Energy and Low Income Tropical Housing

CPD: SUSTAINABLE CONSTRUCTION
ENERGY ANALYSIS OF BUILDINGS & BUILDING MATERIALS

TANZANIA
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Calculations:

- Embodied energy in various building materials
- Embodied energy in different wall constructions
- Variations
Primary Energy

- Energy found in nature in raw fuels
- It has not been subjected to any conversion or transformation process.
- It can be non-renewable (fossil fuels) or renewable
Embodied Energy

Everything we use has embodied energy
Embodied Energy

- Is sum of all the energy required to produce any goods or services
- It is treated as if that energy was incorporated or 'embodied' in the product.
- Allows comparison between products independent of the source of the energy ....which may be renewable (clean) or non-renewable (fossil fuel)
- It is measured in MegaJoules

IT DOES NOT INCLUDE HUMAN ENERGY!
Embodied Energy in buildings

Occurs throughout the building life

Building Life Cycle stages

- **Product stage**
  - Raw materials supply
  - Transport
  - Manufacturing

- **Construction Process stage**
  - Construction-installation process
  - Transport

- **Use stage**
  - Use
  - Maintenance
  - Repair
  - Replacement
  - Refurbishment

- **End of Life stage**
  - Deconstruction demolition
  - Transport
  - Waste processing
  - Disposal

- **Operational energy use**
- **Operational water use**

Beyond Building Life Cycle stages

Benefits and loads beyond the system boundary

- Reuse-Recovery-Recycling-potential
Embodied Energy in buildings

- It includes the energy taken to get raw goods such as plants, stone, sand or aggregate.
Embodied Energy in buildings

- and it includes the energy taken to move these raw goods to a factory
Embodied Energy in buildings

- and it includes the energy taken to manufacture or transform these into a product.
Embodied Energy in buildings

- and it includes the energy taken to move these products to where they are needed
Embodied Energy in buildings

- and it includes the energy taken to operate the building
Embodied Energy in buildings

- and it includes the energy taken to maintain or repair them - for example paints, mortars, polish
Embodied Energy in buildings

- and it includes the energy taken to demolish and dispose of them
The embodied energy can be identified and quantified at each stage and can then be used to plan an effective reduction strategy.
But... it’s about more than energy
Because different forms of energy have different embodied pollution
Non-renewable (fossil fuel) Energy

Renewable (Clean) Energy
Consequences

- Using energy creates pollution
- But some energy creates more pollution:-
  - non-renewable (fossil fuel) energy releases carbon dioxide when burned
  - renewable (clean) energy does not
- Carbon dioxide contributes to climate change
- We call this pollution **embodied carbon**
Embodied Carbon (kgCO₂/kg)

- The energy used by buildings creates carbon emissions throughout a building life cycle.

- Due to energy consumption and chemical processes during extraction, manufacture, transportation, assembly, replacement and deconstruction of construction materials or products.

- Embodied carbon is usually expressed in kg of CO₂ per kg of product or material.
Climate Change
A measure of the relative impact of a gas on global warming.

### Table 1 Global warming potentials (GWP) of greenhouse gases

<table>
<thead>
<tr>
<th>Greenhouse gas</th>
<th>GWP over 100 years</th>
<th>Typical sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO₂)</td>
<td>1</td>
<td>Energy combustion, biochemical reactions</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>25</td>
<td>Decomposition</td>
</tr>
<tr>
<td>Nitrous oxide (N₂O)</td>
<td>298</td>
<td>Fertilizers, car emissions, manufacturing</td>
</tr>
<tr>
<td>Sulfur hexafluoride (SF₆)</td>
<td>22,800</td>
<td>Switch gears, substations</td>
</tr>
<tr>
<td>Perfluorocarbon (PFC)</td>
<td>7,390–12,200</td>
<td>Aluminium smelting</td>
</tr>
<tr>
<td>Hydrofluorocarbon (HFC)</td>
<td>124–14,800</td>
<td>Refrigerants, industrial gases</td>
</tr>
</tbody>
</table>


- Methane has a global warming potential of 25
  - 1 kg of Methane has the same impact on climate change as 25 kg of CO₂
  - 1 kg of Methane counts as 25 kg of CO₂ equivalent emissions or CO₂e
Embodied energy of grid electricity depends on the mix of fuels
Resources

RICS Professional Information, UK

Methodology to calculate embodied carbon of materials

1st edition, information paper

rics.org/standards
Handout

- Generic data base
- Produced by University of Bath
- Supplied by manufacture
- Average values for materials
- Global sources
- Range of studies
- Cradle to gate
- Non-specific
Materials or product manufacture cradle-to-gate emissions are those associated with the production of construction products/materials.

- The emissions arise from the energy used in
  - extracting materials,
  - refining them (i.e. primary manufacture),
  - transporting &
  - processing them to produce a finished product (i.e. secondary manufacture).
UK Context

- Design: 0.5%
- Manufacture: 15%
- Distribution: 1%
- Construction: 1%
- Operation: 83%
- Refurbish/Demolish: 0.4%
WORKSHOP

Calculations
Compare Embodied Energy of MBEKI Concrete Block & NHBRA Interlocking Brick

% difference
### Embodied energy case study

<table>
<thead>
<tr>
<th>Item</th>
<th>MATERIAL TYPE</th>
<th>VOLUME</th>
<th>DENSITY</th>
<th>WEIGHT</th>
<th>EMBODIED ENERGY INTENSITY</th>
<th>TOTAL EMBODIED ENERGY (MJ)</th>
<th>EMBODIED CARBON</th>
<th>TOTAL EMBODIED CARBON</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m3</td>
<td>Kg/m3</td>
<td>KG</td>
<td>(MJ/KG)</td>
<td>MJ</td>
<td>(kgCO2/Kg)</td>
<td>(KGCO2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>from manufacturer</td>
<td>from manufacturer</td>
<td>calculate from data sheet</td>
<td>WEIGHT X EE</td>
<td>from data sheet</td>
<td>WEIGHT x EC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-
Compare Embodied Energy of MBEKI Concrete Tile & NHBRA Tile

% difference
### Embodied energy case study

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Compare Embodied Energy of
MBEKI Concrete Tile Roof/m²
&
NHBRA Tile Roof/m²
Embodied energy case study

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<td></td>
<td></td>
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Compare Embodied Energy of
MBEKI Concrete Block House Wall
&
NHBRA Brick House Wall

> inclusive of internal and external finishes
Consider a cavity Wall
Break into component parts
Establish quantities and types of materials source
Establish embodied carbon for each part (kgCO₂/kg)
Multiply
Summate
## Embodied energy case study

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<td></td>
</tr>
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Next

- Add a timber frame opening of $1m^2$
- Add Glass
- Add Burglar bars
- Change frame to aluminium
Key Issues

- Understand the local context
- What do we need to know to help us make good decisions?
- How much is manufacture/operational/transport/construction/disposal?
- Which areas need most attention?
- Identify the highest impacts (carbon hotspots) or low hanging fruit.
- Calculating absolutes may not be necessary!
- Is it heavy or dense or highly processed ---steel, concrete, aluminium?
  ★ ee/ec may be high
- Is it local sourced?..
  ★ then travel component may be low
Design interventions

• Is it possible to use less material?
• Is it possible to change material to a low carbon alternative?
• DO NOT FORGET WASTAGE!
• DO NOT FORGET TOXICITY!
• Is it possible to design for recycling?
• Is it possible to design for re-use?
• Is it possible to use products with high recycled content, e.g. cement replacement materials such as GGBS (ground granulated blast furnace slag) or PFA (pulverised fuel ash)?
• Is it possible to use low carbon design details, e.g. exposed concrete ceilings; aerated block work?
• Is it possible to design to the site? i.e reduce amount of soil movement?
ECCM Calculator

- useful to get some quick comparison
- not to be relied upon
### ECCM Calculator

#### FOUNDATION MATERIALS

<table>
<thead>
<tr>
<th>TYPE</th>
<th>MATERIAL</th>
<th>QUANTITY</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>Pouring Concrete</td>
<td>0</td>
<td>tonnes</td>
</tr>
<tr>
<td></td>
<td>Reinforced Concrete</td>
<td>0</td>
<td>tonnes</td>
</tr>
<tr>
<td></td>
<td>Concrete Block</td>
<td>0</td>
<td>m(^3)</td>
</tr>
<tr>
<td></td>
<td>Aerated Concrete</td>
<td>0</td>
<td>m(^3)</td>
</tr>
<tr>
<td>Wood</td>
<td>Joists</td>
<td>0</td>
<td>tonnes</td>
</tr>
<tr>
<td>Gravel</td>
<td>Gravel</td>
<td>0</td>
<td>m(^3)</td>
</tr>
<tr>
<td>Steel</td>
<td>Steel</td>
<td>0</td>
<td>tonnes</td>
</tr>
</tbody>
</table>

**Current CO\(_2\)e emissions:** 0.0 tCO\(_2\)e
# ECCM Calculator

**REPORT**

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>tonnes CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundations</td>
<td>0.1</td>
</tr>
<tr>
<td>Roof</td>
<td>2.1</td>
</tr>
<tr>
<td>Frame</td>
<td>1.5</td>
</tr>
<tr>
<td>Walls</td>
<td>0.7</td>
</tr>
<tr>
<td>Flooring</td>
<td>0.2</td>
</tr>
<tr>
<td>Insulation</td>
<td>0.0</td>
</tr>
<tr>
<td>Building Finishes</td>
<td>5.9</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>10.5</strong></td>
</tr>
</tbody>
</table>

**Contribution to Overall GHG Emissions**

- **Foundations**: 56.1%
- **Roof**: 13.9%
- **Frame**: 19.7%
- **Walls**: 6.9%
- **Flooring**: 0.2%
- **Insulation**: 0.0%
- **Building Finishes**: 0.0%

**View Calculations**
Get ideas and information from here

**Circular Economy**

Download ICE data base from here

**ICE Database**

Download ECCM's building materials carbon indicator - updates

**ECCM calculator**
Close of Day