ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Life Cycle Assessment for Green Buildings

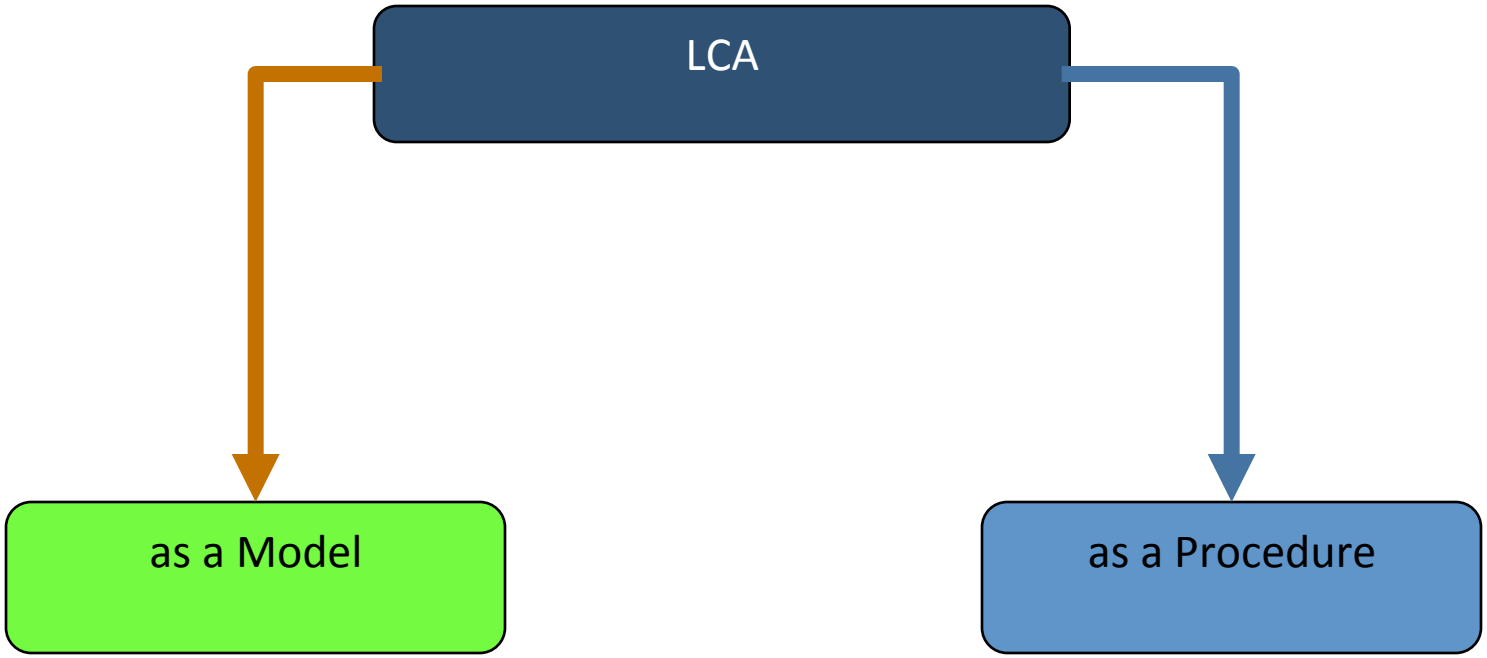
Getachew Assefa W., Ph.D.
Associate Professor
Athena Chair for Life Cycle Assessment
ISEEE Fellow
Faculty of Environmental Design
University of Calgary
gassefa@ucalgary.ca

February 25, 2014

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Life Cycle Assessment (LCA)

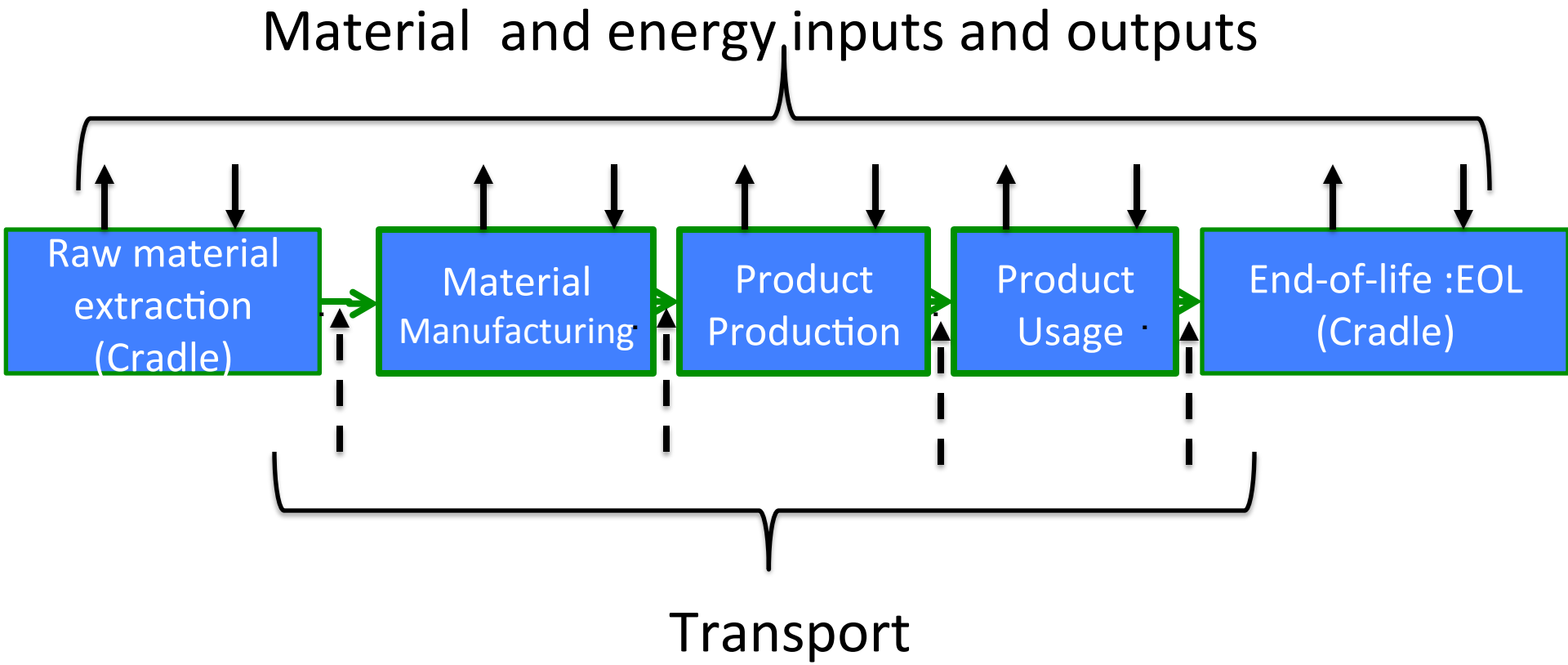
- A method for analysis and assessment of the <u>environmental impacts (e.g. climate change)</u> associated with :
  - products (e.g. building materials, buildings)
  - services (e.g. waste management, renewable energy supply, transport)
  - activities (e.g. consumption activity)
- throughout the **<u>entire life cycle</u>**


LCA
as a Model
as a Procedure

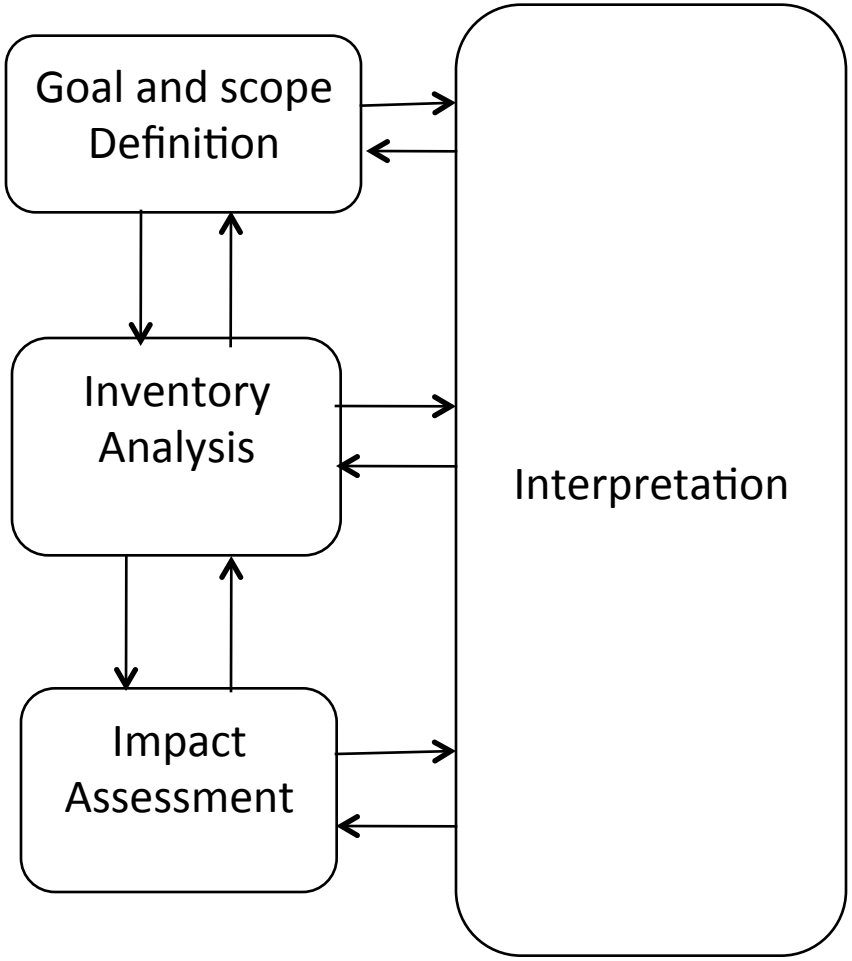
ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

LCA as **Modeling**

- calculation of impact of a product, service or activity from cradle to grave (cradle to cradle)



LCA as a procedure



ISO (2006)

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Impact Categories

		Reference and indicator results
1	Abiotic Depletion (DE)	kg antimony(Sb)-equivalent
2	Global warming Potentials (GWP)	kg CO_2-equivalent
3	Ozone Depletion Potentials (ODP)	kg CFC-11-equivalent
4	Acidification Potentials (AP)	kg SO_2-equivalent
5	Eutrophication Potentials(EP)	kg PO_4^{3-}-equivalent
6	Human Toxicity Potentials (HTP)	kg 1,4 dichlorobenzene-equivalent
7	Freshwater Aquatic Ecotoxicity(FAETP)	kg 1,4 dichlorobenzene-equivalent
8	Marine Aquatic Ecotoxicity (MAETP)	kg 1,4 dichlorobenzene-equivalent
9	Terrestrial Ecotoxicity (TETP)	kg 1,4 dichlorobenzene-equivalent
10	Photochemical ozone creation Potentials(POCP)	kg Ethylene-equivalent

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

LCA for Buildings

- Provides a consistent and systematic approach to identification and assessment of impacts of "building products" over their life cycle
  - Materials
  - Energy
- Example: University Building (Scheuer et al, 2003)

Materials

	Material	Ton	MJ/kg
1	Sand	8030	0.6
2	Gravel	2350	0.2
3	Cement (in concrete)	1320	3.7
4	Water (in concrete , drywall, mud, paint)	622	0.2
5	Steel, EAF	471	12.3
6	Brick	386	2.7
7	Mortar	173	< 0.1
8	Fly-ash (in concrete)	168	< 0.1
9	Cement (fireproofing)	110	3.7
10	Steel, primary, cold rolled	84	28.0
11	Gypsum, synthetic	80	< 0.1
12	Steel, primary, electro-galvanized	76	30.6
13	Steel, secondary, hot rolled	72	14.1
14	Gypsum, primary	66	0.9
15	Kraft paper	61	37.7
16	Bauxite ore(fireproofing)	53	0.6

Scheuer et al, 2003

…materials

	Material	Ton	MJ/kg
17	Cast iron	49	32.8
18	Glass	47	6.8
19	Granite	35	0.1
20	SBR latex	31	70.0
21	Polyamide/nylon, primary	30	**125**
22	Copper, primary, extruded	21	71.6
23	Glass fiber, primary	21	17.6
24	Starch	18	15.0
25	Steel, stainless	17	8.2
26	Aluminum, primary	15	**207**
27	Paver tile	14	0.5
28	Copper tube	12	65.8
29	Limestone	12	0.1
30	Clay (fireproofing)	11	32.4
31	Paper, secondary	10	6.9
32	Polypropylene	10	75.0

Scheuer et al, 2003

. . .materials

	Material	Ton	MJ/kg
33	Polyisocyanurate	9	70.0
34	Titanium dioxide	8	73.8
35	Rubber	7	**143**
36	EPDM	7	**183**
37	Kaolin (ceiling tiles)	7	1.3
38	Ceramic and quarry tile	6	5.5
39	Polystyrene	6	94.4
40	Glass fiber, post-industrial secondary	5	11.9
41	Polyamide, secondary	3	< 0.1
42	Wood	3	10.8
43	Vinyl resilient flooring	3	50.8
44	Poly-vinyl chloride (piping, wiring)	2	60.7
45	Brass	1	**239**
46	Ethylene glycol	1	85.1
47	Argon	<1	6.8
48	Waxes	<1	52.0

Scheuer et al, 2003

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

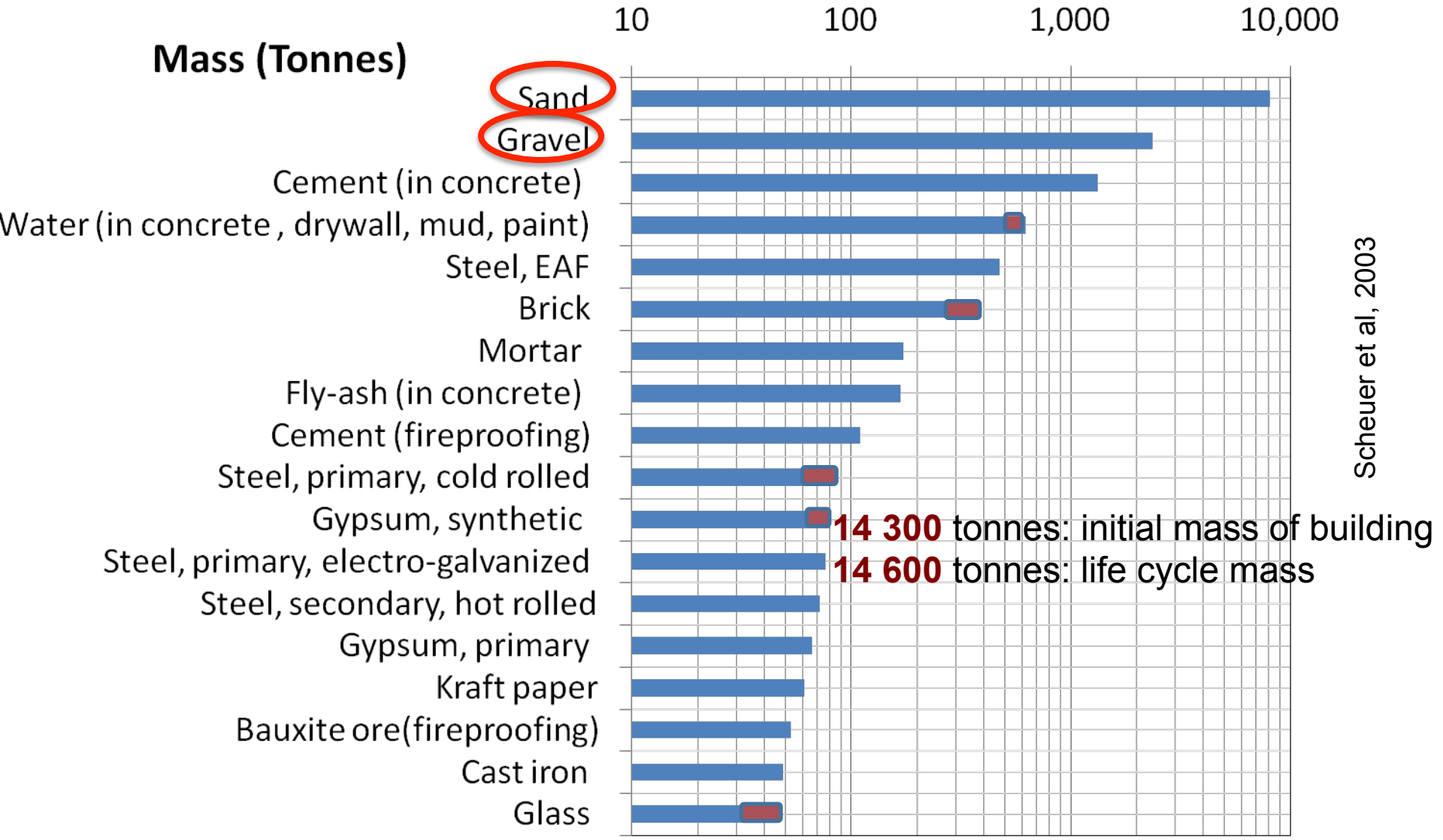
. . . materials

	Material	Ton	MJ/kg
49	Acrylate lacquer (carpet grout)	<1	30.8
50	Xylene (paint, waterproofing)	<1	60.2
51	Asphalt	<1	50.2
52	Polyethylene	<1	79.5
53	Toluene diisocyanate	<1	**101**
54	Toluene	<1	67.9

Scheuer et al, 2003

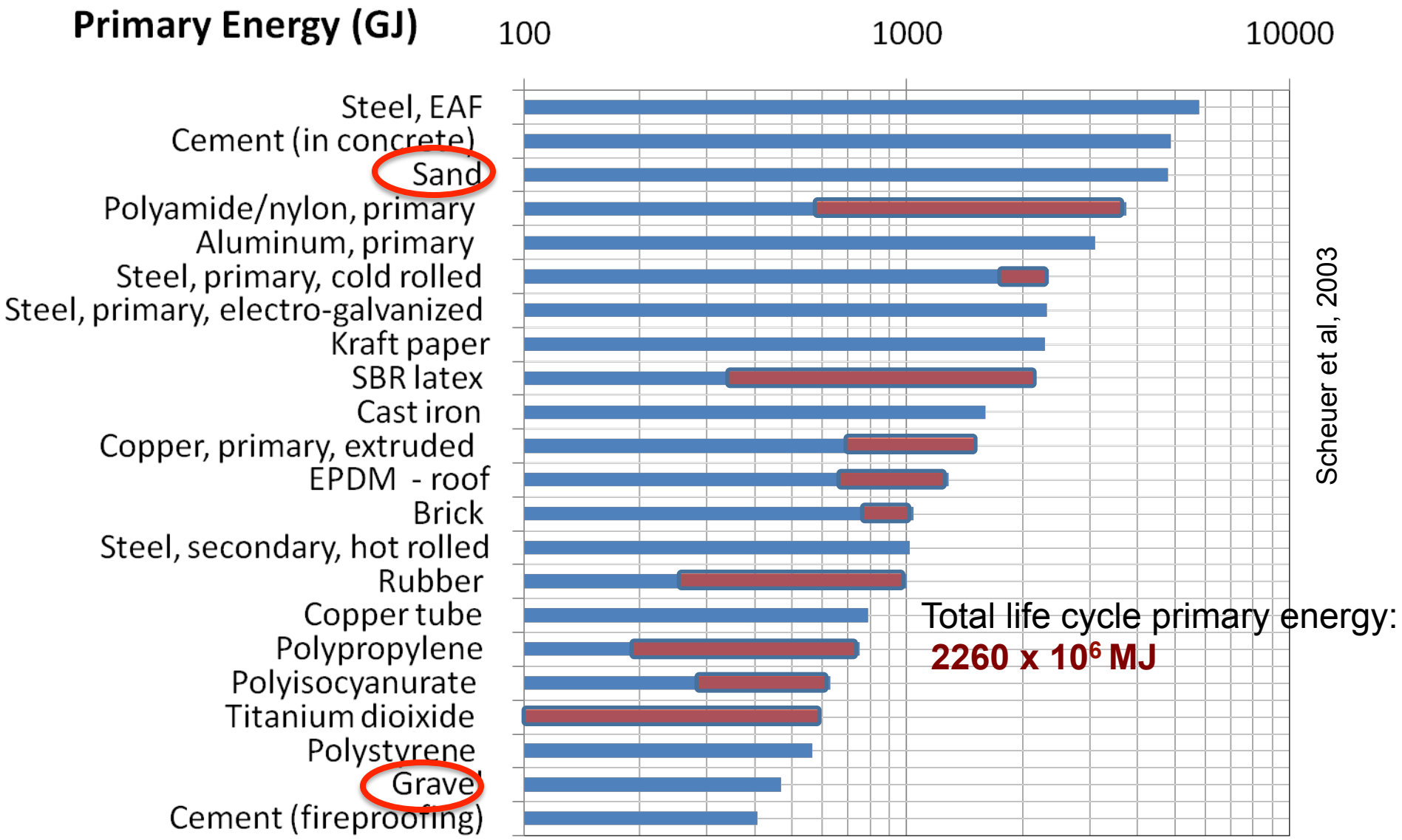
18 materials(99% of mass)

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY



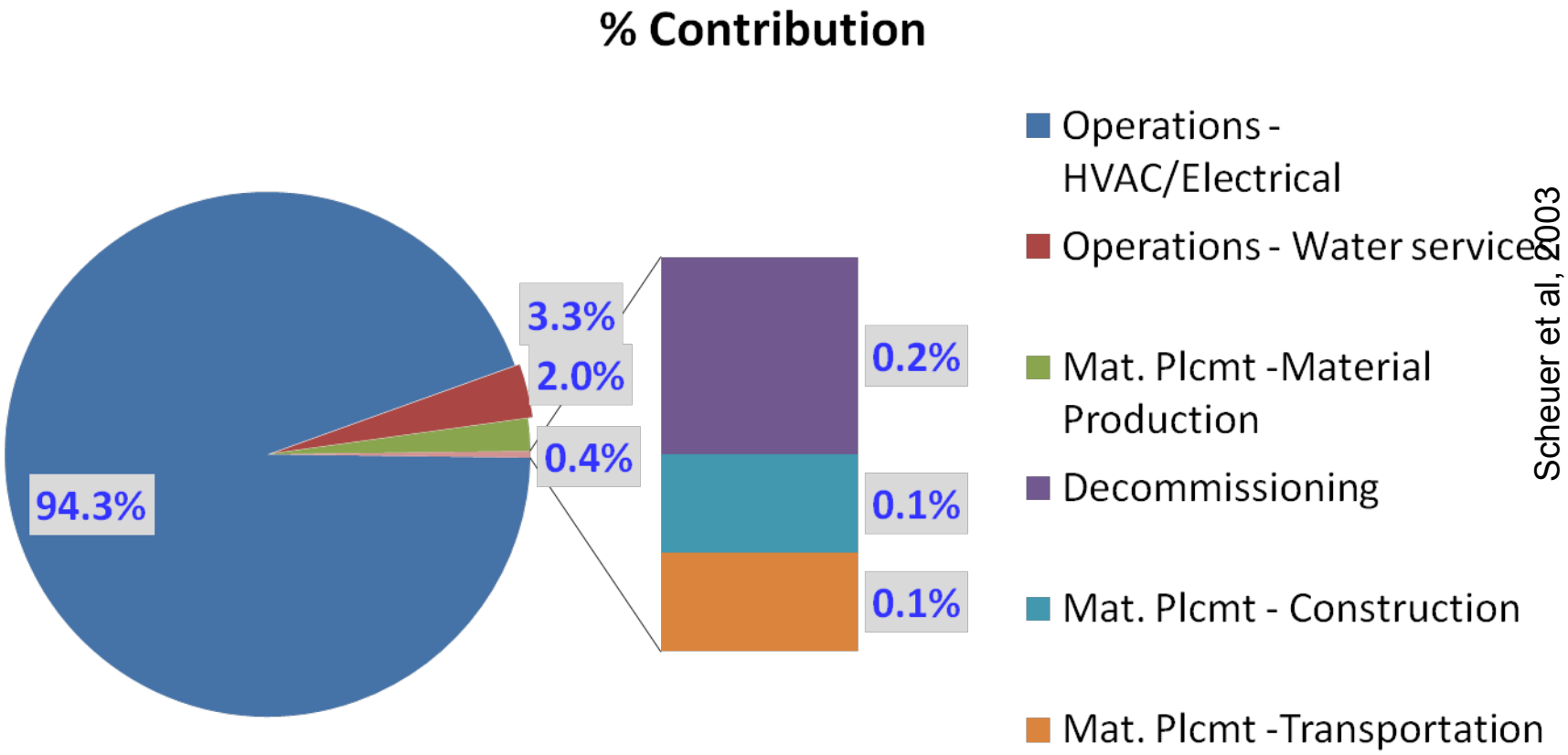
21 materials(94% energy)

74% of total building mass



ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

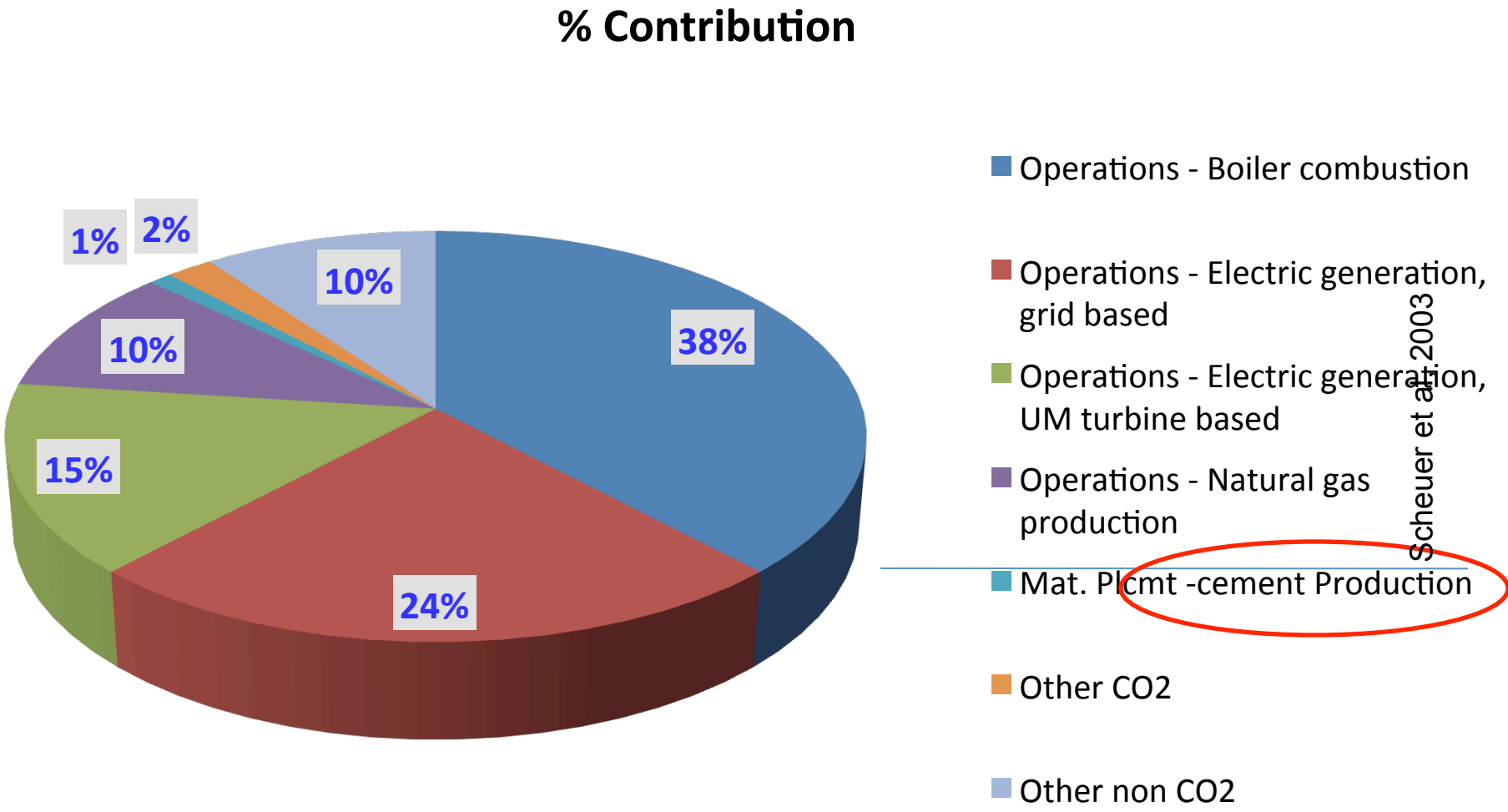
Life Cycle Energy



Life cycle energy consumption: 2260 x 10^6 MJ

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

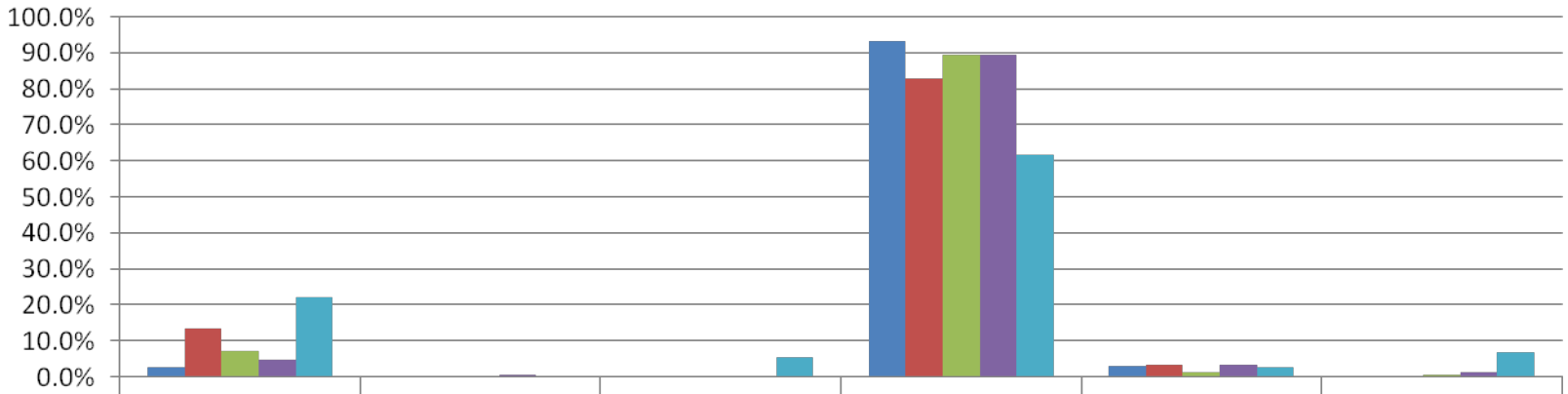
Global Warming



Life cycle CO_2 equivalent : 135 x 10^3 tonnes

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Impact Summary



	Mt Plcm - Material Production	Mt Plcmt - Transportation	Mt Plcmt - Constrcution	Operations-HVAC/Electrical	Operations-Water Services	Decommissioing
GWP	3.0%	0.1%	0.1%	93.4%	3.1%	0.2%
ODP	13.5%	0.0%	0.2%	82.9%	3.4%	0.0%
AP	7.4%	0.4%	0.4%	89.5%	1.5%	0.8%
NP	4.7%	0.7%	0.5%	89.5%	3.3%	1.3%
Waste	22.4%	0.1%	5.8%	61.9%	2.8%	6.9%

Scheuer et al, 2003

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Life Cycle Conclusions

- Priority: reducing operation burdens
  - For more than 83%, except for waste generation
  - High performance buildings
  - Design with future innovations in mind
  - Use LCA to resolve tradeoffs
- Maximizing service life of Materials
  - High replacement rate materials often have high embodied energy
- Design buildings to enable integration of more sustainable technologies
  - Energy generation technologies

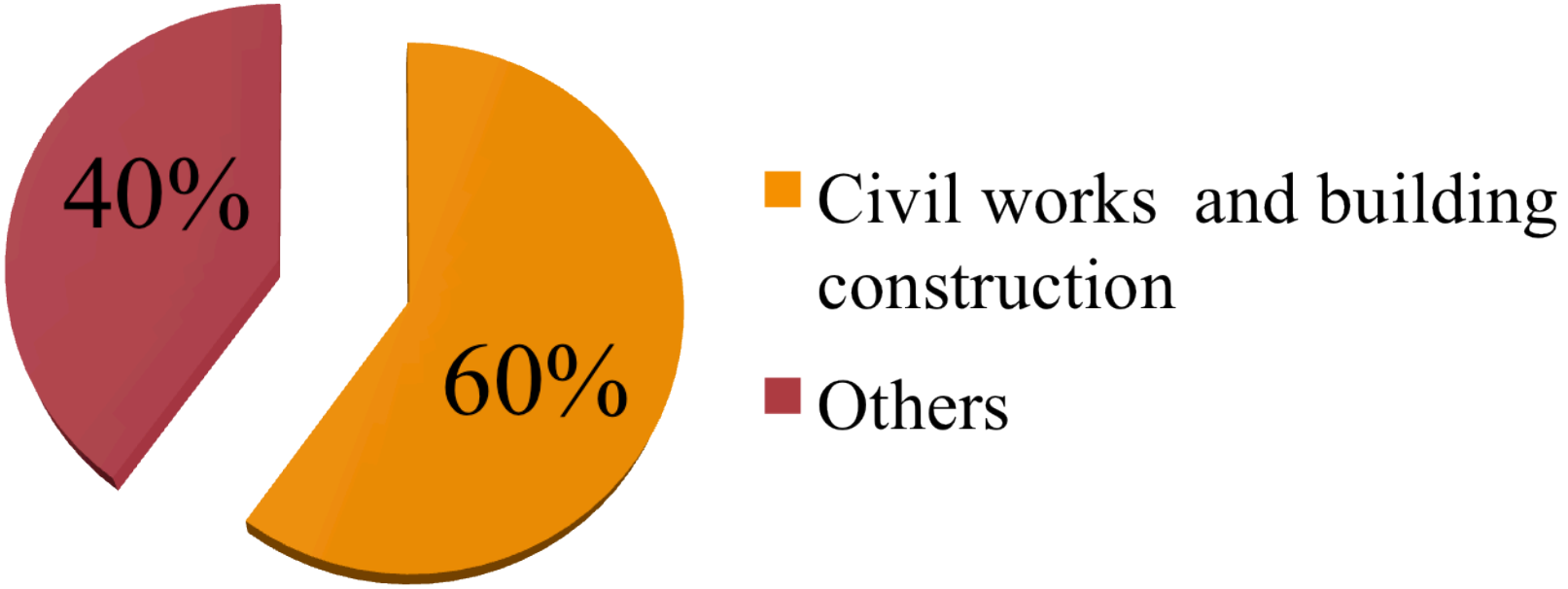
ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Why Life Cycle Assessment

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

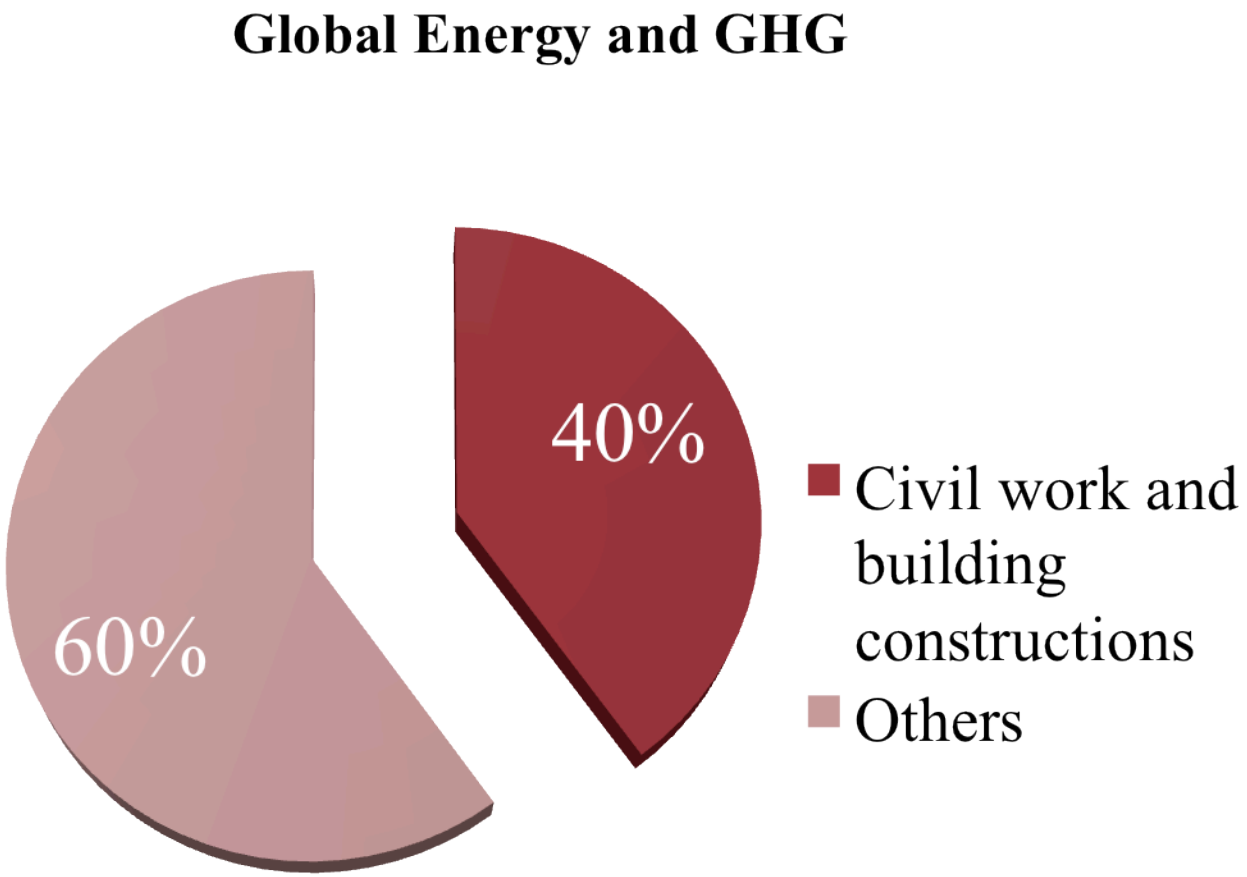
Non-Green Built Environment

Global raw material extraction



ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Non-Green Built Environment



ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Non-Green Built Environment

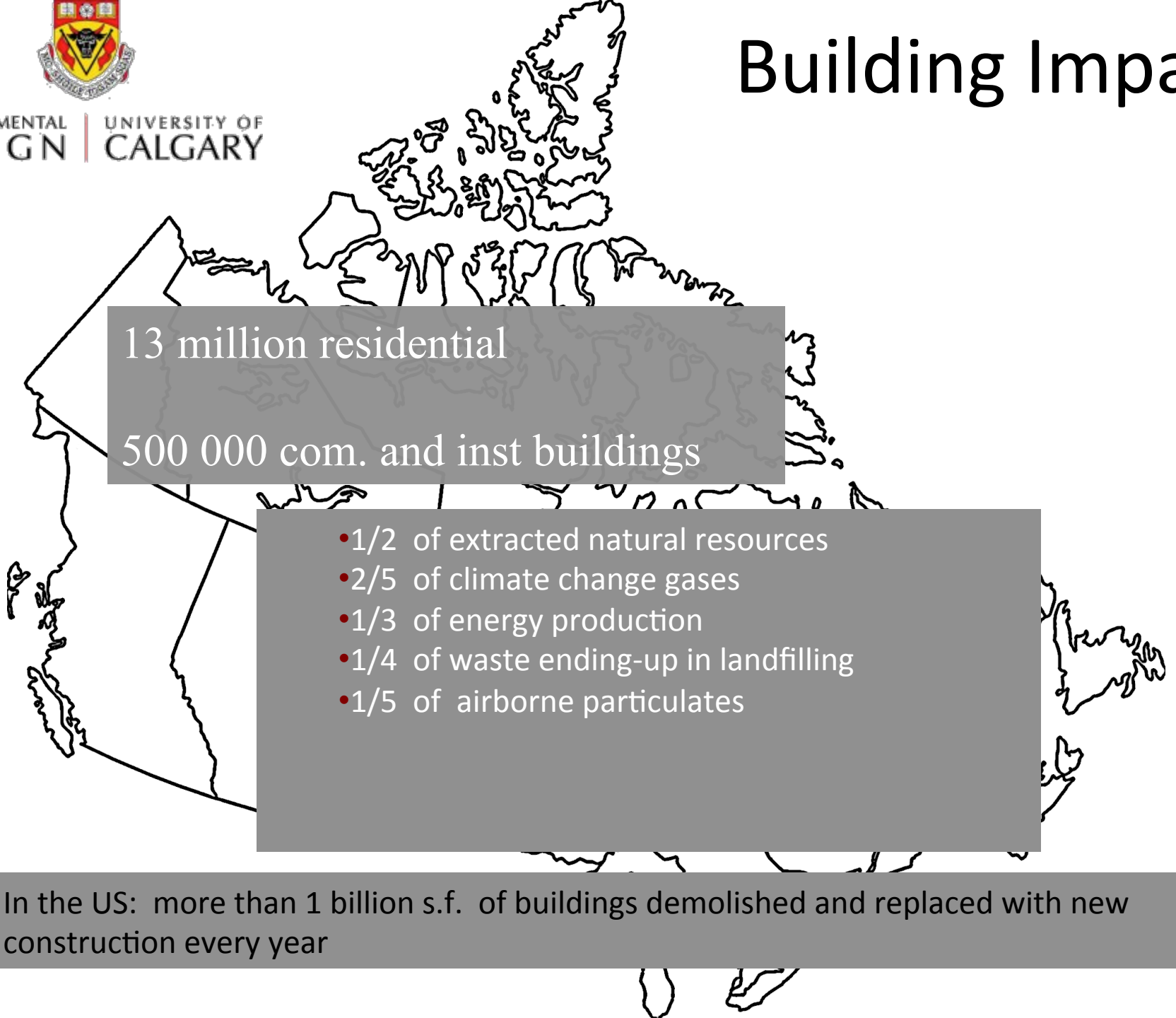
2-3 tonnes

1 habitable m^2

6 tonnes

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Building Impact



13 million residential

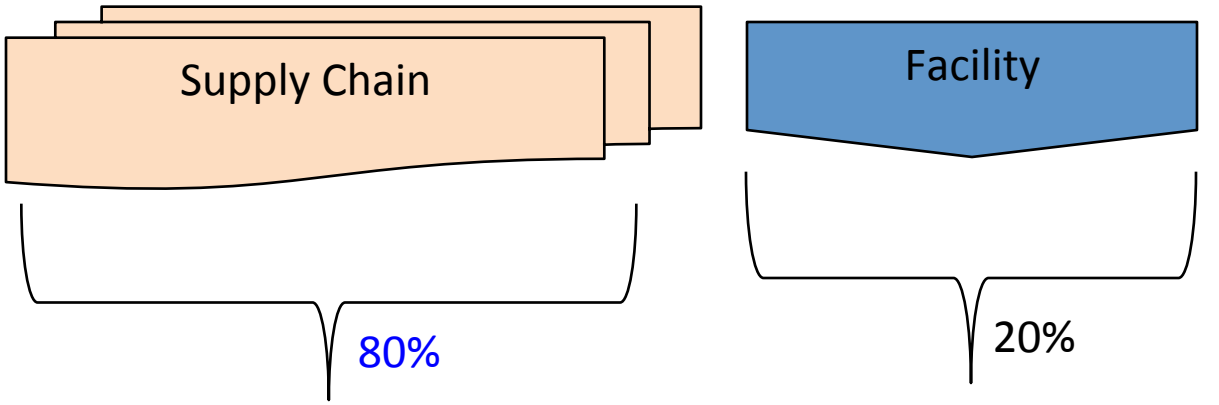
500 000 com. and inst buildings

- 1/2 of extracted natural resources
- 2/5 of climate change gases
- 1/3 of energy production
- 1/4 of waste ending-up in landfilling
- 1/5 of airborne particulates

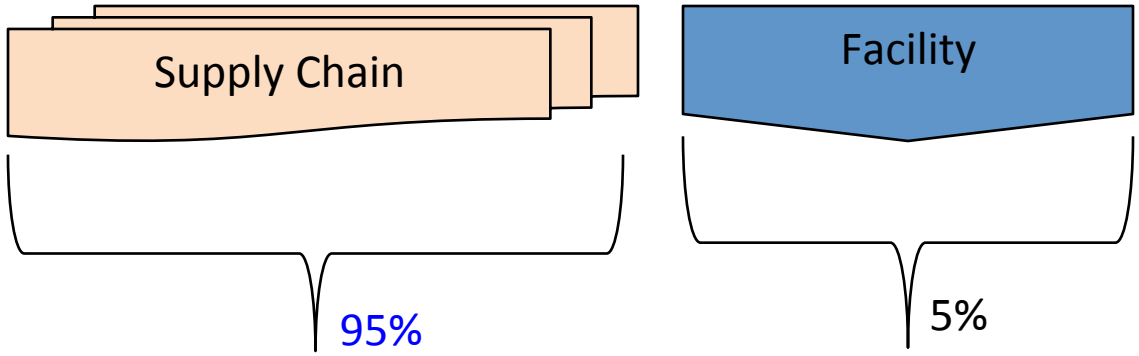
In the US: more than 1 billion s.f. of buildings demolished and replaced with new construction every year

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Where to change?



All sectors of US economy



For 50% of the sectors

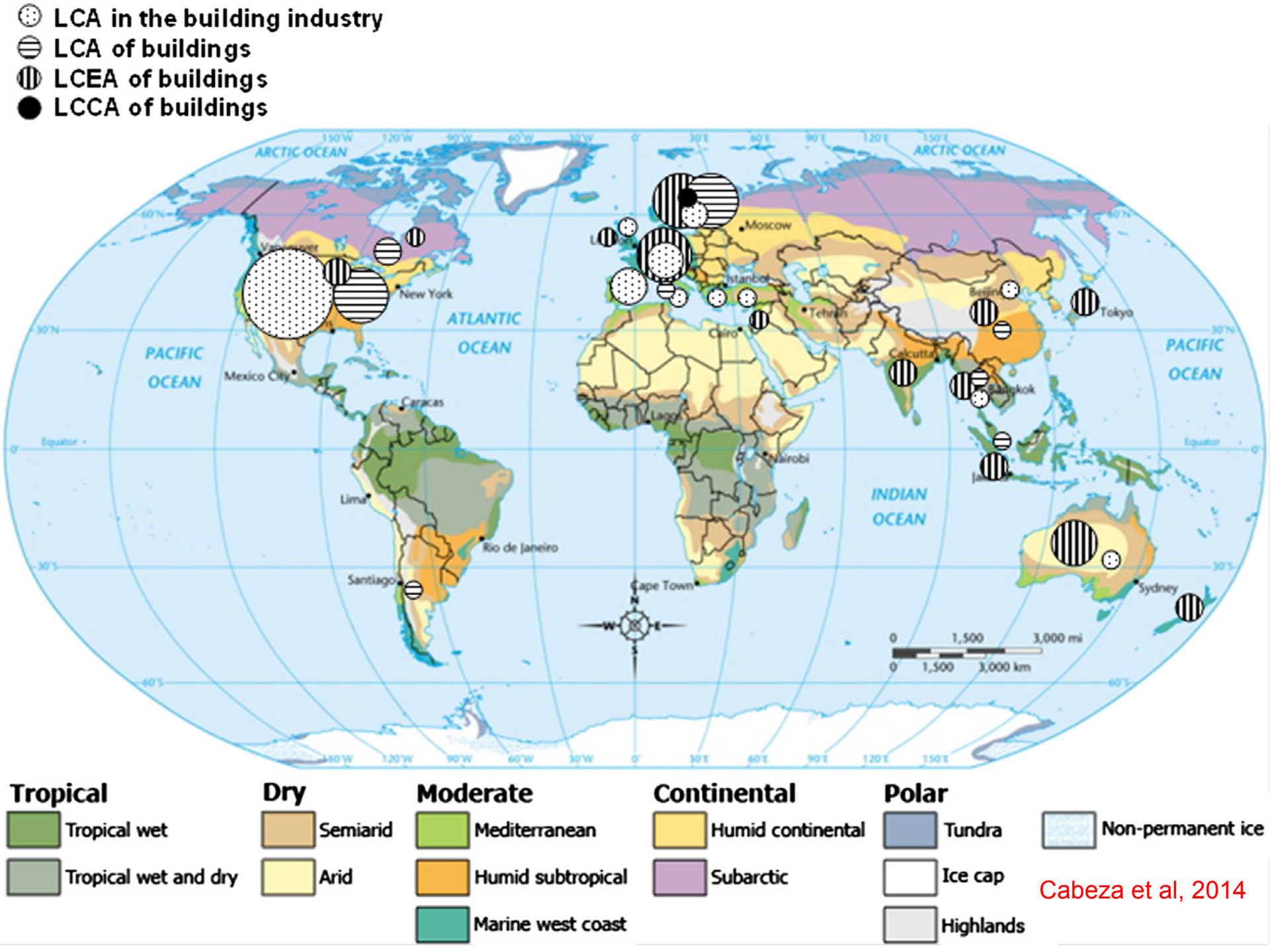
ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

How LCA is being used in the Green Building industry

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

LCA in Building Sector

- LCA of products and processes
  1. construction products selection
  2. construction systems/process evaluation
- LCA of whole structures:
  1. Residential buildings
  2. Non-residential buildings
  3. Civil engineering structures
- Approaches related to industry
  1. Tools and databases
  2. Methodological developments



Cabeza et al, 2014

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Two major contribution areas

1. Rating and Certification Schemes
   – guide building products comparison
2. Environmental Product Declarations
   – verify performance claims

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Rating and Certification

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Critics of non-LCA based rating

- "does not provide a consistent, organized structure for achievement of environmental goals" from a life cycle perspective
  - **2002**: analyzed Material and Resources (MR) and Energy and Atmosphere (EA) categories in LEED credits for an institutional building from energy and solid waste impacts perspective
  - recommended incorporating LCA for further development of the LEED system
- significant variations in overall environmental benefits represented by various LEED credits
  - **2007**: LEED-certified office building from a life- cycle perspective
  - criticized certain LEED credits for having negative effects on environment
  - proposed a new scoring system for LEED credits

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Merits of LCA

- Verifiable information
  - science-based
  - Peer-review
  - Consistent
- comparable information
- green marketing: fighting green-washing

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

LEED

- LEED 2009
  1. Sustainable Sites
  2. Water Efficiency
  3. Energy and Atmosphere
  4. **Material and Resources**
  5. Indoor Environmental Quality
  6. Innovation in Design
  7. Regional Priority
- LEED v4 : Life Cycle Credits (New and Modified) as part of **Materials and Resources**

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

LCA Credits in LEED

- **Building Product Disclosure and Optimization – Environmental Product Declarations**
  - "encourage the use of products and materials for which **life cycle information** is available and that have environmentally, economically, and socially preferable **life cycle impacts**."
  - Rewards selection of products from manufacturers who have verified improved environmental **life cycle impacts**
- **Building Life Cycle Impact Reduction**
  - "encourage reuse of products and materials to optimize their environmental performance."
  - Rewards reuse of existing building resources, maintaining or renovating existing structures or reusing salvaged materials, or reduction in materials use through LCA

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Green Guide to Specification

- Used in BREEAM:
  - > 250, 000 buildings assessed and certified
  - over 1 million registered for certification
- LCA-based **ranking** of building elements (A^+ to E)
- > 1500 specifications
- Designers and builders: choosing assessed materials

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Building Types

1. Residential
2. Commercial buildings (e.g. offices)
3. Educational
4. Healthcare
5. Retail
6. Industrial

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Building Elements

1. External walls
2. Internal walls and partitions
3. Roofs
4. Ground floors
5. Upper floors
6. Floor finishes
7. Insulation
8. Windows
9. Landscaping

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Impacts and Weights

1. Climate change: 21.6
2. Water extraction: 11.7
3. Mineral resource extraction: 9.8
4. Stratospheric ozone depletion: 9.1
5. Human toxicity: 8.6
6. Ecotoxicity to Freshwater: 8.6
7. Nuclear waste (higher level): 8.2
8. Ecotoxicity to land: 8.0
9. Waste disposal: 7.7
10. Fossil fuel depletion: 3.3
11. Eutrophication: 3.0
12. Photochemical ozone creation: 0.20
13. Acidification: 0.05

- Weighting: developed by Panel of 10 experts

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

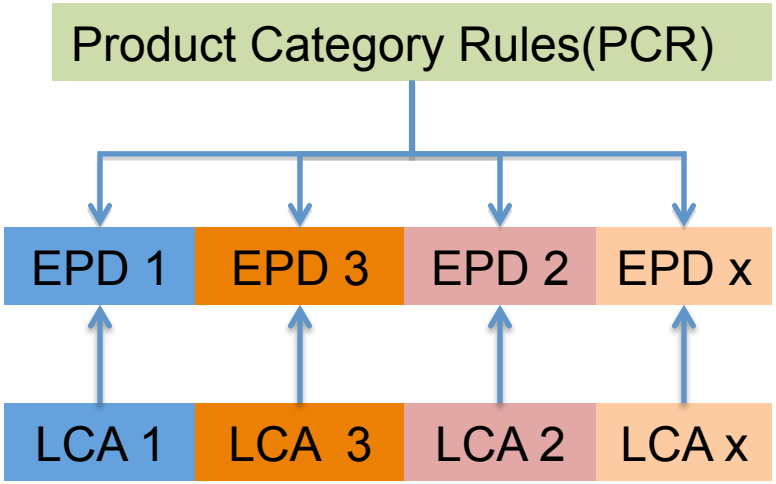
Environmental Product Declarations(EPDs)

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

EPDs

Shall be based on LCA

Non-tariff trade barrier



Nutrition Facts
Serving Size 2 CUPS (30g)
Servings per Container VARIED

Amount per Serving	
Calories 150	Calories from Fat 70
	% Daily Value*
Total Fat 7g	**11%**
Saturated Fat 1.5g	**6%**
Cholesterol 0mg	**0%**
Sodium 120mg	**5%**
Total Carbohydrate 20g	**7%**
Dietary Fiber 4g	**15%**
Sugars 9g	
Protein 1g	

Vitamin A 0% • Vitamin C 0%
Calcium 0% • Iron 2%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

ISO 14025:2006

"Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures"

- International
- Establishes: principles and procedures for developing EPD programs and EPDS
- Establishes: use of the LCA standards (ISO 14040 and ISO 14044) in development of EPD programs and EPDs
- EPDs are primarily intended for use in:
  - **business-to-business communication**
  - **business-to-consumer communication** under certain conditions

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

ISO 21930:2007

"Sustainability in building construction -- Environmental declaration of **building products**"

- International
- Contains principles, specifications and requirements for EPDs of **building products**
- Provides framework and basic requirements for **PCRs** for EPDs of building products
- Primarily intended for use in:
  - business-to-business communication
  - business-to-consumer communication under certain conditions

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

EN 15804:2012

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

- European Standard
- Provides **core PCRs** for **all construction products and services**
- Provides a structure to ensure harmony in all EPDS of construction:
  - Products
  - Services
  - Processes
- Harmony: in deriving, verifying and presenting EPDs

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Guidance for Product Category Rule Development

Version 1.0
August 28, 2013

Product Category Rule
Guidance Development Initiative

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Product Category Rules

- North American Structural and Architectural Wood Products
  - 15 products
- North American Gypsum Boards
  - 13 gypsum board products
- North American Market Pulp - under development

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Opportunities and Challenges of conducting LCAs

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

March 2012

Full Report: http://nrtee-trnee.ca/canadas-opportunity

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Opportunities

- International Competitiveness
  - Trade restrictions
  - Lack of market access
- Firm Competitiveness
  - Enhancing supply chain efficiencies
  - Enhancing internal operation efficiencies
- Integration in Rating and Certification systems

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Challenges

- Data Availability

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Canadian Database

- Canadian Raw Material Database : 18 datasets

  http://crmd.uwaterloo.ca

- Quebec Life Cycle Inventory Database:

  http://www.ciraig.org

  - Quebec adaptation from Swiss ecoinvent database
  - beginning with data from: energy, mines and metals, and pulp and paper

- Athena Impact Estimator:

  http://calculatelca.com

  - can model over 1200 structural and envelope assembly combinations, allowing for comparisons of various design options

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Challenges

- Data Availability
- Data Quality
  - **Western Red Cedar** example in BREEAM
- Methodological challenges: allocation, cut-off, **weighting**
- Buildings: complex “product”

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Recommendations on Data

1. Canadian Industry Association
2. North American Industry Association
3. Specific Canadian Manufacturer
4. Specific North American Manufacturer

- In the absence of the above:
  1. commercial databases
  2. published or unpublished literature sources
  3. Extrapolation from similar products

ENVIRONMENTAL DESIGN | UNIVERSITY OF CALGARY

Contact: Getachew Assefa W., Ph.D.
Faculty of Environmental Design
University of Calgary
gassefa@ucalgary.ca
403 220 6961