrete	1.9
Glue-laminated timber	11	Precast steam-cured concrete	2
Laminated veneer lumber	11	Precast tilt-up concrete	1.9
Plastics - general	90	Clay bricks	2.5
PVC	80	Concrete blocks	1.5
Synthetic rubber	110	AAC	3.6
Acrylic paint	61.5	Glass	12.7
Stabilised earth	0.7	Aluminium	170
Galvanised steel	38	Copper	100

(adapted from Milne G 2005)

www.rmit.edu.au

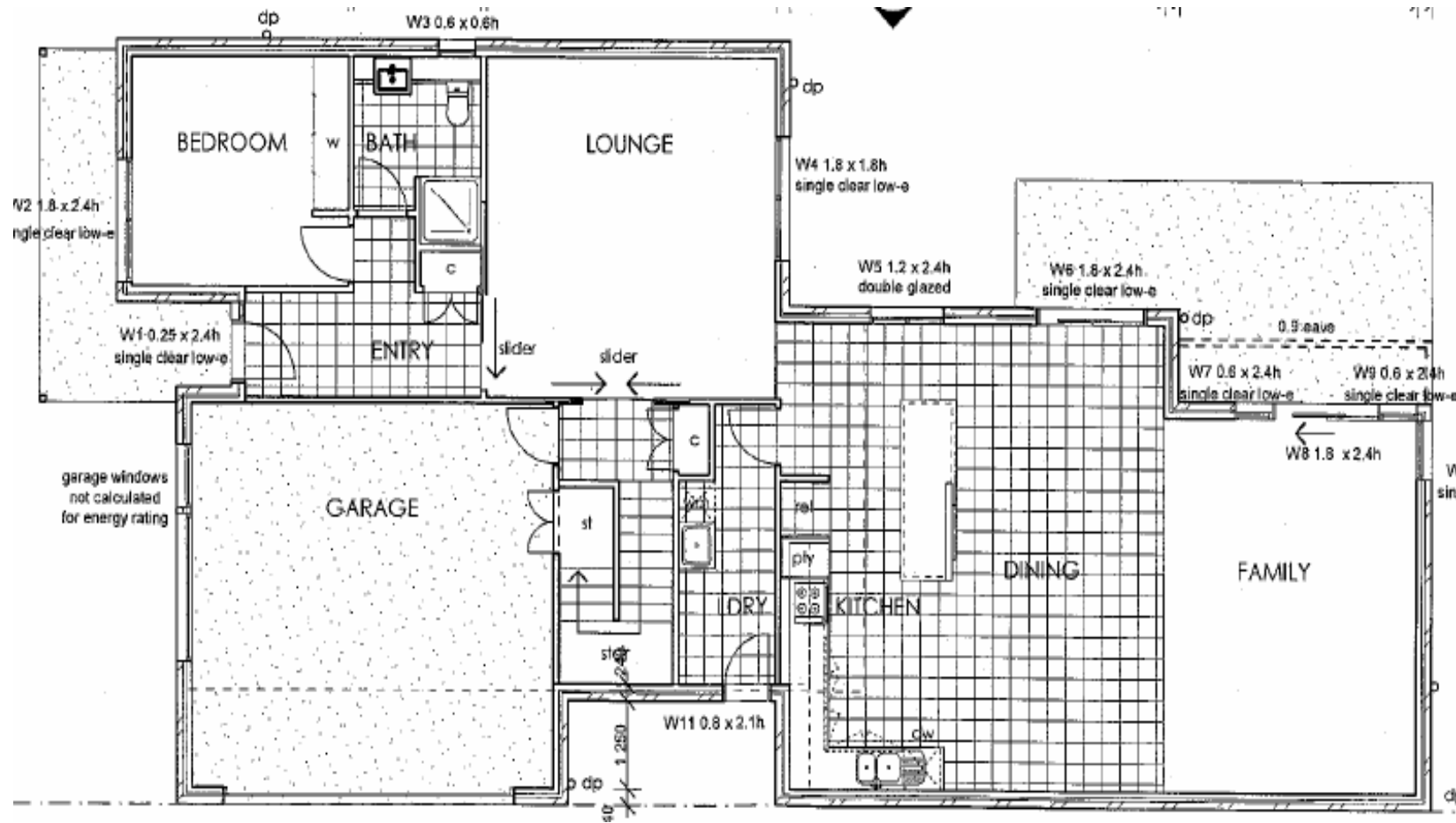
Case study: Housing in Victoria

- Goal - provide a transparent energy evaluation of the:
 - Materials used to construct a house;
 - Operational energy required to heat and cool a house;
 - Maintenance over the life of the house (demolition not included).
- Functional unit:
 - Provision of a typical family house over a fifty year life span including construction, operation and maintenance
- Method:
 - Modelled operational heating and cooling energy results from AccuRate inputted into SimaPro to allow calculation of the total energy demand
 - Single common plan for a relatively 'standard' single storey 3-4 bedroom house
 - 4 options: Brick veneer, concrete slab: Mud brick, concrete slab: Weatherboard, concrete slab: Weatherboard, timber floor

The materials

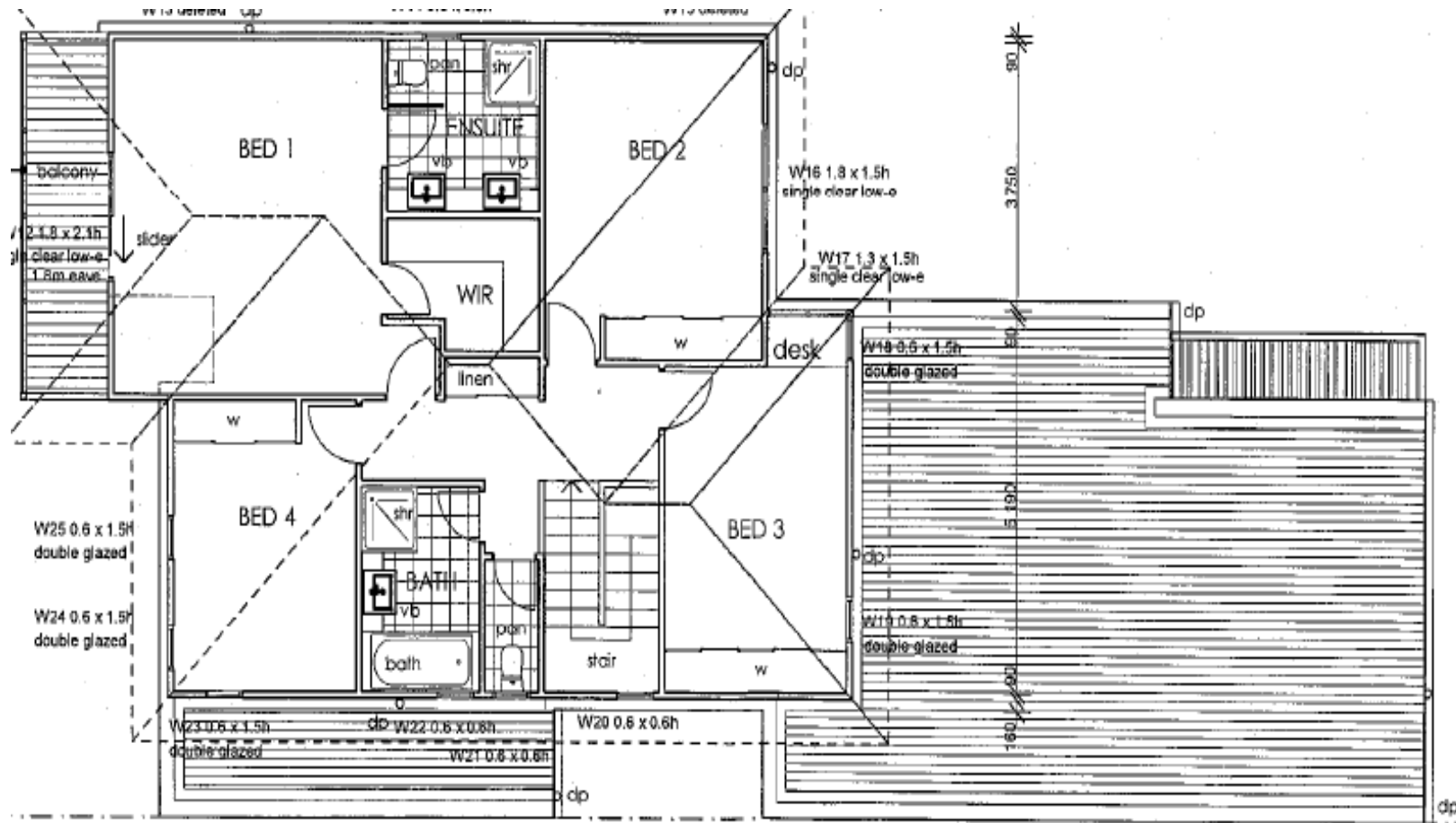
Materials	Mud brick House	Timber House	Brick Veneer House
Concrete slab			
Timber flooring			
Brick veneer			
Weatherboards			
Mud brick			
Timber ceiling			
Plaster ceiling			
Wooden framed windows			
Ceiling insulation			
Wall insulation			
Floor insulation			

Ground floor



garage windows
not calculated
for energy rating

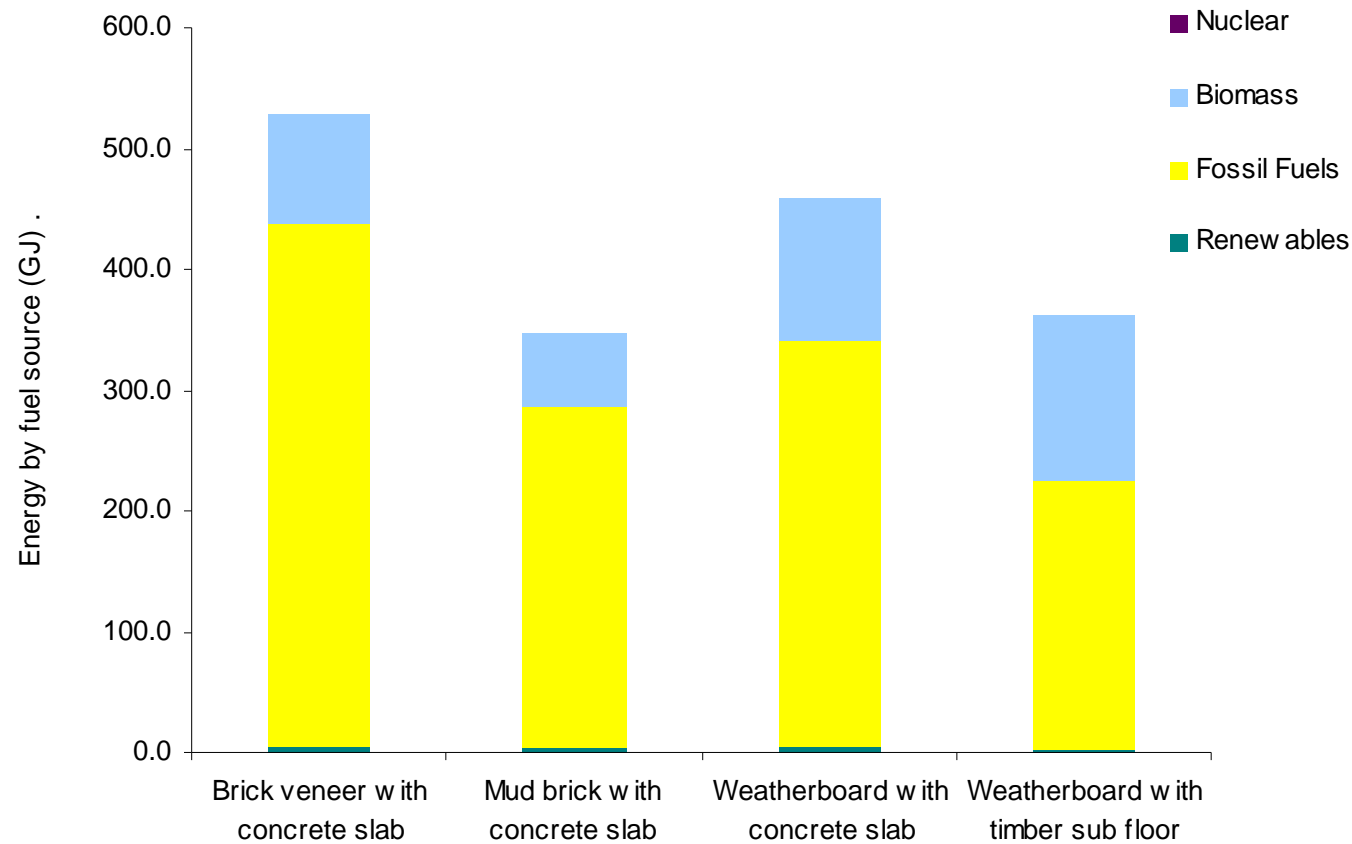
Upper floor



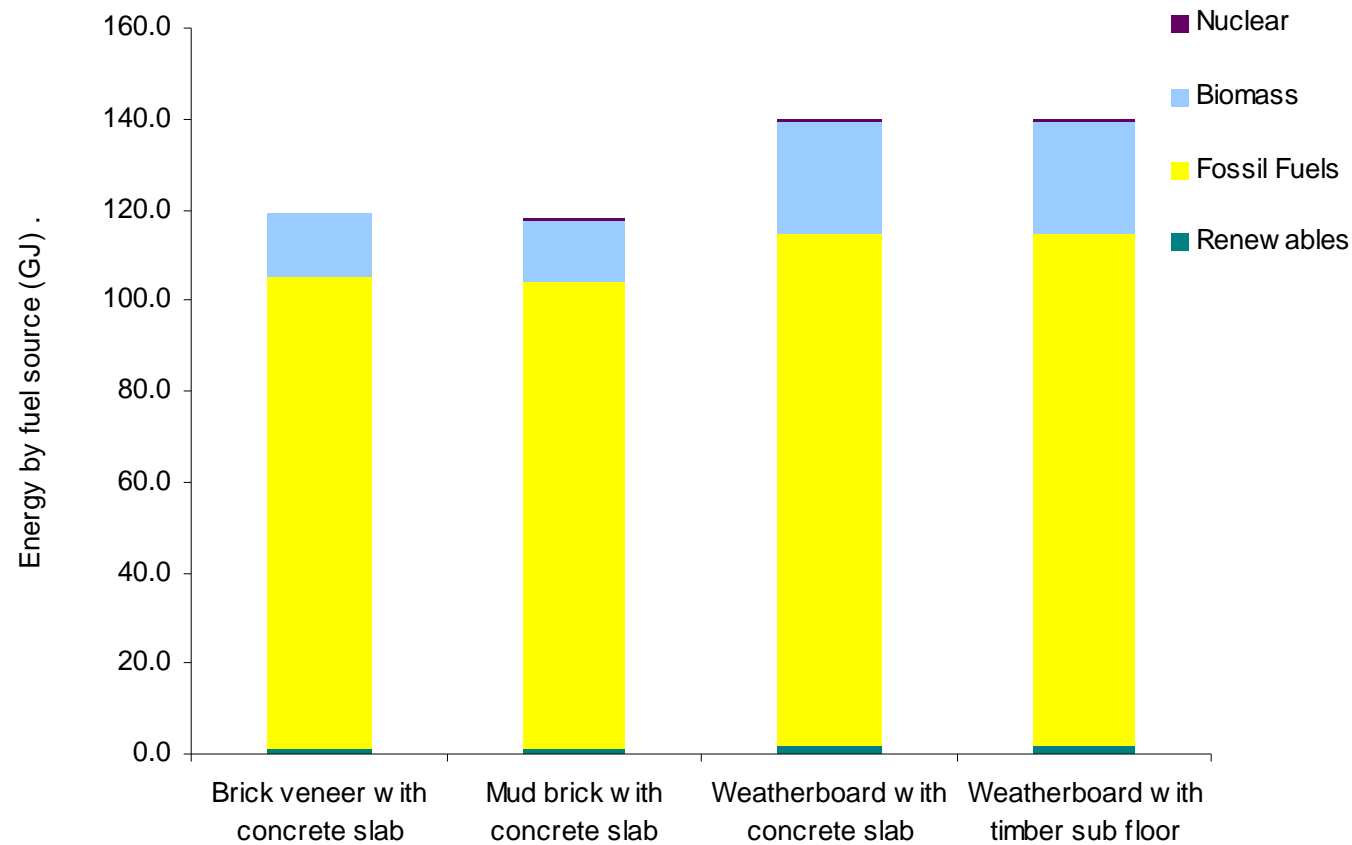
Assumptions

Material	Assumption
Mud bricks	Mud bricks will be manufactured professionally using the 'puddle' method, though no manufacturing energy has been included. No cement or other stabilisers have been modelled in the mud brick manufacture.
Brick Veneer	1% of the bricks/mortar will need to be replaced after 25 years.
Concrete	Density of concrete 2300kg/m ³ . Concrete slab will not have a percentage of fly ash or slag content. The slab will be 110mm thick.
Weatherboard	Weatherboards will be made of soft wood, typically baltic pine. The weatherboards will be pre primed with an oil based primer. 20% of the weatherboards will be needed to be replaced after 25yrs. The external walls will need painting every 10yrs.
Window frames	All houses will have timber hardwood frames.
Internal walls	All internal walls in all houses will have stud walls with timber & plaster.

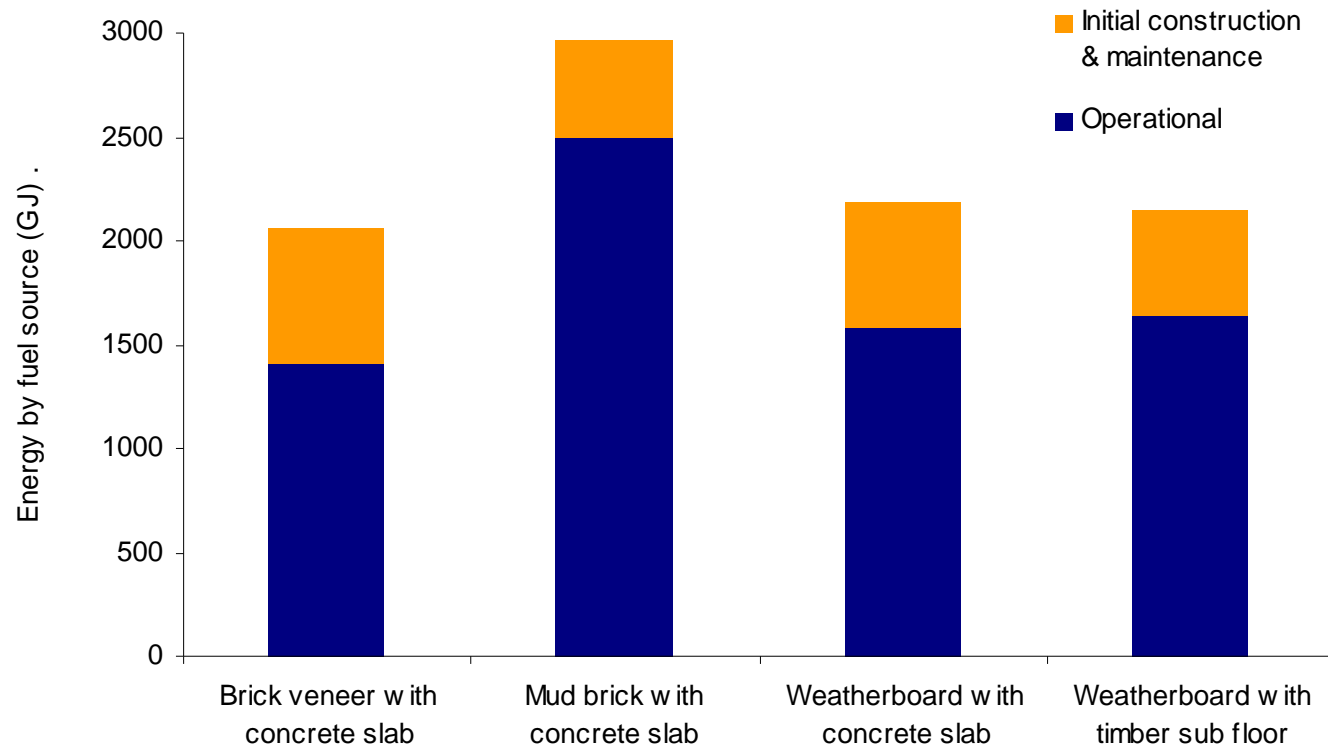
Energy Demand – Construction



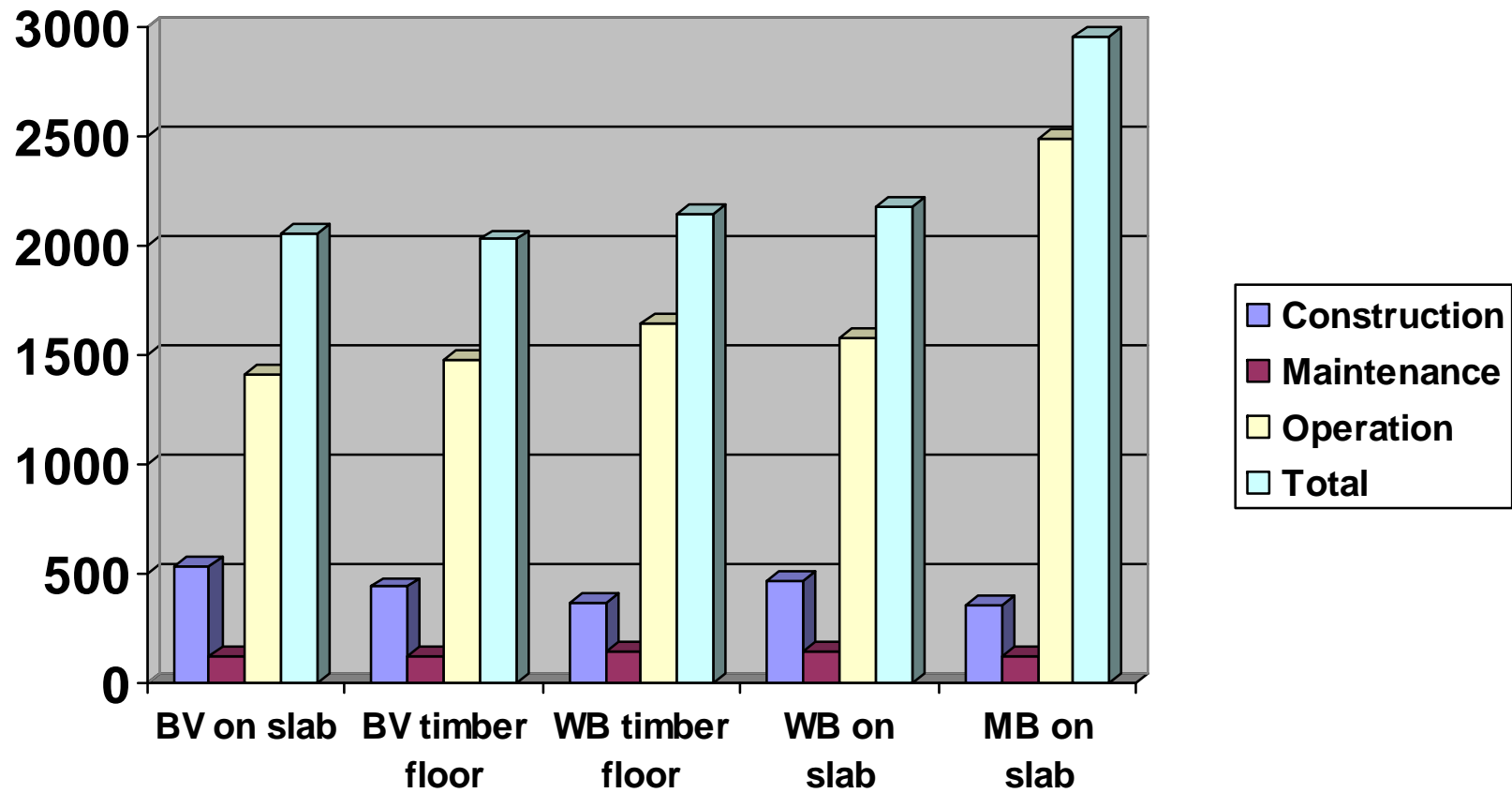
Energy Demand - Maintenance



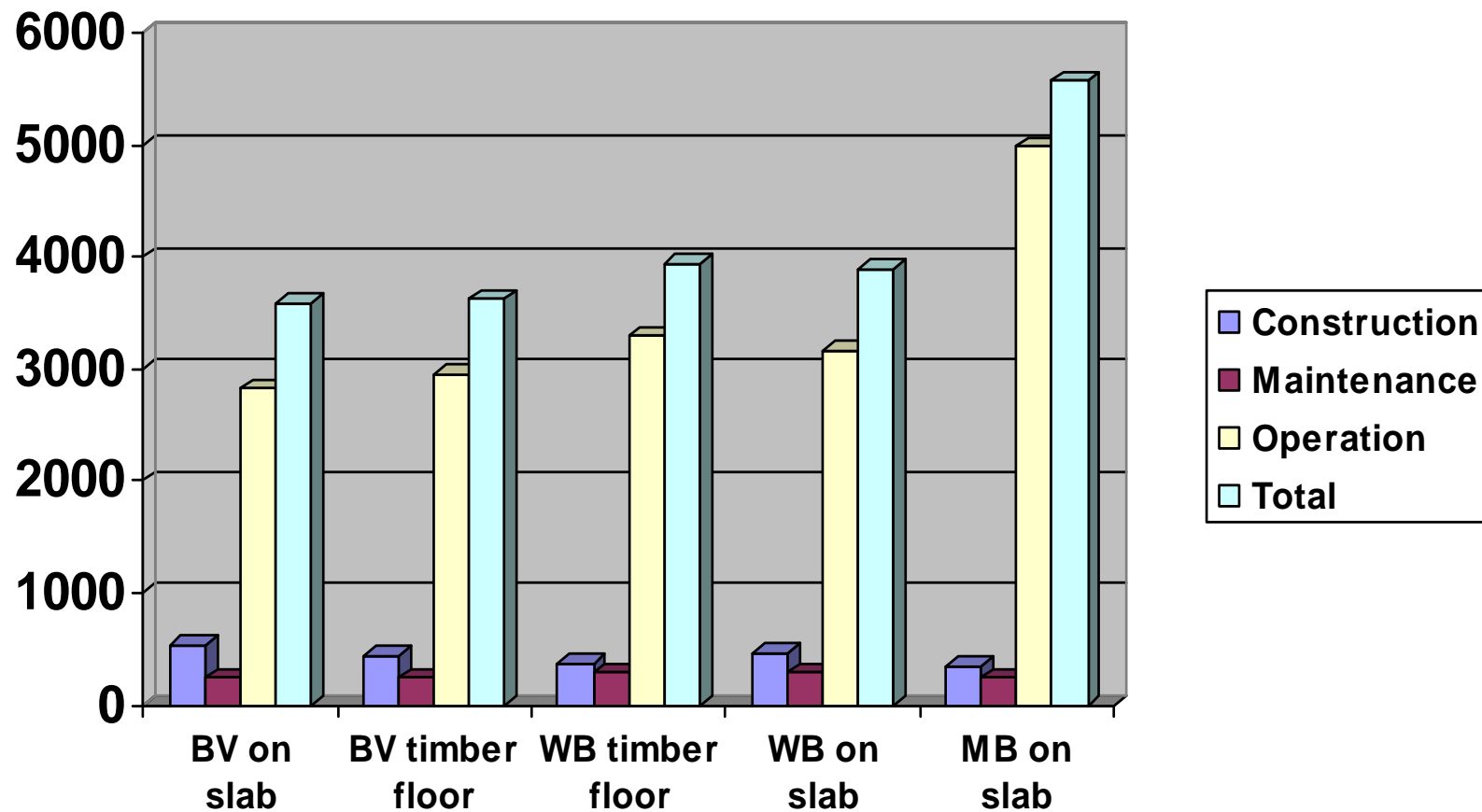
Energy Demand - Life Cycle



Life cycle energy demand – 50 year life



Life cycle energy demand – 100 year life



Main findings of the review

- In proportion to life cycle/operational energy, EE comprises:
 - Average of 10-15% for conventional residential dwellings
 - Average between 40-60% for highly energy efficient residential buildings
 - Average of 20-25% for conventional commercial buildings
 - Average of 40-60% for highly energy efficient commercial buildings

Main findings of the review (2)

- EE represents typically 5-30 years (depending on scenario) of operational energy use
- EE impacts decrease as building life increases
- Some low embodied energy buildings have higher operational energy requirements than high embodied energy buildings; leading to a higher total energy over the life of the building
- Low EE materials sometimes require more maintenance and have a lower durability

In Victoria...

- Similar results ranges for residential and commercial buildings compared to international studies for EE
- Multiple studies have shown that operational energy far exceeds EE in the total energy of a building over its life
- Commercial buildings: A study of 5 multi-storey buildings in Melbourne by Treloar et al (2001) found that the two highest buildings (42 and 52 floors) had 60% more EE per unit of gross floor than the two low rise buildings (3 and 7 floors) - the higher you go the more EE is required

4. Future scenarios

When should we regulate for EE?

- As energy efficiency of buildings continues to increase, EE will increase as a proportion of total energy
- Studies concerning low-energy housing show that embodied energy can account for as much as 40–60% of total energy use (Thormark, 2006)
- At some point EE could become the higher energy contributor over the life of the building
- At what point does EE become important enough to warrant a change of approach? **There is no widely held consensus in the literature**

4. Future scenarios (2)

- Maintain key aim - reduce total energy over the life of the building
- Extend building life cycles where possible
- More appropriate building sizes are required (proportions between EE and OE say nothing building utility, use or size)
- Since building turnover is low, focus should be on reducing current building stock operational impacts
- Greater reuse and recycling of materials will help to reduce impacts from materials

5. Conclusions and prospects

- Efforts should continue to focus on reducing operational energy;
- No consensus regarding the point at which EE becomes important enough to warrant regulation;
- EE should be considered where possible, but in the context of life cycle energy rather than in isolation and EE should not be reduced if it leads to an increase in life cycle energy;
- The two most promising starting points for addressing embodied energy are:
 1. Increasing use of more durable and recycled materials (where the durability of the material is not compromised);
 2. Designing more appropriate building sizes and more flexible uses, as part of design strategies for longer building lifespans.