Bureau of Energy Efficiency

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ANGAN

Augmenting Nature by Green Affordable New-habitat

A Courtyard for Revolutionary Change in Building Energy Efficiency

An International Conference on Building Energy Efficiency

9th-11th September, 2019 | Hotel The LaLiT, New Delhi

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THIS PRESENTATION WAS SHARED BY

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FOR THE SESSION:

"Embodied Energy and the Life Cycle Approach"

DURING ANGAN 2019

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Energy in Buildings & Sustainability – an overview

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Lecture delivered at 'ANGAN 2019', 11 September 2019, New Delhi

Limited resources

Mass of resources:

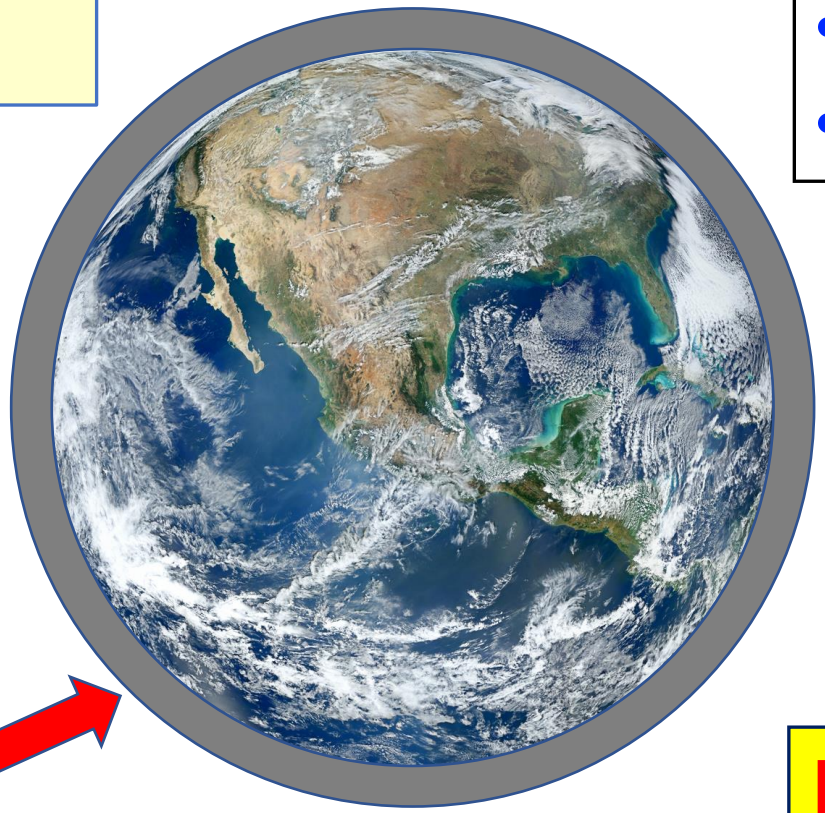
6×10^{21} t

Planets Material & Mineral wealth

- **Limited**
- **Non-renewable**

The Planet Earth

Finite size



Emissions

Mining resources

Anthropogenic activities

Prior 4400 BC	till 1500 AD	after 1800 AD
Zero Embodied Carbon materials	Medium Embodied carbon materials	High Embodied Carbon materials

Global consumption of construction materials: > 60 billion t /annum

Per capita consumption: 8 t/annum (~6.5 t is aggregates)

Material resources

Exhaustible: Soil, Stone, Sand, Minerals & chemicals....

Renewable: Biomass - grasses, bamboo, wood... grown

Recyclable: Solid wastes - Industrial & mine ..

Sustainability?

There are many definitions for sustainability

Definition of sustainable development

Kumarappa (1945) "Economy of permanency"	Brundtland report (1987)
Sustainable society: • Manages its economic growth without causing irreparable damage to environment • Satisfies peoples' needs without jeopardizing prospects of future generations	**Sustainable development:** • Meeting the needs of the present without compromising ability of future generations to meet their own needs

Prime focus in both these definitions is:

- **Sustainable extraction of resources** from the planet earth
- Without causing **irreparable damage** to the environment

… sustainability – renewable/regenerate

Pillars of Sustainability
- Socio…
- Economic..
- Environ..

Demand for Material resources

Mined resources

Sustainability ?????

Need for renewable resources

The planet hosts several living organisms

- **Human societies occupy ~2% of the planet's surface area but consume 75% of the planet's resources (O'Meara 1999)**

What is Green (construction)?

…green is about decarbonization!

refers to the changing relative amounts of carbon and hydrogen in the fuels burnt to generate energy ……..(T. Bradford, 2006)

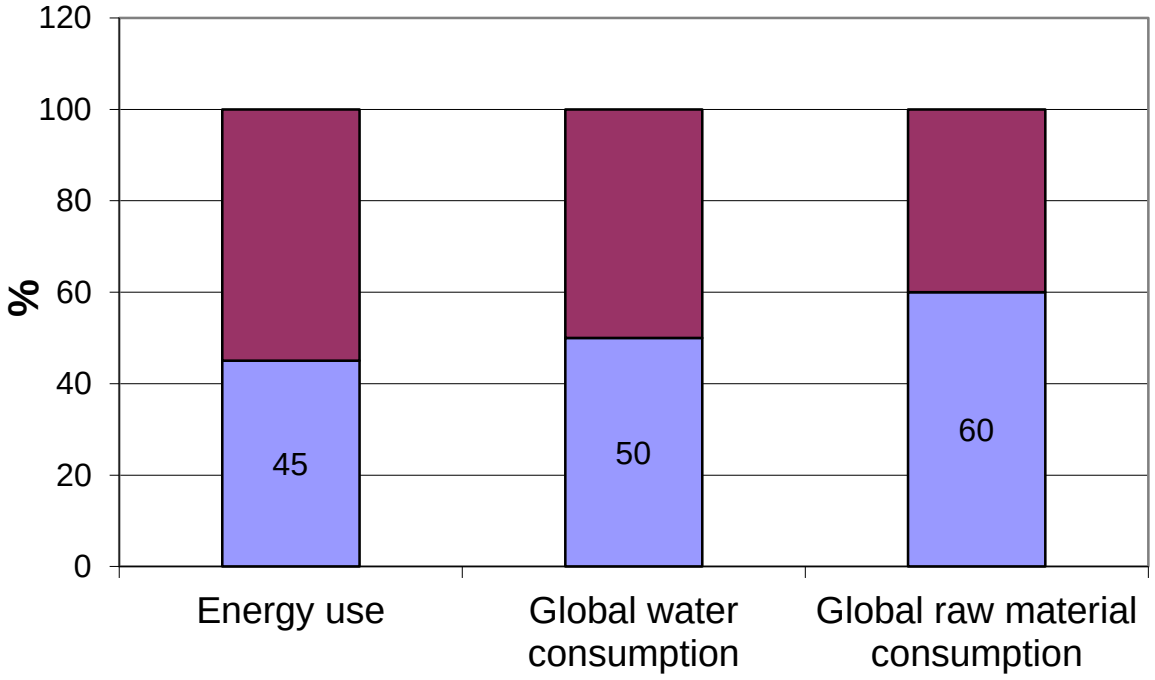
Type of fuel	Carbon	Hydrogen
Firewood	10	1
Coal	2	1
Oil	1	2
Natural gas	1	4
Hydrogen	0	1

… about emission reduction

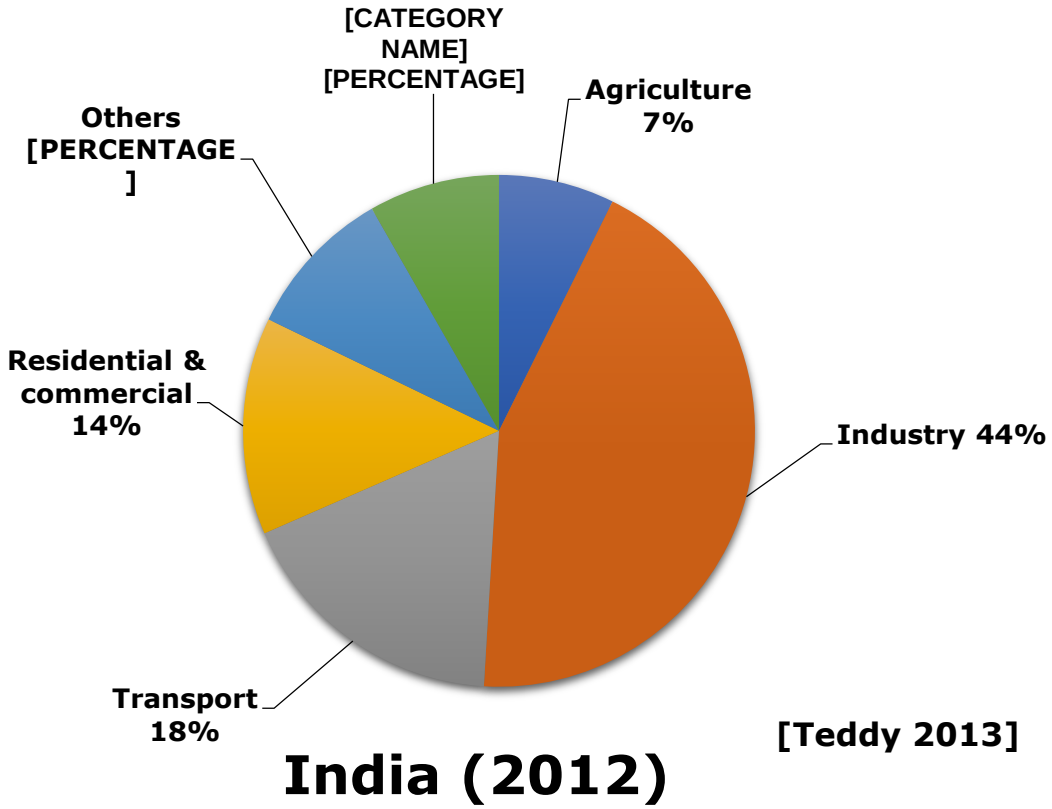
Consume
- **Energy**
- **Material resources**

Built Habitat/Environment

Generate
- **Wastes**
- **Emissions**



[Willmott Dixon Group 2010]

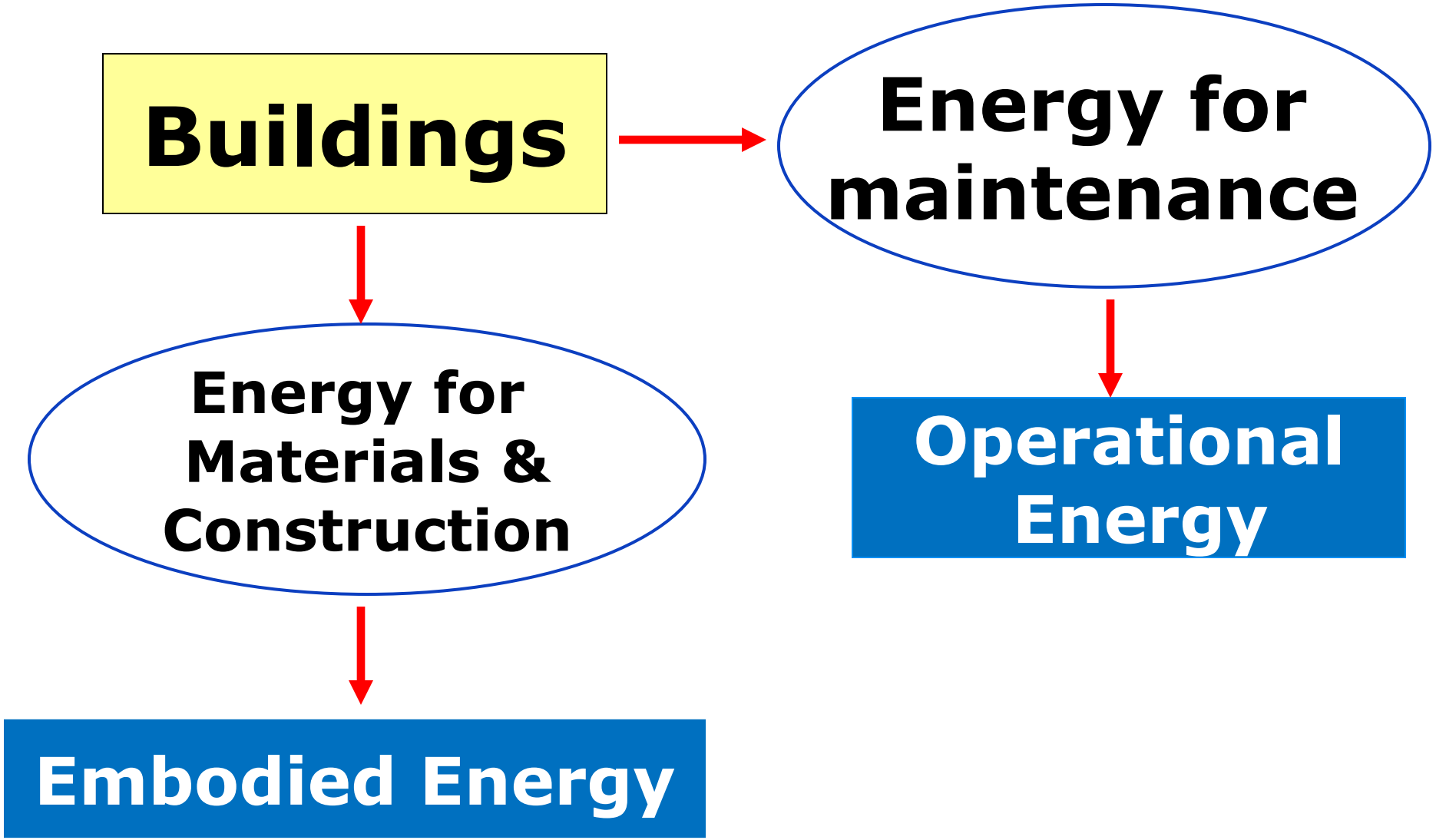


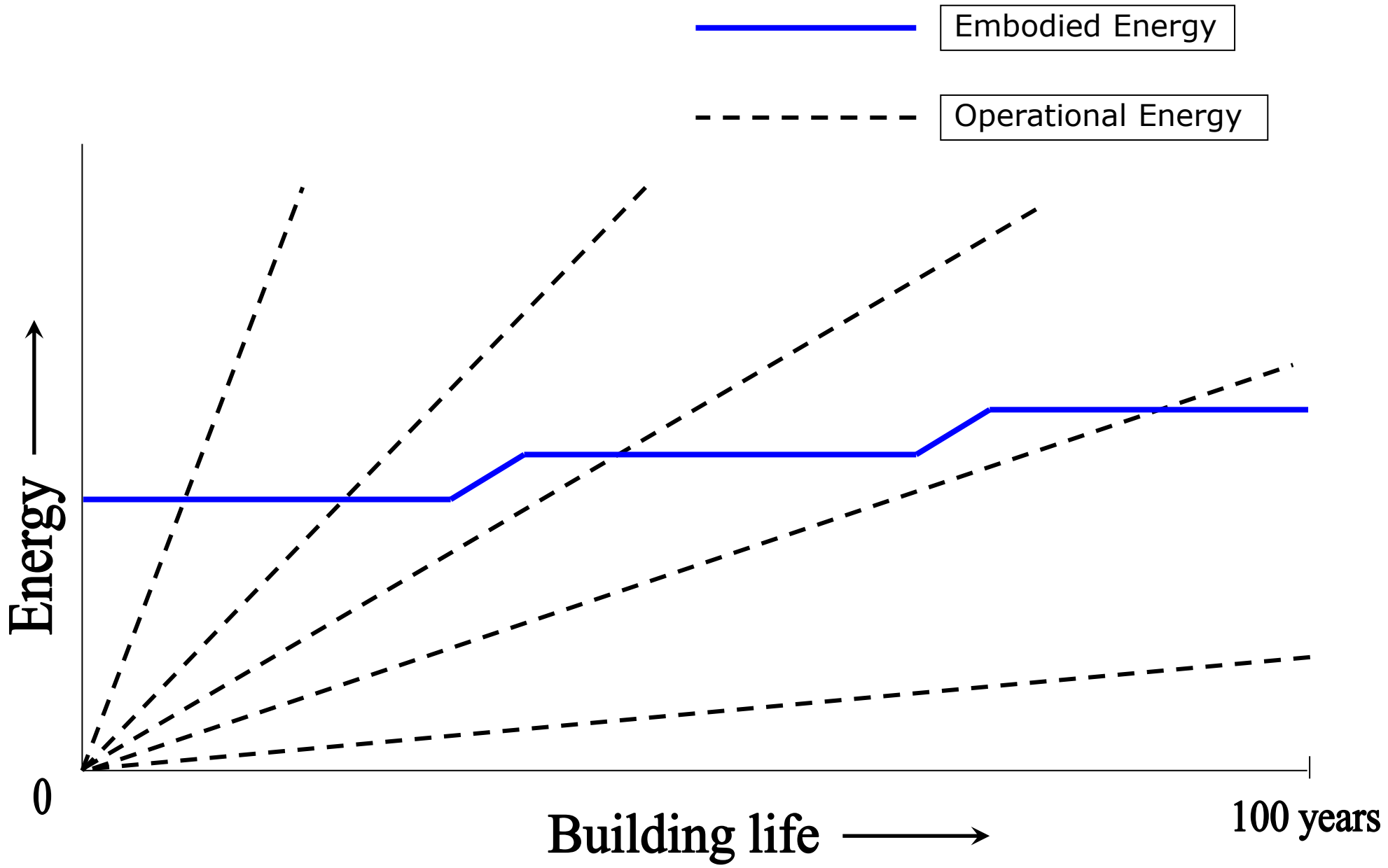
India (2012)

[Teddy 2013]

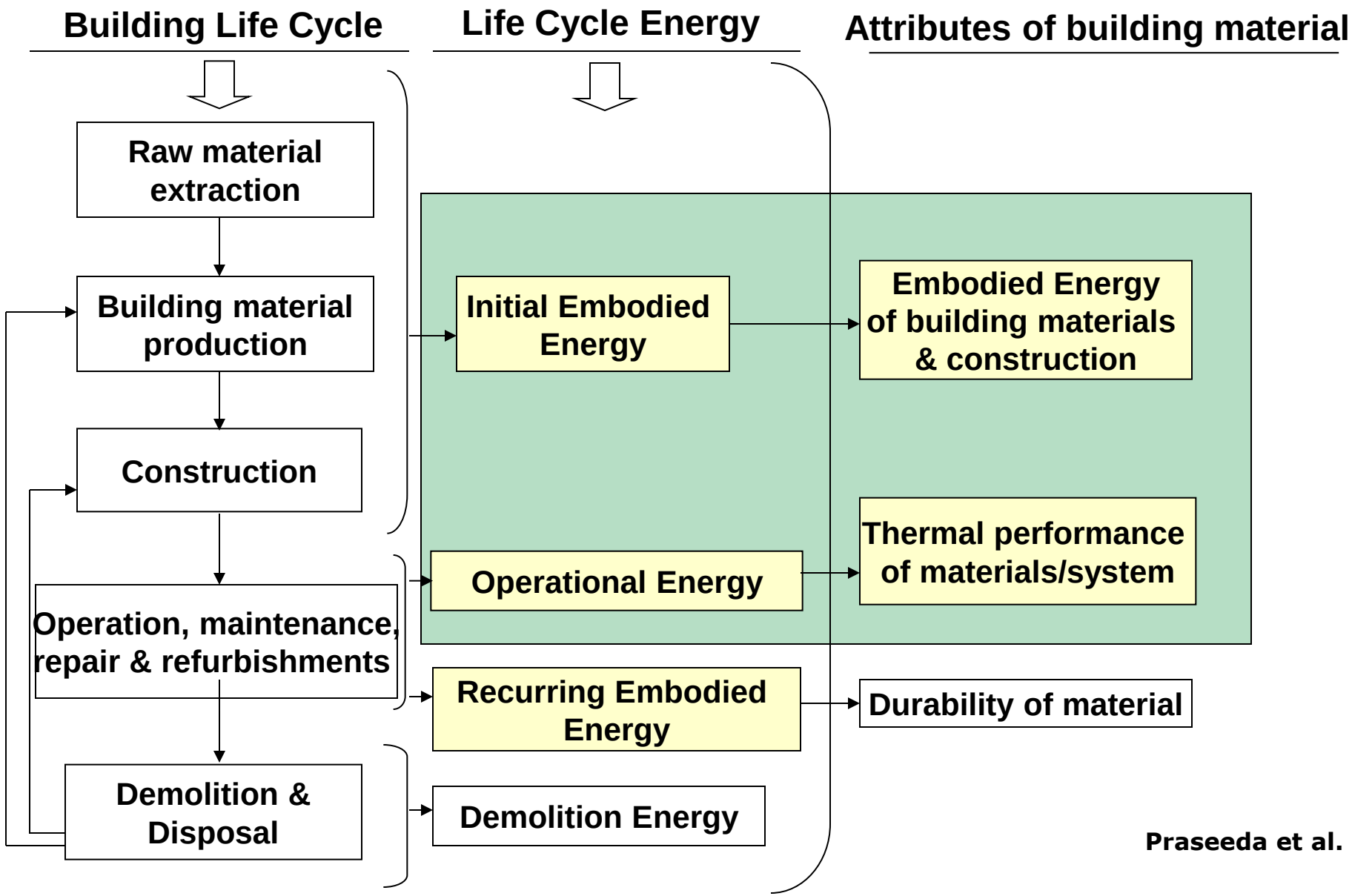
By 2025, Buildings worldwide will be the largest consumers of global energy - greater than the transportation and industry sectors combined.

Energy in Buildings



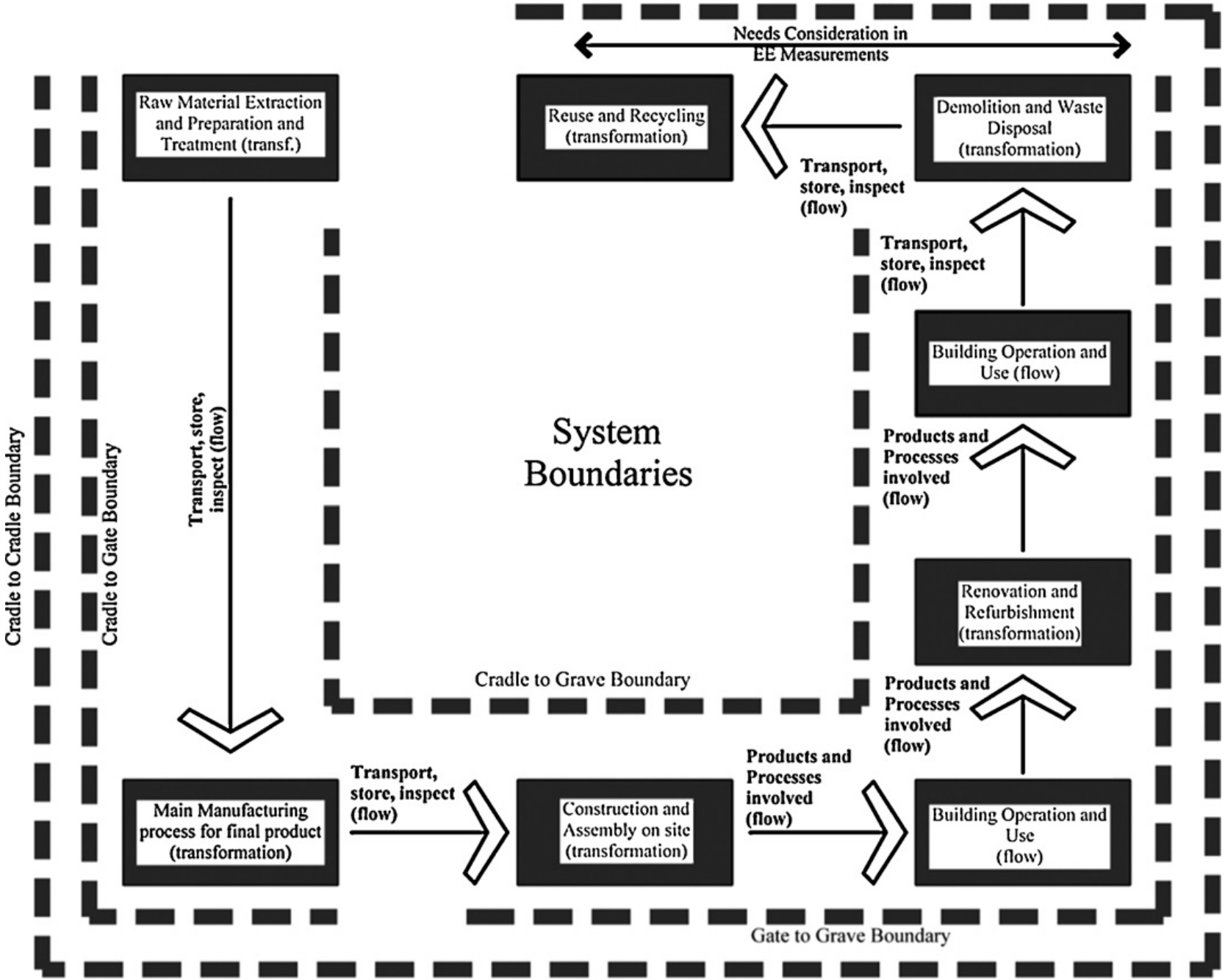

Embodied Energy
Operational Energy
Energy
0
Building life
100 years

Life Cycle Energy (LCE) of a building



Praseeda et al. 2014, E&B, 2015

Embodied Energy (EE) – System Boundaries



[Dixit et al. 2010]

Methods for Embodied Energy Analysis

- **Process analysis**
- **Input – Output analysis**
- **Hybrid methods** [Menzies et al. 2008, Treloar et al. 2000]

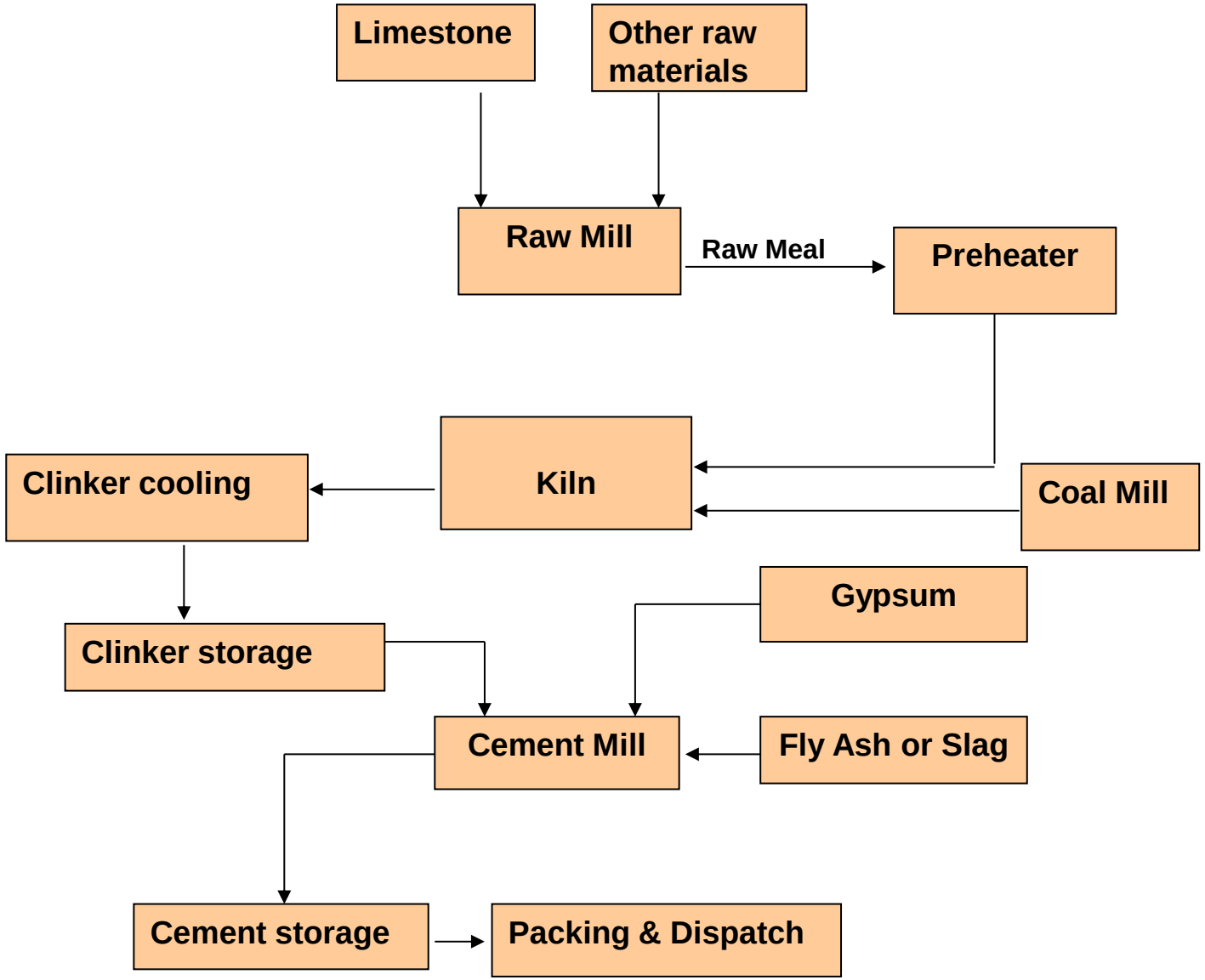
Embodied Energy (EE) value depends upon

- **System boundary considered**
- **Method of analysis**

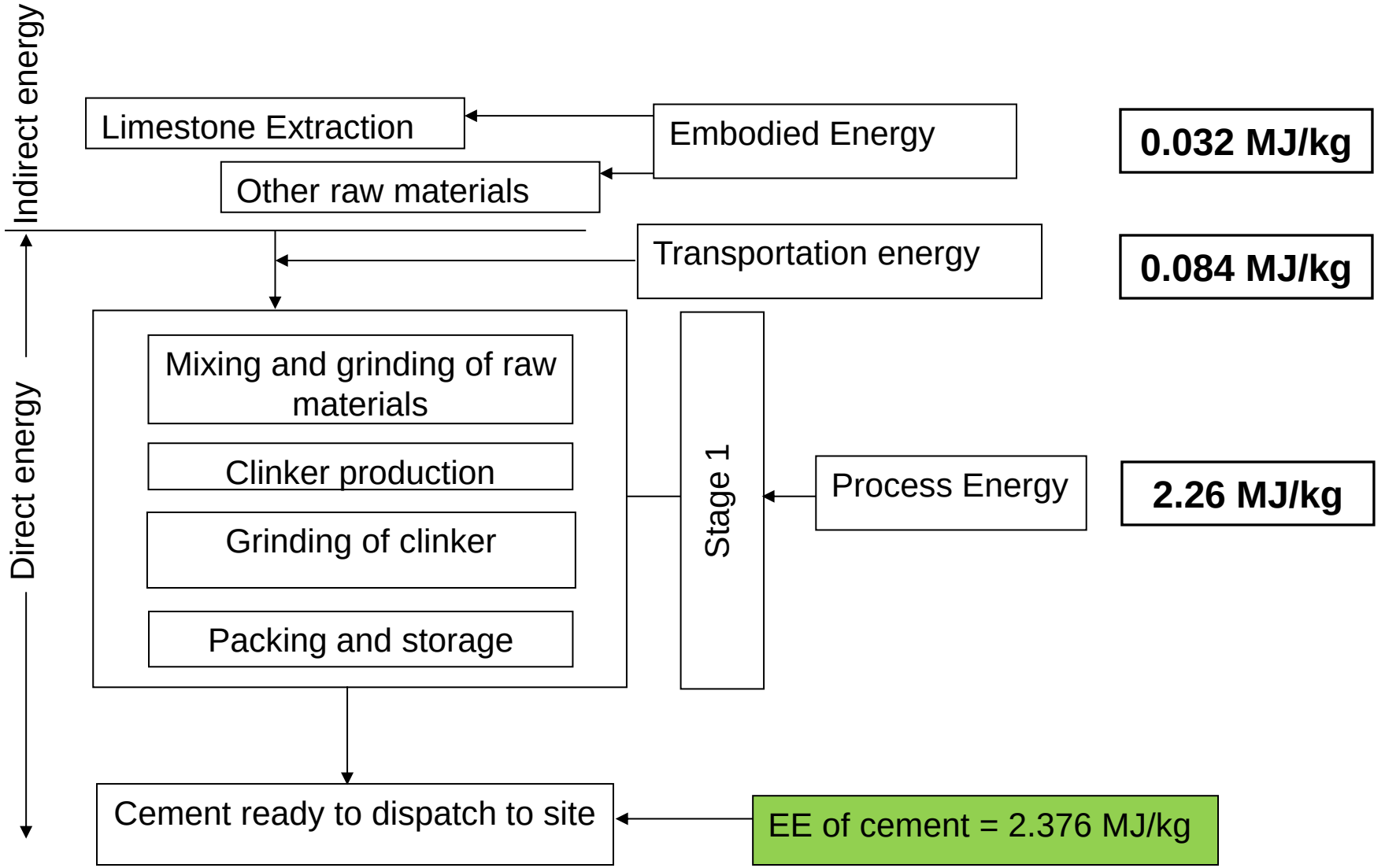
EE is not a unique value – it is a range

Cement: Process of manufacture

Process flow chart



Embodied Energy in Cement



Praseeda et al. 2014, E&B, 2015

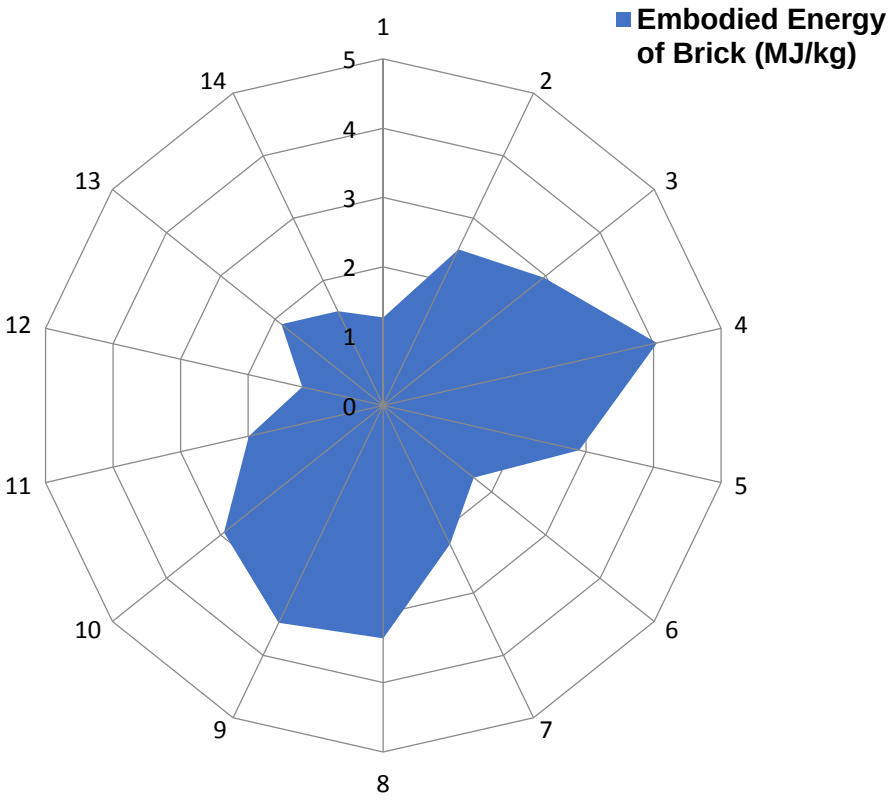
Embodied Energy in building materials

Type of material	Sp. energy consumption (MJ per kg)
Cement	3.00 - 4.00 (2.38 – 3.72)
Lime	4.75 – 5.75
Lime-pozzolana	2.00 – 2.50
Steel	42.0 (30)
Aluminum	236.8 (100 - 140)
Glass	25.8 (10 – 15)
Burnt brick	1 – 2.5 (1.2 – 4.05)
Hollow con. Block	0.60 – 0.75
Vitrified floor tile	5.5 – 6.5 (10.63)

Red colour highlighted – Praseeda et al. E&B 2015

Embodied Energy of burnt clay brick

EE of burnt clay brick: 1.20 – 4.05 MJ/kg



	Types of kiln	EE (MJ/kg)
1	Clamps	1.7 – 2.9
2	Intermittent type	1.88
3	BTKs	1.20 – 4.05
4	CBRI improved BTK	1.51
5	Hoffmanns kiln	2.94
6	Downdraught kiln	3.36 – 3.48
7	VSBK	1.20

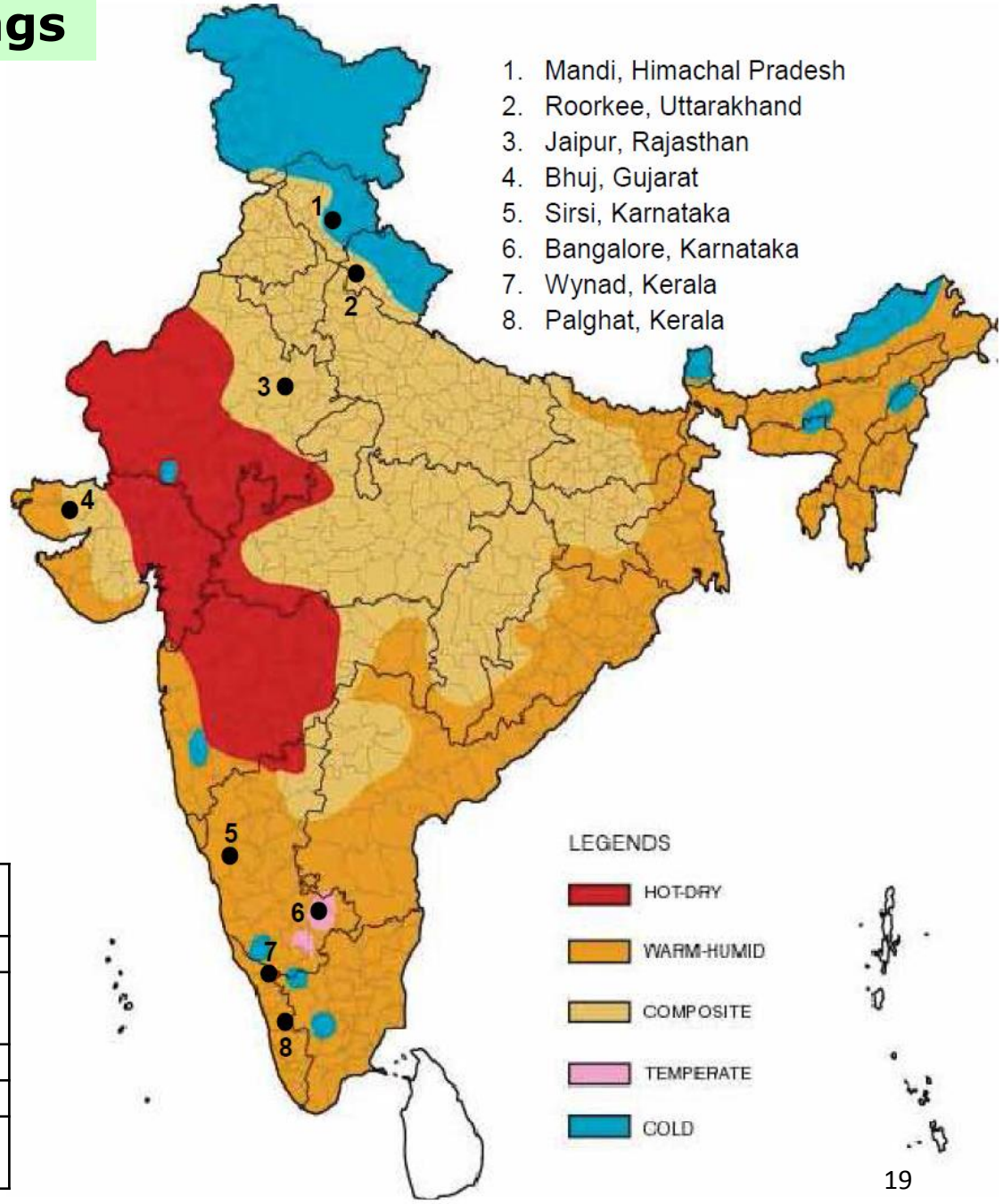
Praseeda et al. 2014, E&B, 2015

Embodied and operational energy in buildings

43 residential buildings in 4 climatic zones

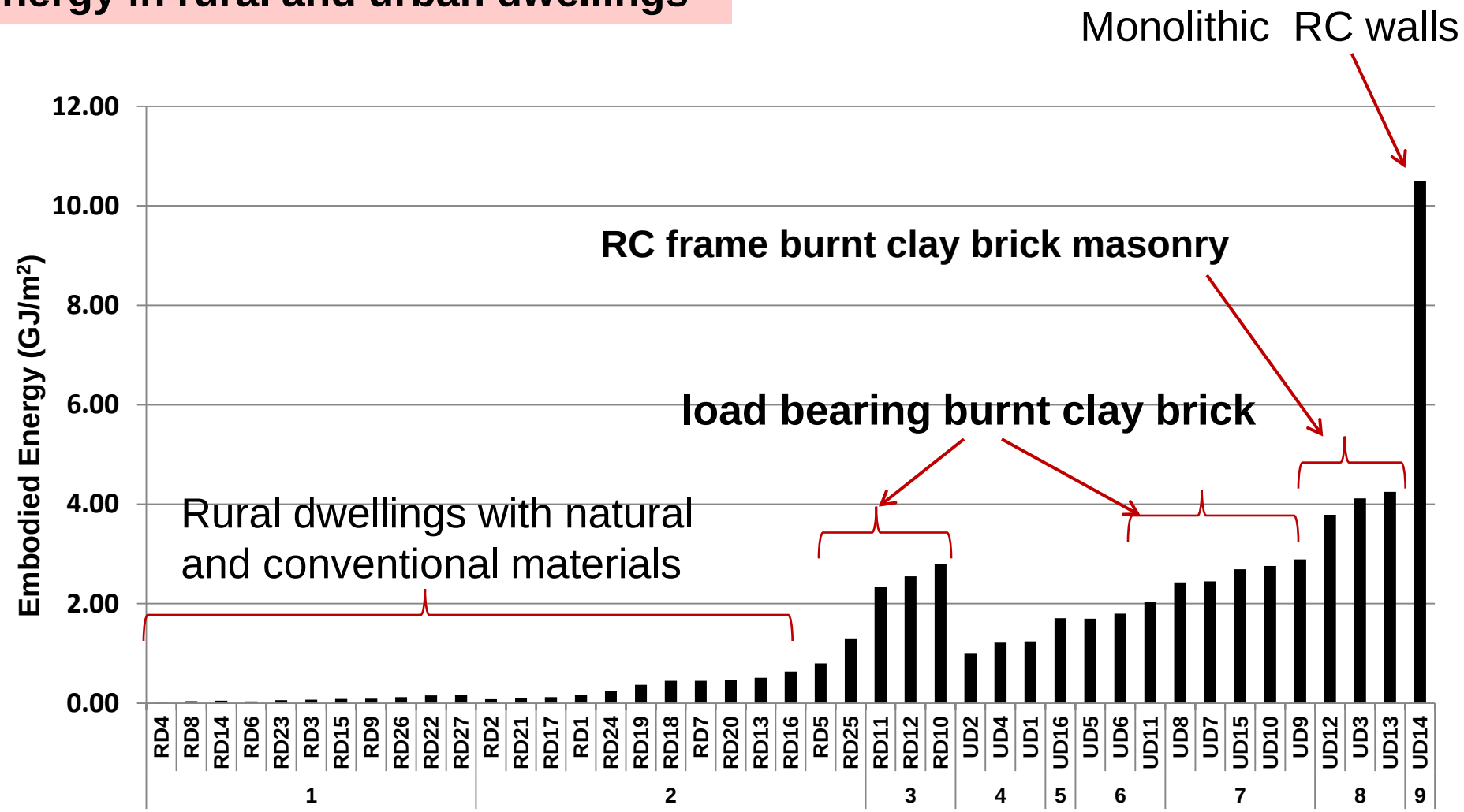
(27 rural dwellings & 16 urban dwellings)

Designated as
RD1 – RD27
UD1 – UD16



Sl. No.	Climatic zone	Mean monthly temperature (°C)	Relative Humidity (RH)	Regions
1	Hot and Dry	Above 30	Below 55%	Western & central part
2	Warm and Humid	Above 30	Above 55%	Coastal regions
		Between 25 - 30	Above 75%	
3	Temperate (Moderate)	Between 25 - 30	Below 75%	Pune, Bangalore
4	Cold	Below 25	For any RH value	Northern parts of India
5	Composite	Six months or more do not fall within any of the above categories		New Delhi, Kanpur, Allahabad etc.

Embodied energy in rural and urban dwellings



EE of dwellings with natural materials is an order of magnitude lower than those with conventional brick-concrete

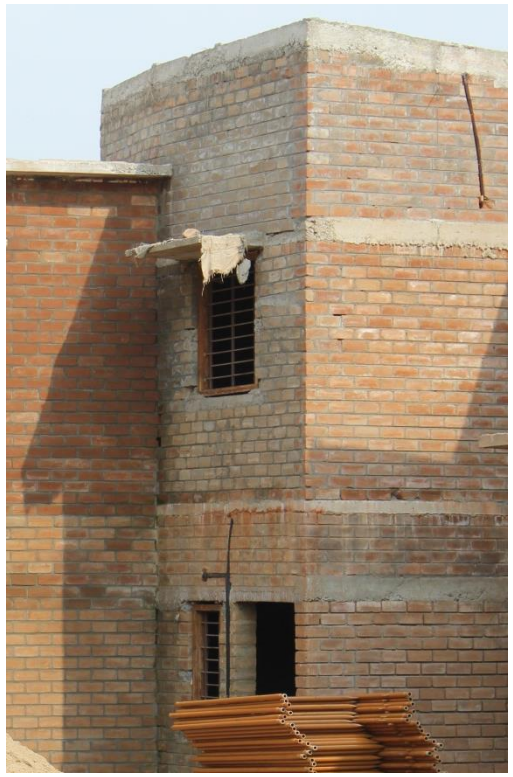
Source: Praseeda et al. E&B, 2016

Monolithic RC walls

Embodied energy = 11 GJ/m^2

RC frame burnt brick masonry

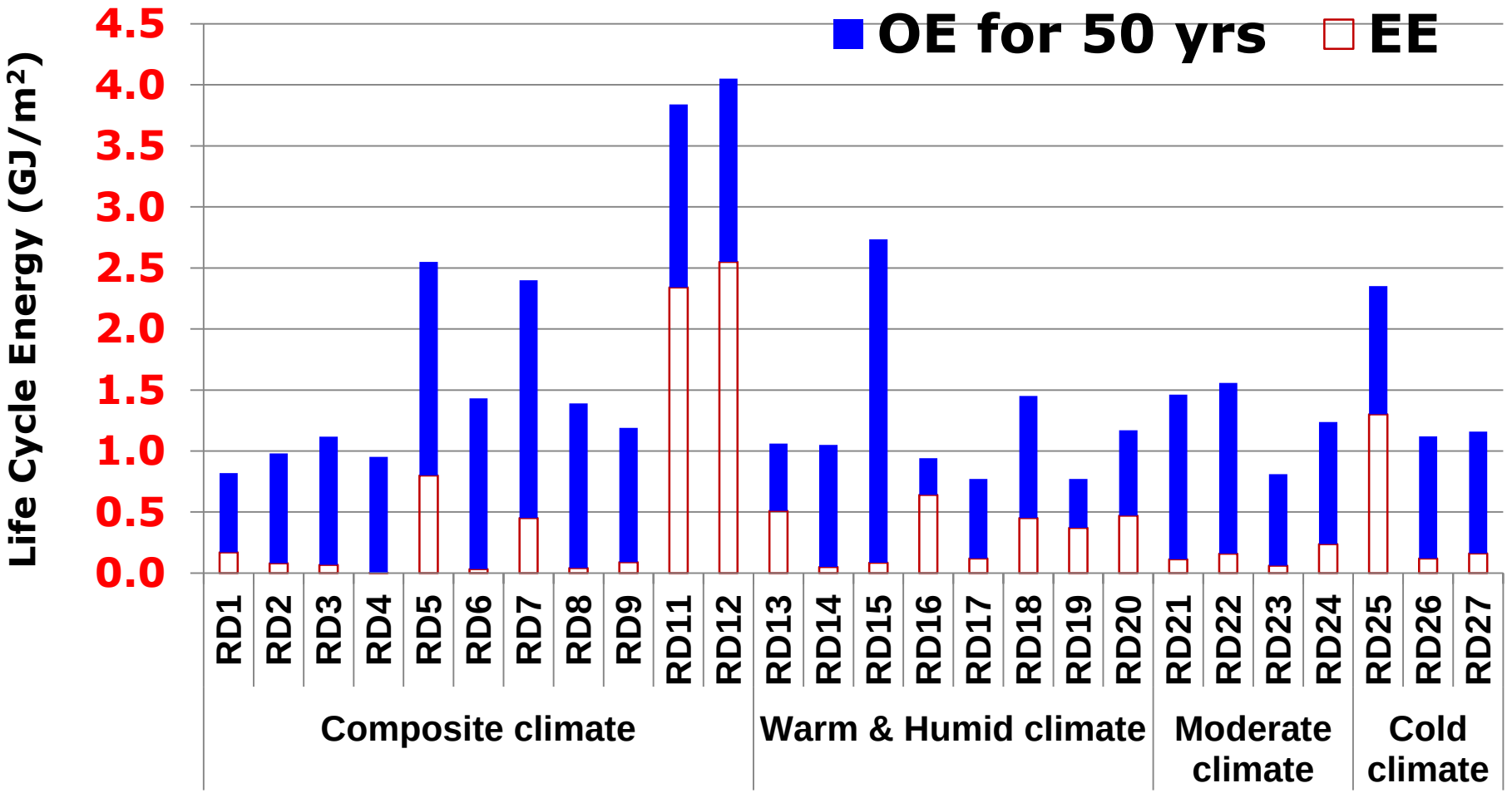
EE = 4 – 6 GJ/m^2



Load bearing brick masonry

EE = 2.5 – 3.5 GJ/m^2

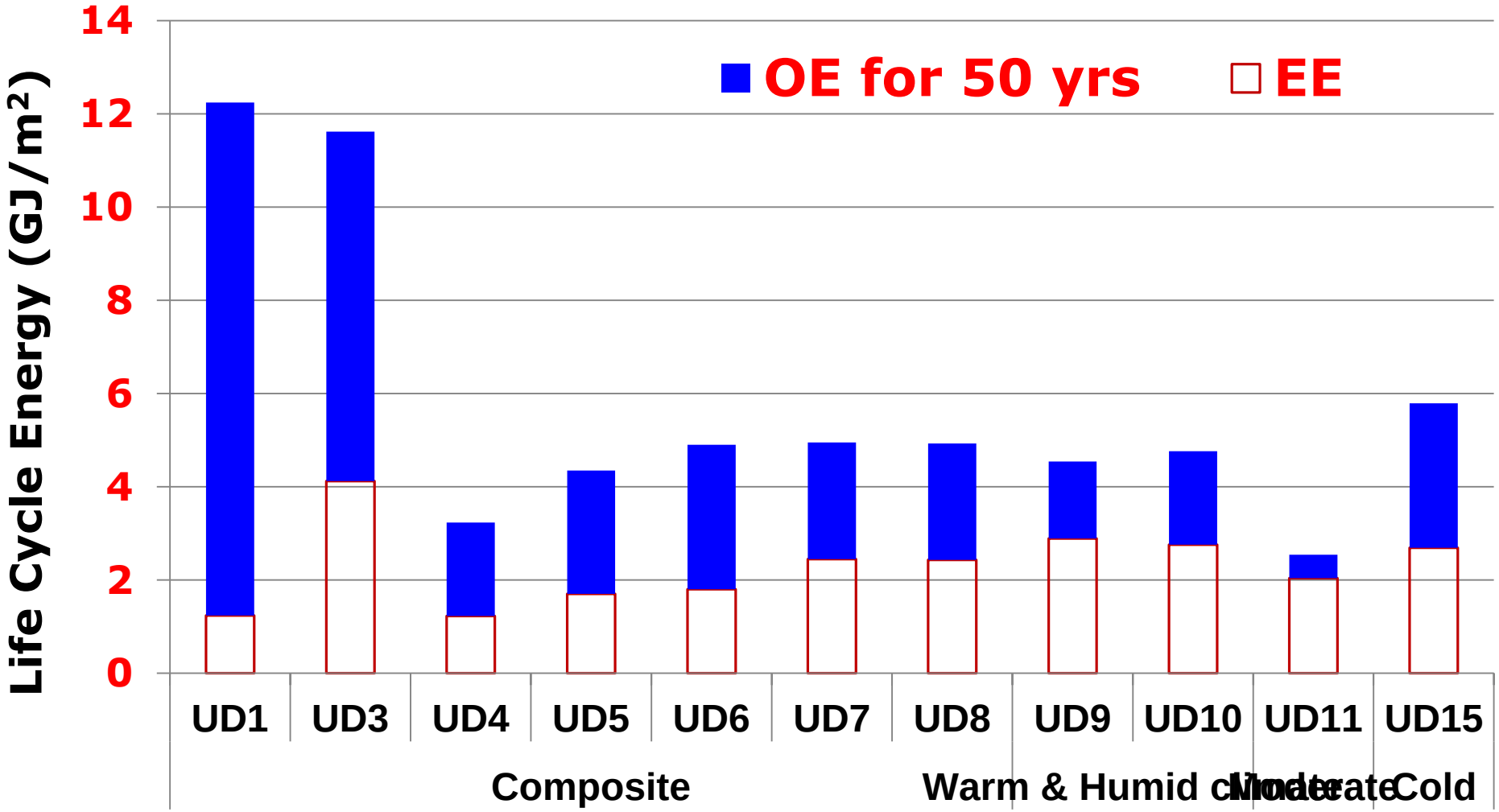
Life Cycle Energy (LCE) in rural dwellings



EE represents 0.21 to 68% of LCE in rural dwellings

Source: Praseeda et al. E&B, 2016

Life Cycle Energy (LCE) in urban dwellings

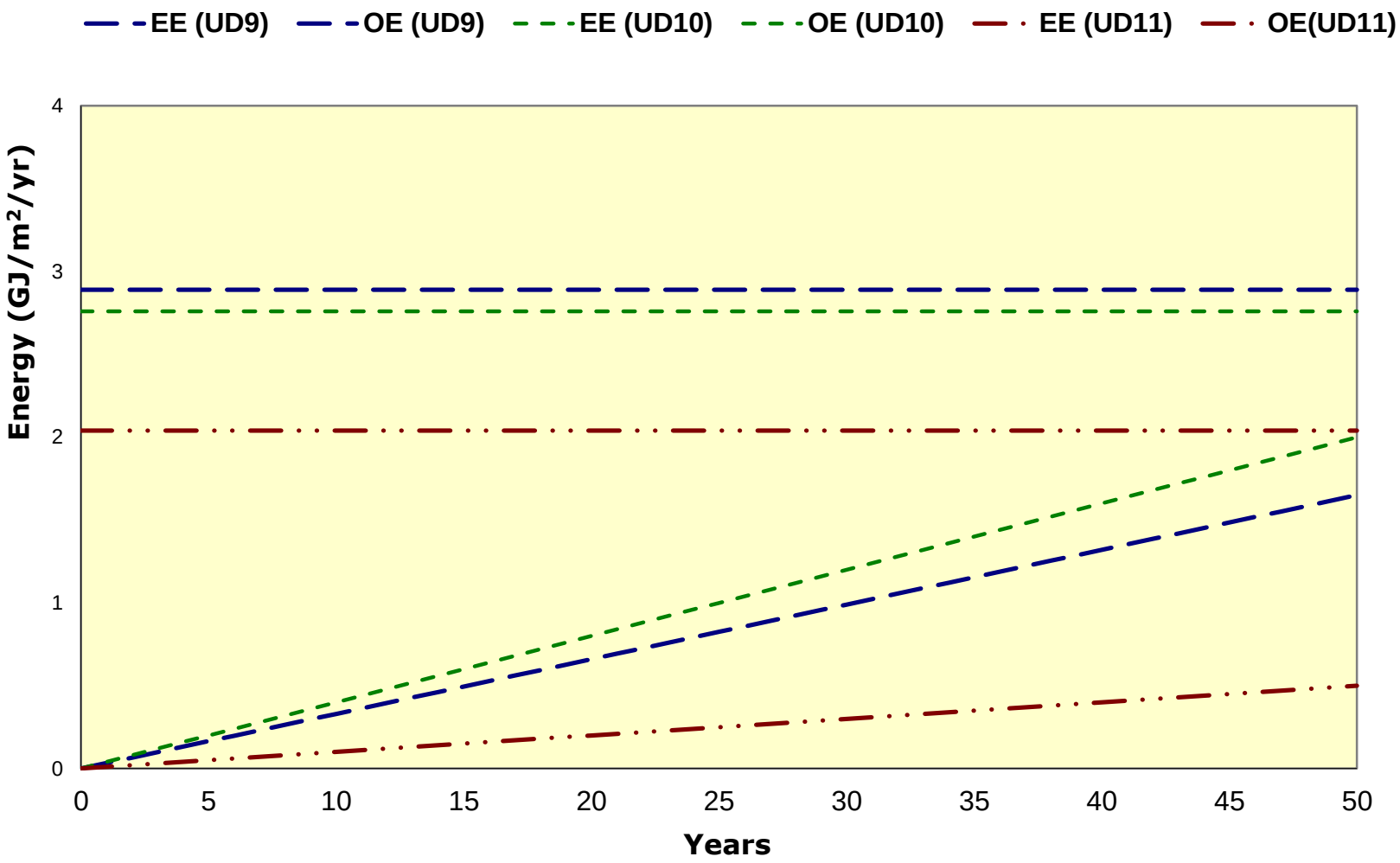


EE represents 10 to 80% of LCE in urban dwellings

Source: Praseeda et al. E&B, 2016

Embodied vs Operational Energy

Urban dwellings from warm – humid and moderate climate zones



EE < OE

EE > OE

Depends on

- **Climate**
- **Conditioning type**
- **Envelope/materials**

Source: Praseeda et al. E&B, 2016

Current rating systems

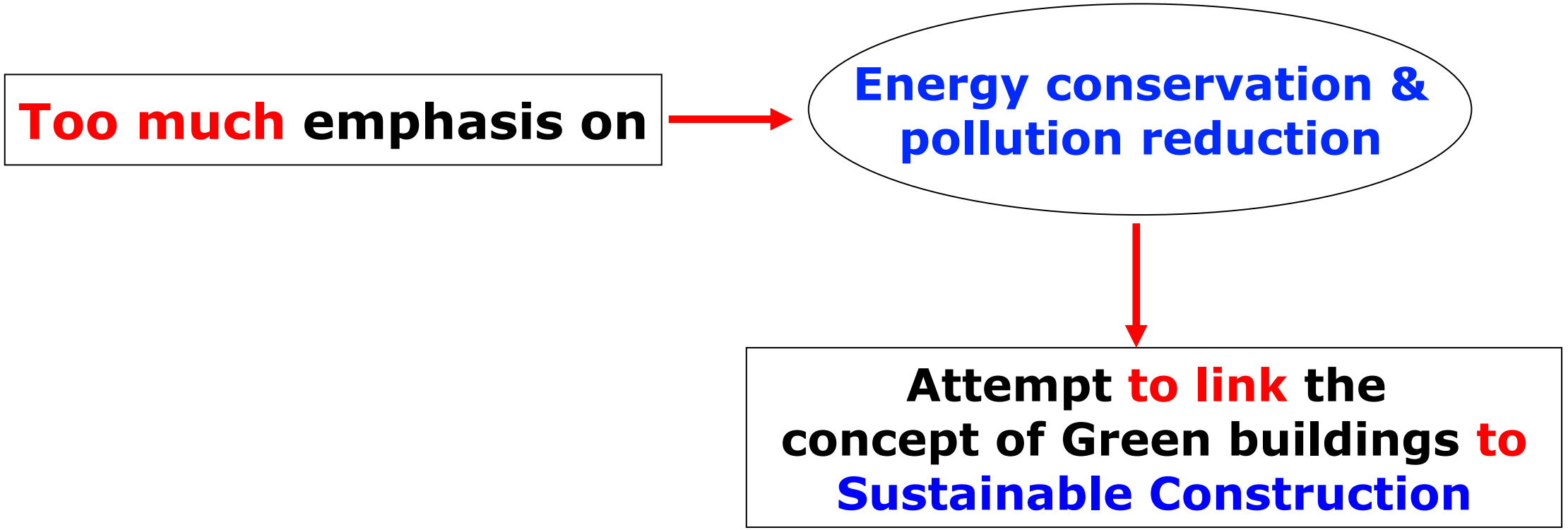
Attempt to address……..

- Site planning, location & linkages
- Design, materials & construction
- Water & waste management
- Awareness & education
- Healthy living conditions

- Energy consumption, generation…
- Indoor environment quality, space conditioning…

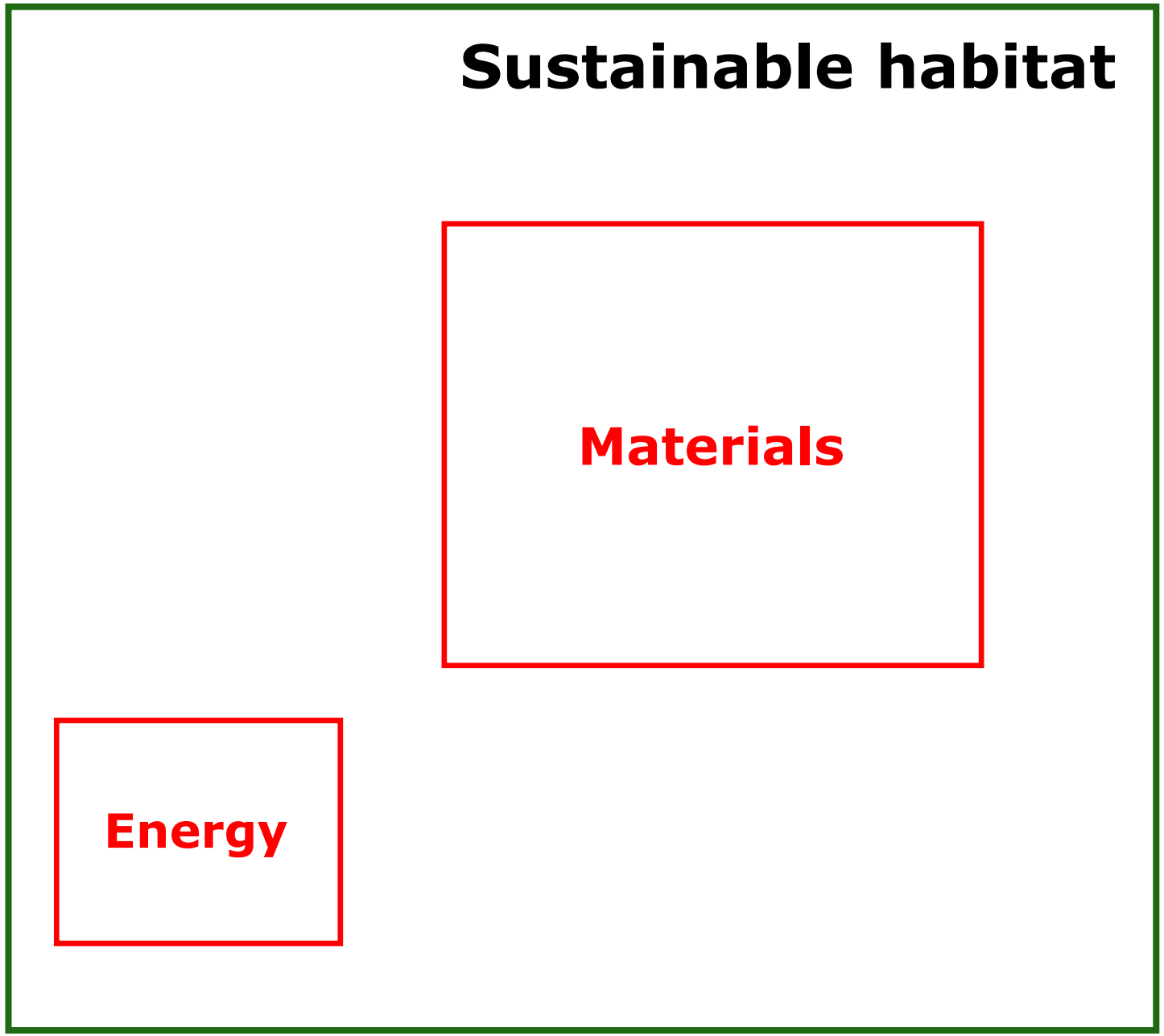
Parameter	Weightage		
	LEED-USA	BREEAM - UK	GRIHA-India
Materials, and construction methods	6 – 9%	13.5%	10%
Energy (consumption/generation, Indoor environment quality, space conditioning)	57%	39%	50%

Current rating systems



Little or less emphasis on:

- Conservation of dwindling basic material resources
- Environmental damage due to indiscriminate mining of materials



Green Buildings address only

- **Part of the sustainability issues**

Share of sustainability parameters in built habitat

Sustainable habitat

Major issues

- **Managing material resources**
- **Minimising pollution – Energy**

Thank you

Summary

- Consumption of construction material is alarming: 8 t (6.5 t aggregates) /capita/annum
- Sustainable constructions: should address both the issues on energy & material resources
- EE: not a unique value – it is a range & dynamic

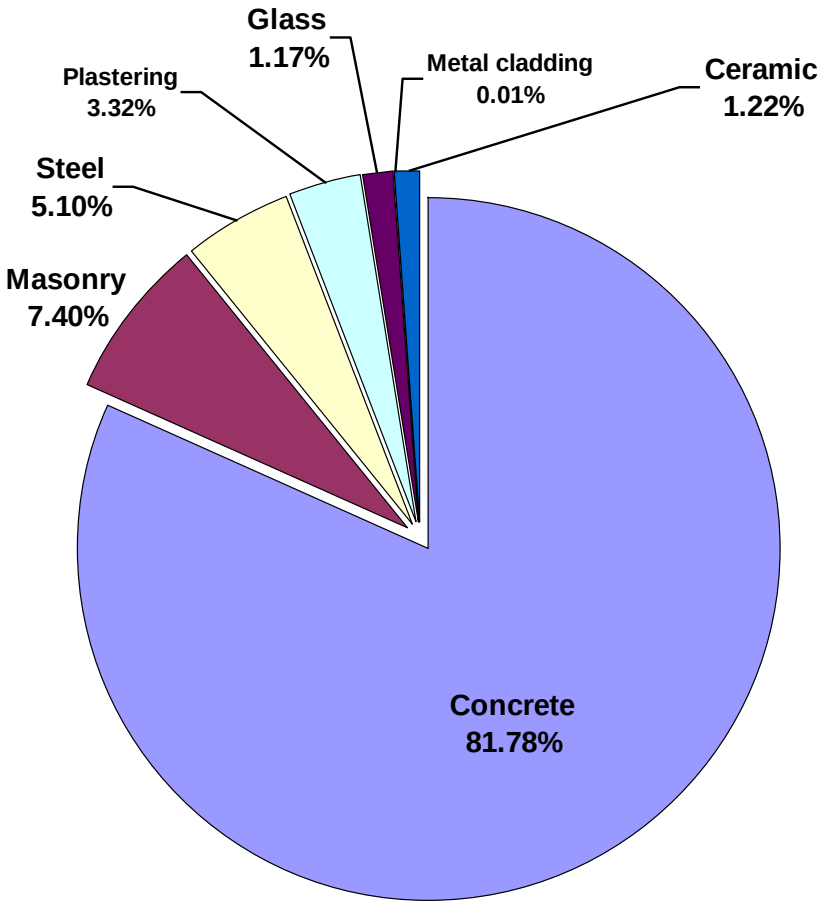
EE < OE

EE > OE

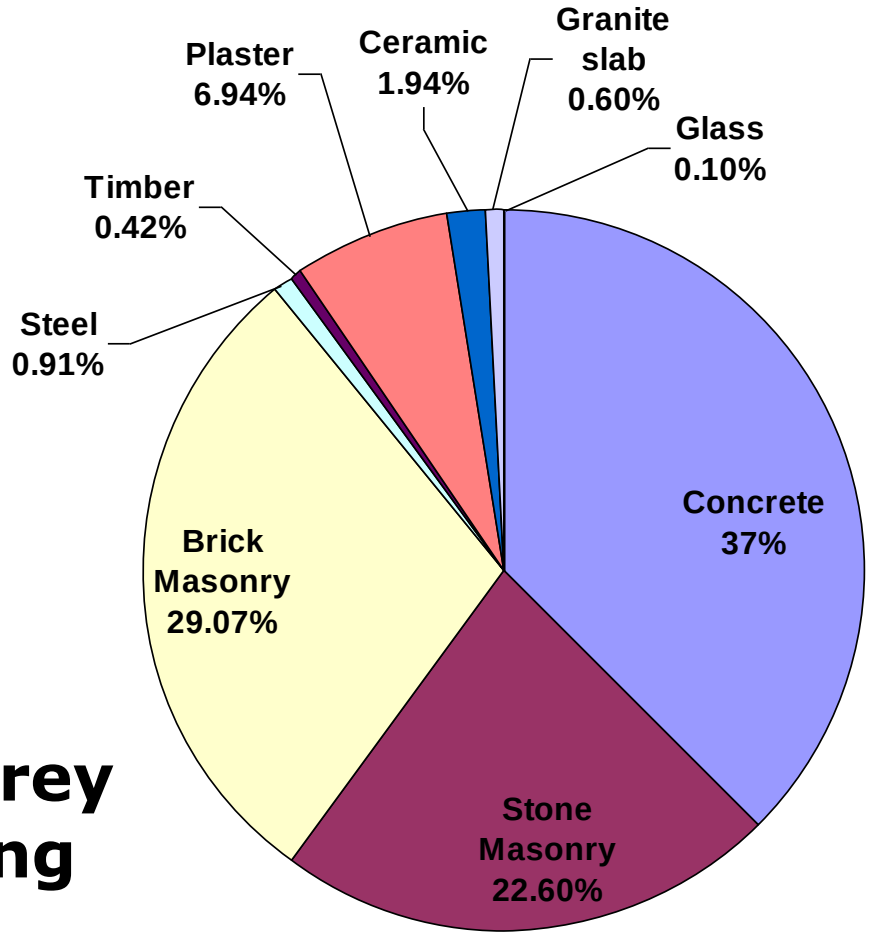
Weight & Embodied Energy of Building

Details	30 - Storey concrete frame	2 - Storey brick wall
Total weight (t)	1,66,944	550
Built up area (m^2)	92,903	251
Weight (t/m^2)	1.79	2.19
Embodied energy (GJ/m^2)	4.28	2.40

Distribution of mass



30 – Storey Building



2 – Storey Building

Possible options for addressing issues on sustainable construction materials

- Judicious use of material resources
- Use natural materials or effect changes with minimum energy expenditure – low carbon materials
- Reduce & recycle – think end of life utilisation
- Great need to use biomass based renewable materials
- Utilise solid wastes for construction products