LABORATÓRIO NACIONAL
DE ENGENHARIA CIVIL

CONCRETE
A MATERIAL FOR SUSTAINABLE CONSTRUCTION

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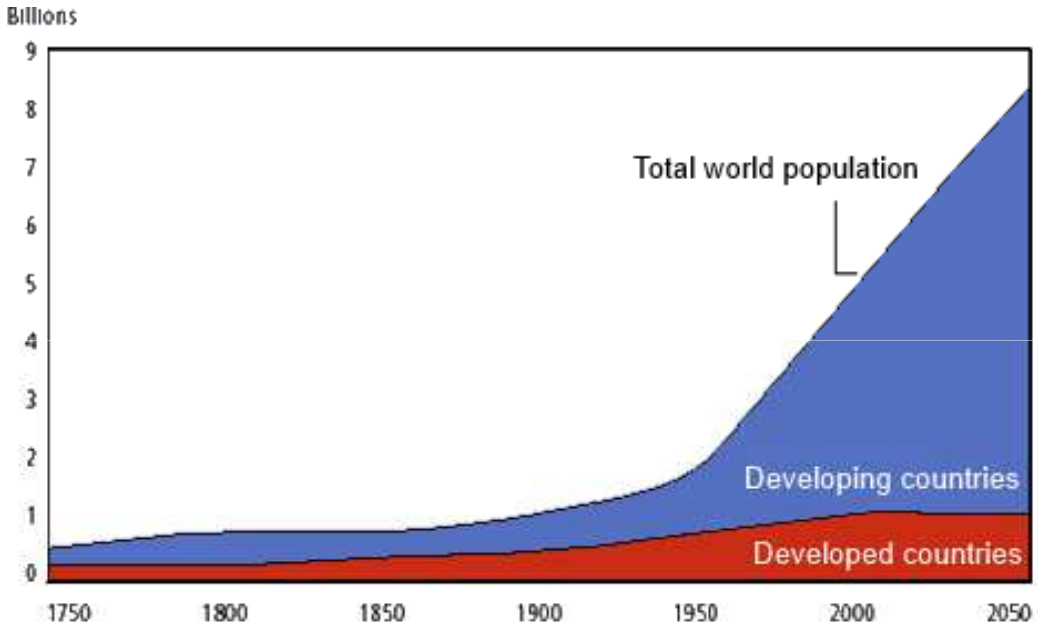
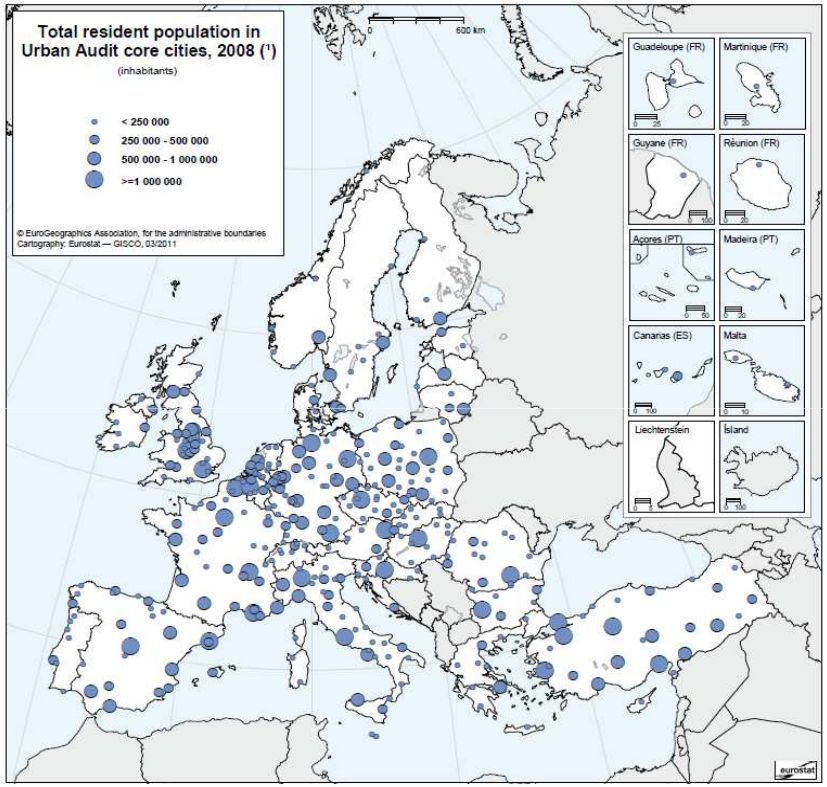
BACKGROUND

Expanding global population





Increased social needs for improved quality of life.

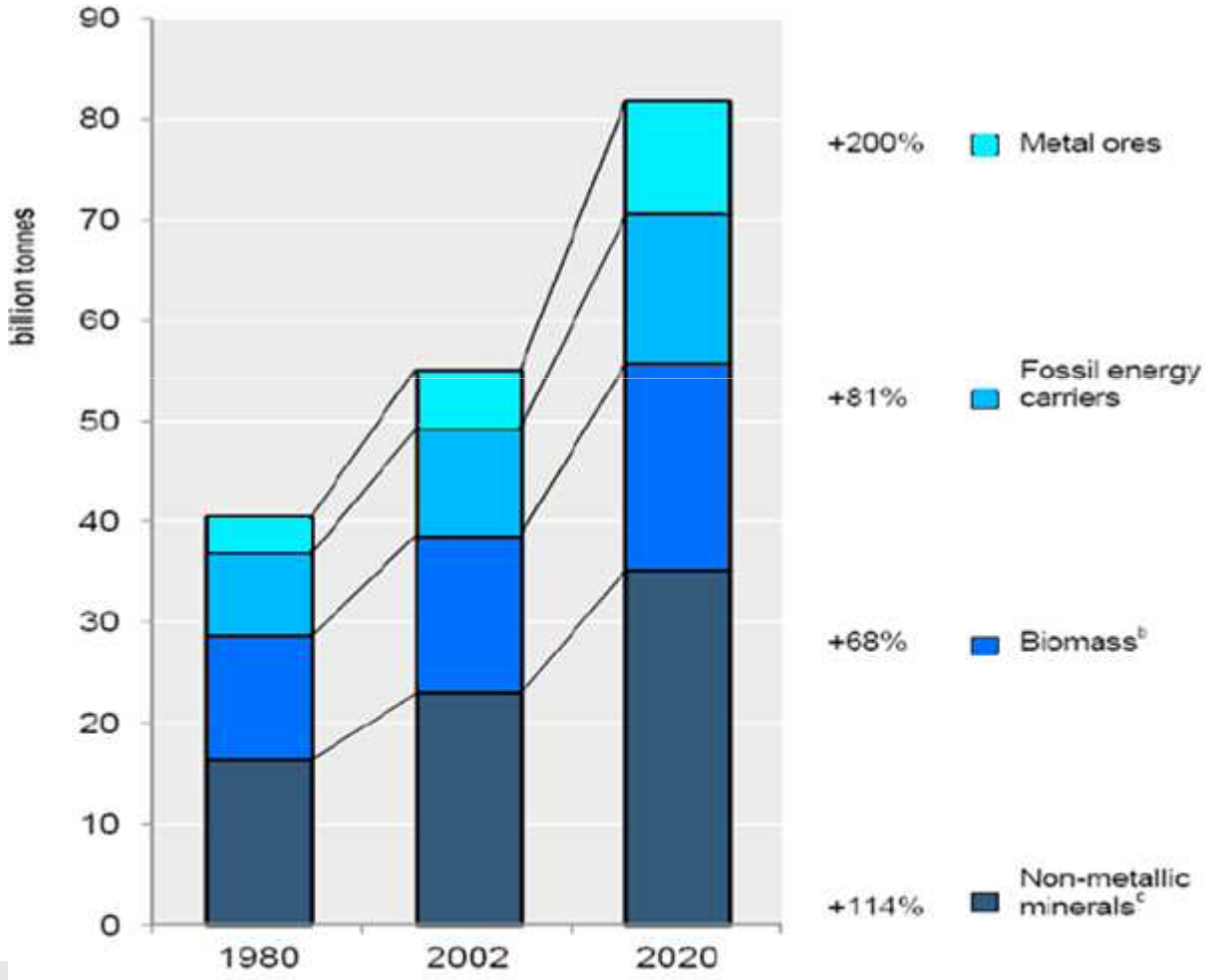
Population in urban areas:

68% - 2008 80% - 2020

BACKGROUND

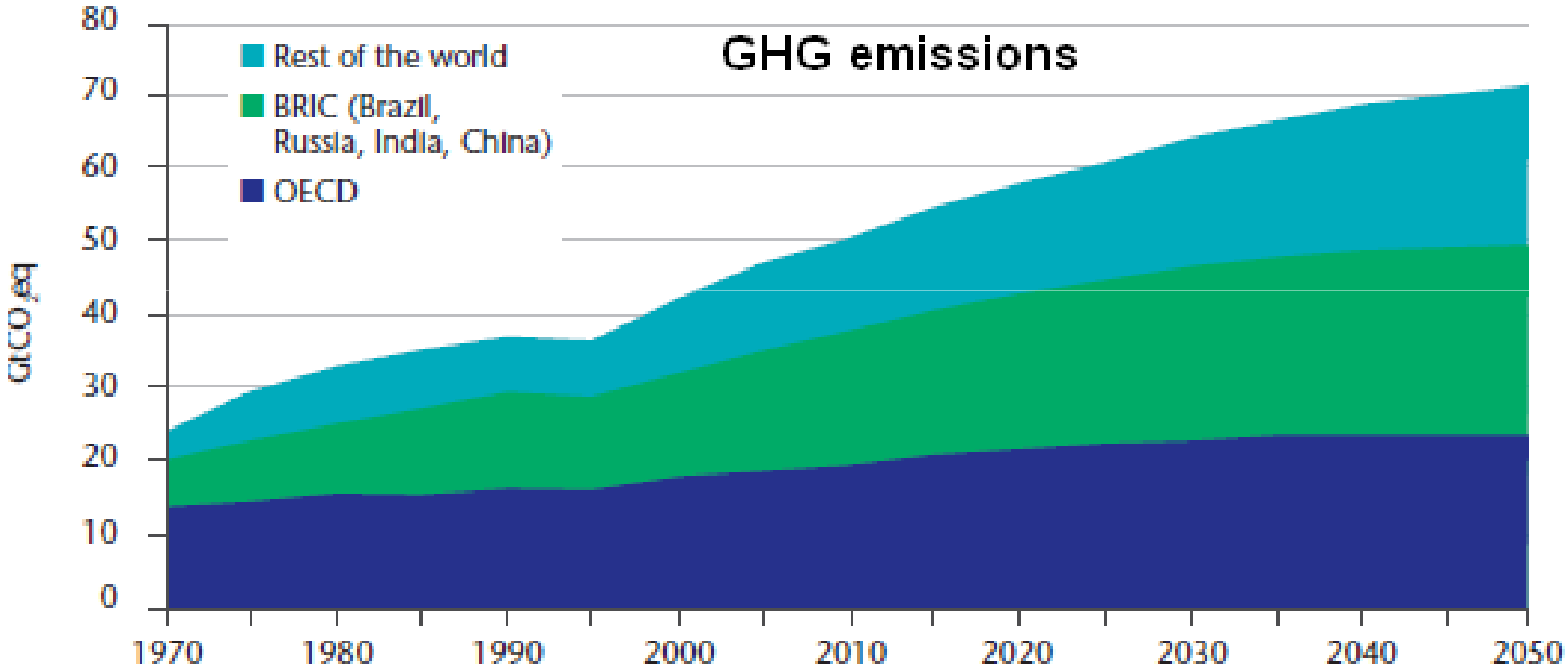
Increased pressure on the environment

Growing demand of raw materials and natural resources



BACKGROUND

Increased pressure on the environment



Higher level of GHG emissions

SUSTAINABLE DEVELOPMENT

Definition:

"meeting the needs of the present generation without compromising the ability of future generations to meet their own needs"

(Brundtland Commission, 1987)

"an enduring, balanced approach to economic activity, environmental responsibility and social progress"

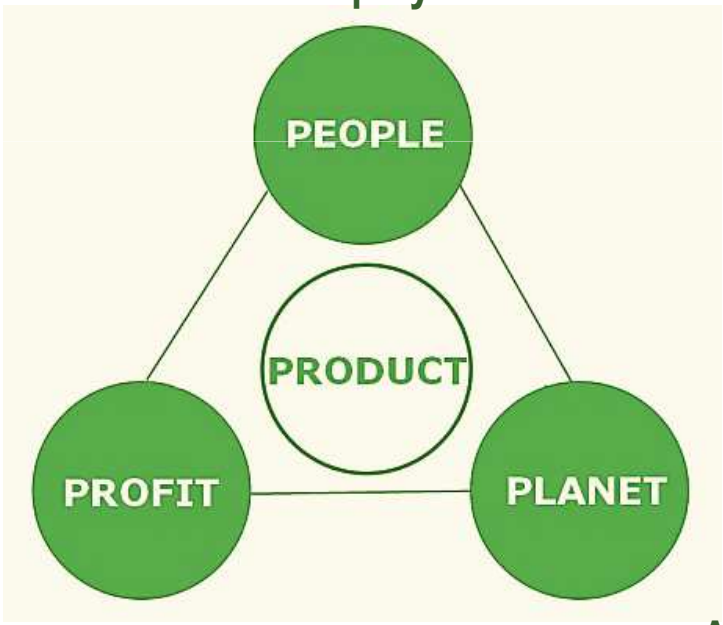
(BS 8905)

"ability of a system to be maintained for the present and future generations"

(EN 15643)

SUSTAINABLE DEVELOPMENT

- Dimensions of sustainable development:
  - Environmental
  - Social
  - Economic



Sustainability is relevant for construction sector!

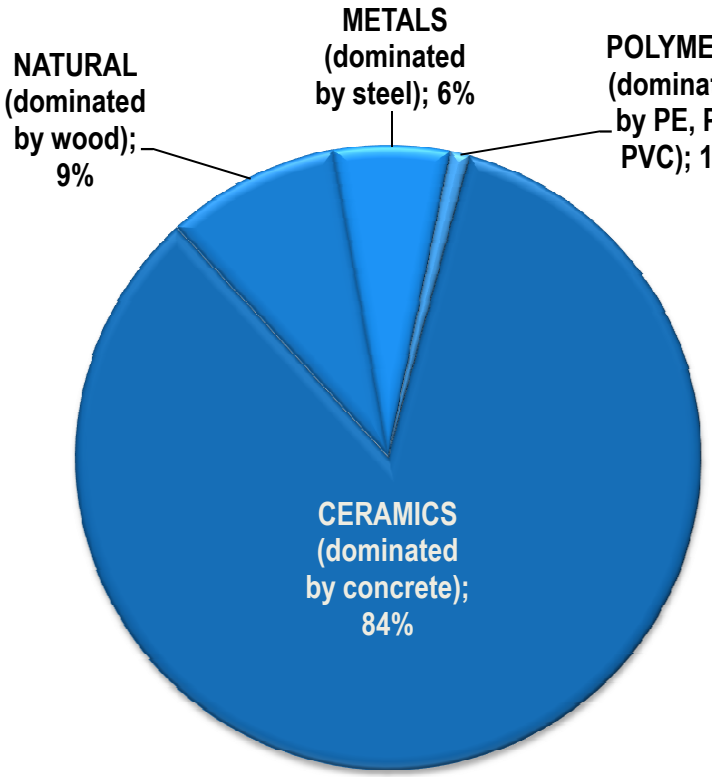
- Consumes 40% of the materials entering the global economy;
- Generates 40–50% of the global output of GHG emissions;
- Produces about 1/3 of the world waste.

SUSTAINABLE CONSTRUCTION

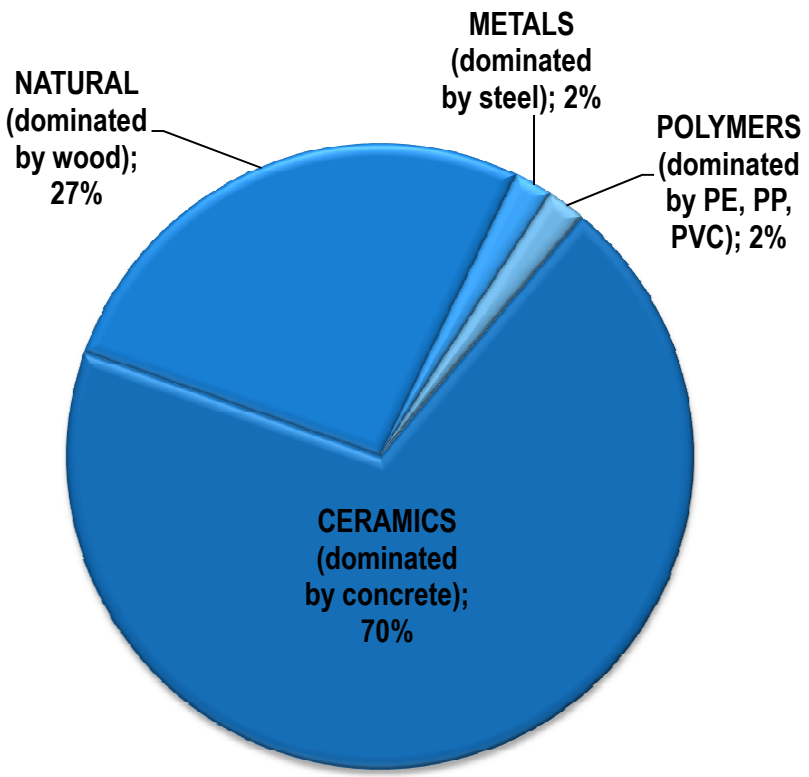
- Existing materials
  - Correct choice and application
  - Improving characteristics and production technologies
  - Recycling
- New materials
  - More sustainable over the 3 dimensions

CONCRETE

Concrete is the most widely used construction and building material



By weight



By volume

CONCRETE

- Availability
- Durability
- Versatility

Transparent concrete - LiTraCon

CONCRETE

DURABILITY

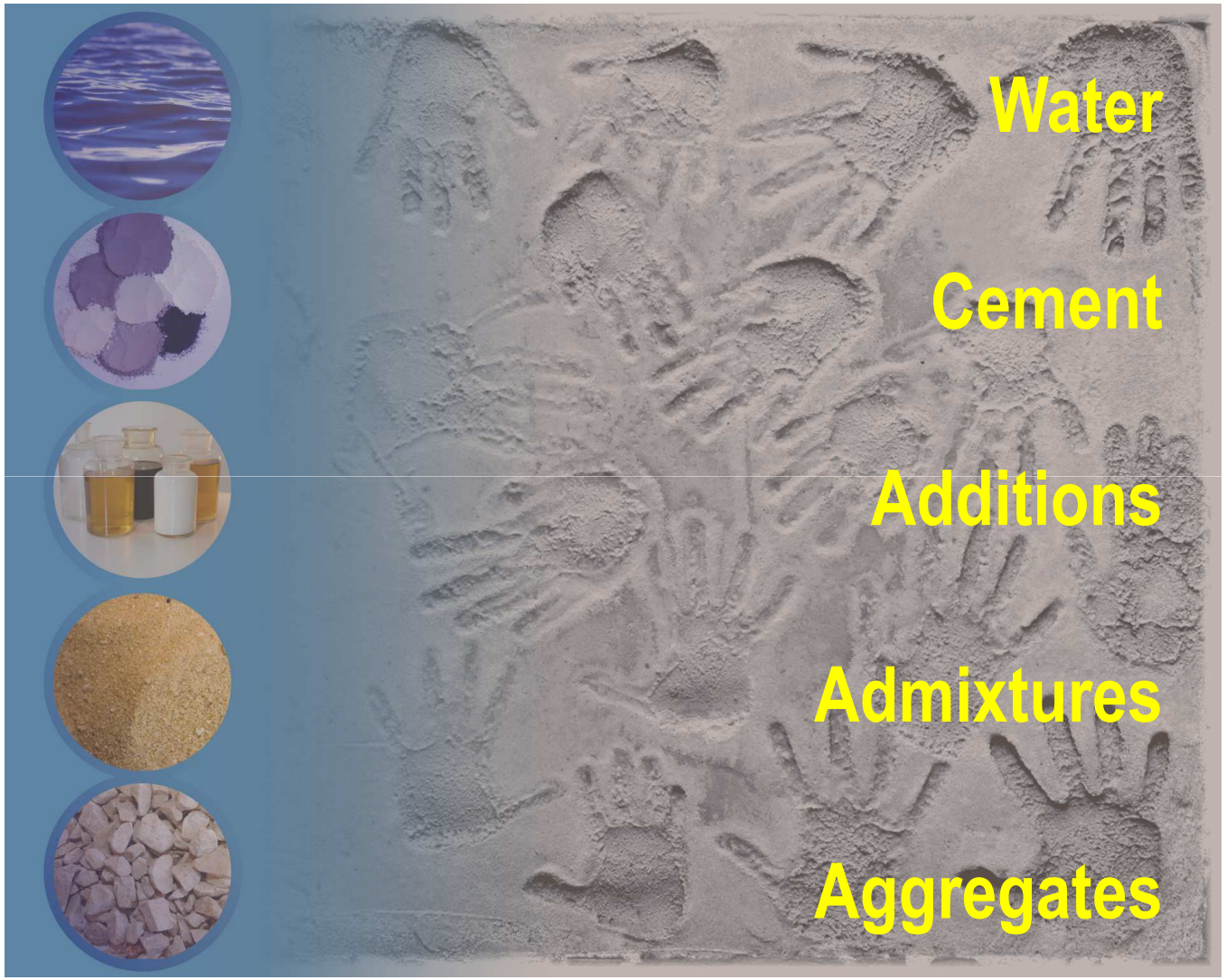
- Long service life
- Safety
- Lower maintenance/repair
- Reduced costs

Durability of concrete is an environmental benefit in a cradle-to-grave life cycle analysis.

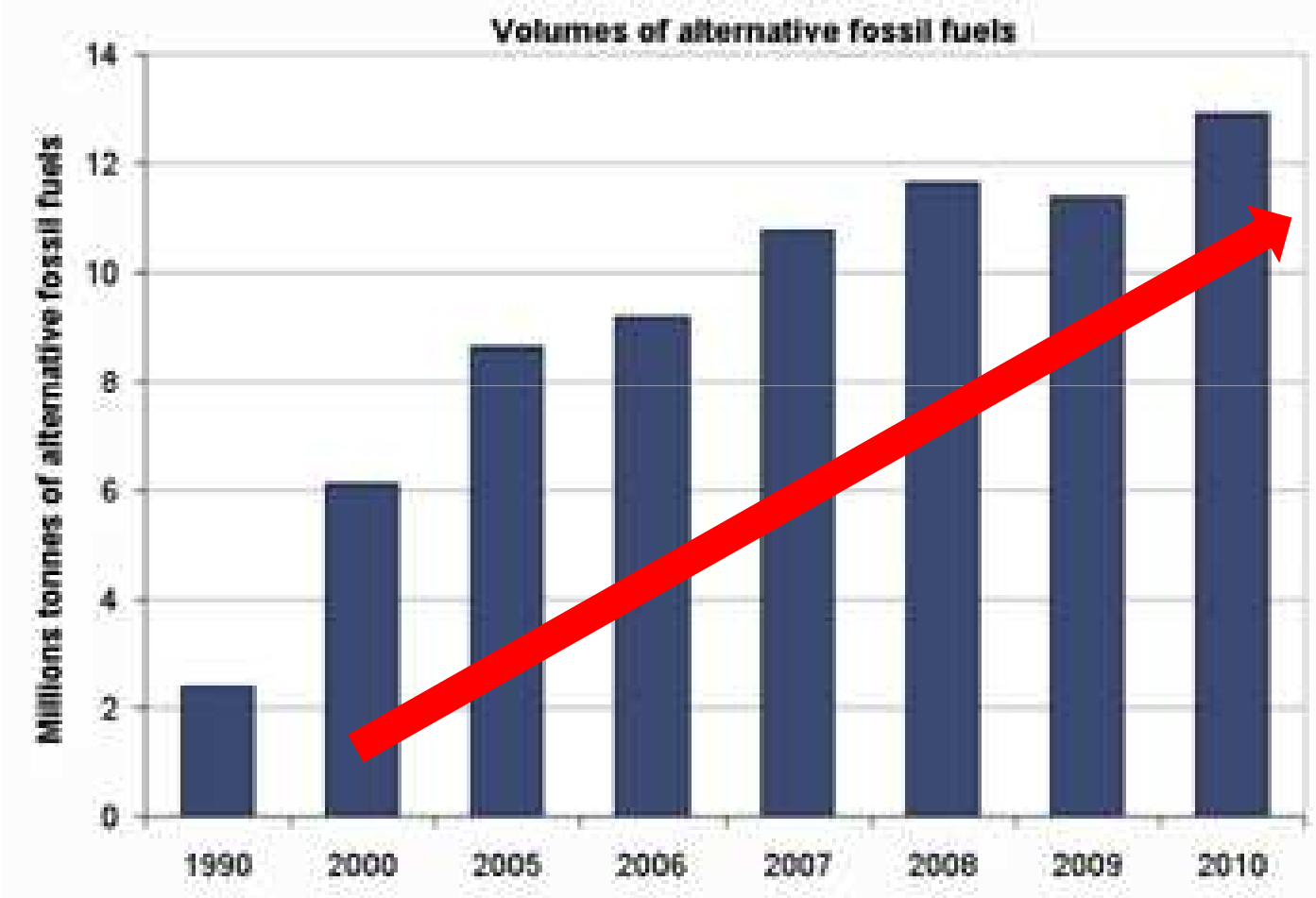
Alqueva Dam - Portugal

Vasco da Gama Bridge

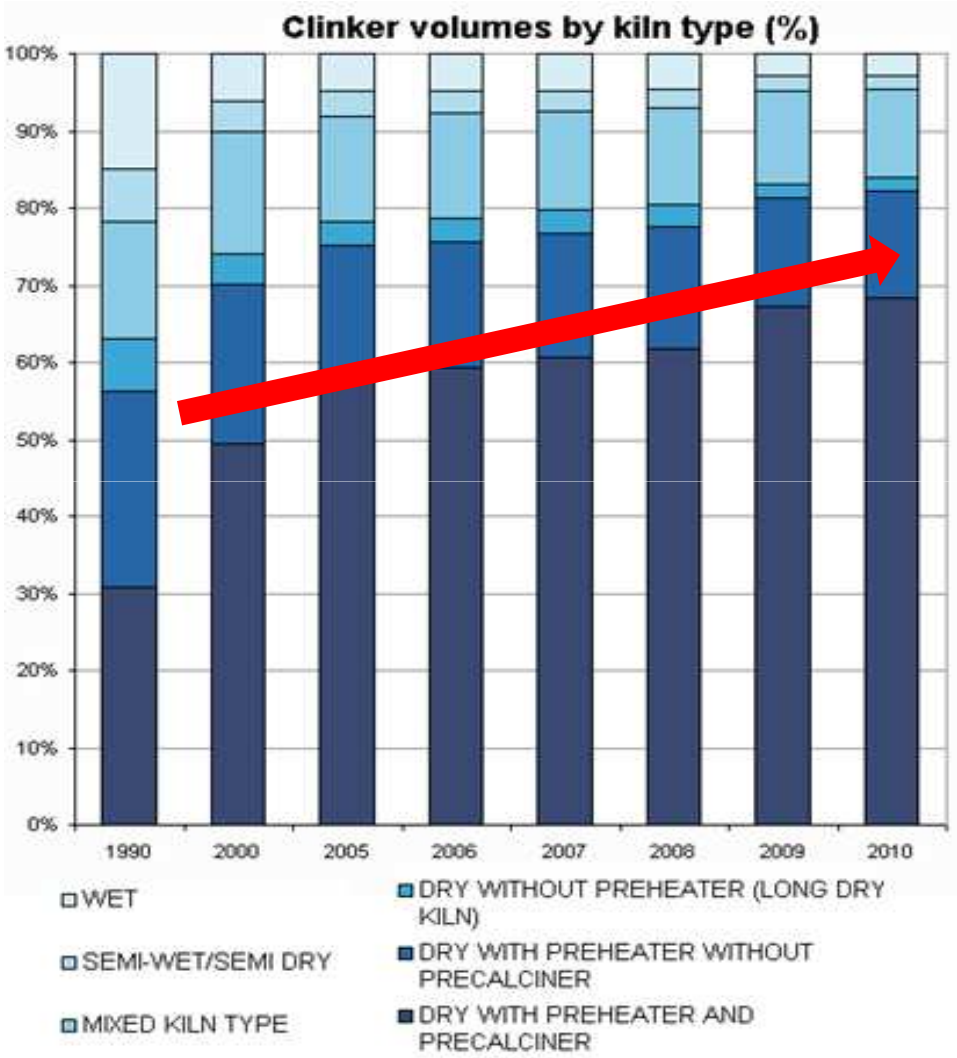
CONCRETE



CEMENT - Fuels

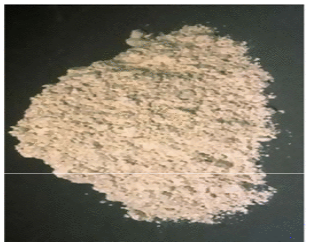


CEMENT - Technology

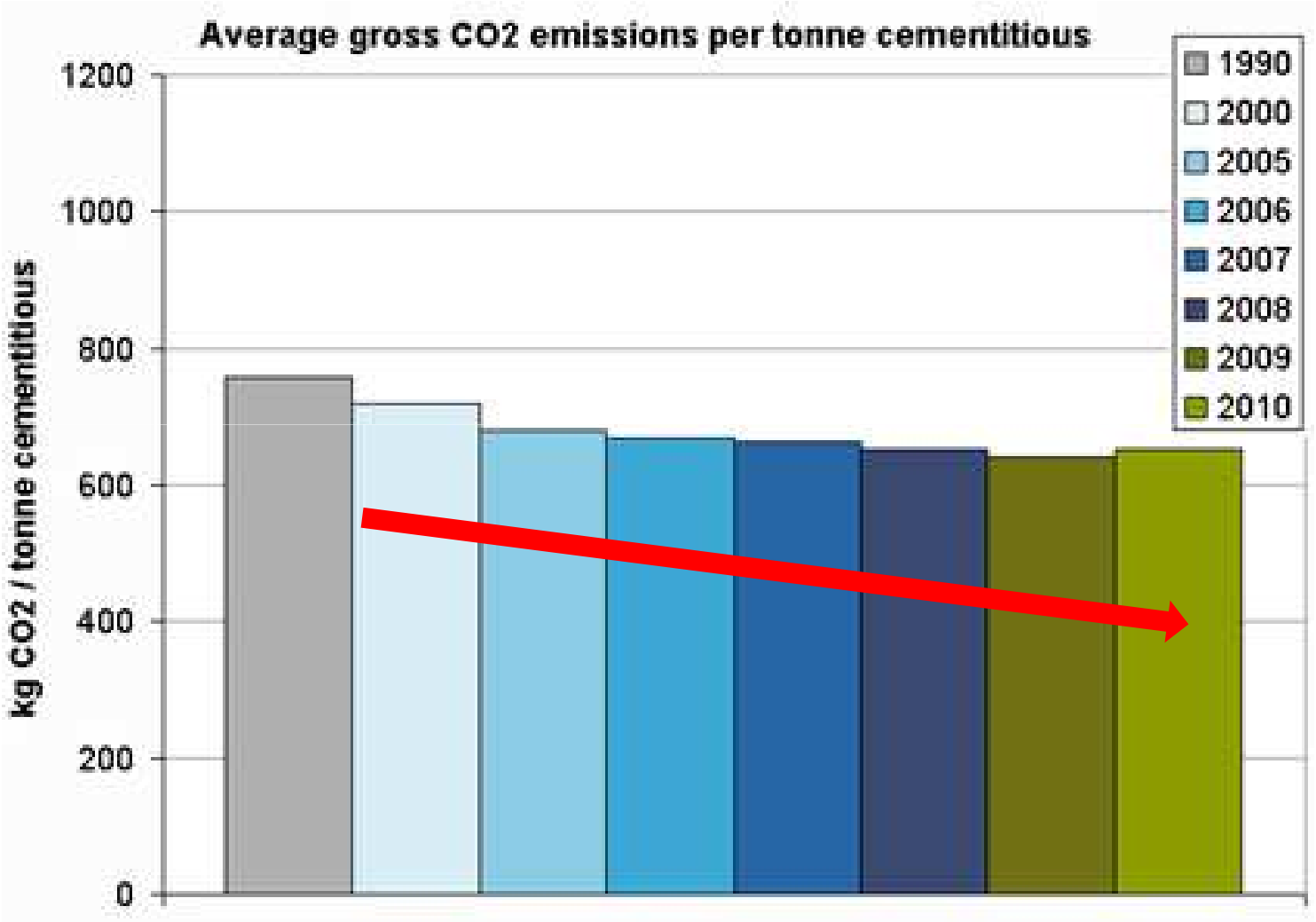


Supplementary Cementing Materials (SCM)

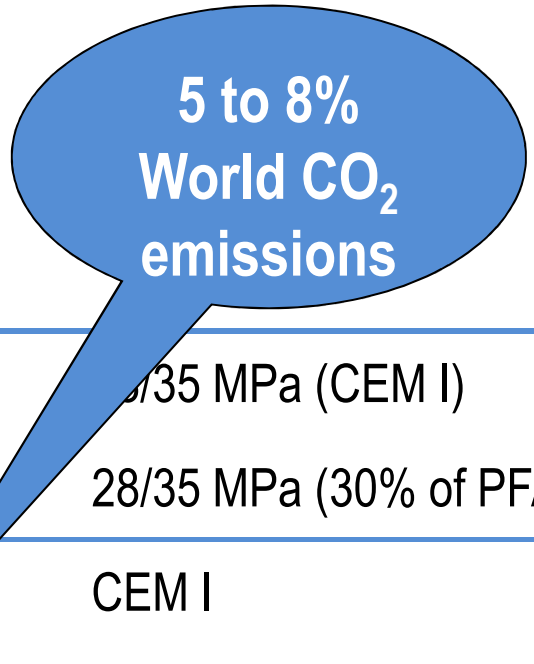
- Coal fly ash
- Silica fume
- Ground granulated blast furnace slag
- Metakaolin
- Rice Husk Ash
- Natural pozzolans



CEMENT – CO_2 emissions



Supplementary Cementing Materials



Material		Primary embodied energy	CO_2 emissions
		MJ/kg	kg CO_2eq/kg
Concrete	/35 MPa (CEM I)	0.95	0.148
	28/35 MPa (30% of PFA)	0.82	0.124
Cement	CEM I	5.5	0.95
	CEM II/B-V (21 - 35% of PFA)	4.45 a 3.68	0.75 a 0.62

ICE V2.0 University of Bath

New binders

- Alkali-activated aluminosilicate binders obtained by interaction of a concentrated alkali hydroxide solution and an aluminosilicate (FA, GGBFS, etc).

- For binders of comparable performance CO2 savings on the order of 80% could be achieved in relation to Portland cement

New binders

- Belite–calcium sulphoaluminate–ferrite cements reduces CO_2 emissions of cement plants by 20 to 30%;

- Partially prehydrated C–S–H-based binders – decrease of 50% CO_2 emissions.

*In "A physico-chemical basis for novel cementitious binders", **by Ellis M. Gartner** and **Donald E. Macphee** (2011)*

Chemical admixtures

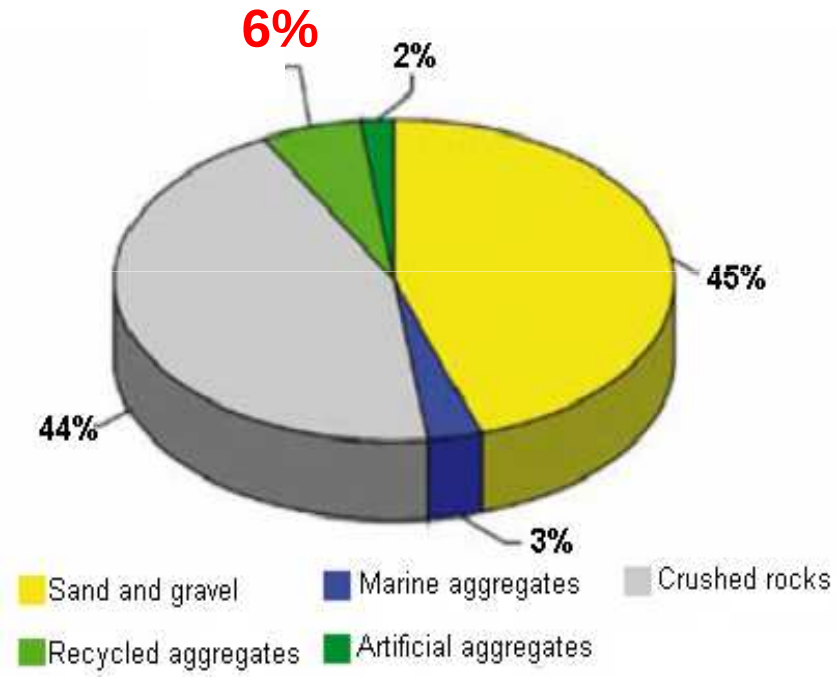
- Allow the decrease of mixing water and therefore the production of concrete with improved compressive strength and durability

- Enable the development of concrete technologies like concrete pumping, self-compacting, shotcreting or underwater concreting.
- *The contribution of admixtures to CO_2 emissions on concrete production is very low.*

Alternative aggregates

- Recycled concrete aggregate
- “Mixed” recycled aggregates
- Recycled tire rubber
- …

Recycled aggregates



UEPG

Low recycling is related to:

- No taxes for landfilling of CDW
- Low cost of virgin aggregates
- Quality assurance of recycled aggregates

BARRIERS TO A MORE SUSTAINABLE CONCRETE

- Local availability of the new constituent materials
- Insufficient knowledge by industry practitioners
- Lack of long-term data on durability of “green concretes”

SUSTAINABLE CONSTRUCTION

- In the near future the choice of materials will be dependent on their sustainability
  - The choice is also possible within each category of products
- The environmental dimension of sustainability has received so far more attention
- The Environmental Product Declaration is the first step to assess product sustainability

Environmental product declaration (EN 15804)

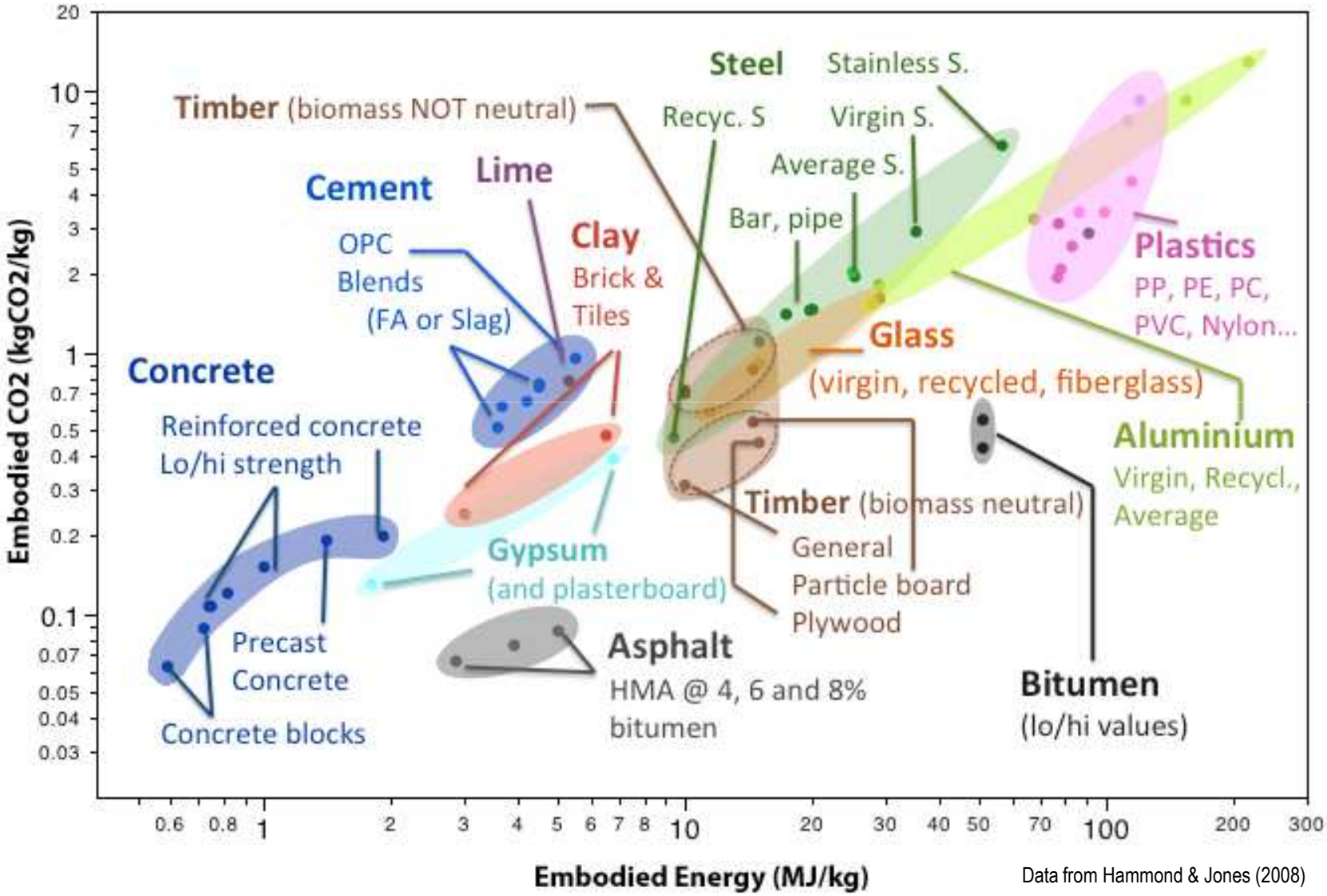
- Indicators describing environmental impacts
  - e.g. global warming
- Indicators describing resource use
  - e.g. total use of renewable primary energy resources
- Indicators describing waste categories
  - e.g. hazardous waste disposed
- Indicators describing the output flows leaving the system
  - e.g. materials for recycling

ENVIRONMENTAL IMPACT

Indicators for environmental impacts

- Abiotic depletion potential:
  - Elements;
  - Fossil fuels;
- Acidification of land and water resources;
- Destruction of the stratospheric ozone layer;
- Eutrophication;
- Formation of ground-level ozone;
- Global warming potential.

CONCRETE versus other materials



Data from Hammond & Jones (2008)

CONCRETE

	Density (kg/m^3)	Embodied energy		Carbon footprint	
		MJ/kg	MJ/m^3	kg/kg	kg/m^3
Primary structure					
Aggregate	1,500	0.10	150	0.006	9
Brick, common	2,100	2.8	5,880	0.22	462
Concrete 30 MPa	2,450	1.3	3,180	0.095	233
Concrete block	2,500	0.94	2,350	0.061	151
Concrete, high-volume fly-ash	2,010	1.14	2,290	0.068	137
Concrete, precast	1,390	2.00	2,780	0.12	167
Concrete, reinforced (8 wt% steel)	2,910	2.49	7,250	0.21	611
Concrete, standard	2,390	1.14	2,700	0.1	239
Soil cement (rammed earth)	1,950	0.42	819	0.03	55
Steel, virgin	7,850	27	212,000	1.8	14,100
Steel, 100% recycled	7,850	7.3	57,300	0.57	4,470
Steel, typical 42% recycled content	7,850	18.7	147,000	1.23	9,660
Straw bale	125	0.22	27	−099	−12
Timber, structural	550	7.3	1,380	0.42	230

HOW TO “COMPARE” SUSTAINABILITY?

- Comparison of construction materials based on:
  - Weight?
  - Volume?
  - Performance?
  - Cradle to gate?
  - Cradle to grave?

Materials or solutions shall always fulfil the same requirements

ENVIRONMENTAL PRODUCT DECLARATION

BUIDING LIFE CYCLE INFORMATION

Product stage

(A1-A3)

- **A1 Raw materials supply**
- **A2 Transport**
- **A3 Manufacturing**

Construction stage

(A4-A5)

- **A4 Transport**
- **A5 Construction-installation process**

Use stage

(B1-B7)

- **B1 Use**
- **B2 Maintenance**
- **B3 Repair**
- **B4 Replacement**
- **B5 Refurbishment**
- **B6 Operational energy use**
- **B7 Operational water use**

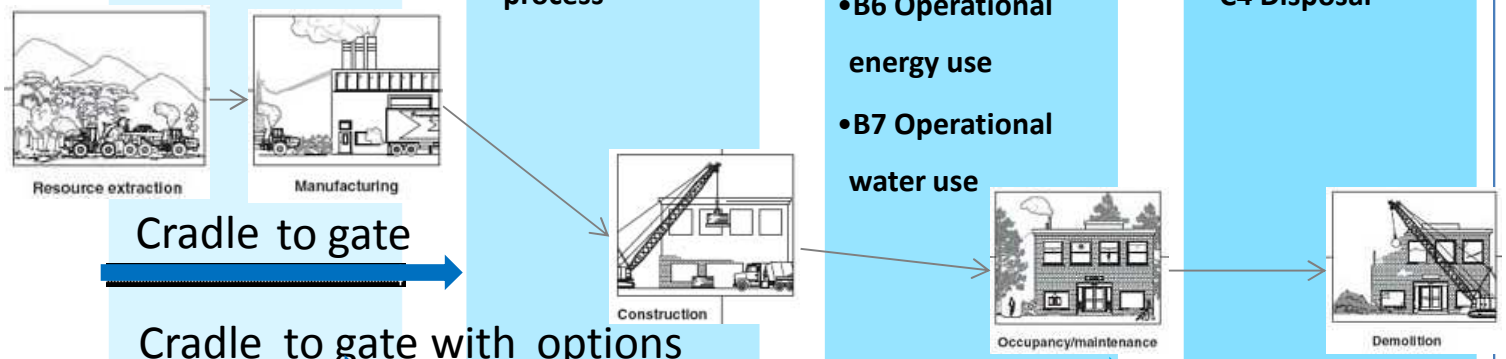
End of life stage

(C1-C4)

- **C1 Deconstruction**
- **C2 Transport**
- **C3 Waste processing**
- **C4 Disposal**

Benefits and loads beyond system boundary (D)

- **Reuse potential**
- **Recovery potential**
- **Recycling potential**



SUSTAINABILITY ASSESSMENT

All LCA stages included:

- Comparison can be performed with products that allow different solutions and different performance

LCA cradle-to-gate:

- Only equal performance allows product comparison

*For products, A **Functional Unit** is used to quantify their performance characteristics*

SUSTAINABILITY ASSESSMENT

The most adequate Functional Unit used on LCA of concrete should address its performance at the level of strength and at the level of service life:

- Amount of binder per m^3 of concrete needed to deliver 1 MPa of strength and 1 year of service life;
- Amount of concrete necessary for a slab that will be under a specific mechanical load and service life.

SUSTAINABILITY ASSESSMENT

Even without taking into account the economical and social issues it is necessary to weigh the environmental impacts.

Different weightings → Different decisions

SUSTAINABILITY ASSESSMENT

Different schemes give different results

BREEAM 2011		LEED 2009		
Environmental Section	**Max. Weighted % Points**	**Environmental Category**	**Weighting**	**Max. Points**
Land Use & Ecology	10%	Sustainable Sites	23.6%	26
Water	6%	Water Efficiency	9.1%	10
Energy	19%	Energy & Atmosphere	31.9%	35
Materials	12.5%	Materials & Resources	12.7%	14
Health & Wellbeing	15%	Indoor Environmental Quality	13.6%	15
Transport	8%	Innovation in Design	5.5%	6
Waste	7.5%	Regional Priority	3.6%	4
Pollution	10%			
Management	12%			
Innovation (additional)	10%			
Total	**110%**	**Total**	**100%**	**110**

EPD - Concrete

- The development of Environmental Product Declaration relies on the definition of the Product Category Rules (PCR) that ensure a consistent assessment for the product
- Development of PCR for concrete, as a standard or as a technical report, will be made within CEN for all concretes covered by EN 206.
- This document should harmonise PCR already elaborated by other parties.

EPD - Concrete

- The WBCSD Cement Sustainability Initiative prepared PCR for unreinforced concrete, complying with EN 15804, which entered into force on February 2013.

Compressive strength class
Environmental exposure class

Included	Excluded
Ready mixed concrete	Aircrete blocks
Concrete blocks	Reinforced concrete including
Concrete kerbstones	fibre cement
Mortar.	

EPD - Concrete

- This PCR covers the product stage, i.e., raw material supply, transport, manufacturing and associated processes. Transport to site and construction stages could also be incorporated
- Under the cradle-to-gate approach the declared unit include relevant aspects of functionality

  - **Concrete**: 1 m3 of concrete with a given compressive strength class, environmental exposure class as per EN 206 relevant to the potential use of the product in the building or construction works (density shall be specified);
  - **Concrete Blocks**: 1 block with a given strength (dimensions and density to be specified).

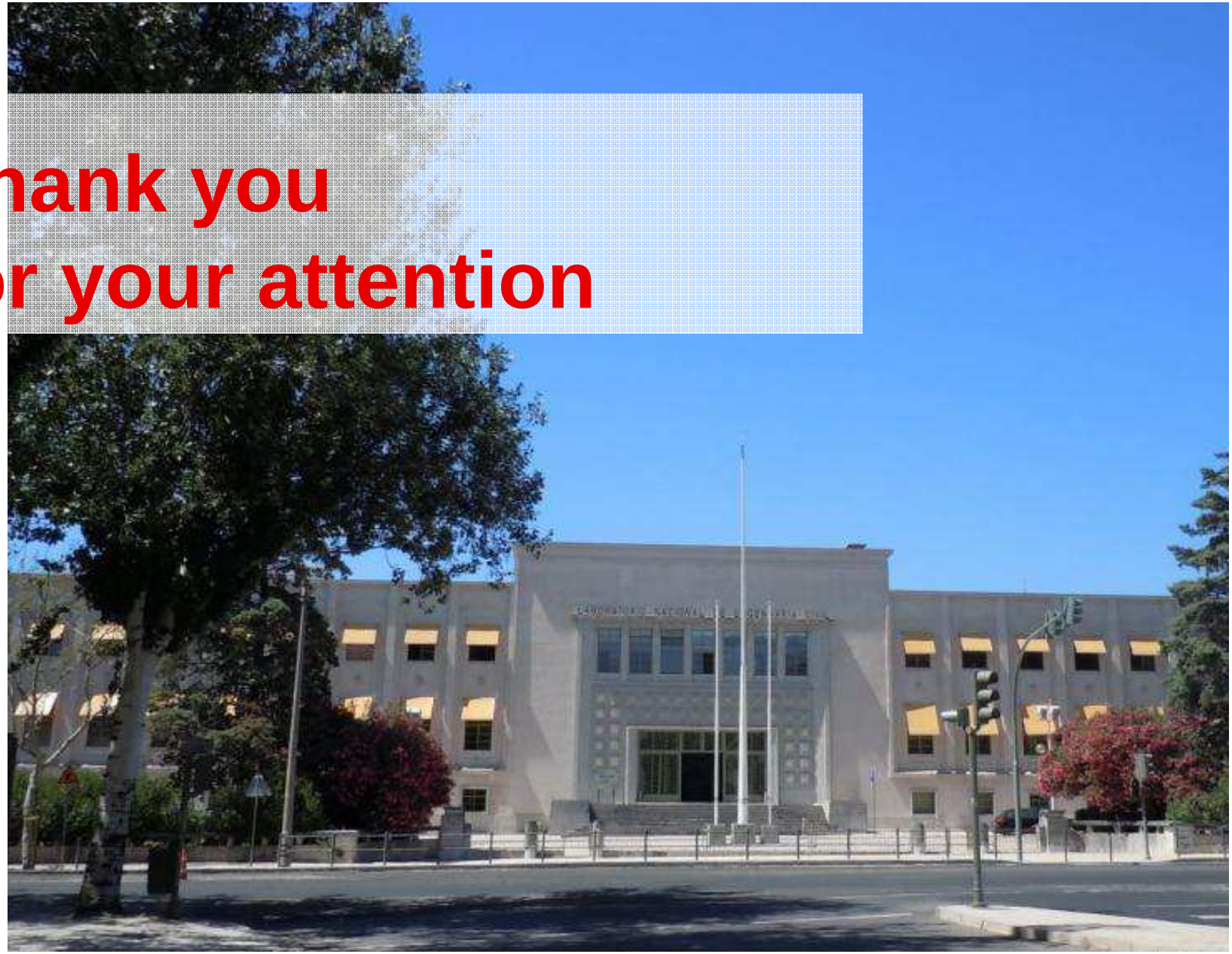
FINAL REMARKS

- Improve the technical and environmental education of civil engineers and architects
- Change design codes
- Encourage the use of alternative concrete constituents
- The LCA cradle-to-gate approach of concrete is not useful as could be for other materials
- The functional unit for concrete should relate also to the service life.

FINAL REMARKS

- The social and economic dimensions are still under development
- The evaluation part of the assessment (weighing of indicators) is still a pending issue and a drawback for harmonization
- Anyway, different weights should be accepted on a regional or local basis

Thank you for your attention



EUROPEAN STANDARDS

CEN/TC 350

> Standards for sustainability of construction works.

> Take into account international standards and European policies:

- ISO standards from TC59/SC 17 and TC 207 (Sustainability in buildings and civil engineering works and Environmental management)
- Construction Products Regulation (BR3 Hygiene, health and environment and BR 7 Sustainable use of natural resources)

EUROPEAN STANDARDS

FRAMEWORK LEVEL

EN 15643-1

- Sustainability of construction works - Sustainability assessment of buildings - Part 1: **General** framework.

EN 15643-2

- Sustainability of construction works — Assessment of buildings — Part 2: Framework for the assessment of **environmental** performance.

EN 15643-3

- Sustainability of construction works — Assessment of buildings — Part 3: Framework for the assessment of **social** performance.

EN 15643-4

- Sustainability of construction works — Assessment of buildings — Part 4: Framework for the assessment of **economic** performance.

EUROPEAN STANDARDS

BUILDING LEVEL

EN 15978

- Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method.

pr EN 16309

- Sustainability of construction works - Assessment of social performance of buildings – Methods.

WI 017

- Sustainability of construction works - Assessment of economic performance of buildings – Methods.

EUROPEAN STANDARDS

PRODUCT LEVEL

EN 15804

- Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products.

CEN TR 15941

- Sustainability of construction works — Environmental product declarations — Methodology for selection and use of generic data.

EN 15942

- Sustainability of construction works — Environmental product declarations — Communication format business-to-business.