Materials research to achieve a circular economy in the built environment

SBE19 Brussels BAMB-CIRCPATH Conference

5-7 January 2019

Prof. Dr. Luisa F. Cabeza

GREiA Technological Capabilities

Energy Engineering

Evaluation and study of the thermal energy storage

Energy optimization of buildings and industrial processes

Sustainable Construction

Green Infrastructure

Structures

Sustainable materials

LCA of construction materials

High temperature pilot plant

Artificial Intelligence

Resolution of computationally difficult problems

Definition of knowledge representation languages that allow the most adequate solution for combinational problems

Design, implementation and evaluation of highly efficient algorithms to find solutions to problems that are modelled with those languages

Design of smart control algorithms for thermal/electrical energy systems

GREiA Staff

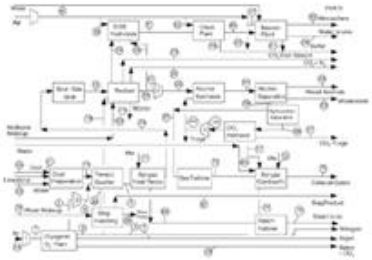
The GREiA team:

- 8 Professors / Assist. Prof.
- 1 Project manager
- 3 Postdoctoral Researchers
- 12 Graduate Students
- 3 Undergraduate Students
- 1 Laboratory Technicians
- 2 Visiting researchers

TOTAL: about 30 people

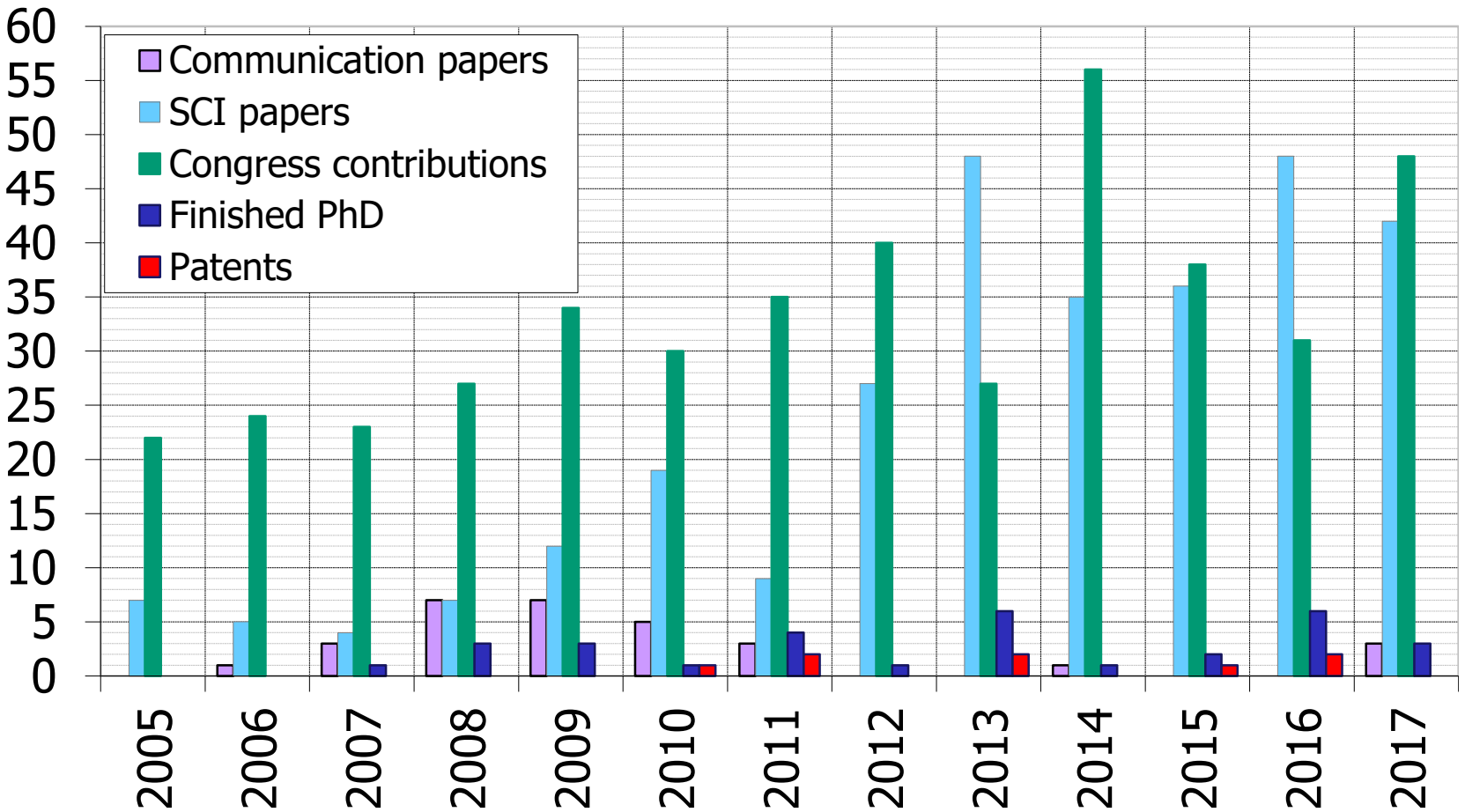
GREiA R&D vision

R&D → Pilot plant or real test → Commercial project



TRL1 → TRL2 → TRL3 → TRL4 → TRL5 → TRL6 → TRL7 → TRL8 → TRL9

GREiA evolution



Networking

Catalonia Government consolidated Research Group

Generalitat de Catalunya

TECNIO network of Generalitat de Catalunya

tecnio catalonia Fins a 31/12/2019 | ACCIÓ Generalitat de Catalunya

Reference network of advanced materials for energy (XaRMAE)

XaRmae
XARXA DE REFERENCIA EN MATERIALS AVANÇATS PER A L'ENERGIA

Campus IBERUS

campus iberus CAMPUS DE EXCELENCIA INTERNACIONAL DEL VALLE DEL EBRO

upna · Universidad de La Rioja · Universidad Zaragoza

Spanish Thematic Network of Thermal Energy Storage

European Technology Platform on Renewable Heating & Cooling

RHC Renewable Heating & Cooling
European Technology Platform

International Energy Agency Energy Conservation through Energy Storage (ECES-IEA)

ECES

European Association SPIRE

SPIRE
Sustainable Process Industry through Resource and Energy Efficiency

International Solar Energy Society (ISES)

ISES International Solar Energy Society

Research Centre for Sustainable Technologies (INSPIRES)

inspires
Institut Politècnic d'Innovació i Recerca en Sostenibilitat

Universitat de Lleida

Lleida Biotech, local bioproducts industries cluster

Lleida Biotech

Industry cooperation

Some definitions

- Built environment
  - Human-made surroundings that provide the setting for human activity, from buildings to parks
  - The human-made space in which people live, work, and recreate on a day-to-day basis

Definitions not mine

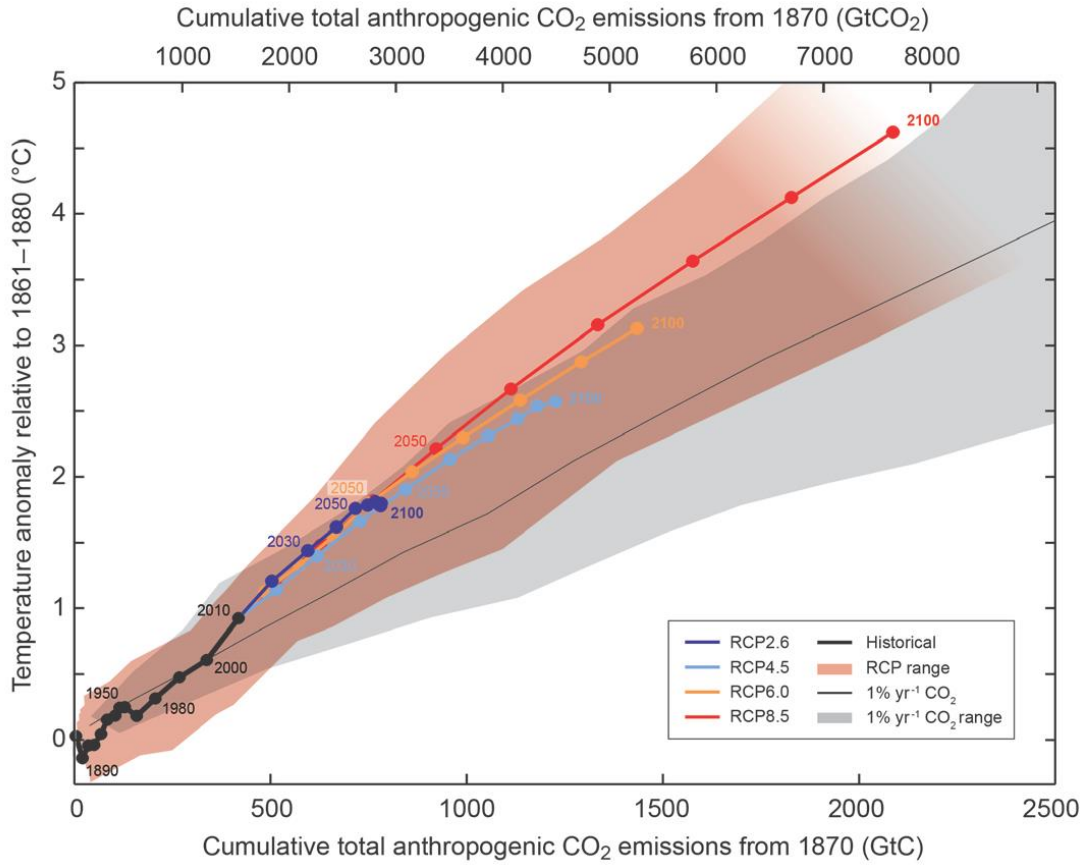
Some definitions

- Sustainable
  - Capable of being sustained
- Sustainable development
  - Development that meets the needs of the present without compromising the ability of future generations to meet their own needs
  - According to the IPCC*: a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations

Definitions not mine
*www.ipcc.ch

The world today: environment challenges

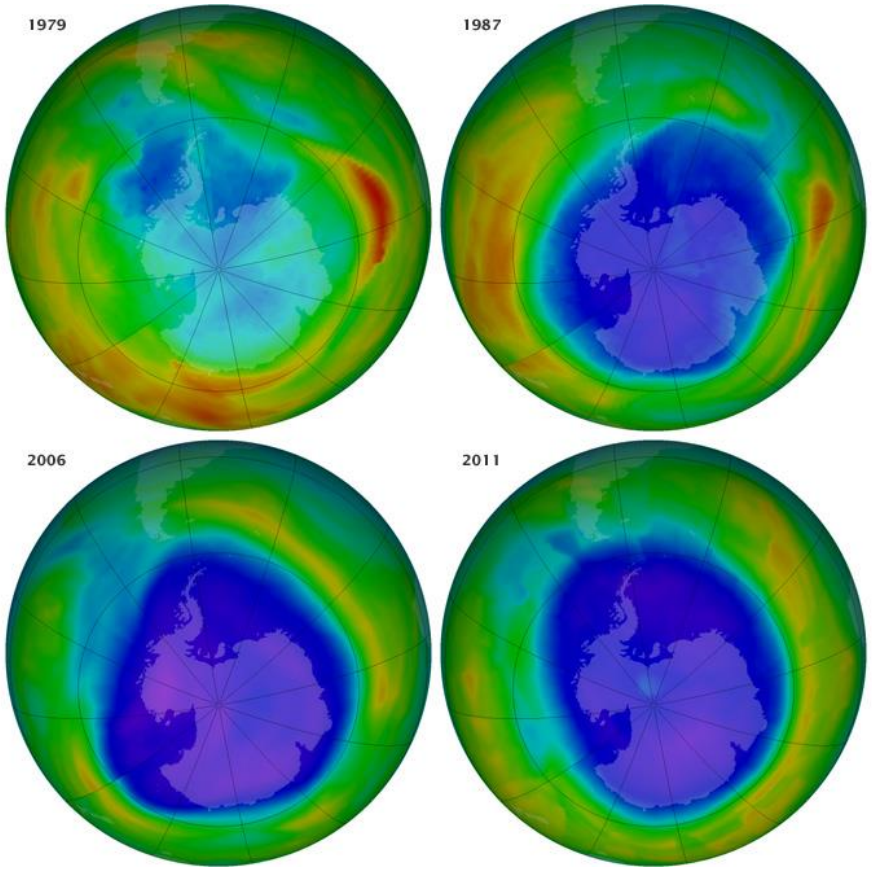
- Global warming:
  - According to the IPCC, there is clear evidence



Source:
IPCC SPM.10, WG I, AR5

The world today: environment challenges

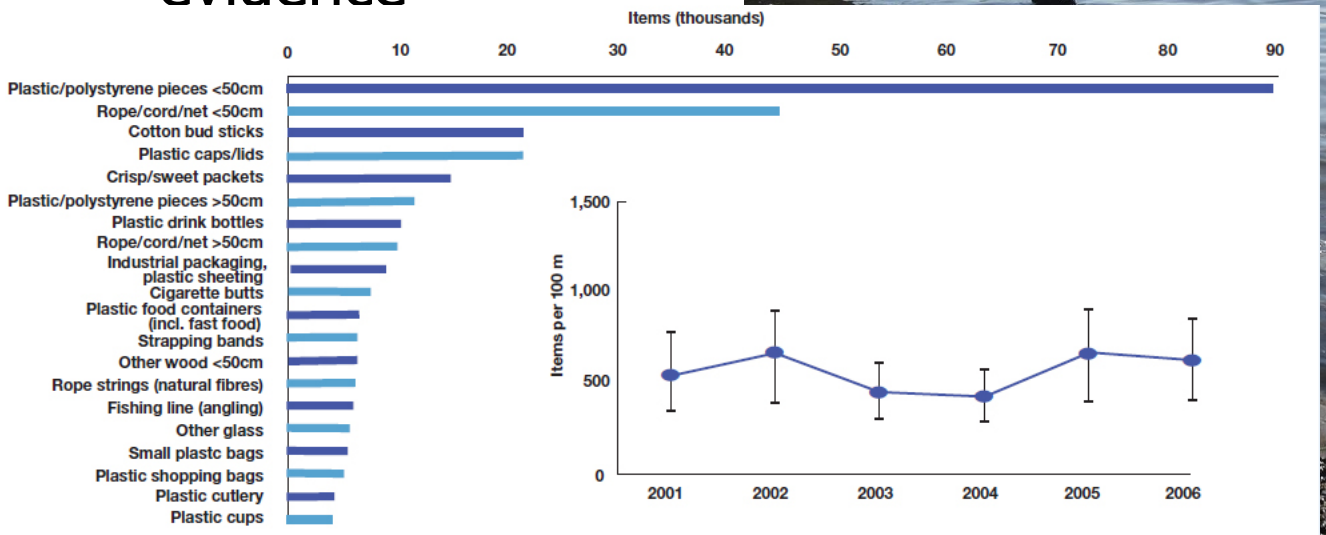
- Ozone layer depletion:
  - According to NASA, there is clear evidence

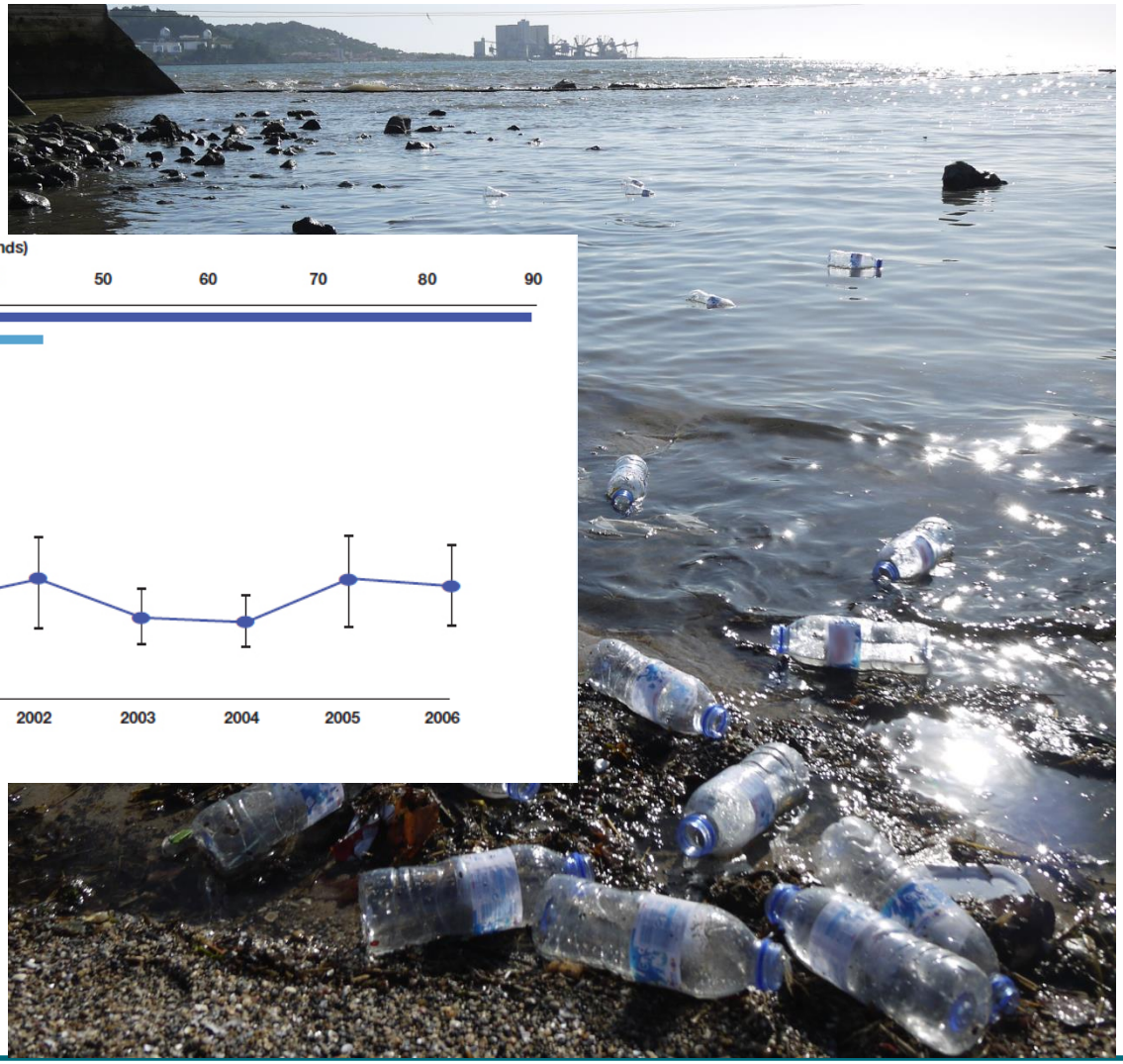


Source:
NASA, USA

The world today: environment challenges

- Waste accumulation:
  - According to the EC, there is clear evidence

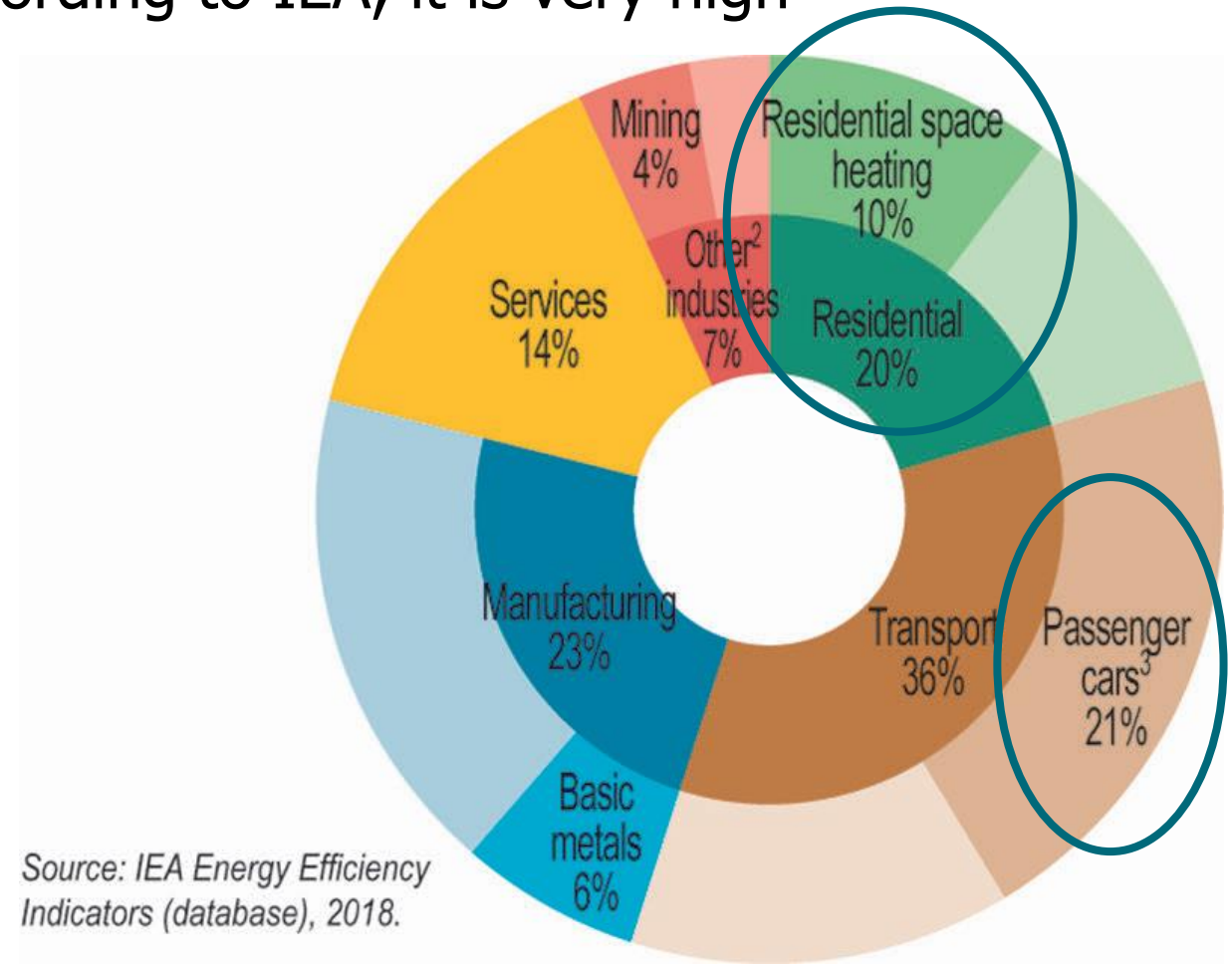




Source:
OSPAR Convention

The world today: the built environment

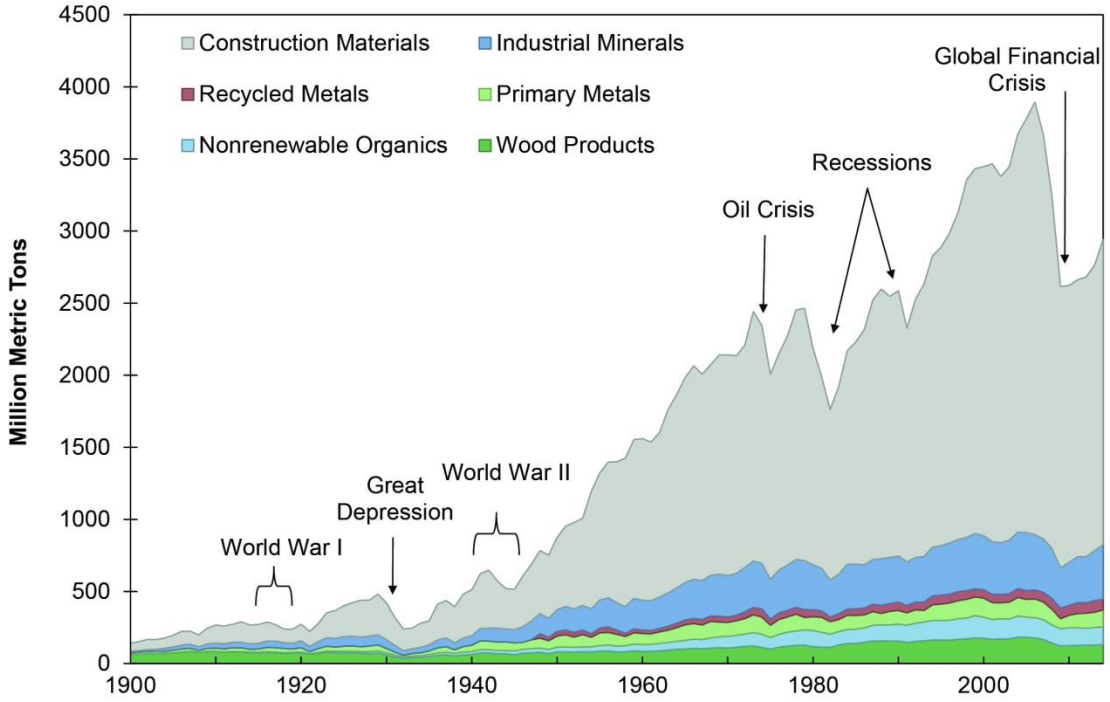
- Role in the energy consumption:
  - According to IEA, it is very high



Source: IEA Energy Efficiency Indicators (database), 2018.

The world today: the built environment

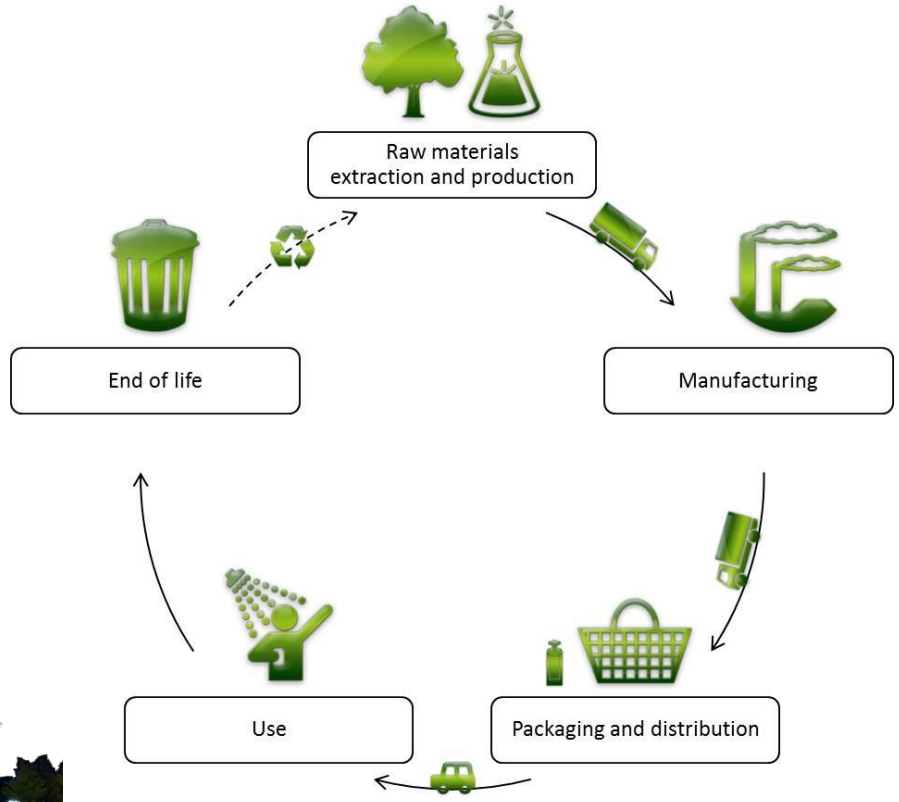
- Role in natural resources consumption:
  - Data is more difficult to get, but it is still evident



Source:
Center for Sustainable Systems, University of Michigan, USA

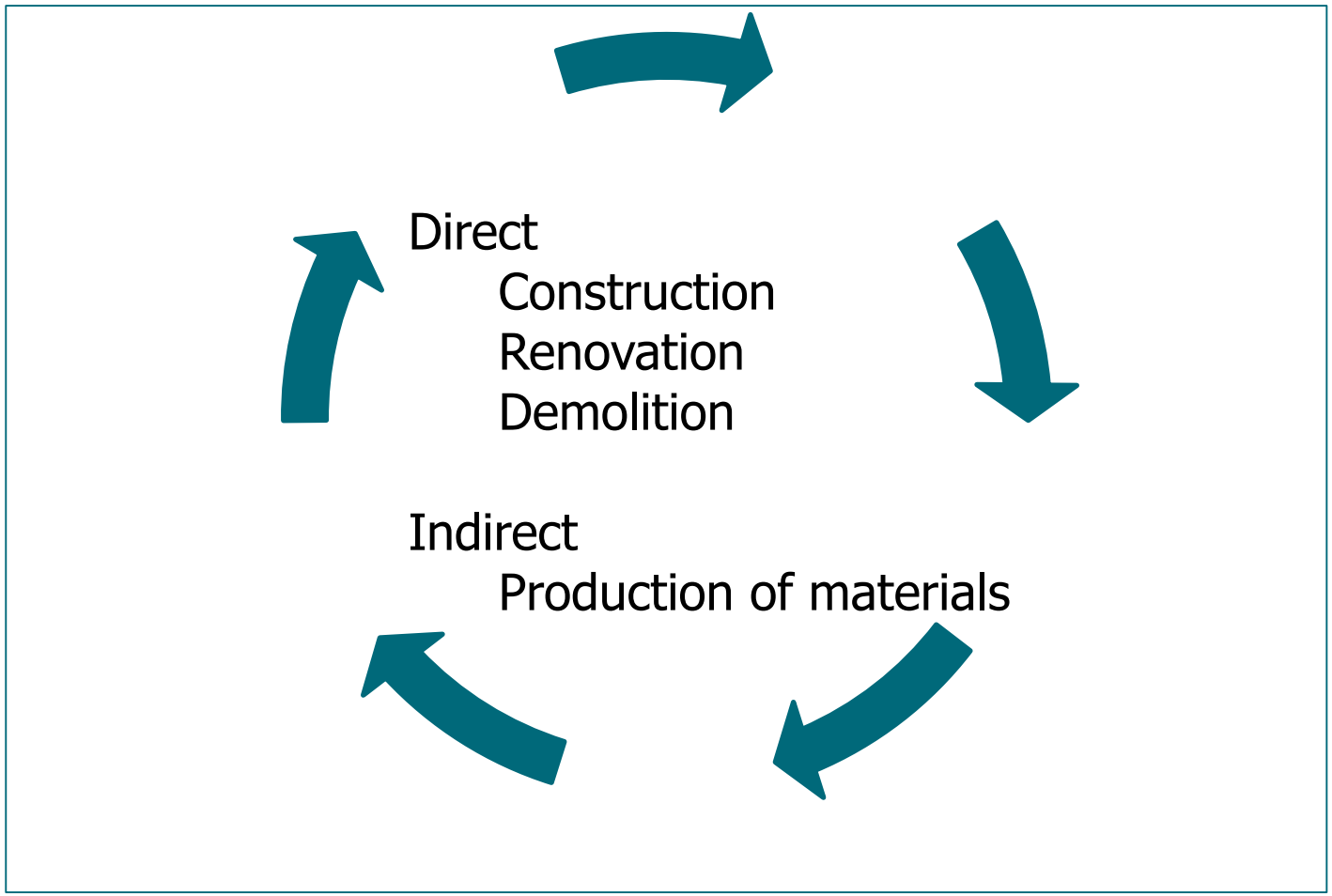
Materials in modern buildings

- Use of materials should include evaluating:
  - Embodied energy in materials
  - Natural resources consumed
  - Raw materials consumed
  - Recycling and safe disposal
  - Impact in the environment



Energy in the built environment

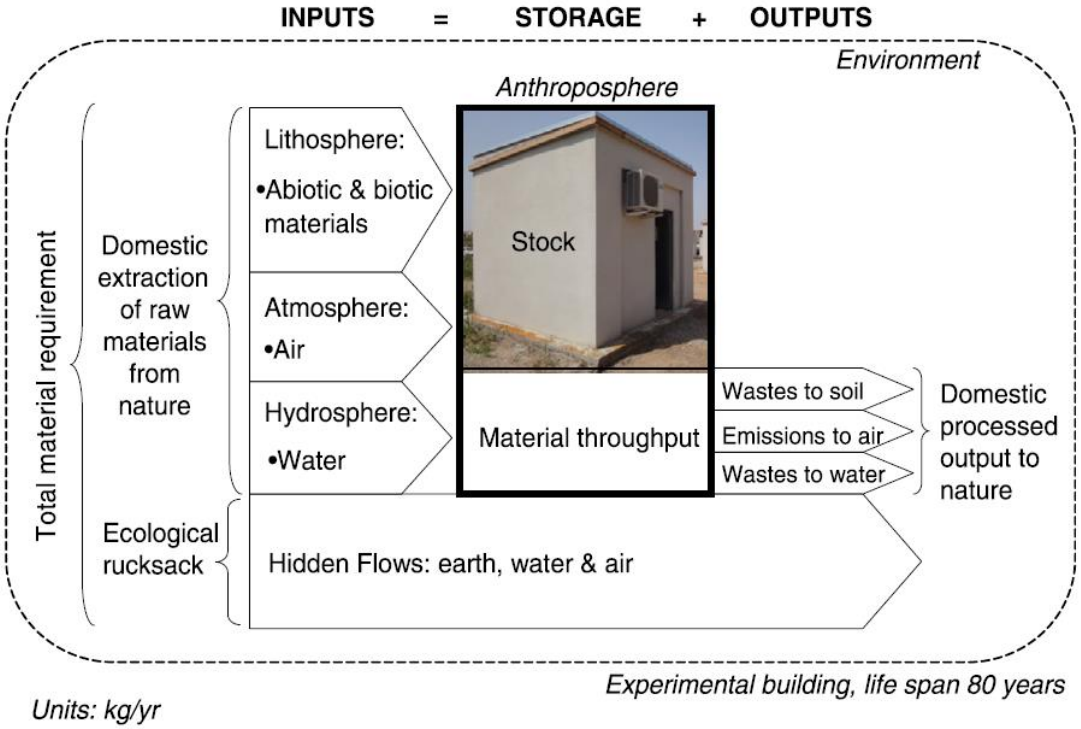
- Use of energy in the building life cycle:



Materials in modern buildings

- MFA (materials flow analysis) may be used to account the materials in one building

$$\sum \dot{m}_{input} = \dot{m}_{storage} + \sum \dot{m}_{output}$$



Source:
Rincon et al. Applied Energy 109 (2013) 544–552

Materials in modern buildings

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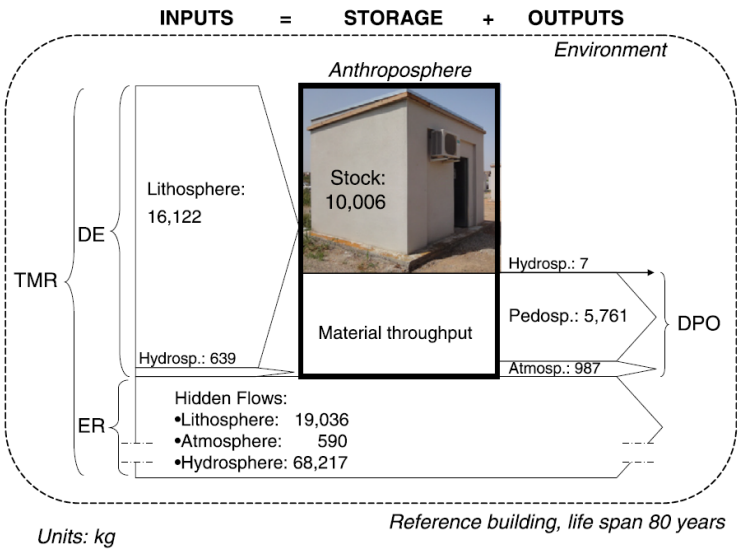
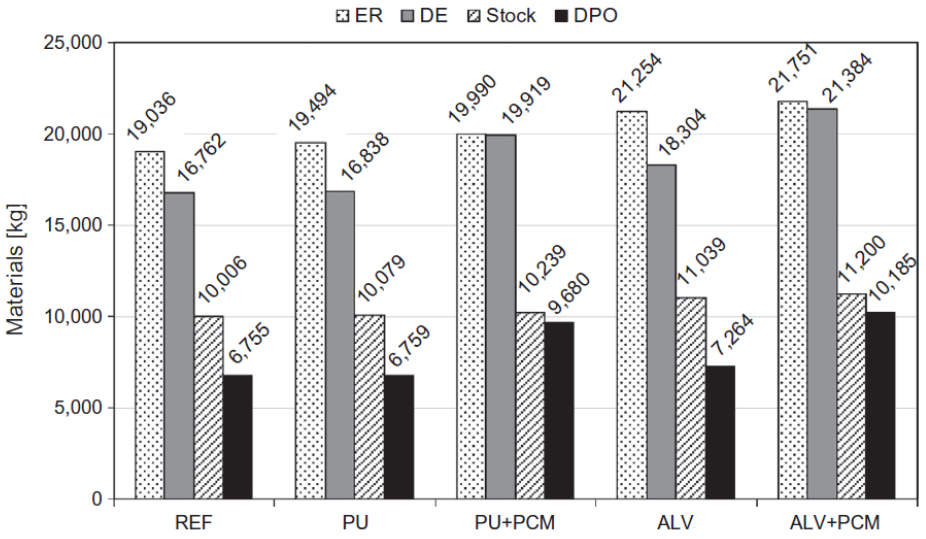




Source:
Rincon et al. Applied Energy 109 (2013) 544–552

Materials in modern buildings

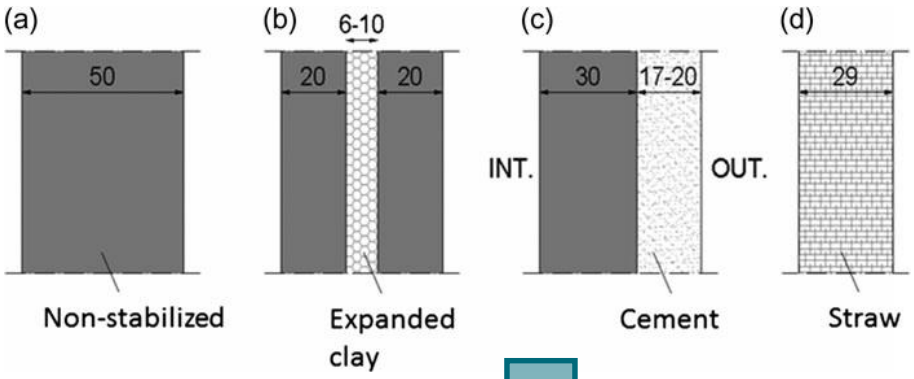
- Use of sustainable materials in modern buildings: rammed earth

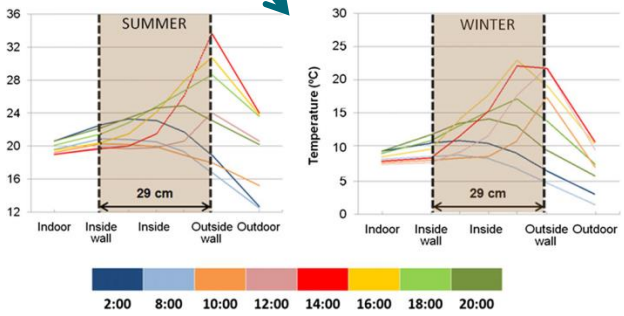
Source: Wikipedia

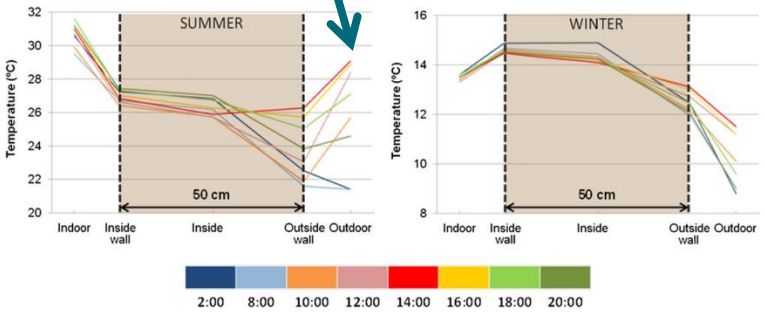
The Graham Sheppard lecture theatre, WISE building
Source: Geograph

Materials in modern buildings

- Use of sustainable materials in modern buildings: rammed earth



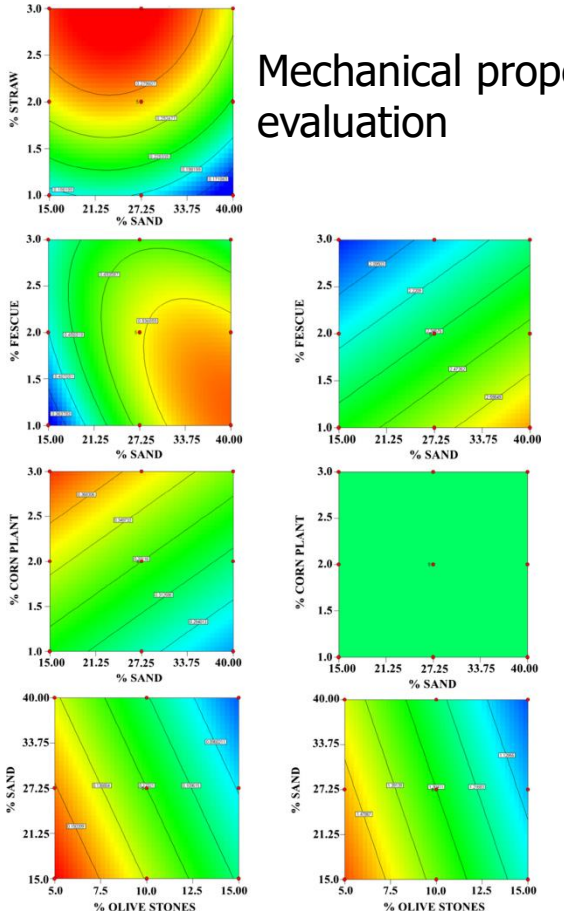




Source:
Serrano et al. Int J Low-Carbon Techn 12 (2017) 281-288

Materials in modern buildings

- Use of sustainable materials in modern buildings: rammed earth

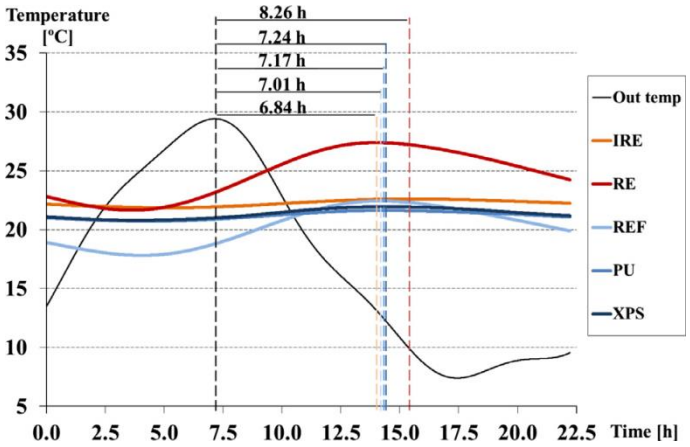


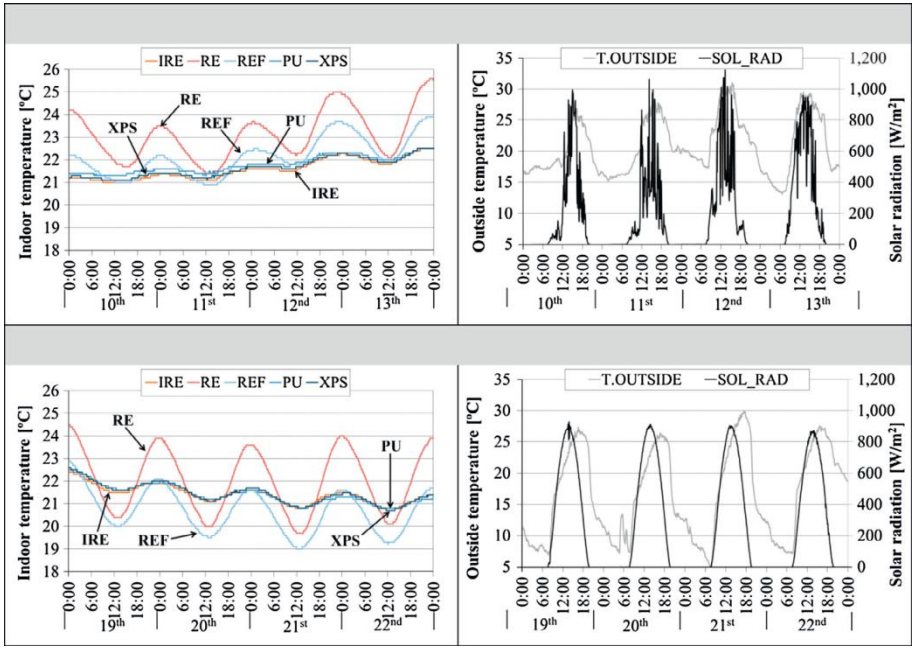
Mechanical properties evaluation

Source:
Serrano et al. Const & Build Mat 47 (2013) 872-878
Serrano et al. Const & Build Mat 108 (2016) 105-111

Materials in modern buildings

- Use of sustainable materials in modern buildings: rammed earth
  - Thermal behaviour





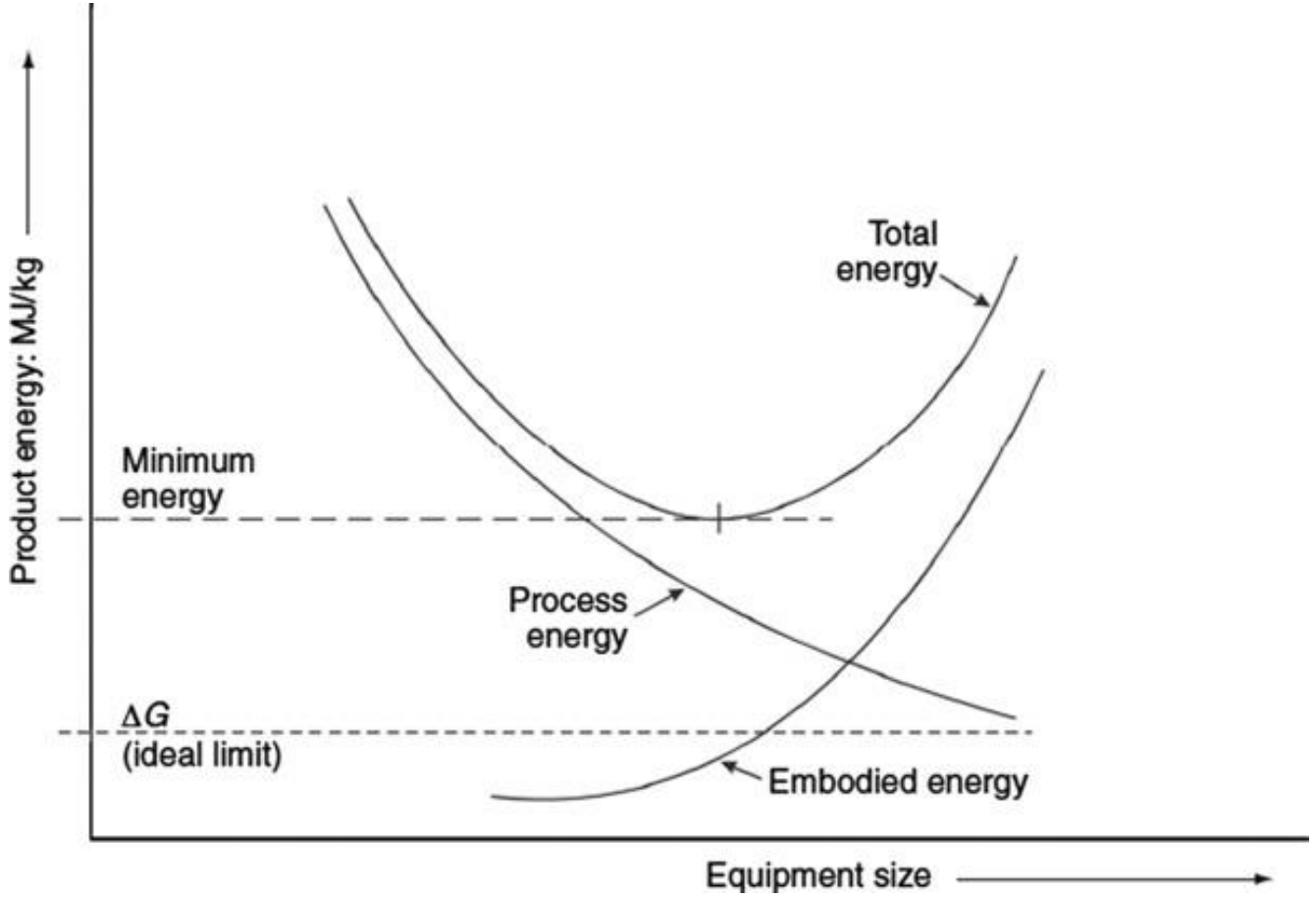
Source:
Serrano et al. Applied Energy 175 (2016) 180-188

Energy in the built environment

- Embodied energy in building materials
- Even when energy efficient strategies are implemented
- Embodied energy should compensate the reduction of operational energy

Energy in the built environment

- Embodied energy in building materials

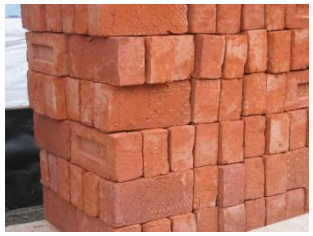


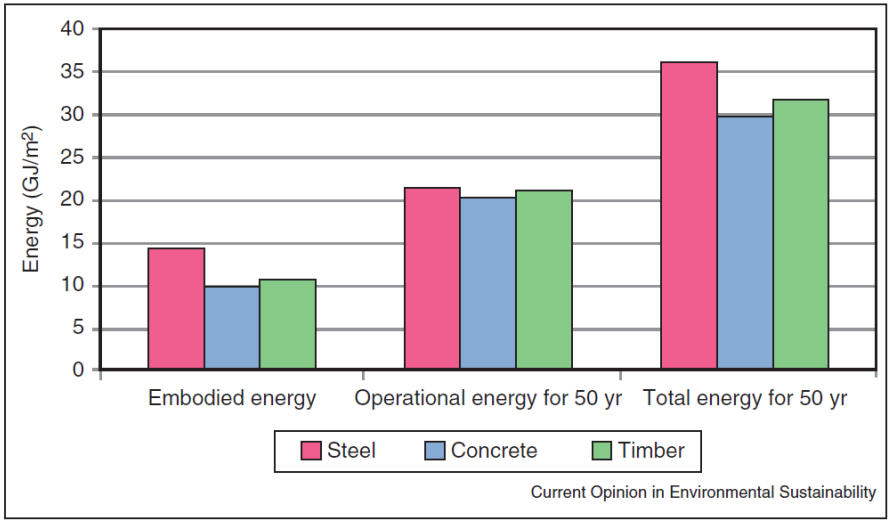
Source:
Hammond Applied Energy 84 (2007) 675-700

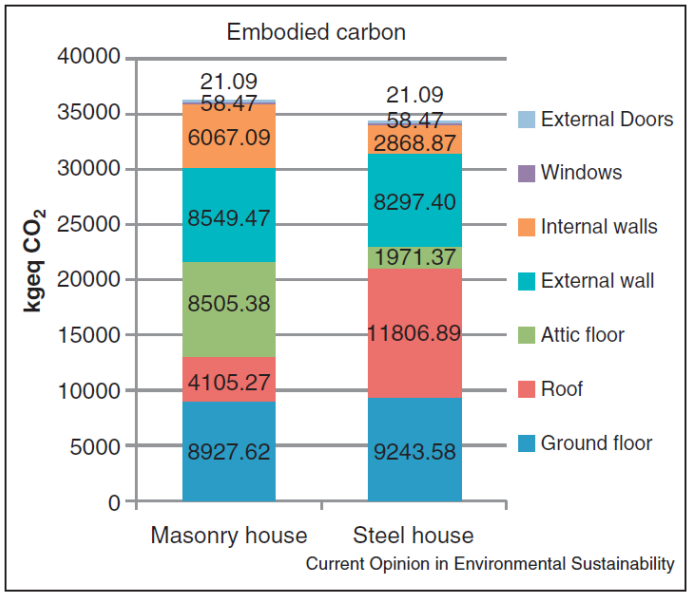
Energy in the built environment

- Embodied energy in building materials
  - Materials used in buildings
    - Concrete
    - Wood
    - Bricks
    - Sandstone







Source:
Cabeza et al. CoSUST 5 (2013) 229-236

Energy in the built environment

- Embodied energy in buildings
  - Energy sequestered in building materials during all processes of production, on-site construction, and final demolition and disposal
- Operating energy
  - Expended in maintaining the inside environment through processes such as heating and cooling, lighting, and operating appliances

Life cycle assessment

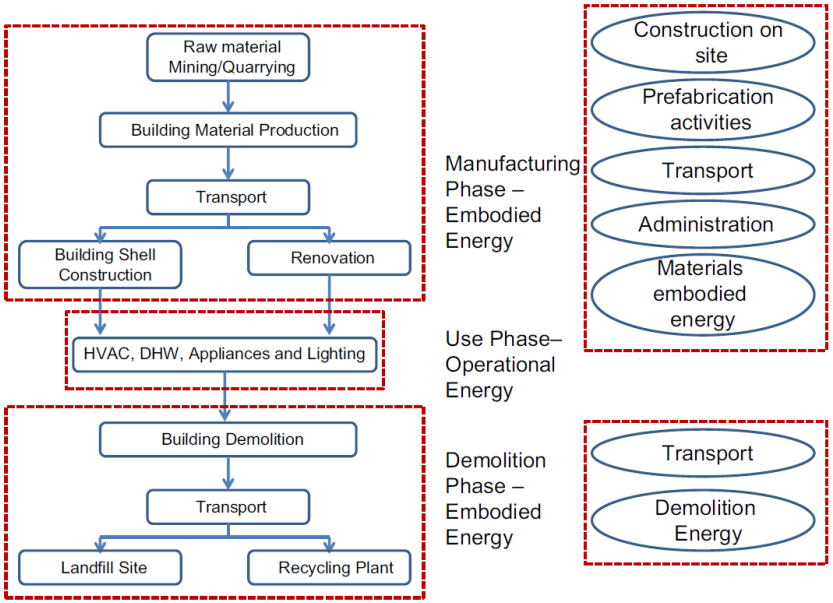
Source:
Cabeza et al. Renew & Sust Ener Rev 23 (2013) 536-542

Energy in the built environment

- Embodied energy in building materials
- Even when energy efficient strategies are implemented
- Embodied energy should compensate the reduction of operational energy

LCA of the built environment

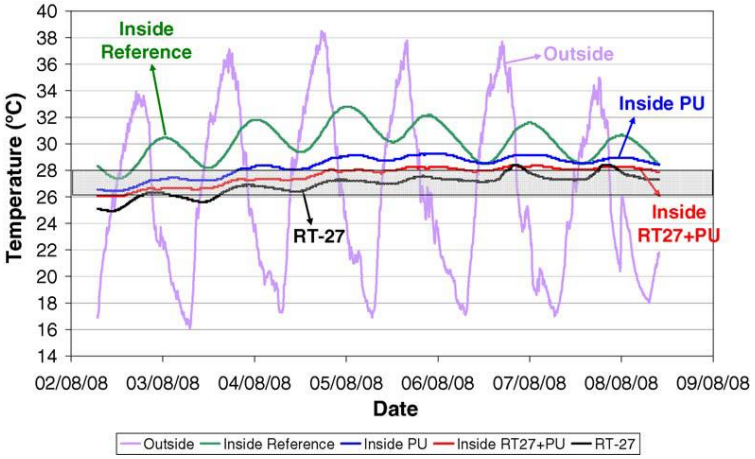
- LCA
  - It is a tool for systematically analysing the environmental performance of products/processes over their entire life cycle (material extraction, manufacturing, use, and end-of-life disposal and recycling)

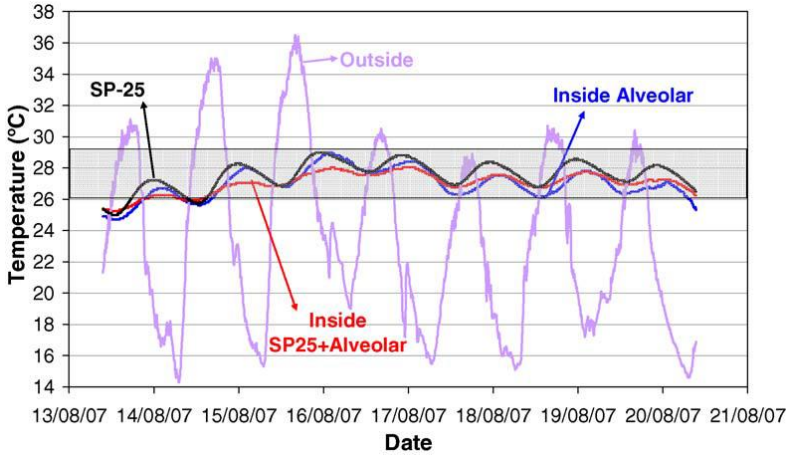


Source:
Cabeza et al. Renew & Sust Ener Rev 29 (2014) 394-416

LCA of the built environment: an example

- LCA of using PCM for passive cooling





Source:
Castell et al. Energy and Buildings 42 (2010) 534-540

LCA of the built environment: an example

- LCA of using PCM for passive cooling

Accumulated energy consumption and savings for the different cubicles.

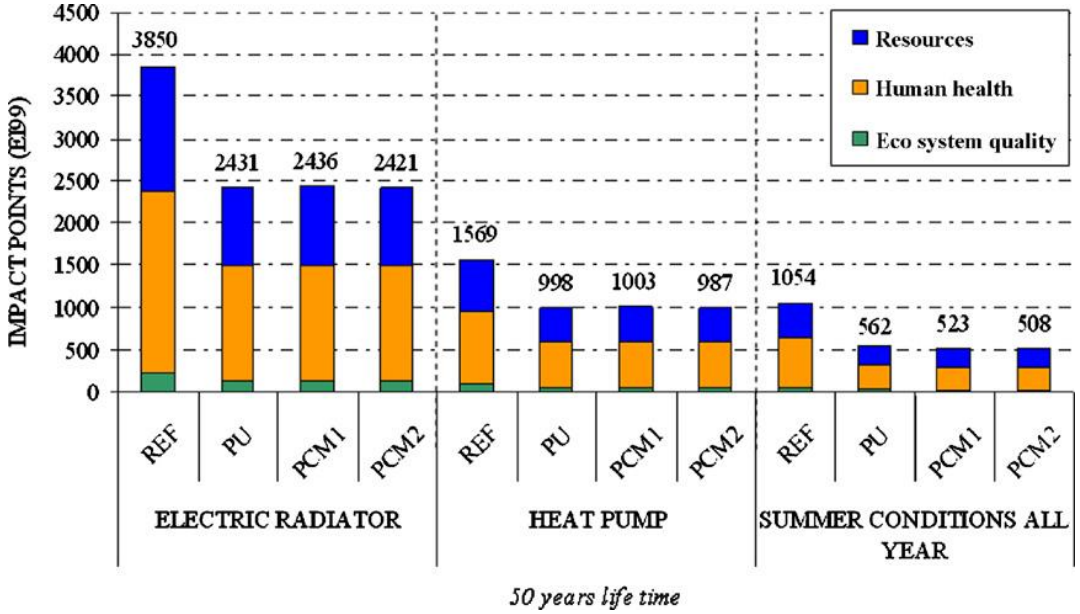
	Energy consumption[a] (Wh)	Energy savings[b] (Wh)	Energy savings[b] (%)	Improvement[c] (%)
Reference	9376	0	0	–
PU	4583	4793	51.12	0
RT27 + PU	3907	5469	58.33	14.75
Alveolar	5053	4323	46.11	0
SP25 + Alveolar	4188	5188	55.33	17.12

[a] Set point of 24 °C during 5 days.
[b] Referred to the Reference cubicle.
[c] Referred to the cubicle with analogue constructive solution and without PCM.

Source:
Castell et al. Energy and Buildings 42 (2010) 534-540

LCA of the built environment: an example

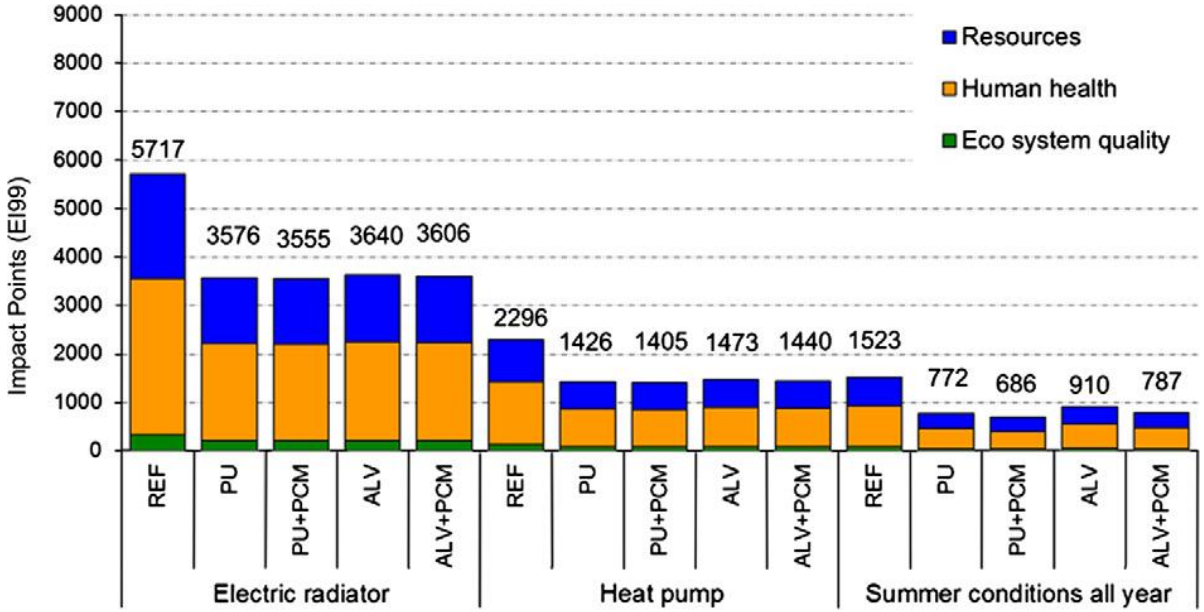
- LCA of using PCM for passive cooling



Source:
de Gracia et al. Energy and Buildings 42 (2010) 1517-1523

LCA of the built environment: an example

- LCA of using PCM for passive cooling



Source:
de Gracia et al. Applied Energy 101 (2013) 600-608

Energy use in cities

- Increase of ambient temperature:
  - Deteriorates the outdoor and indoor comfort condition
  - Increases stress to vulnerable populations
- Reduction of energy use, use of renewable energies, changes towards circular economy (recycle of wastes), needed for more resilient cities (cities with higher ability to react to stresses and shocks related to climate change)

Drivers needed in our cities

- Energy and materials

- Water
- Wastes

We want to still have…

Acknowledgements

The work partially funded by the Spanish government (ENE2015-64117-C5-1-R (MINECO/FEDER).

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Thank you for your attention!

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