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# APPLICATION OF LIFE CYCLE ASSESSMENT FOR RESIDENTIAL BUILDING CONSTRUCTION

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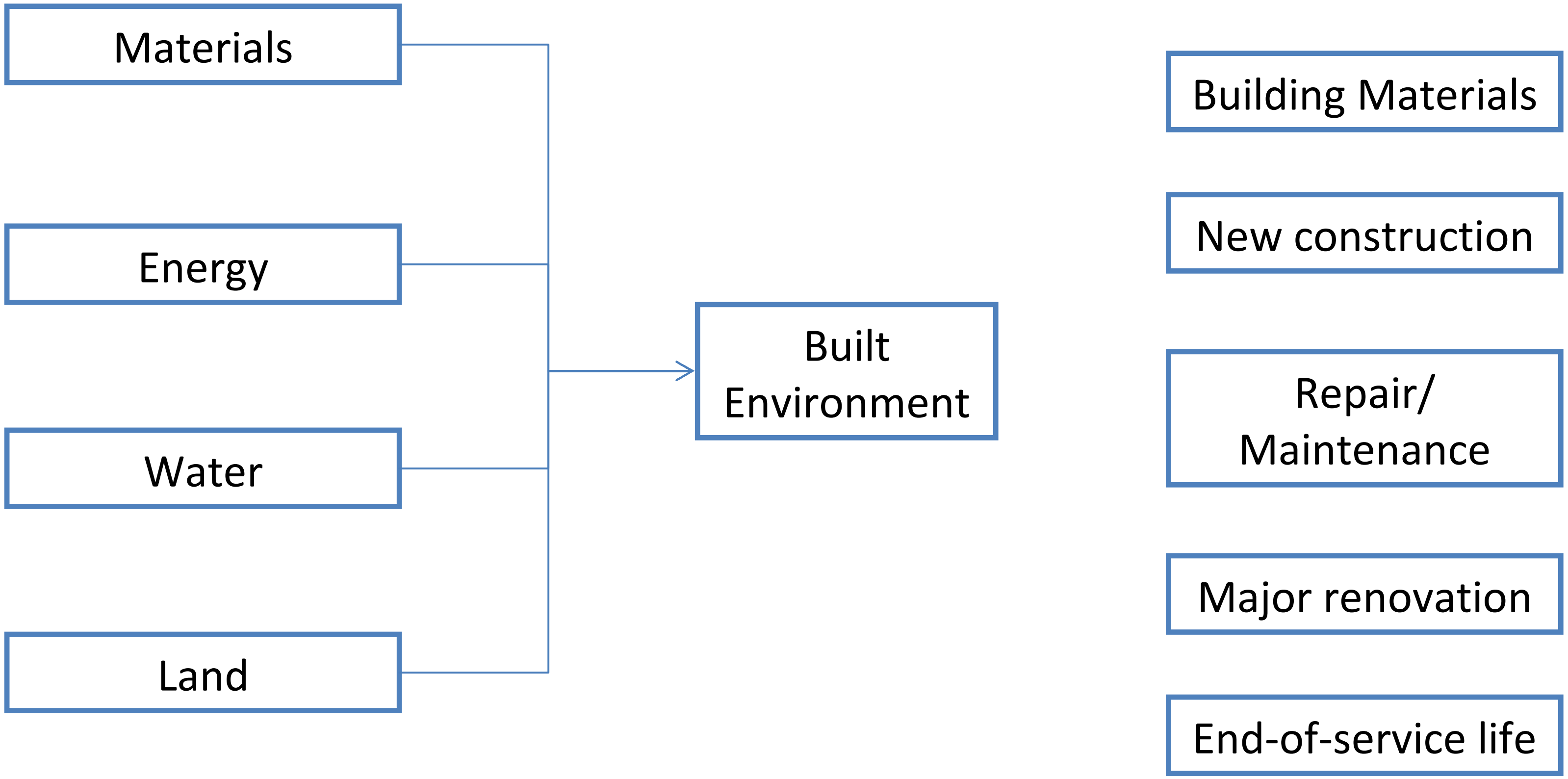
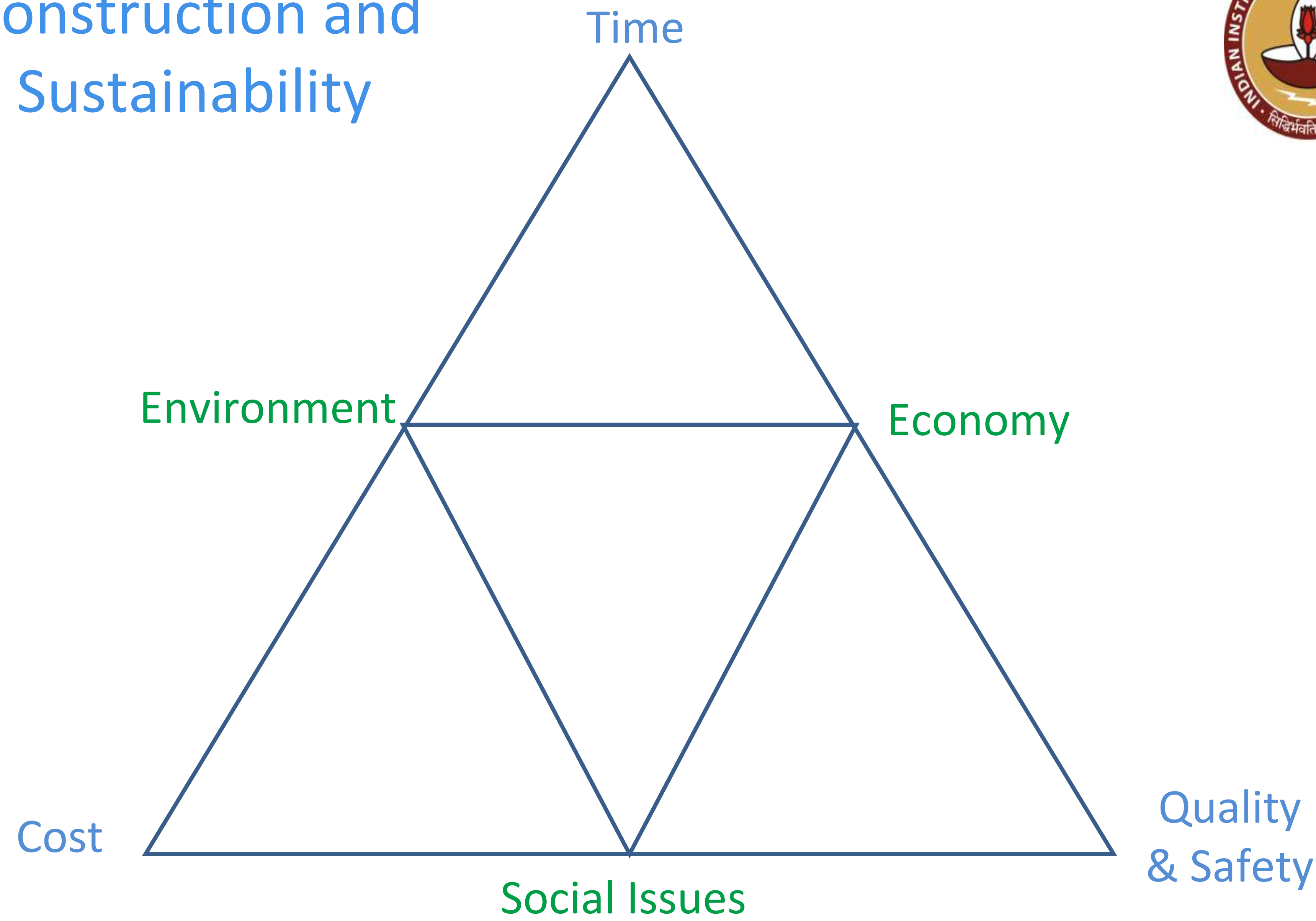
# Resource Use in the Built Environment



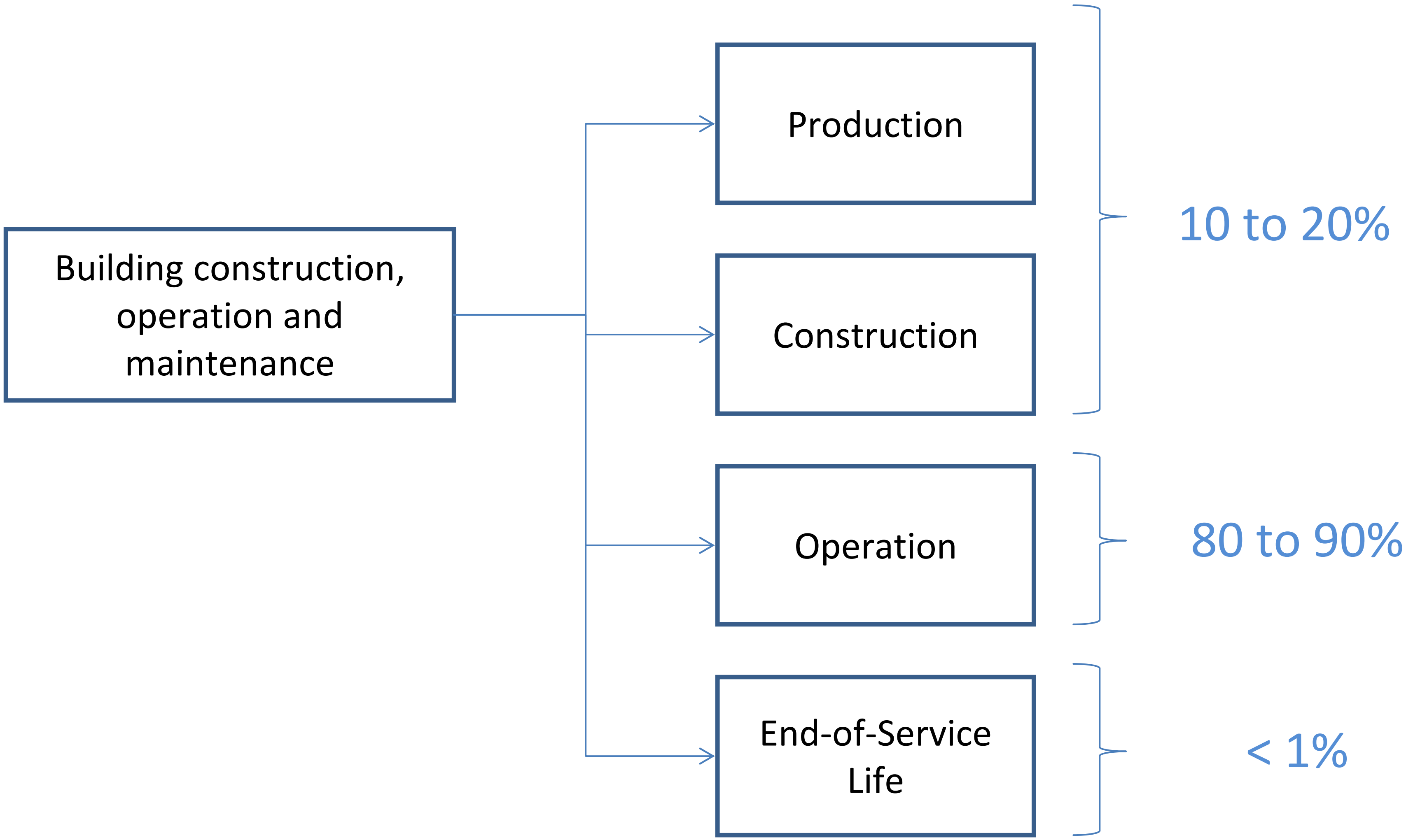
# Resource Use in the Built Environment

- Built environment uses approximately 40% of the materials and 33% of the energy in the world economy (Rees, 1999)
- The construction industry uses significant amount of materials and energy in different phases of a project life cycle (Horvath, 2004).

# Construction and Sustainability



# Built Life Cycle – Life cycle energy use and impacts



# Initiatives towards sustainable development

- Main focus is on reducing the energy use in the building operation

- After achieving the energy efficiency of the building operation, the next focus improvement are the production and the construction phases (Cole and Kernan 1996, Guggemos and Horvath 2005).

# Initiatives towards sustainable development

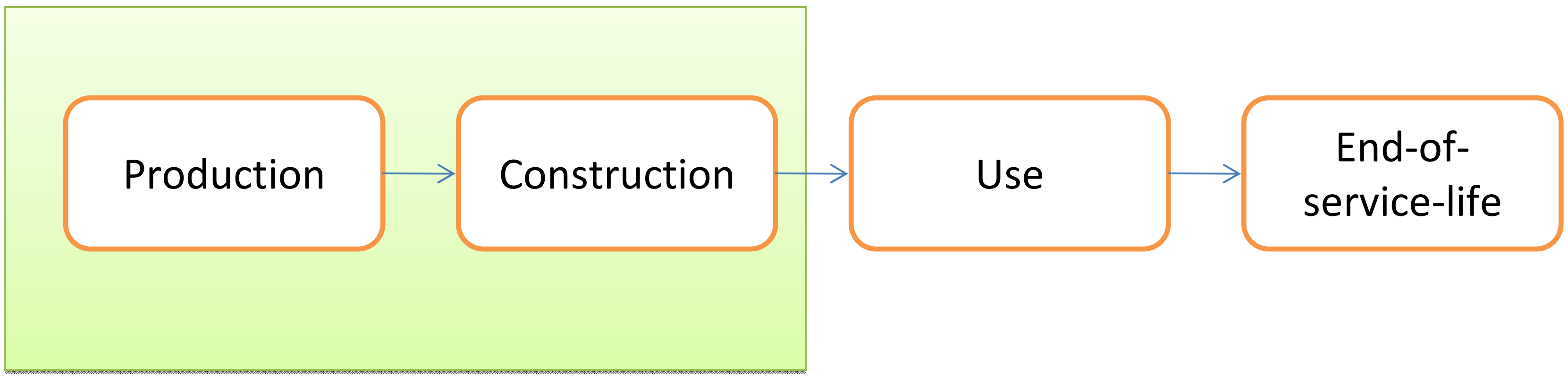
- Role of LCA
  - Provides a scientific approach
  - Helps overcome subjectivity in measuring greenness of a product or a process.

- LCA provides a holistic view of resource use and impacts of a product/process by considering the entire life cycle.
  - Shifting resource use and impacts from one life cycle phase to another phase is NOT truly sustainable.

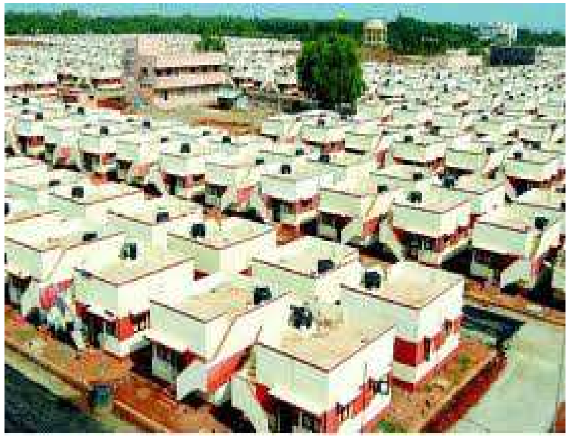
# Objectives and Scope

- To investigate the application of LCA for residential building construction in India.

- The scope of this work is limited to the production and the construction phases of the building life cycle.



# Residential building construction case study



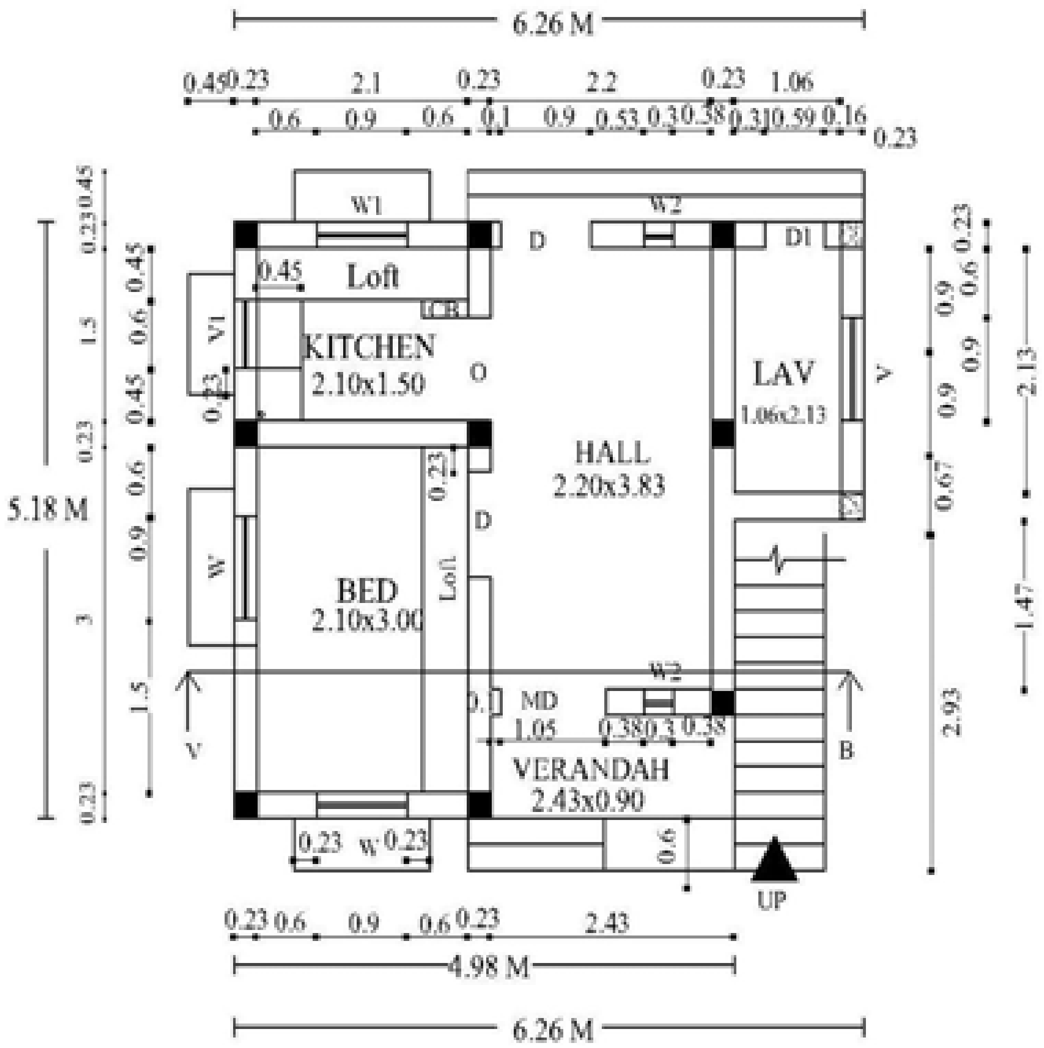
Home size: 350 sq. ft. (Studio type homes)

Constructed in coastal areas for people affected by Tsunami in 2004

Low-income housing:

Cost: Rs. 1,50,000 [ @ USD 3000
@ 2150 Euros]

# Residential building construction case study



# Residential building construction case study

1

2

3

4

# Residential building construction case study

1

2

3

4

# Steps

Work Breakdown Structure and Bill of Materials

Model development using SimaPro 7.3 software tool

DATABASE: Eco-invent database and the European Life Cycle Database (ELCD)

Eco-indicator 99 (E) : Human health (30%), Eco-system (50%), and Resources (20%)

# Bill of Quantities

| Building components | PCC (cum) | Concrete (cum) | Sand (cum) | Reinforcement (kg) | Brick-work (sqm) | Mortar (sqm) | Timber (sqm) | Paints (sqm) |
|---|---|---|---|---|---|---|---|---|
| Foundation works | 3.04 | 6.22 | 4.66 | 219.72 | | | | |
| Grade beam | | 2.69 | | 273.47 | 3.45 | | | |
| Column | | 1.89 | | 182.71 | | | | |
| Lintel | | 2.98 | | 218.01 | | | | |
| Roof Slab and beam | | 3.28 | | 373.62 | | | | |
| Staircase | | 0.61 | | 38.88 | 8.87 | | | |
| Masonry work | | | | | 98.09 | | | |
| Plastering | | | | | | 241.03 | | |
| Painting | | | | | | | | 241.03 |
| Flooring | 3.05 | | | | | | | |
| Wood work | | | | | | | 14.15 | |
| **Total** | **6** | **18** | **5** | **1306** | **110** | **241** | **14** | **241** |

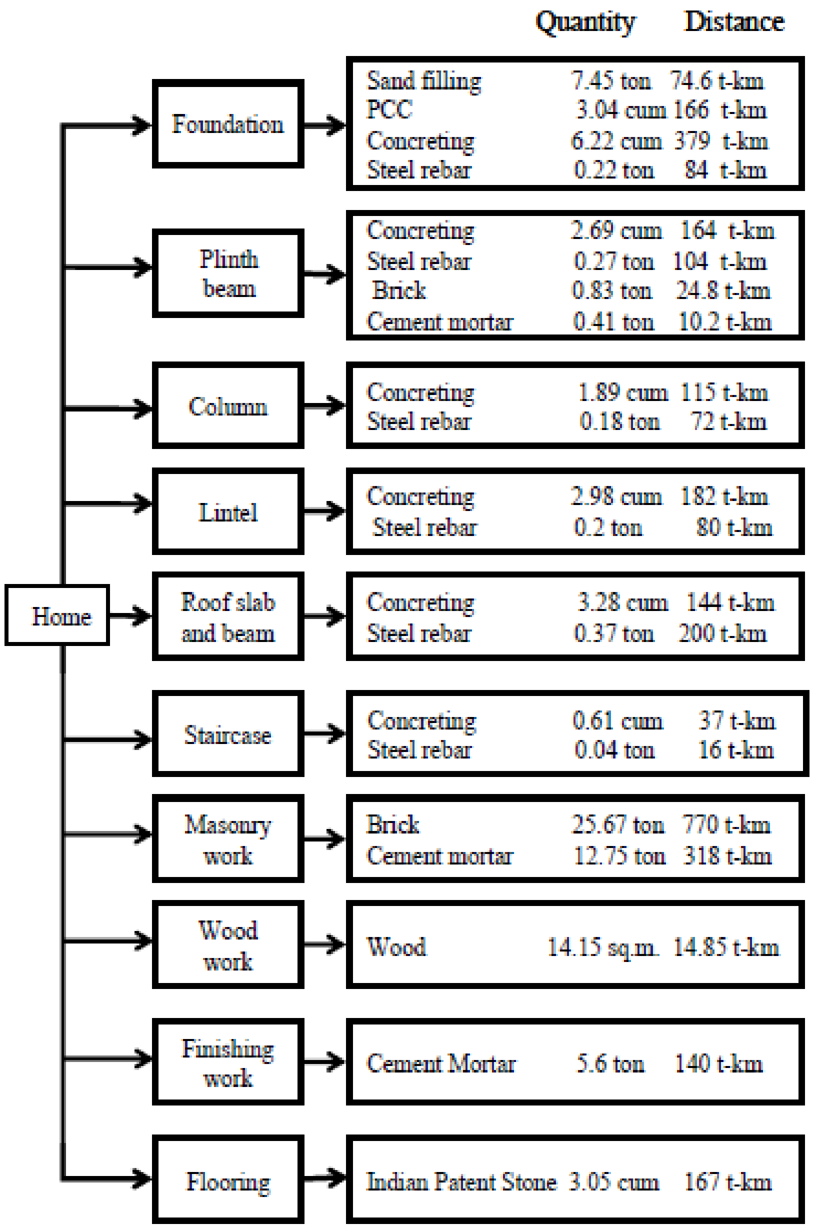
# Assumptions regarding on-site construction

- No construction equipment is used.
- All work items are performed manually.
- Impacts due to steel formwork is considered negligible due to high number of repetitions.
- Transportation distances for building materials:

  steel – 400 km, concrete – 25 km, wood- 50 km,

  brick – 30 km and sand – 10 km.

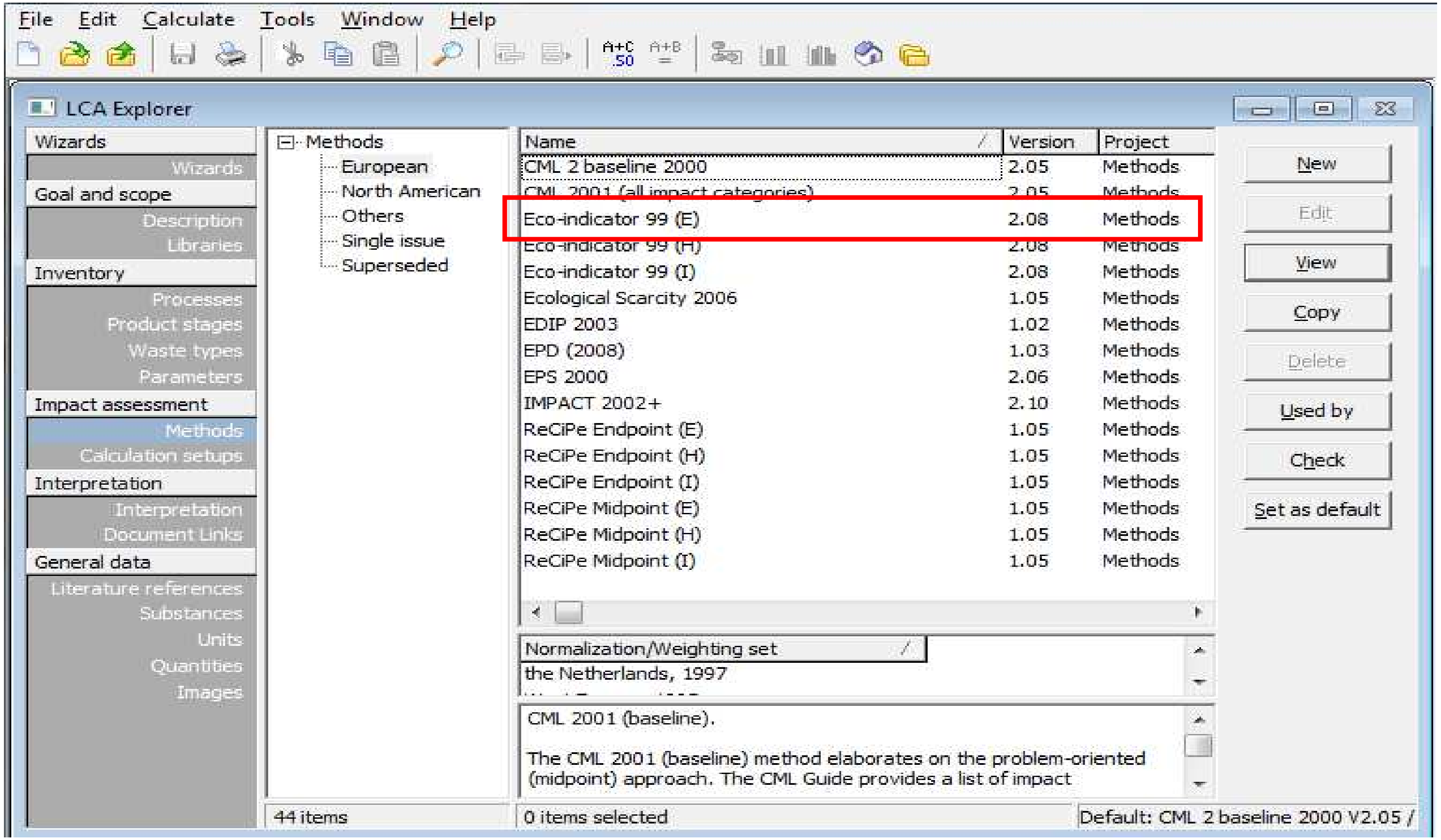
# WBS diagram


Quantity Distance
Home
Foundation
Sand filling 7.45 ton 74.6 t-km
PCC 3.04 cum 166 t-km
Concreting 6.22 cum 379 t-km
Steel rebar 0.22 ton 84 t-km
Plinth beam
Concreting 2.69 cum 164 t-km
Steel rebar 0.27 ton 104 t-km
Brick 0.83 ton 24.8 t-km
Cement mortar 0.41 ton 10.2 t-km
Column
Concreting 1.89 cum 115 t-km
Steel rebar 0.18 ton 72 t-km
Lintel
Concreting 2.98 cum 182 t-km
Steel rebar 0.2 ton 80 t-km
Roof slab and beam
Concreting 3.28 cum 144 t-km
Steel rebar 0.37 ton 200 t-km
Staircase
Concreting 0.61 cum 37 t-km
Steel rebar 0.04 ton 16 t-km
Masonry work
Brick 25.67 ton 770 t-km
Cement mortar 12.75 ton 318 t-km
Wood work
Wood 14.15 sq.m. 14.85 t-km
Finishing work
Cement Mortar 5.6 ton 140 t-km
Flooring
Indian Patent Stone 3.05 cum 167 t-km

# Material assumptions

| Material | Technical specification | Database from SimaPro |
|---|---|---|
| Sand | River sand | Sand 0/2, wet and dry quarry,at plant, undried RER S |
| Plain Cement Concrete | Mix: 1:3:6 40 mm HGS | Poor concrete, at plant/CH S |
| Concrete | Mix: M20 (1:1.5:3) | Concrete, exacting,at plant/CH S |
| Reinforce-ment / Steel rebar | ISI standard HYSD steel rebars | Reinforcing steel,at plant/ RER S |
| Brick for plinth beam and walls | Fly Ash brick/ Kiln burnt brick | Brick,at plant /RER S |
| Cement mortar for plastering and brickwork | Mix: 1:6 | Cement mortar, at plant/CH S |
| Flooring | Indian Patent Stone | Poor concrete, at plant/CH S |
| Wood work | Non-sal wood | Door,inner, wood at plant/RER S |

# User Interface for choosing impact assessment methods



# User Interface for choosing impact assessment methods

- Methods
  - European
  - North American
  - Others
  - Single issue
  - Superseded

| Name | Version | Project |
|---|---|---|
| CML 2 baseline 2000 | 2.05 | Methods |
| CML 2001 (all impact categories) | 2.05 | Methods |
| Eco-indicator 99 (E) | 2.08 | Methods |
| Eco-indicator 99 (H) | 2.08 | Methods |
| Eco-indicator 99 (I) | 2.08 | Methods |
| Ecological Scarcity 2006 | 1.05 | Methods |
| EDIP 2003 | 1.02 | Methods |
| EPD (2008) | 1.03 | Methods |
| EPS 2000 | 2.06 | Methods |
| IMPACT 2002+ | 2.10 | Methods |
| ReCiPe Endpoint (E) | 1.05 | Methods |
| ReCiPe Endpoint (H) | 1.05 | Methods |
| ReCiPe Endpoint (I) | 1.05 | Methods |
| ReCiPe Midpoint (E) | 1.05 | Methods |
| ReCiPe Midpoint (H) | 1.05 | Methods |
| ReCiPe Midpoint (I) | 1.05 | Methods |

- Methods
  - European
  - North American
  - Others
  - Single issue
  - Superseded

| Name | Version | Project |
|---|---|---|
| BEES | 4.02 | Methods |
| TRACI 2 | 3.03 | Methods |

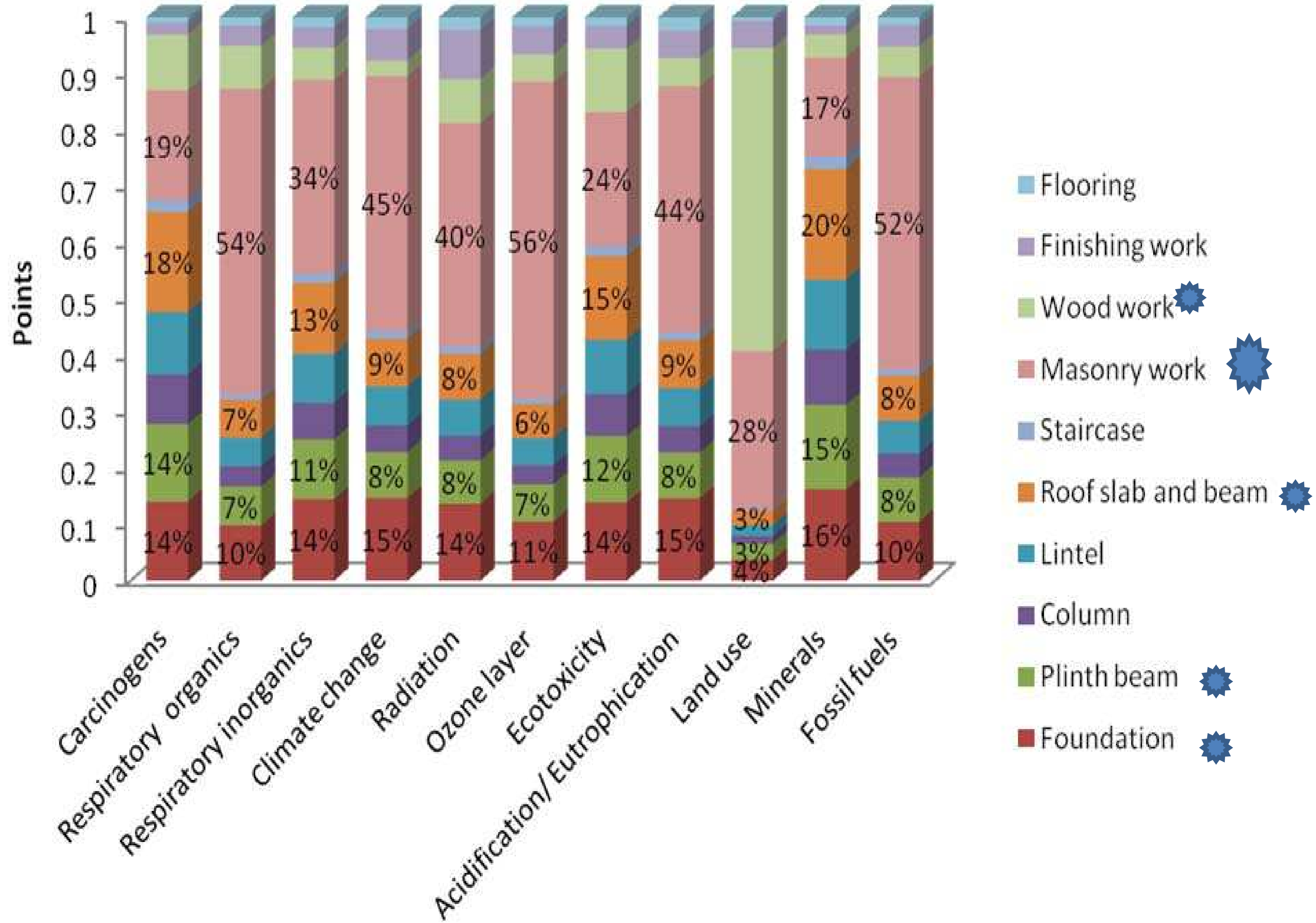
- Methods
  - European
  - North American
  - Others
  - Single issue
  - Superseded

| Name | Version | Project |
|---|---|---|
| Cumulative Energy Demand LCA food | 1.02 | LCA Food DK |
| Eco-indicator 99 (H) LCA Food | 2.03 | LCA Food DK |
| Ecopoints 97 (CH) LCA Food | 2.02 | LCA Food DK |
| EDIP, LCA Food | 1.00 | LCA Food DK |

- Methods
  - European
  - North American
  - Others
  - Single issue
  - Superseded

| Name | Version | Project |
|---|---|---|
| Cumulative Energy Demand | 1.08 | Methods |
| Cumulative Exergy Demand | 1.02 | Methods |
| Ecological footprint | 1.01 | Methods |
| Ecosystem Damage Potential | 1.00 | Methods |
| Greenhouse Gas Protocol | 1.01 | Methods |
| IPCC 2007 GWP 100a | 1.02 | Methods |
| IPCC 2007 GWP 20a | 1.02 | Methods |
| IPCC 2007 GWP 500a | 1.02 | Methods |
| Selected LCI results | 1.03 | Methods |
| Selected LCI results, additional | 1.03 | Methods |
| USEtox Recommended | 1.01 | Methods |

# Impact Assessment by Building Component



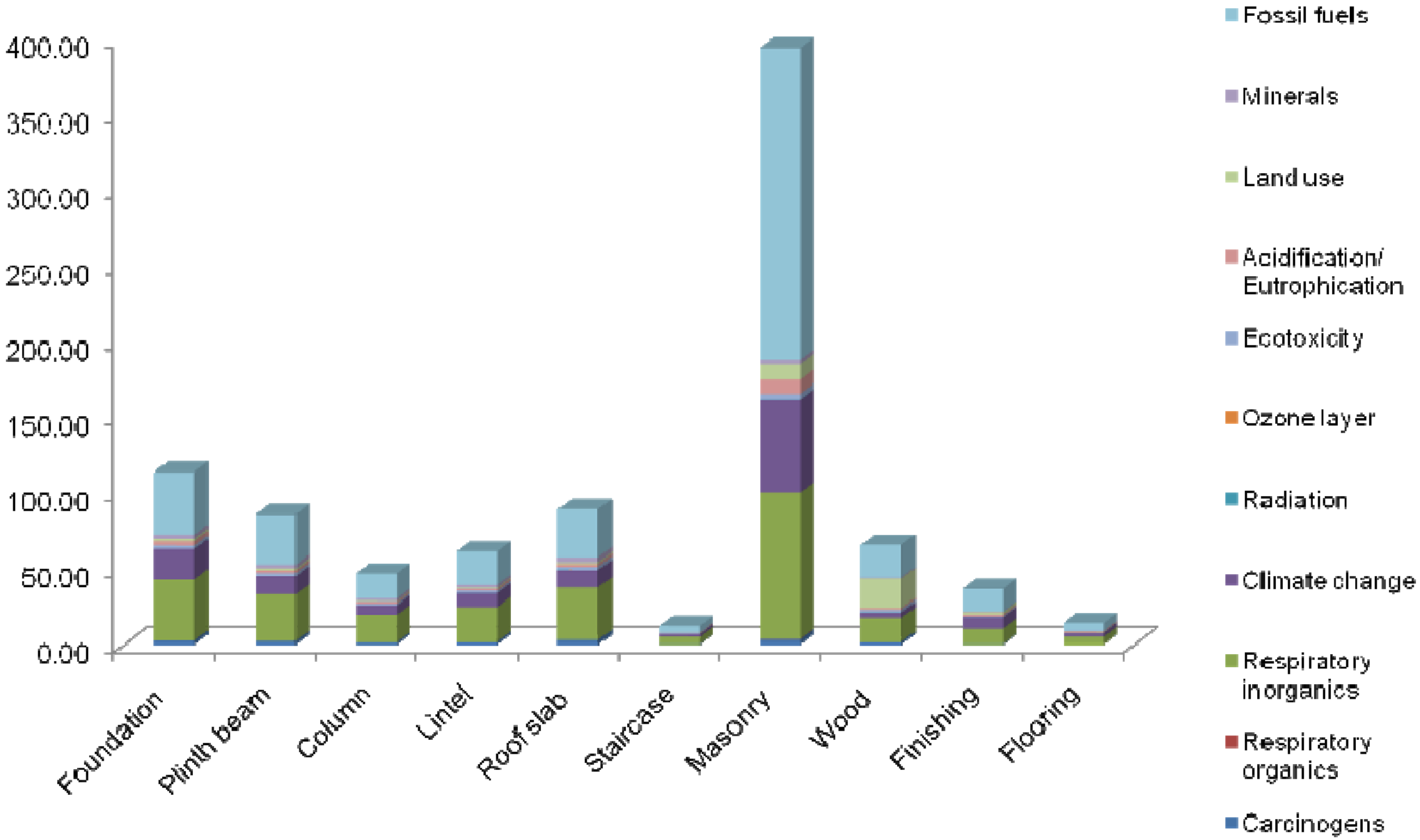
# Impact Assessment by Building Component

The building walls (exterior /interior masonry work) is found to be the most significant component except land use.

In almost all the cases, the contribution of masonry work is almost twice or thrice the contribution of the next highest component.

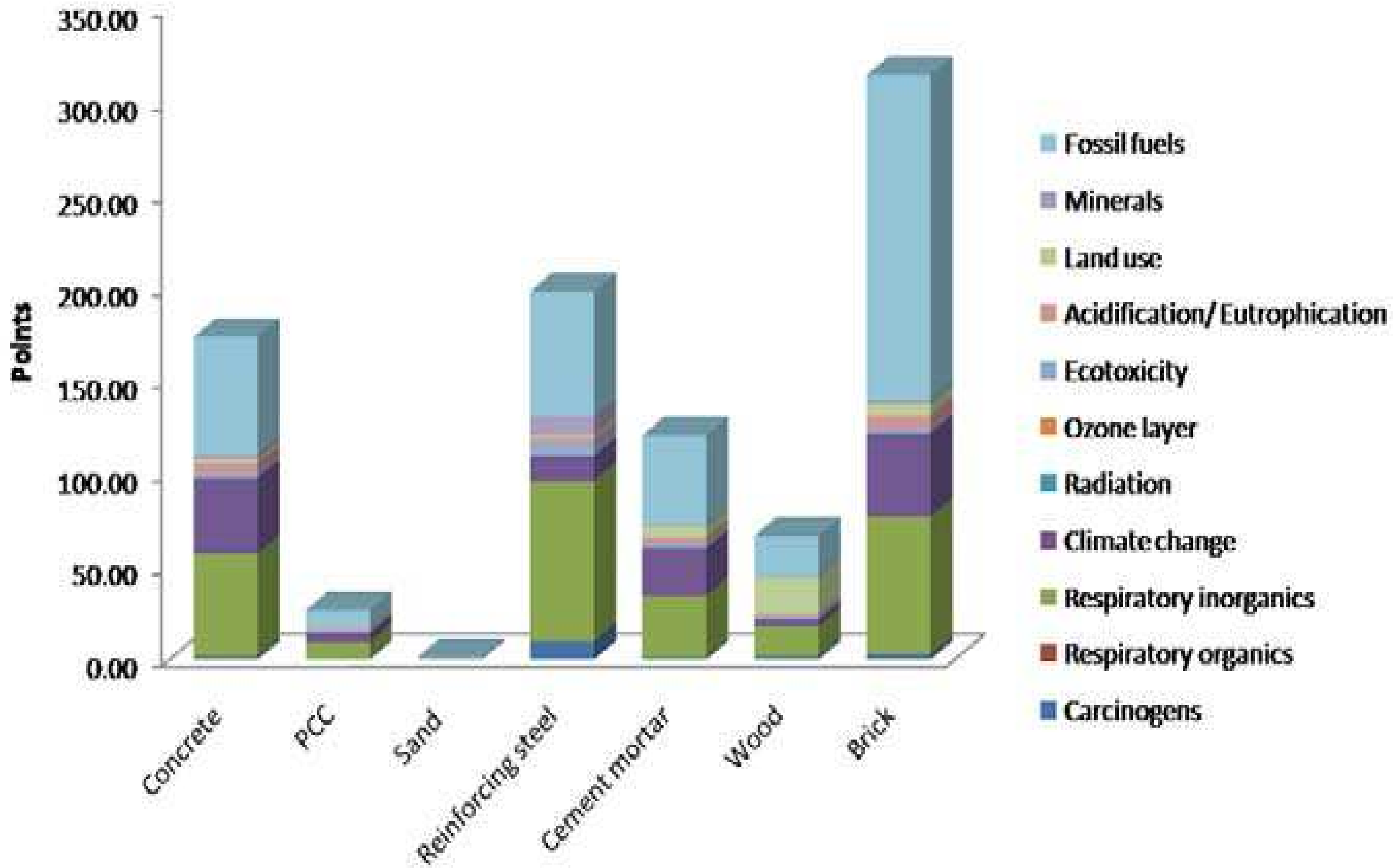
# Impact Assessment by Building Component

## Comparison using single score



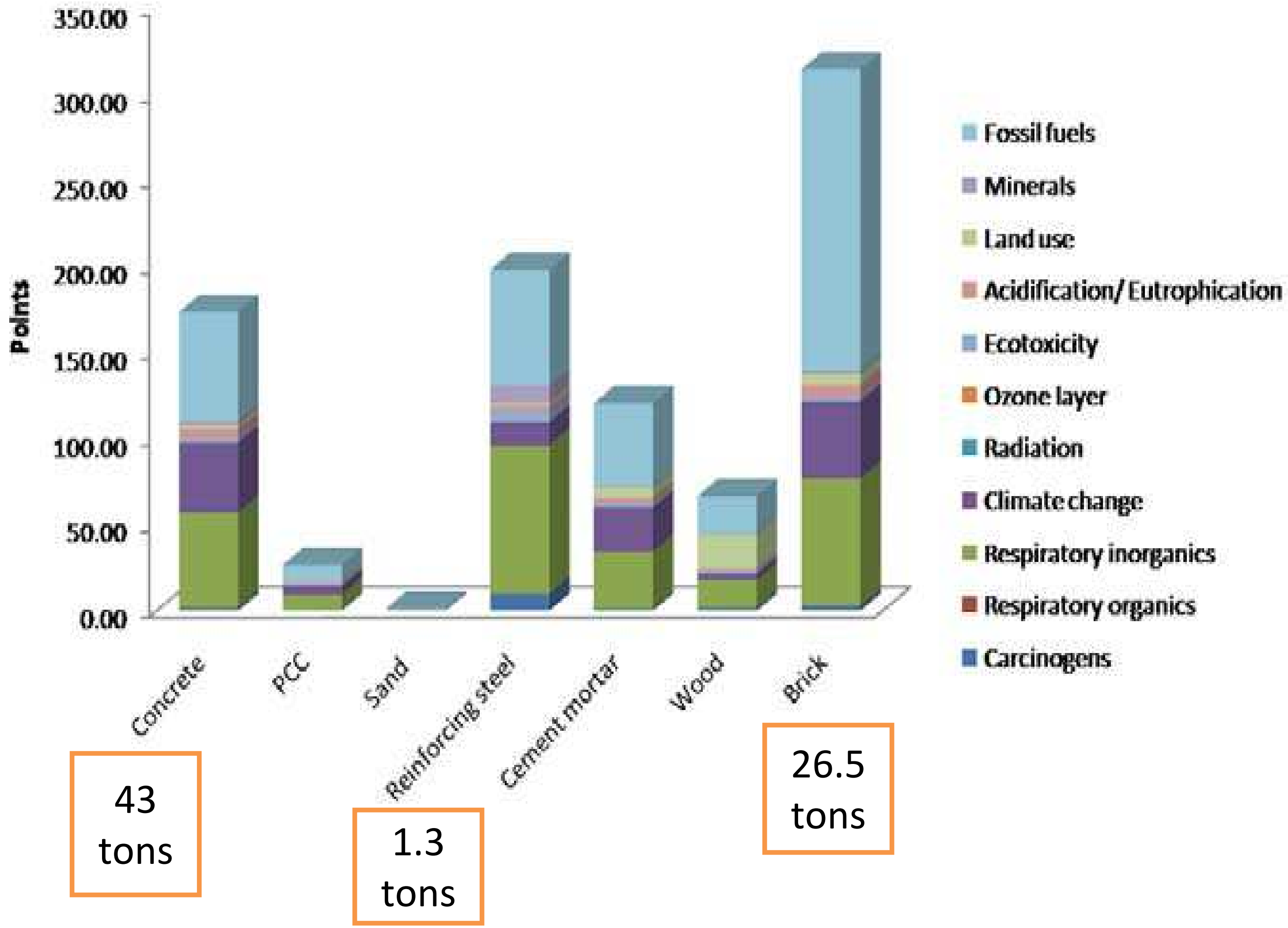
# Impact Assessment by Building Material

## Comparison using single score



# Impact Assessment by Building Material

## Comparison using single score



# Comparison of results with previous studies

- Blengini  and Carlo (2010)
- Energy and Buildings, 42, 869-880.

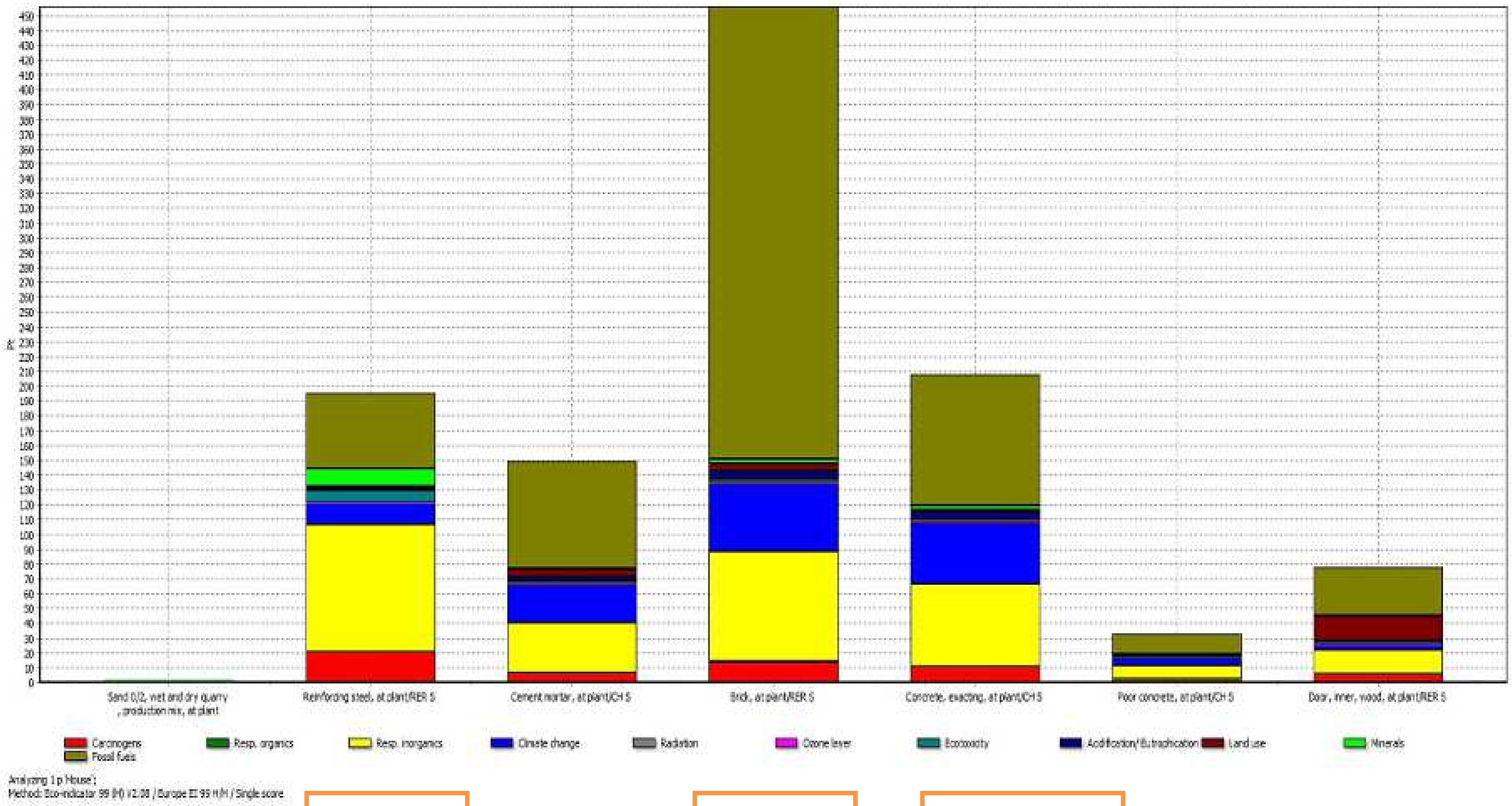
Shell materials have the highest energy contributions.

# Different impact assessment methods

| Impact | Eco-indicator 99 (E) | Eco-indicator 99 (H) | Eco-indicator 99 (I) |
|---|---|---|---|
| Human health | 30% | 30% | 55% |
| Ecosystem quality | 50% | 40% | 25% |
| Resources | 20% | 30% | 20% |

# Impact Assessment by Building Material

## Eco-indicator 99(H)



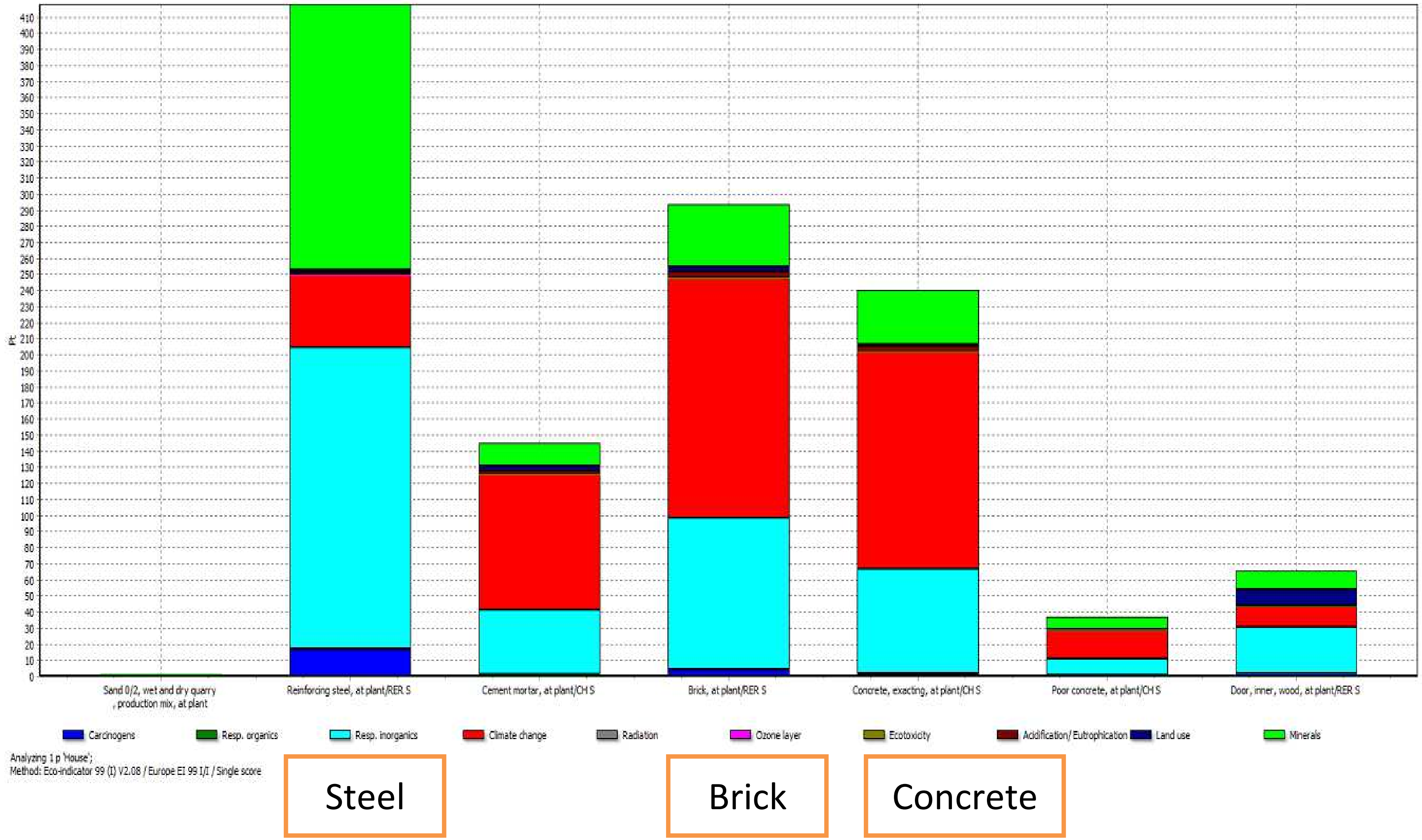

Steel

Brick

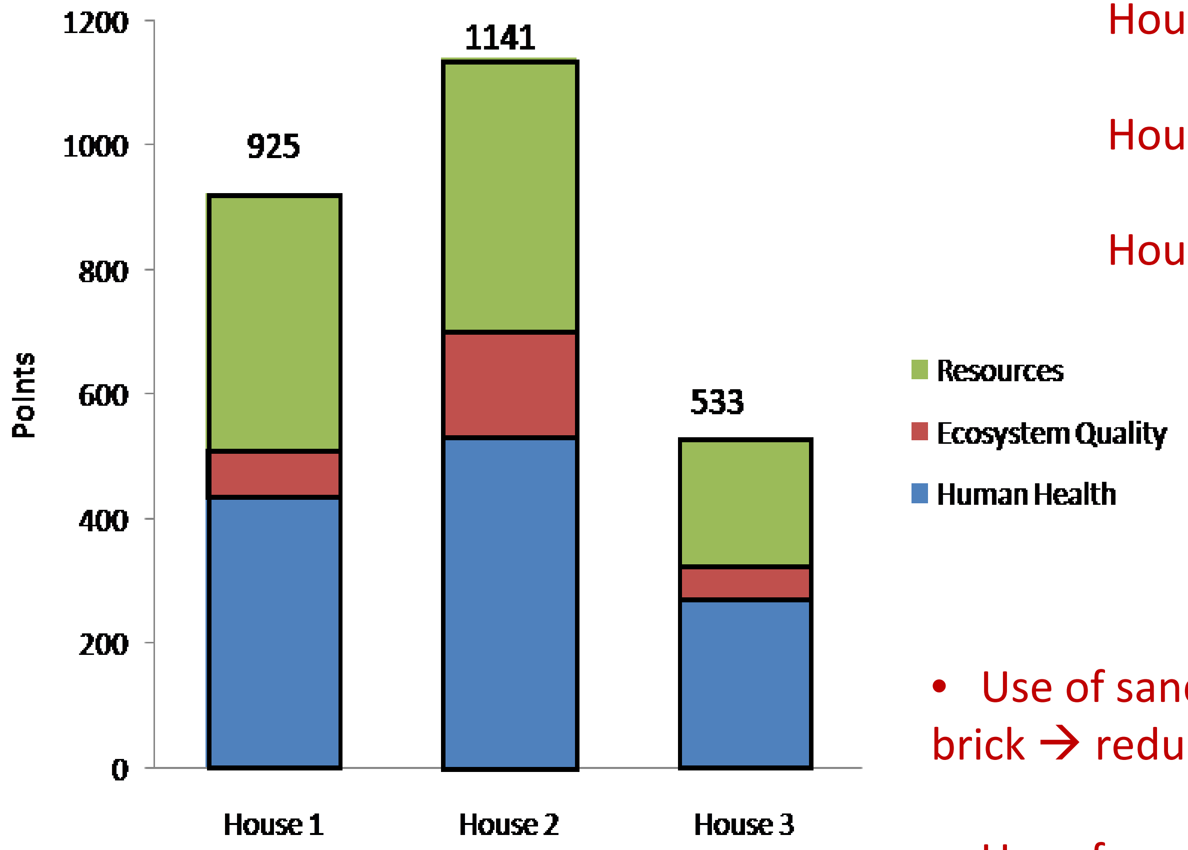
Concrete

# Impact Assessment by Building Material

## Eco-indicator 99(I)



# What-if analysis for envelope material comparison using single score




House-1: normal brick

House-2: light clay brick

House-3: sand lime brick

- Use of sand lime brick instead of normal brick → reduces the impact score by 42%.

- Use of sand-lime brick instead of conventional brick reduces the embodied energy by 40% (Chani et al. 2003).

# Energy and Carbon Footprint

| ***Energy footprint*** | **Carbon footprint** |
|---|---|
| Cumulative Energy Demand (SimaPro) | IPCC 100 a (SimaPro) |
| 5580 MJ / sq.m. | 577 kg $CO_2$ equivalent/sq.m. |
| 519 MJ/sq.ft. | 54 kg $CO_2$ equivalent/sq.ft. |

# Comparison of Energy Footprint (Production phase)

| Inventory of carbon and energy data (ICE, Univ. of BATH) | Indian data | SimaPro (Cumulative Energy Demand data) |
|---|---|---|
| 4874 MJ/sq.m. | 5372 MJ/sq.m. | 5580 MJ/sq.m. |
| 453 MJ/sq.ft. | 500 MJ/sq.ft. | 519 MJ/sq.ft. |

# Discussion / Conclusions

- Significant building components:
  - Building walls (masonry work)
  - Foundation
  - Roof slab and beam
  - Plinth beam

- Significant materials:
  - Brick
  - Steel
  - Concrete

# Discussion / Conclusions

- Impacts of building component / material depends on Quantity and the energy intensity

- The building envelope (masonry) is found to be the most significant component primarily due to the large quantity than the energy intensity.

# Scope for further work

- Extend this study by including the building operation and end-of-service life phases.

- Study the influence of building service life on the relative contribution of construction and operation phases.

# Scope for further work

Focus on <u>typical residential construction</u>:

- Medium size apartments
  - 2 bed room apartments: 800- 1500 sq. ft.

- High-end apartment
  - large residential apartments
  - 3 or 4 bed rooms: more than 1500 sq.ft.

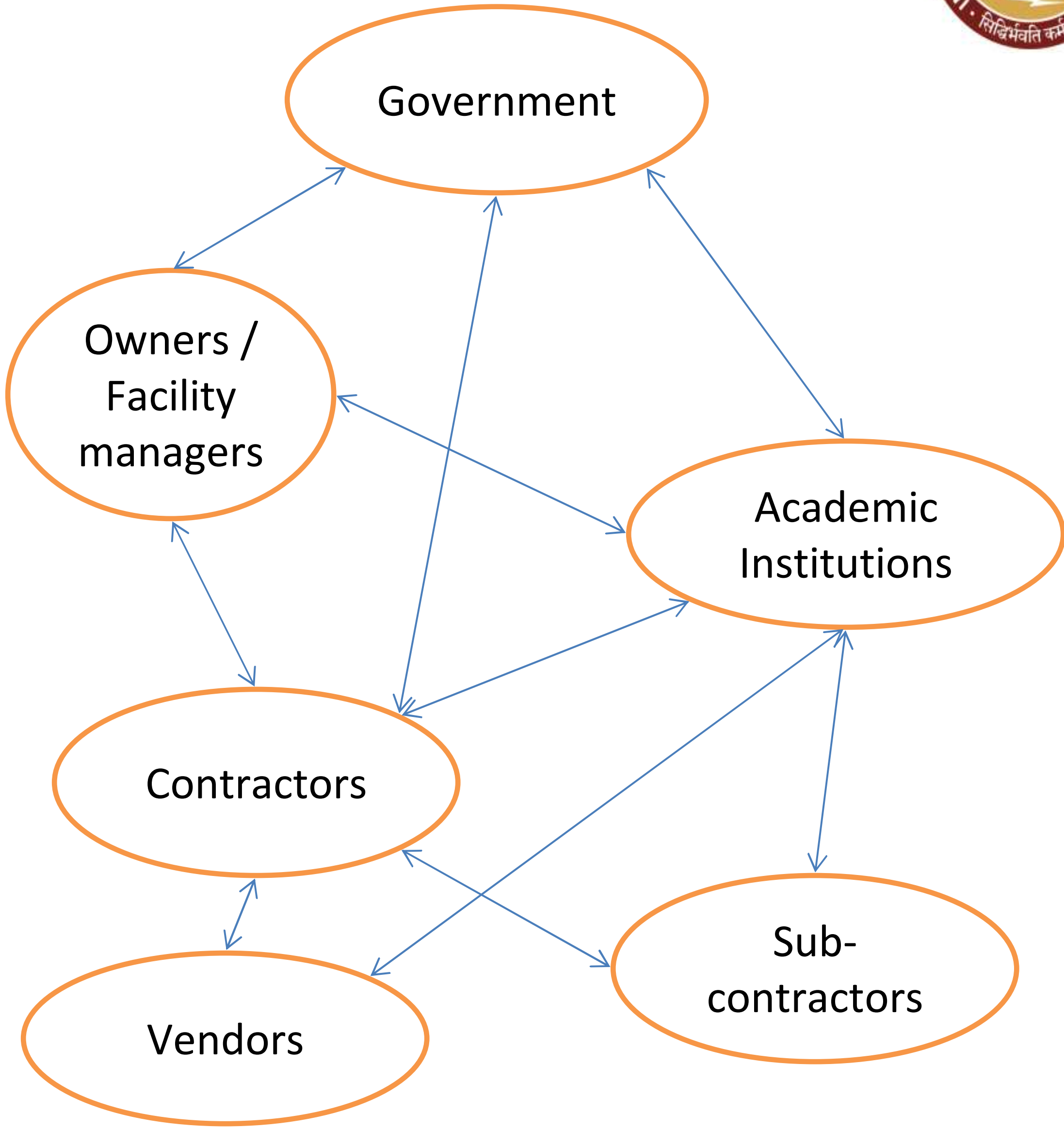
# Scope for further work

- Results are based on life cycle inventory database developed in Europe.  We feel that the general trend in the results are more valuable than the absolute numbers.

- One should be careful in using the results in terms of absolute values.

# Development of life cycle inventory database specific to Indian context

- <u>Lack of coordinated effort</u> in collecting building life cycle inventory data.
- <u>Development of data collection templates</u> which can be used by building industry stakeholders.



Thank you very much for your attention