What role can Life Cycle Assessment play in the selection of green construction materials?

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Outline

• Environmental sustainability in perspective

• Life Cycle Assessment (LCA) in a nutshell

• Construction life cycle phases and environmental impacts

• LCA-based considerations for materials selection
Environmental sustainability in perspective
Environmental sustainability in perspective

Prerequisites for environmentally sustainable “green economy”

- Preserve input capability
- Absorb pollution (air, water, soil)
Environmental sustainability in perspective

Life cycle of “natural economy”
- Efficiency
- Zero pollution

Life cycle of conventional “human economy”
- Inefficiency
- Excessive pollution

Closed loop
- Resource Extraction
- Manufacture
- Use
- Disposal

Open loop
- Resource Extraction
- Manufacture
- Use
- Disposal
Environmental sustainability in perspective

Attributes of the “construction economy”……..

Inputs (global)
✓ Raw materials: 50%
✓ Energy: 50%

Outputs (global)
✓ Solid waste: 50%
✓ Air pollution: 40%

……….. are not aligned with the purpose of Sustainable Construction, i.e.

“Creation and operation of a healthy built environment based on ecological principles and resource efficiency”.
Environmental sustainability in perspective

The challenge: mismatch between intents and practice………………

- Renewability = no environmental impact ?
- Low embodied energy = low GHG emissions ?
- Recycled content = material efficiency ?

Wrong answers may carry as much weight as the right ones

………. Life Cycle Assessment (LCA) can help
LCA in a nutshell
LCA in a nutshell
what is LCA?

- Environmental decision-support tool since 1970s
- Central to sustainable consumption and production (UNEP)
- Essential for a “life cycle” (green) economy (WSSD)
- International standard: ISO 14040 series from late 1990s
LCA in a nutshell – what is LCA?

Climate change, Acidification, Summer smog, Human toxicity, Ecotoxicity, Eutrophication, Ozone layer depletion, Radioactive releases, ...

Life Cycle Inventory of product system

Energy carrier extraction
Extraction of rawmaterial A
Extraction of rawmaterial B
Extraction of rawmaterial C
...

Production of electricity
Production of intermediates
Production of parts
Production of final product

Utilisation

Material recycling
Incineration
Land filling
...

Material and energy resource consumption, land use

Production phase
Use phase
End-of-Life phase

Life Cycle Phases

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# LCA in a nutshell

## Why LCA?

### LCA principles
- Pollution prevention - 21\textsuperscript{st} Century policy approach
- Systems perspective – whole life cycle (supply chain) approach
- Scientific (performance oriented) and quantitative

### “Green” principles
- Pollution control “end-of-pipe” – outdated policy approach
- Fragmented perspective – dissociates product from supply chain
- Performance oriented intents versus prescriptive requirements
LCA applications

Life Cycle Thinking (Conceptual LCA)
Product-oriented regulation e.g., IPP (DfE + CP + EPR)

Life Cycle Management (Simple LCA)
Product-oriented industry strategies e.g., DfE, CP.

Life Cycle Assessment (Detailed LCA)
Product-oriented decision support for industry e.g., eco-labelling
LCA applications in construction

Tools and what they do

Level 1B tools: Specification
- Materials and components e.g., BEES (North America)

Level 2 tools: design concept
- Whole buildings and complex assemblies e.g., Athena EIE (North America)

Level 3 tools: rating/ certification
- Whole building e.g. BREEAM (UK)
Life cycle phases and environmental impacts
Construction life cycle phases and environmental impacts – energy use profile

- Pre-use phase: 10-20% of total life cycle energy
- Use phase: 80-90% of total life cycle energy
- End-of-life: less than 1% of total life cycle energy

Environmental problems associated with energy use:
- Acidification, climate change, eutrophication, human toxicity, smog
Construction life cycle phases and environmental impacts - materials use profile

Pre-use phase

- Depletion of energy (embodied + transportation)
- Depletion of virgin raw materials (extraction + construction waste)
- Land use impacts (loss of habitat, etc)
- Toxic emissions to soil and water
Construction life cycle phases and environmental impacts – materials use profile

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Raw material extraction and processing</td>
</tr>
<tr>
<td>2</td>
<td>Construction material and component fabrication</td>
</tr>
<tr>
<td>3</td>
<td>On-site construction</td>
</tr>
<tr>
<td>4</td>
<td>Facility operation and maintenance</td>
</tr>
<tr>
<td>5</td>
<td>End-of-life</td>
</tr>
</tbody>
</table>

**Use phase**

Service life (replacement, maintenance) is critical due to long life of buildings

**Structural elements**
- No replacement factor, low maintenance
- High embodied energy = lower operational energy

**Non-structural elements**
- High replacement and maintenance factors
- Significant impacts (materials, energy, pollution, costs)
## Construction life cycle phases and environmental impacts – materials use profile

### Use phase (High impact materials/components)

| Material /component                          | Reasons                                                        |
|----------------------------------------------|                                                               |
| Steel-based products (galvanised, reinforced, etc) | High embodied energy, large quantities, high emissions         |
| Cement-based products (concrete, plaster, render, screed) |                                                            |
| Carpets                                       | High embodied energy, high emissions, frequent replacement / maintenance |
| Paints                                        |                                                               |
| Copper products                               | Toxic contents (even in small quantities)                       |
| PVC flooring                                  |                                                               |
Construction life cycle phases and environmental impacts – materials use profile

**Use phase (service life considerations)**

<table>
<thead>
<tr>
<th>Material /component</th>
<th>Assumed service life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bricks and blocks</td>
<td>50</td>
</tr>
<tr>
<td>Concrete</td>
<td>50</td>
</tr>
<tr>
<td>Structural steel</td>
<td>50</td>
</tr>
<tr>
<td>Roof assembly</td>
<td>15</td>
</tr>
<tr>
<td>Carpet</td>
<td>10</td>
</tr>
<tr>
<td>Paint</td>
<td>10</td>
</tr>
</tbody>
</table>
Construction life cycle phases and environmental impacts – *materials use profile*

- **End-of-life phase**
  - Approximately 90% of extracted stock of materials may be contained in the built environment, making it a potential future resource, or alternatively, a potential future source of waste.
Construction life cycle phases and environmental impacts – materials use profile

End-of-life phase

Key challenges

- No waste management hierarchy – even “green” buildings are not designed for decoupling or disassembly
- Landfilling = wasted materials + embodied energy

Environmental consequences

- Resource depletion (energy and materials)
- Land use impacts
- Pollution – soil and water
LCA limitations

LCA is not the answer to all material-related problems. Does not easily address:
- Indoor environmental quality
- Land-use impacts
- Uncertainty and risks related to toxic releases

LCA barriers
- Accessibility and availability of life cycle inventory (LCI) data
- Mindset – dominance of prescriptive “green” approaches
LCA-based considerations for materials selection
LCA-based considerations for materials selection

The reality

- Environmentally sustainable *(green)* materials *do have* environmental impacts

- “*Green*” materials function in systems – the supply chain, from materials production to green building certification needs to go “*green*”

- Meeting regulatory requirements – e.g. Waste Management Bill, carbon taxes, etc has shifted from subjective to objective, science-based data
Select “green” materials in consideration of trade-offs:

- Multiple life cycle stages and phases; and
- Material combinations which reduce long-term impacts
LCA-based considerations for materials selection

Select “green” materials in consideration of multiple environmental inputs:

- Materials
- Energy
- Water
- Land
LCA-based considerations for materials selection

Select “green” materials in consideration of their contribution to multiple environmental issues of concern to society, i.e.,

- Acidification
- Climate change
- Eutrophication
- Ecotoxicity
- Human toxicity
- Stratospheric ozone depletion
- Photochemical Oxidant formation
Questions??
Thank you