Combined Life-cycle Cost Assessment of Roof Construction

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First published in Proceedings of the Institution of Civil Engineers - Engineering Sustainability 160 Issue ES4, December 2007

Introduction

A Problem:

- Selection of building materials invariably based on supply and installation cost of materials (unlikely to change)
- Cheaper materials are often less sustainable alternatives
  - Higher maintenance requirements
  - Less sustainable manufacturing processes

Introduction

A Solution[?]:

- Take account of indirect life-cycle costs (e.g. Embodied energy, GHG emissions)
- Incorporate these with direct (economic) life-cycle cost
- Present a more holistic assessment of the true “cost” of building materials
- Allow informed decision making when comparing the sustainability of competing alternatives

Methodology

Life-cycle Inventory Analysis

- Four roof configurations tested
  - Combinations of cladding and framing materials commonly used in NZ
- Inputs-outputs determined for construction, maintenance and disposal phases with respect to;
  - Direct economic costs (Materials and Labour)
  - CO_2 Emissions
  - Embodied Energy

Methodology

Functional Unit

- Roof required to cover NZ Modal House
- Dual pitch (Gable) trussed roof with flat ceilings
- Trusses at 900mm crs
- Designed to NZ Loadings Code (NZS 4203:1992)

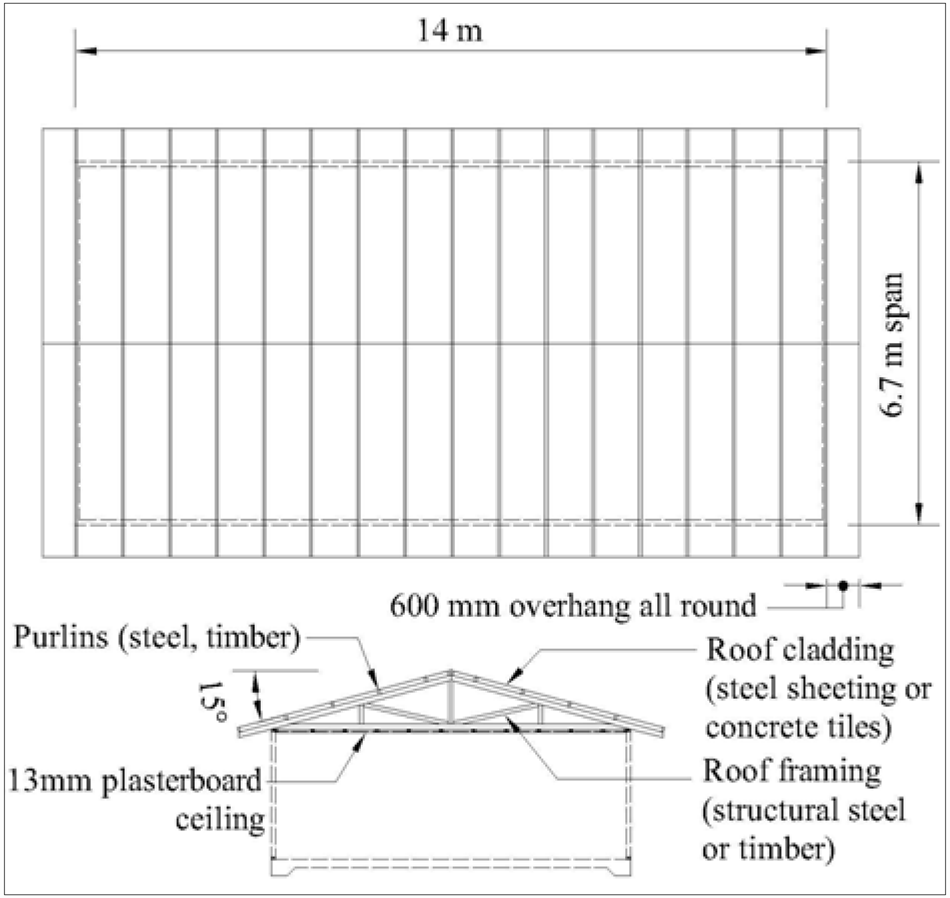


Figure: Adapted from Mithrartne (2004)

Methodology

Cladding Options

Lightweight steel sheeting

Concrete roofing tiles

Images: (top) www.secretsydney.com.au (bottom) www.freewebs.com

Methodology

Framing Options

Pre-nailed timber trusses

Light gauge steel trusses

Images: (top) gb.inmagine.com (bottom) www.bluescopesteel.com.au

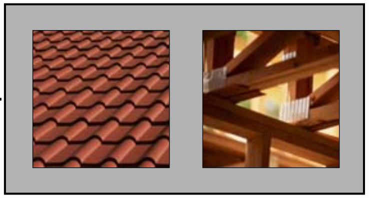
OPUS ice Institution of Civil Engineers ICSER

Methodology

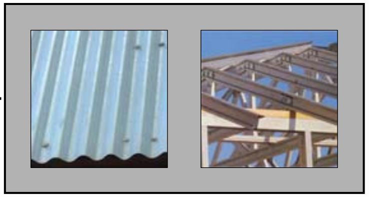
Roof Configurations

Steel Sheet – Timber Frame

Concrete Tile – Timber Frame



Steel Sheet – Steel Frame



Concrete Tile – Steel Frame

Methodology

Assumptions and Limitations

- Building design life = 100 years
- All roofs are “perfectly insulated” - no account of different effects on heating, ventilation etc.
- Subjective criteria not assessed (e.g. aesthetics)
- No attempt to qualify the environmental impacts
- All criteria given equal weighting

Methodology

Initial Construction

- All materials locally sourced
- Transported 100km to site
- Except steel framing – imported
- Costs occur at year zero – not discounted

Image: www.freefoto.com

Methodology

Maintenance

- Pro-rata from initial construction cost.
- Discounted to Net Present Value (discount factor 5%)
- No. of replacements

$$= \frac{\text{Design life of building}}{\text{Expected material life}} - 1$$

Image: www.vincegrayeroofing.com

Methodology

Expected Useful Life of Materials

Material	Expected Life	# of replacements
Steel Sheets	40 yrs[1]	2
Concrete Tiles	50 yrs[2]	1
Steel framing	>100 yrs[1]	-
Timber framing	>100 yrs[1]	-
Paint systems	12 yrs (concrete tile)	8
	10 yrs (steel)[1,3]	9

[1] Mithraratne (2004)
[2] CSR Roofing (2007)
[3] Resene Paints Ltd. (2007)

Methodology

Disposal Scenario

- All materials transported 20km to landfill
- Except timber (trusses):
    - (50% landfill, 50% thermal use)
- Only transport energy and emissions up to landfill gate included

Image: www.greengeek.ca

Inventory

Material and Labour

- NZ Building Economist (2007)
  - Installed cost of building materials
  - Plus 12.5% NZ Goods and Services Tax (GST)

Image: www.freefoto.com

Inventory

CO_2 Emissions

- Emissions Factors for NZ materials (Alcorn 2003)
- NZ Treasury 2005 predicted value of tradable emissions units (Kyoto)
- $US 7.00 per tonne
  - ~$NZ 9 per tonne (May 2007)

Image: www.freefoto.com

Inventory

Embodied Energy

- Embodied Energy Factors for NZ materials (Alcorn 2003)
- February 2007 average weighted cost of NZ domestic energy (Ministry for Economic Development)
- 20c/kWh = ~5.5c/MJ

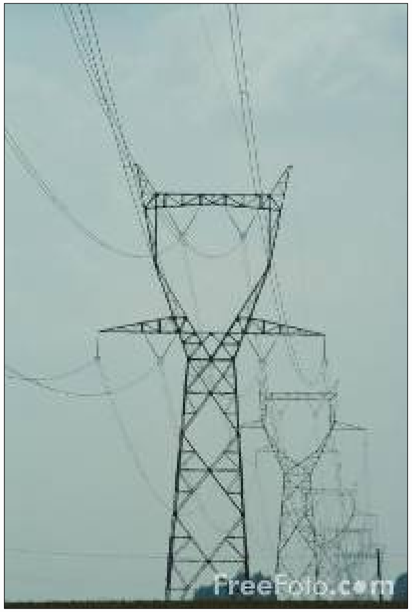
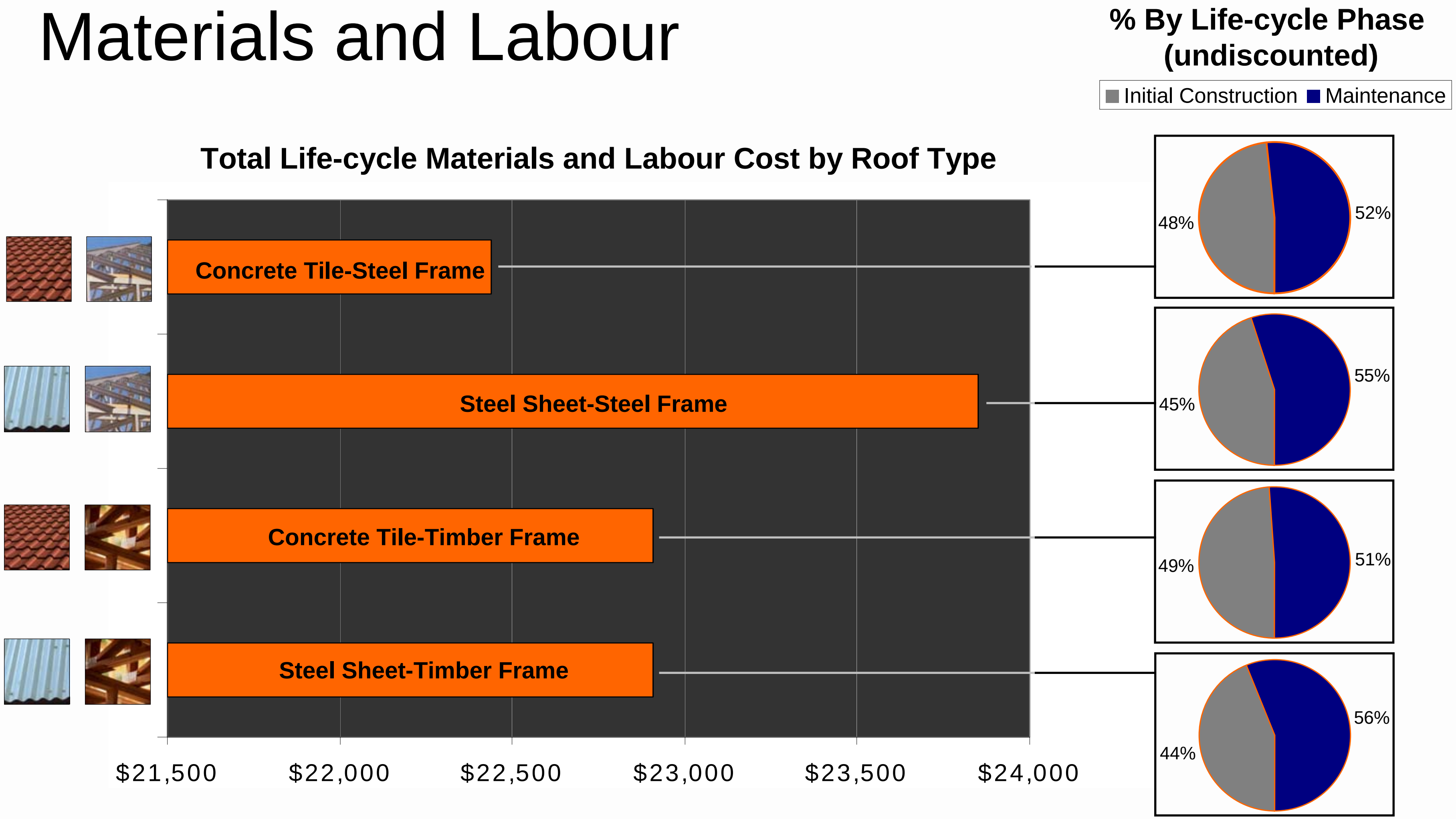


Image: www.freefoto.com

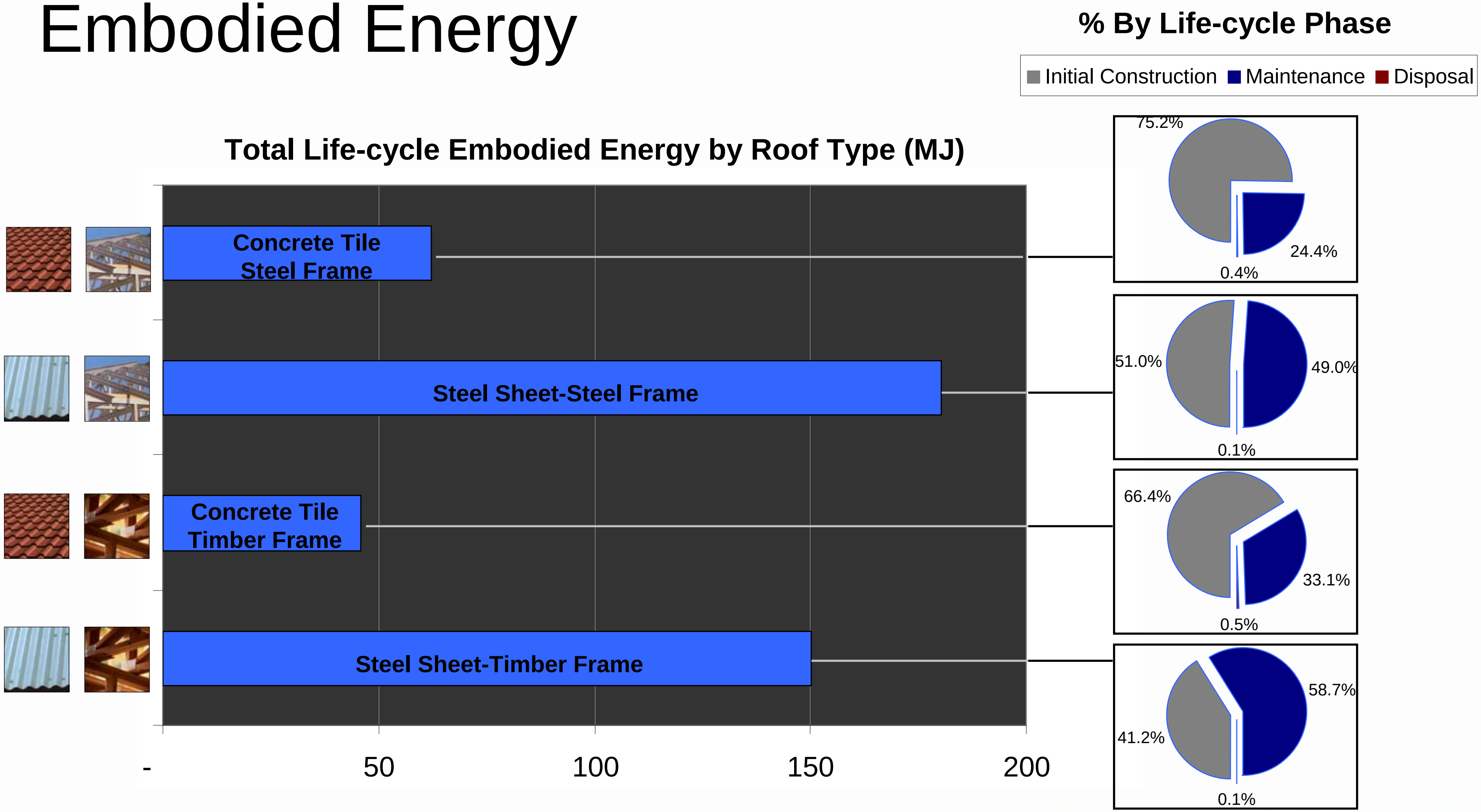
Results

Materials and Labour



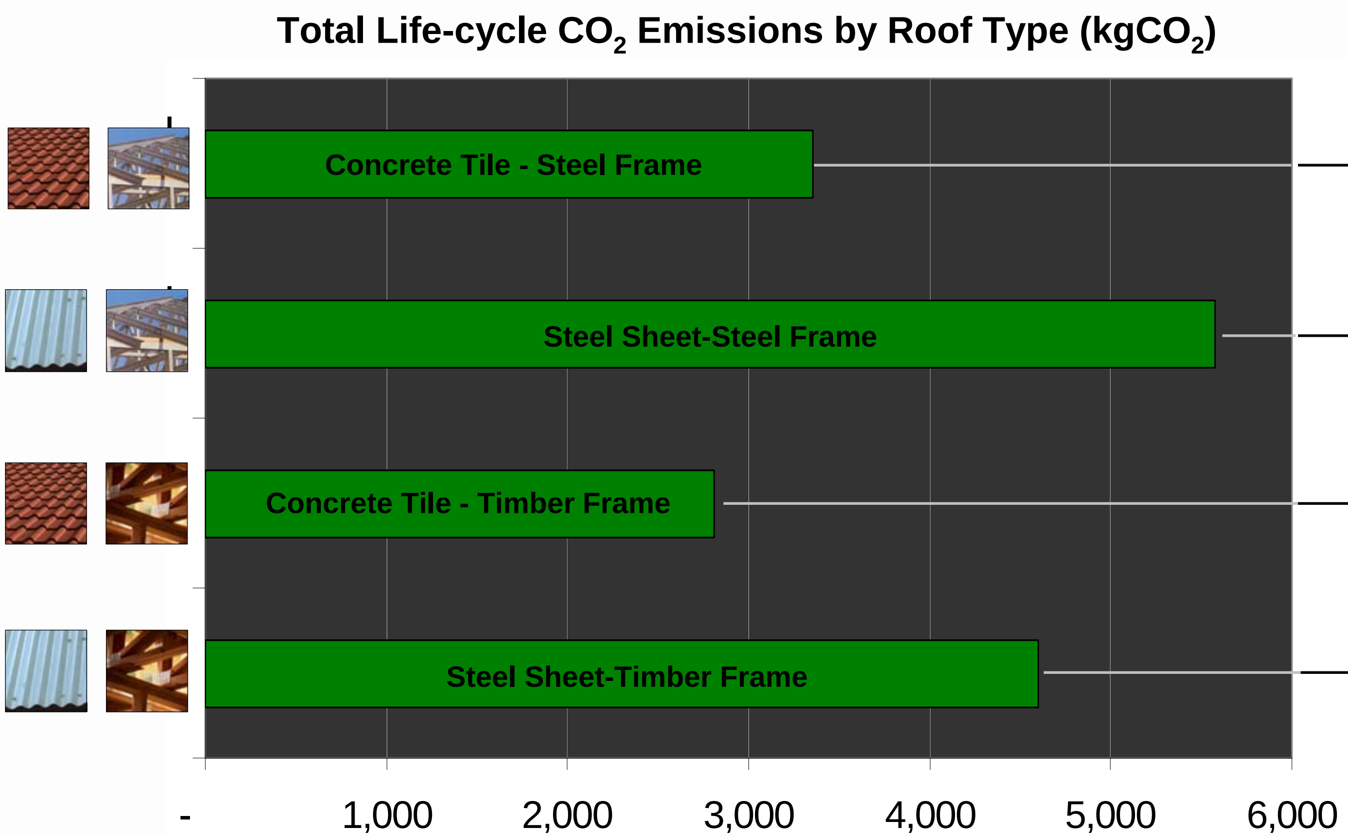
Results

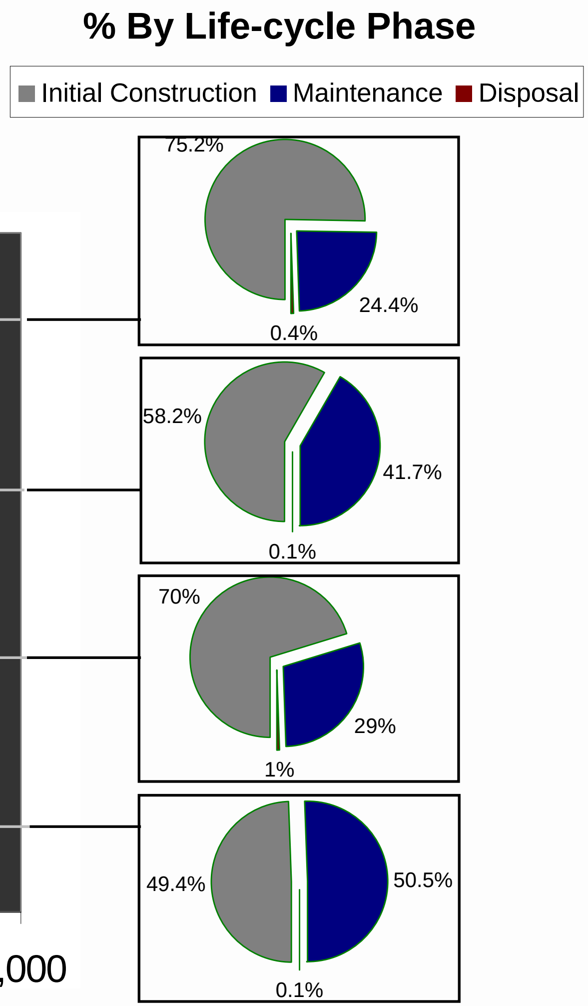
Embodied Energy



Results

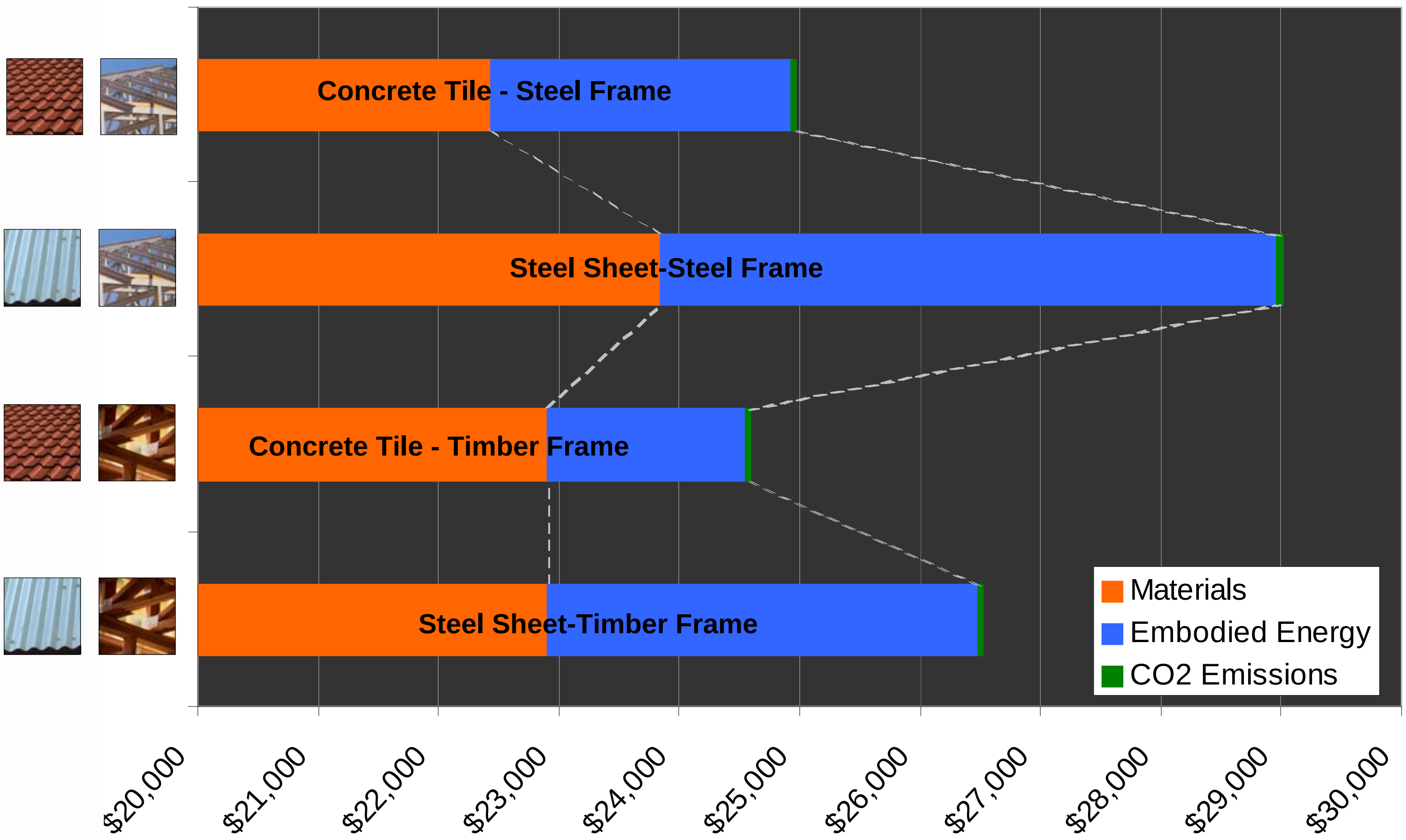
CO_2 Emissions





Results

Combined Life-cycle Cost



Results

Combined Life-cycle Cost

	Materials & Labour	Embodied Energy	CO_2 Emissions	Total
Concr. Tiles / Timber Frame	$ 22,910	$ 1,650	$ 20	$ 24,580
Concr. Tiles / Steel Frame	$ 22,440	$ 2,490	$ 30	$ 24,960
Steel Sheet / Timber Frame	$ 22,910	$ 3,580	$ 20	$ 26,510
Steel Sheet / Steel Frame	$ 23,850	$ 5,120	$ 30	$ 29,000

All costs shown as Net Present Value (NPV)

Sensitivity

Virgin vs. Recycled Steel Sheet

- Analysis repeated using recycled steel sheet
- 50-60% reduction in life-cycle Embodied Energy
- ~60% reduction in life-cycle CO_2 emissions
- Marginal (6-7%) reduction in combined life-cycle cost
- Framing selection becomes critical factor
  - both timber frame options perform better than steel frame options when recycled steel sheet used

Sensitivity

Discount Factor

- Analysis repeated using 3% and 8% discount factors
- Concrete tile options least sensitive to discount factor
- Steel sheeting options most sensitive to discount factor
- Lowering discount rate (3%) increases combined life-cycle cost of steel sheet options
- Raising discount rate (8%) decreases combined life-cycle cost of steel sheet options

Conclusions

- Concrete tile-Timber Frame roof performed best
  - Lower life-cycle maintenance cost
  - Lower embodied energy cost of materials
- Options with low material cost can still have a high combined life-cycle cost
- Combined life-cycle cost better reflects the true “cost” of materials
- Single monetary value that can be easily understood by stakeholders

Questions?

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