



PROGETTO, COSTRUZIONE E AMBIENTE

TORINO 9-10 MAGGIO 2017

**LIFE CYCLE ASSESSMENT E  
LE CERTIFICAZIONI DEGLI  
EDIFICI**



Eleonora Sablone, ingegnere edile dedita alla progettazione integrata e sostenibile dal 2007 con particolare riferimento alla gestione degli asset immobiliari nella loro progettazione, realizzazione, gestione e valorizzazione., svolgendo attività di consulenza per i maggiori player italiani.

Ha maturato molteplici esperienze nell'ambito dell'edilizia sostenibile con particolare riferimento alla certificazione degli edifici secondo i protocolli Leed e Breeam, partecipando al processo come Leed AP, Breeam Assessor (NC, IRFO, In Use), Breeam AP (Accredited Professional), e operando analisi LCA specialistiche.

Dal 2013 è Breeam Assessor gli interventi di costruzione e ristrutturazione del JRC (Joint Research Centre) di Ispra. Dal 2016 referente italiano di Bionova, sviluppatori del software Leader europeo per la LCA degli edifici.





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CONSTRUCTION INDUSTRY WITH LOCAL DATA & CERTIFICATIONS**

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IN FINLAND

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BUILDING  
CHALLENGE™

**CEEQUAL**



**EXTREMELY FAST**



**VERY EASY TO USE**



**LCC, MATERIALS, MORE**



**GREAT SUPPORT**



**LOCAL DATA & APPROVALS**



**USE BIM, EXCEL + MORE**



**SIMPLE TO USE WITHOUT BIM, AND WITH BIM IT'S FULLY AUTOMATED**

**Cloud**



**Excel**



**Energy models**



**BIM**

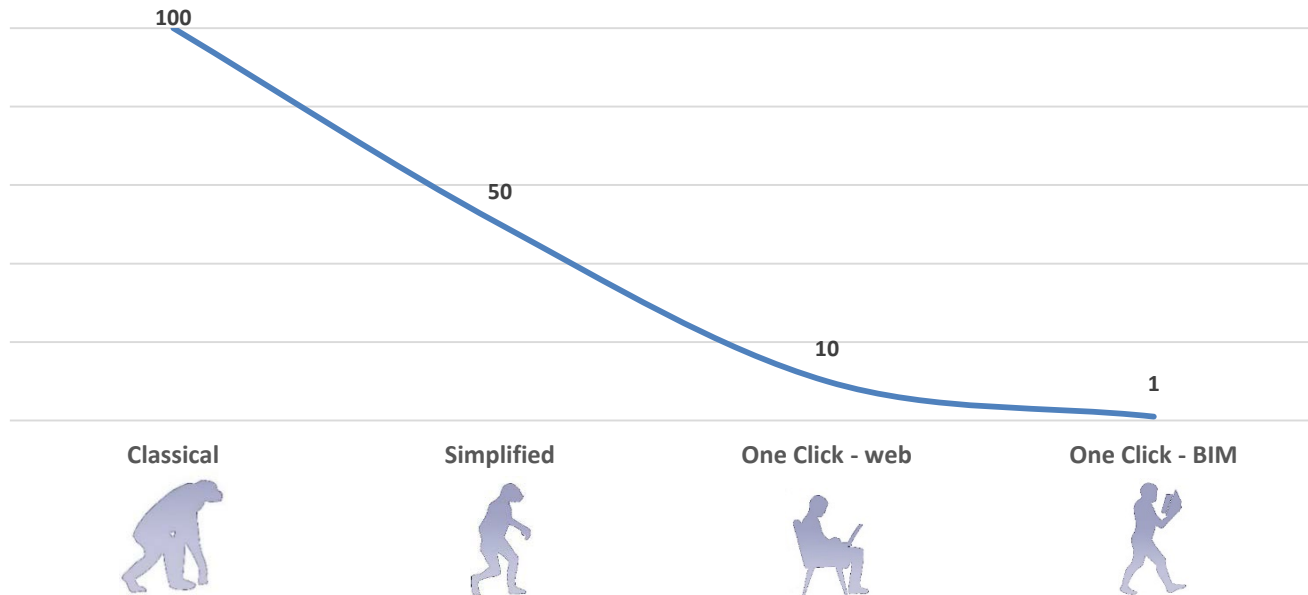


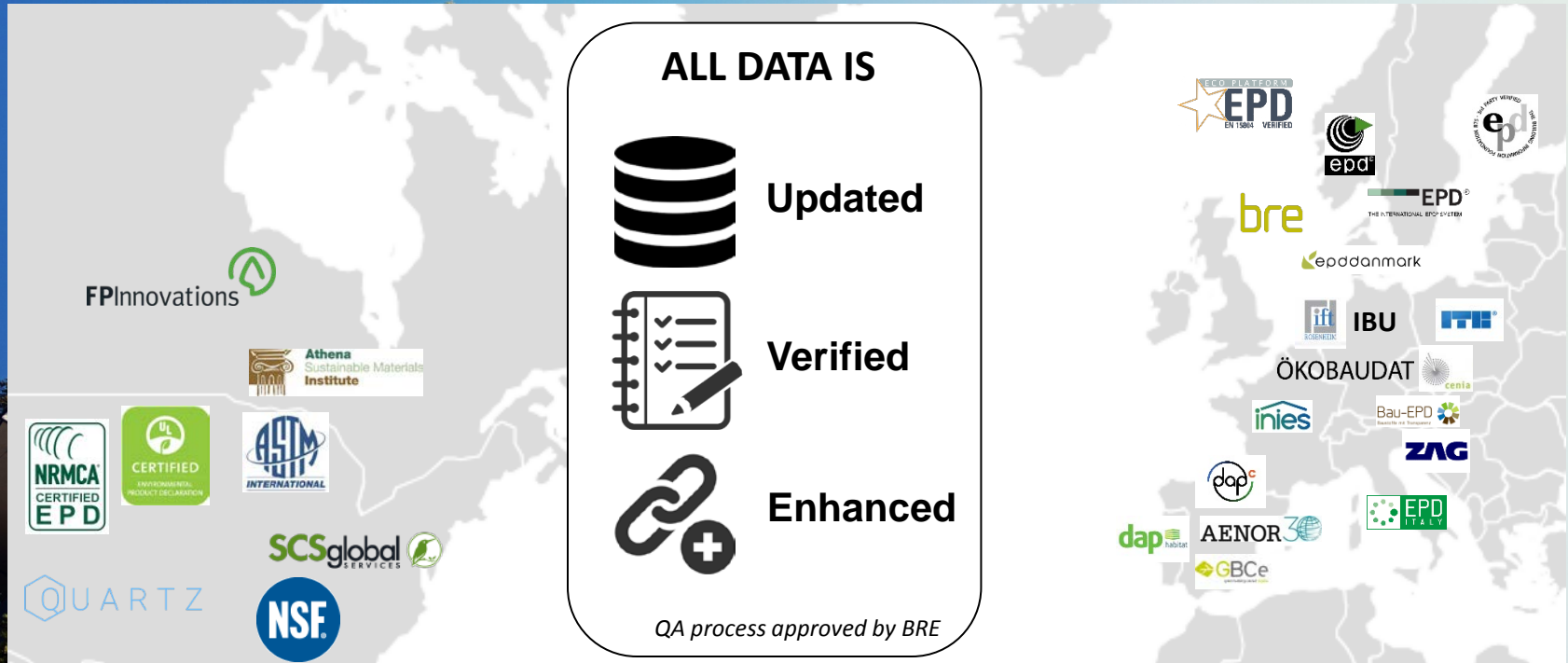
**Revit plugin**





## THE TIME YOU SAVE IS PROFITS YOU KEEP





ARUP



SKANSKA



CONSOLIS







Sustainability is..



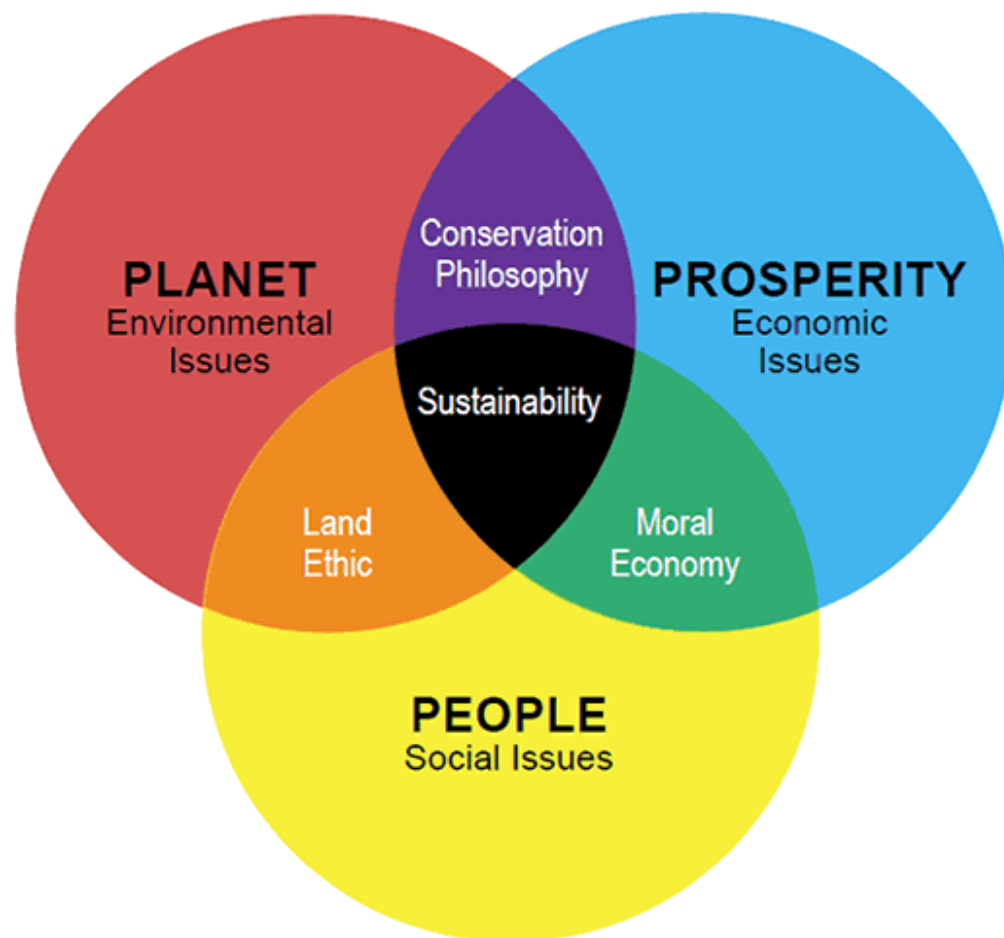
# Sustainability is..





# Sustainability is..

COESISTENZA POSITIVA ED  
EFFICACE DELLA MATRICE  
AMBIENTALE SOCIALE ED  
ECONOMICA



# Sustainability is..

## Global CO<sub>2</sub> Emissions by Sector

#1. Buildings

#2. Transportation

#3. Industry

Source: Energy Information Administration (2006). Emissions of Greenhouse Gases in the United States.

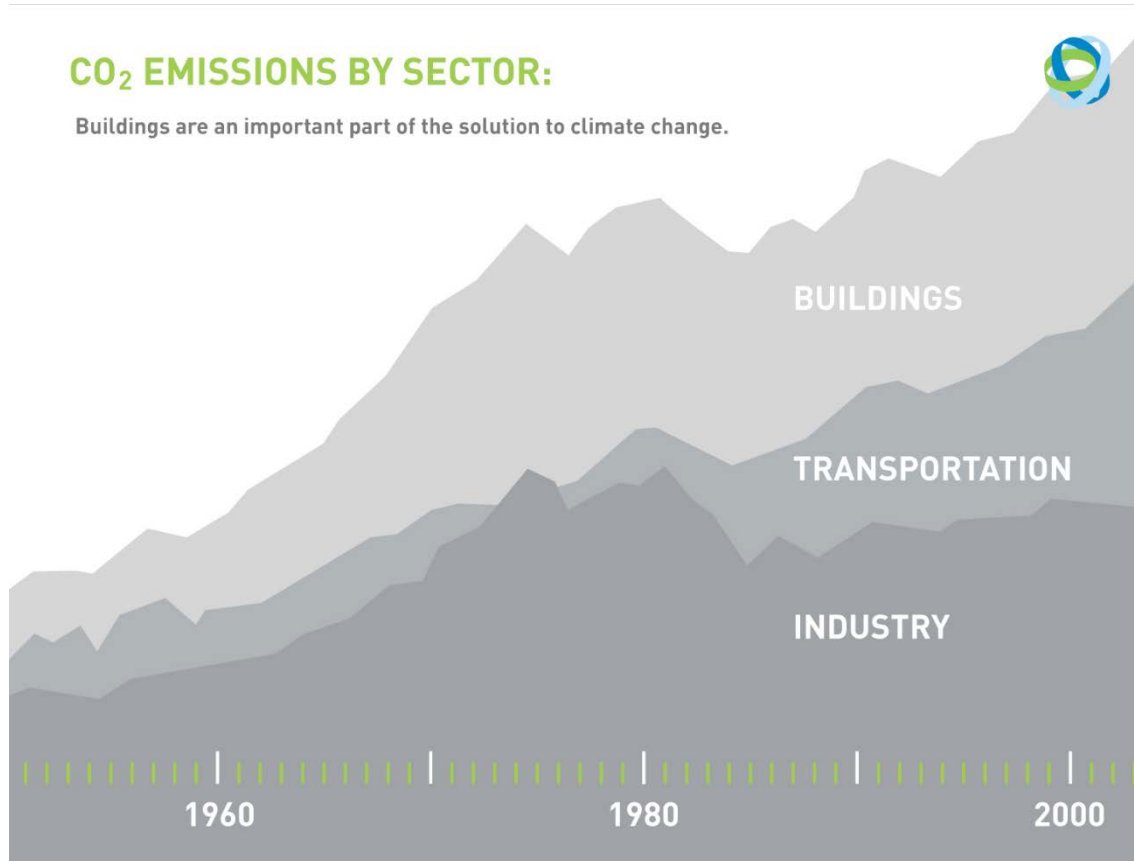


Is your  
building  
**sick?**

Most businesses  
don't know...

### CO<sub>2</sub> EMISSIONS BY SECTOR:

Buildings are an important part of the solution to climate change.







## APPLICARE I PRINCIPI DELLA SOSTENIBILITÀ ALL'EDILIZIA : GREEN BUILDING



### Takes an intelligent approach to energy

- Minimising energy use in all stages of a building's life-cycle, making new and renovated buildings more comfortable, less expensive to own and helping building users learn to be efficient too.
- Integrating renewable and low carbon technologies to supply buildings' energy needs, once design has maximised inbuilt and natural efficiencies.

**ENERGIA**



### Safeguards our water resources

- Exploring ways to improve drinking and waste water efficiency and management, harvesting water for safe indoor uses in innovative ways and generally minimising water use in the sector.
- Considering the impact of the built environment on stormwater and drainage infrastructure, ensuring these are not put under undue stress or prevented from doing their job.

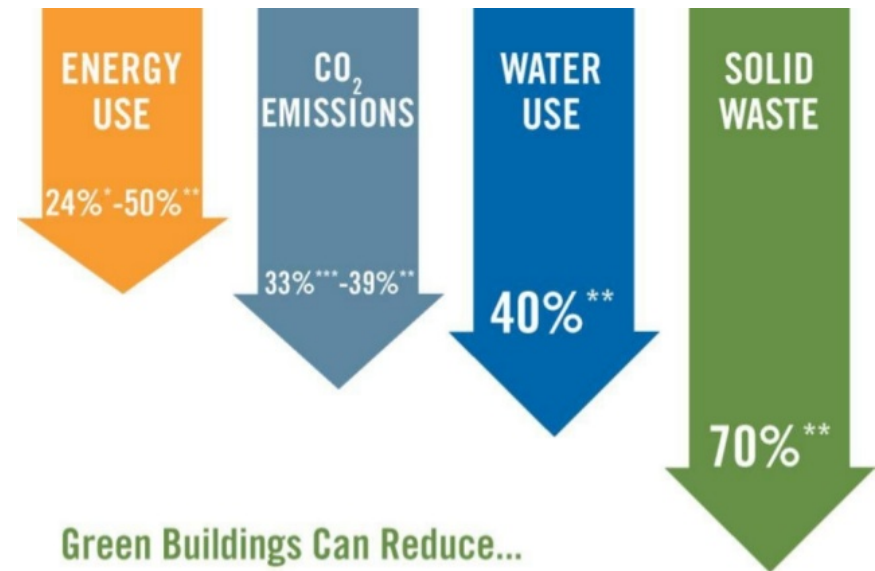
**ACQUA**



### Minimises waste and maximises reuse

- Using fewer, more durable materials and generating less waste, is vital in accounting for a building's end of life stage by designing for demolition waste recovery and reuse.
- Engaging building users in reuse and recycling.

**RIFIUTI**



\* Turner, C. & Frankel, M. (2008). Energy performance of LEED for New Construction buildings: Final report.

\*\* Kats, G. (2003). The Costs and Financial Benefits of Green Building: A Report to California's Sustainable Building Task Force.

\*\*\* GSA Public Buildings Service (2008). Assessing green building performance: A post occupancy evaluation of 12 GSA buildings.



### Promotes health and well-being

- Bringing a breath of fresh air inside, delivering high indoor air quality through good ventilation and avoiding materials and chemicals that create harmful emissions.
- Incorporating natural light and views to ensure building users' comfort and enjoyment of their surroundings, reducing lighting energy needs in the process.
- Designing for ears as well as eyes. In the education, health and residential sectors, acoustics and proper sound insulation play important roles in helping concentration, recuperation, and peaceful enjoyment of property.
- Ensuring people are comfortable in their everyday environments, creating the right indoor temperature as the seasons pass through passive design or building management and monitoring systems.

**SALUTE**



### Keeps our landscape green

- Recognising that our urban environment should preserve nature, ensuring diverse wildlife and land quality are protected or enhanced, for example by remediation of building on polluted land or creating green spaces.
- Looking for ways we can make our urban areas more productive, bringing agriculture into our cities.

**NATURE**





## Creates resilient and flexible structures

- Adapting to a changing environment, ensuring resilience to events such as flooding, earthquakes or fires so that our buildings stand the test of time and keep people and their belongings safe.
- Designing flexible and dynamic spaces, anticipating changes in their use over time and avoiding the need to demolish and rebuild or significantly renovate buildings to prevent them becoming obsolete.

# RESILIENZA



## Connects us

- Creating diverse environments that connect and enhance communities, asking what a building will add to its context in terms of positive economic and social effects and engaging local communities in planning.
- Ensuring transport and distance to amenities are considered in design, reducing the stresses of personal transport on the environment, roads and railways and encouraging environmentally friendly options such as cycling.
- Exploring the possibilities of smart technologies and ICT to communicate better with the world around us, for example through smart electricity grids that understand how to transport energy where and when it is needed.

# CONNETTIVITA'



## Considers all stages of a building's life-cycle

- Seeking to lower all environmental impacts and maximise social and economic value over a building's whole life-cycle: through design, construction, operation, maintenance, renovation, and demolition. The fragmented nature of the building industry value chain means we have long looked at parts of the life-cycle in isolation, but Green Building Councils are bringing the sector's whole value chain together through our members to build a wider vision.
- Making the invisible visible. Embodied resources are the invisible resources used in buildings: for example, the energy or water used to produce and transport the materials in the building. Green building considers these amongst a building's impacts, ensuring that our buildings are truly low impact.

# LCA





# How to measure?





# How to measure?

BREEAM

LEED

CASBEE

HQE

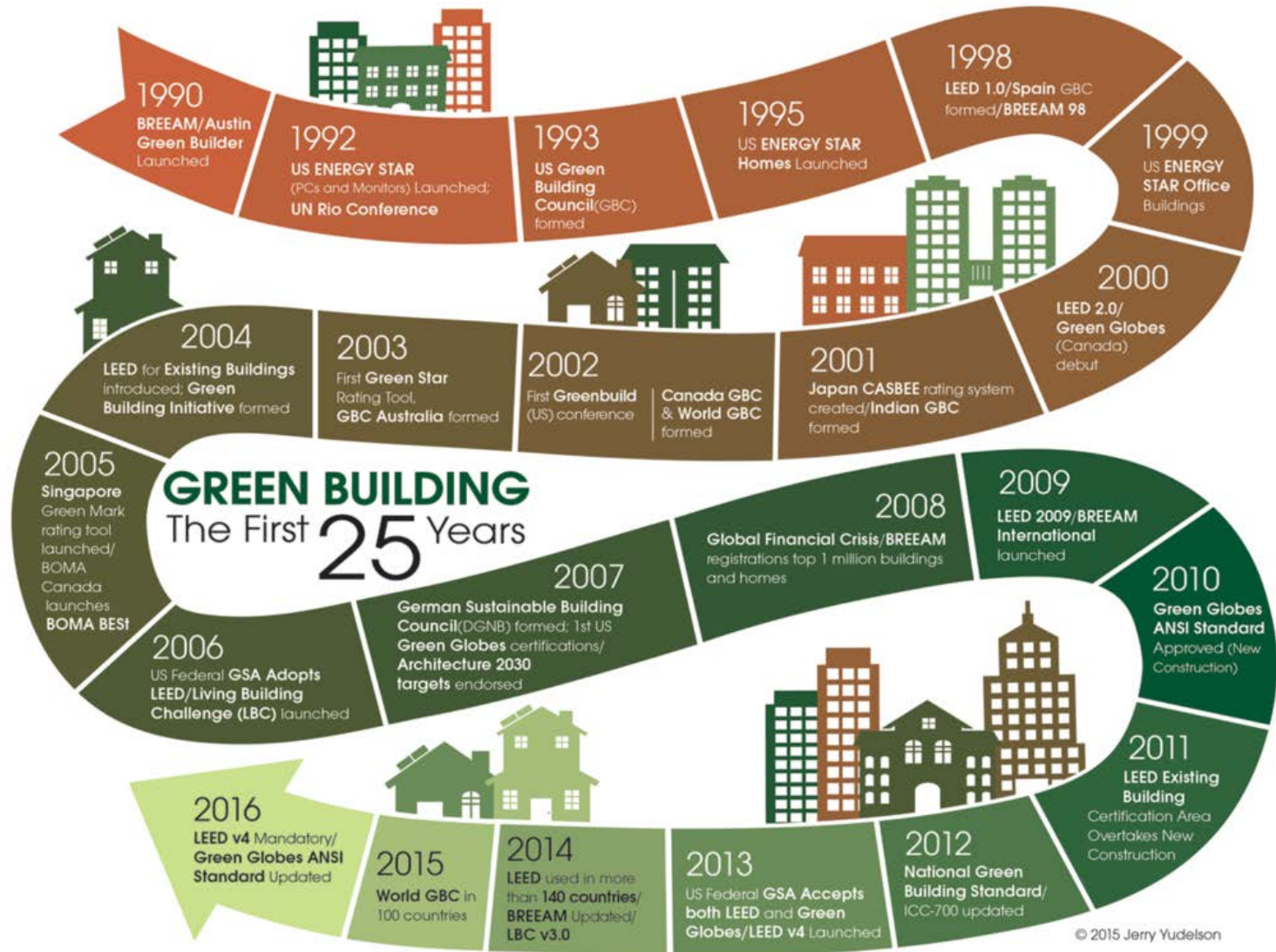
DGNB

GREEN STAR

LBG

EDGE

ESTIDAMA ...











# Life-Cycle Assessment is a metrics tool

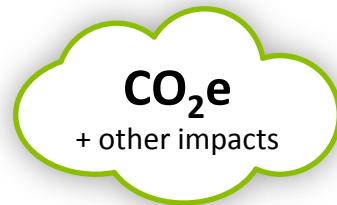
Life-cycle metrics provide a numerical assesment of a projects/products impacts on different aspects of the environment over it's life-cycle. It does not tell whether a thing is good or bad – that depends on alternative's LCA.



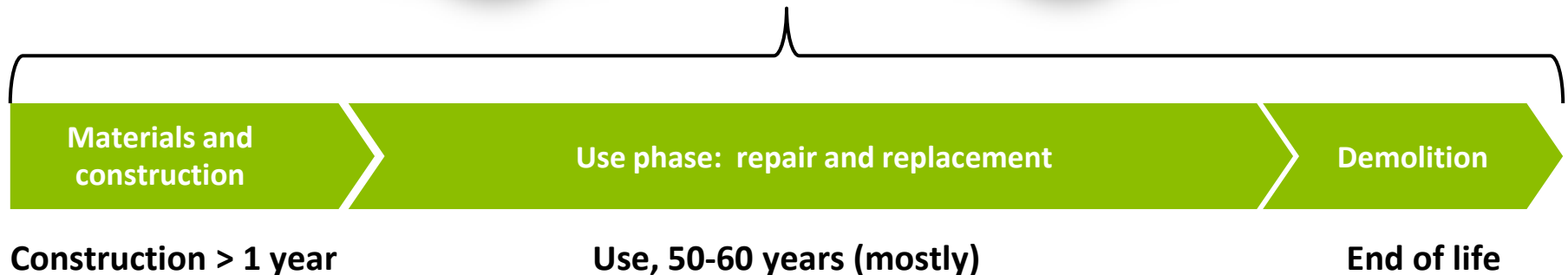
# Life-Cycle Assessment gives you the big picture

LCA ensures you get a holistic picture of the performance that helps avoid sub-optimization. It ensures a scientific basis for environmental impacts. It also makes it impossible to shift burden of environmental impacts to others.

## Life-cycle assessment, LCA



## Life-cycle cost, LCC





# LCA principles in a nutshell

Life-cycle assessment may be done with several different scopes:

- cradle to gate (product before use),
- cradle to grave (product, including use and final disposal) basis, or
- for construction projects, the natural scope is always cradle to grave.

The construction LCA standards use attributional approach. Attributional LCA assigns responsibility using allocation methodology and avoids the use of system expansion. LCA can also be used in situations where major impacts are at a system level. Such system-level LCA may be referred to as "system expansion" and it is more complex.

Conduct of an LCA in business follows agreed upon EN & ISO standards. An LCA may be used to identify performance gaps, compare products, make procurement decisions or improve designs, amongst others.

# LCA's output are environmental indicators

Each indicator describes a particular category of environmental impacts. The impacts are expressed as quantities of a matter that has the potential to cause such impacts – but they do not represent the actual harm (final impact, e.g. endpoint) eventually caused. For instance, global warming potential represents the amount of CO<sub>2</sub>e gases released. But the final impact is the acceleration to the polar melt, for instance.

**EFFETTO SERRA - Global Warming Potential** describes how much a product contributes to climate change. When LCA concerns only this impact category, it's called the carbon footprint.

**ACIDIFICAZIONE - Acidification** describes how much product acidifies the environment, resulting e.g. acid rain.

**EUROFIZZAZIONE - Eutrophication** describes flow of nutrients to ecosystems, resulting e.g. to algae growth.

**BUCO NELL'OZONO - Ozone Depletion** describes damage caused to the Ozone Layer in the stratosphere.



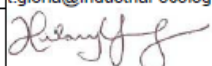
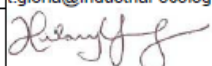
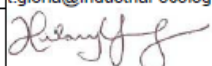
**SMOG FOTO-CHIMICO - Tropospheric Ozone** describes the quantity of summer smog causing gases emitted.

**CONSUMO DI RISORSE - Depletion of minerals** describes how much minerals are withdrawn from geosphere weighted by rarity.

**CONSUMO DI RISORSE ENERGETICHE - Depletion of fossil resources** describes how much fossil resources are withdrawn, simply as MJ.

# An EPD is an LCA for a product with additional rules for calculation, verification and publication

## Example environmental product declarations

ENVIRONMENTAL PRODUCT DECLARATION		Page 1 of 22																																						
 Insulated Metal Panels Industry-Wide EPD		According to ISO 14025																																						
<p>bre</p> <h3>Environmental Product Declaration</h3> <p>BREG EN EPD No.: 000001 Issue: 05 ECO EPD Ref. No.: 000091</p> <p>This is to certify that this verified Environmental Product Declaration provided by: <b>Forterra Building Products Ltd</b></p> <p>Is in accordance with the requirements of: <b>EN 15804:2012+A1:2013</b></p> <p>This declaration is for: <b>Thermalite Autoclaved Aerated Concrete Block (470-770 kg/m3)</b></p> <p><b>Company Address</b> 5 George Park Court</p>		<p>ation in accordance with ISO 14025. This EPD marks, including environmental performance information on the environmental aspects of the informed comparisons between products. EPDs are improvement of environmental performance and provide products of products over their life cycle. EPDs not based on a different PCR, are examples of declarations that programs may not be comparable.</p>  <table border="1"><tr><td colspan="2">on Association (MCA)</td></tr><tr><td colspan="2">1</td></tr><tr><td colspan="2">Panels</td></tr><tr><td colspan="2">Panels &amp; Metal Composite Panels, and Metal Cladding: Roof and Wall (October 2012)</td></tr><tr><td colspan="2"></td></tr><tr><td colspan="2"></td></tr><tr><td colspan="2">n and information about building physics</td></tr><tr><td colspan="2">t basic material and the material's origin</td></tr><tr><td colspan="2">e product's manufacture</td></tr><tr><td colspan="2">duct processing</td></tr><tr><td colspan="2">t the in-use conditions</td></tr><tr><td colspan="2">ment results</td></tr><tr><td colspan="2">nd verifications</td></tr><tr><td></td><td>UL Environment Review Panel</td></tr><tr><td></td><td>Thomas Gloria (Chairperson)</td></tr><tr><td></td><td>35 Bracebridge Road</td></tr><tr><td></td><td>Newton, MA 02459-1728</td></tr><tr><td></td><td>t.gloria@industrial-ecology.com</td></tr><tr><td>ccordance with ISO</td><td></td></tr></table>	on Association (MCA)		1		Panels		Panels & Metal Composite Panels, and Metal Cladding: Roof and Wall (October 2012)						n and information about building physics		t basic material and the material's origin		e product's manufacture		duct processing		t the in-use conditions		ment results		nd verifications			UL Environment Review Panel		Thomas Gloria (Chairperson)		35 Bracebridge Road		Newton, MA 02459-1728		t.gloria@industrial-ecology.com	ccordance with ISO	
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# Life-cycle assessment standards

- **Cornerstone standards**

- ISO 14040 and ISO 14044 – fundamentals for LCA; used in all industries and in professional context, almost all the time

- **Construction works specific standards**

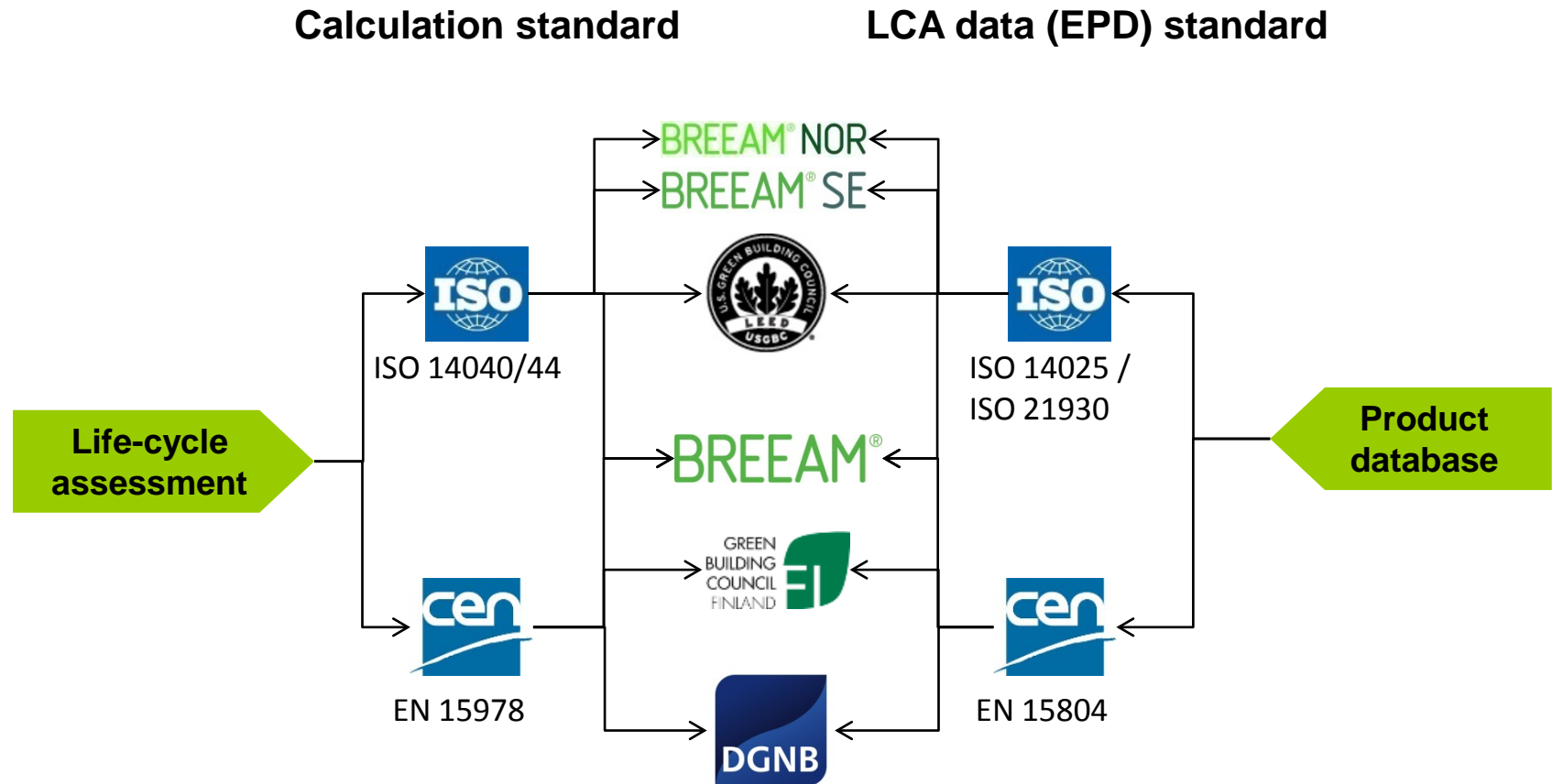
- EN 15978 – LCA standard for construction projects
- ISO 21929-1 and ISO 21931-1 - hardly used LCA standards

- **Environmental Product Declaration standards**

- ISO 14025 – publishing and verification requirements
- EN 15804 (EPD data) and EN 15942 (EPD format)
- ISO 21930 – now being revised to conform with EN 15804

# LCA data, standards and applications

All rating systems and methods approve either ISO- or EN-based LCA; or both.  
One Click LCA supports all systems shown below and others as well.



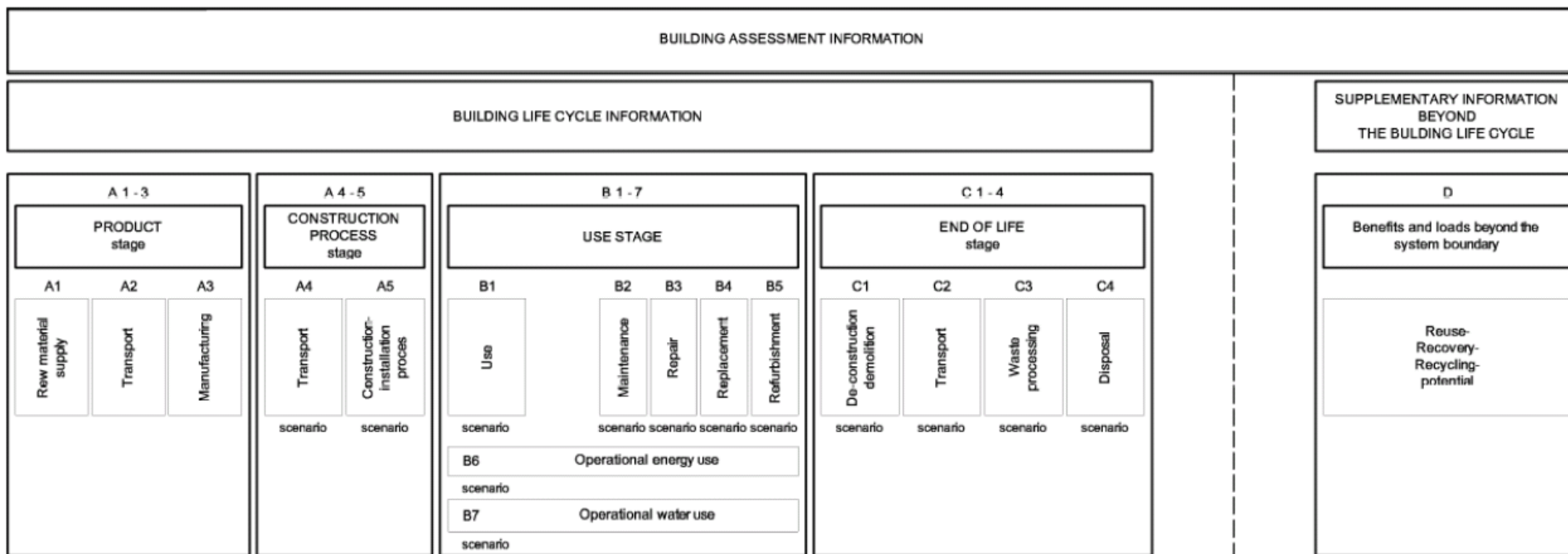
# Life-cycle model of the CEN/TC 350 – uniform and prevents e.g. double-counting of benefits

**Cradle to gate**

Construction products only

**Cradle to grave (materials to deconstruction) – until End of Waste state**

**Recovered energy/material**



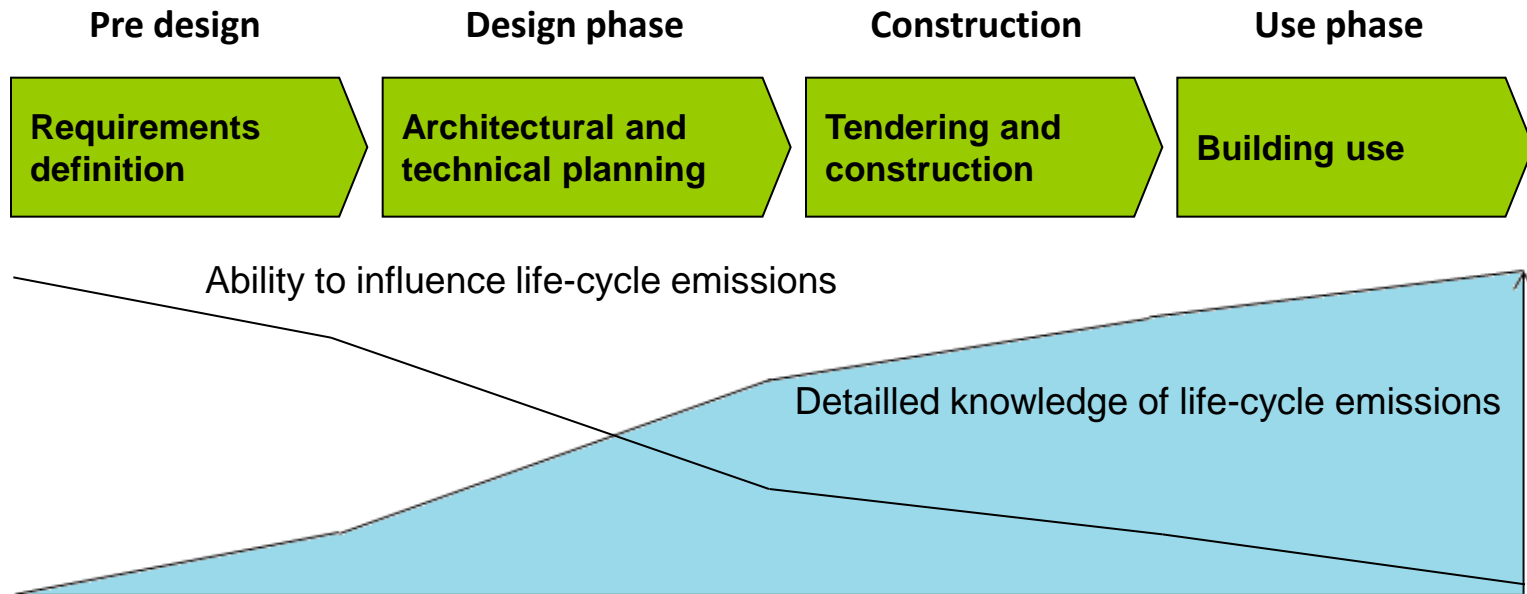


# Key steps in conducting an LCA in practise

- **Choose the right tool for your purpose**
  - To compare building elements you do not need whole building LCA
  - To arbiter between energy and material impacts you do need it
- **Collect the required input data (materials, energy)**
  - You may choose the scope based on your purpose
  - CEN/TC 350 rules
    - requires 95 % coverage; mass or energy more than 1% can't be cut off
    - user equipment energy and non structural systems are not in scope
- **Perform the assessment (using a software tool)**
  - Check credibility of the results and help improve the design

# Early stage offers highest potential but has the least information

You should do LCA as early as possible to be able to influence plans. Use what information is available. When it's all there, it's too late.



# Different applications of LCA in construction

- Achieving certification credits
- Choosing between designs or materials
- (Carbon) awareness – transparency and understanding
- Regulating life-cycle or materials impacts of projects
- Awarding competition prizes based on LCA
- Zoning and urban planning supporting LCA





# Drivers for LCA in certification systems

LEED v4 and other certification systems recognize the value of LCA and provide corresponding credits for design performance improvements proven using LCA.



**LEED v4: up to 3+exemplary  
2009: 1 innovation credit**

**BREEAM<sup>®</sup>**

**Up to 7 credits**

# The process to earn the credits for BREEAM

**1. Choose a BRE-approved LCA tool for your project**

**2. Calculate the LCA for the building**

**3. Input the LCA scope in the Mat 01 calculator to calculate credits**

**4. Generate the detailed results reporting Excel as evidence**

**5. Submit documentation to BRE**



# Life-cycle assessment in BREEAM Int'l

BREEAM has supported LCA credits (at least) since BREEAM Europe Commercial 2009. All currently used versions, BREEAM International 2013, RFO 2015 and BREEAM International 2016 have LCA credits.

Below chart summarizes BREEAM's LCA, LCC and some other credits

Credit	Solution	Credits*	Schemes
Mat 01	Deliver a solid LCA	6+1	2013, 2015, 2016
	Use products with EPDs	1	2016
Ene 04	Prove the impact of LZC	1	2013
Man 05	Various LCC calculations	3	2013, 2015, 2016
Man 03	Get data from the site	3	2013, 2015, 2016
Wst 05	Adaptation to climate change	1+1	2015, 2016

*Exact number of credits varies between schemes, see [www.lcaforbreeam.com](http://www.lcaforbreeam.com)*

## The logic of LCA for BREEAM

- The philosophy is that performing an extensive and high quality LCA achieves higher points; no comparative performance is required
- You can only use approved and verified software
- One Click LCA is the only achieving all+exemplary credit
  - Verified maximum score for LCA / Mat 01: 97,5 %
  - This is 14,5 % higher than the second highest application
- From the end user point of view this means that an LCA does not have to cover all of the building for max credits

# MAT 01 Calculator

Software quality section:  
Uses software's values

Calculation scope section:  
Has to be filled in



## BREEAM International 2013 New Construction Mat 01 Calculator

### Materials Assessment tool/method and data

Note: where 'M' is indicated against a section heading, at least one item must be indicated 'Y'.

	Mandatory	Maximum	Included in LCA tool?
<b>Output Indicators available</b>		Sum:-	
Embodied carbon (CO2e)	M	2	N
Embodied water OR waste processing		2	N
AND any two additional indicators		4	N
Points		8	0

### (M) Output Life stage(s) available (for all indicators selected)

	Score:-	
Cradle to Gate total	2	N
Cradle to Gate total AND End of Life	4	N
Cradle to Grave total	6	N
Cradle to Grave total WITH operational energy (reported separately)	8	N
Cradle to grave with separate life stage reporting to:-	12	N
a. Product stage		
b. Construction process stage		
c. Use stage (with operational energy reported separately)		
d. End of life		
Points	12	0

### (M) Assessment level(s) available. Life cycle impact comparisons

### Materials Assessment Scope

	Mandatory (if present)	Present in building?	Maximum	Included in assessment?
<b>Building elements included</b>				
<b>Fabric:-</b>			Sum:-	
External walls (envelope, structure and finishes)	M	Y	2,00	N
External windows and rooflights	M	Y	2,00	N
Foundations (including excavation)		Y	2,00	N
Internal floor finishes (incl. access floors)	M	Y	2,00	N
Structural frame (vertical)		Y	2,00	N
Upper floors (including horizontal structure)	M	Y	2,00	N
Basements/retaining walls (including excavation)		Y	1,00	N
External solar shading devices, access structures etc.		Y	1,00	N
Ground/lowest floor	M	Y	1,00	N
Internal ceiling finishes (incl. suspended/access ceilings)		Y	1,00	N
Internal walls and partitions	M	Y	1,00	N
Roof (including coverings)	M	Y	1,00	N
Stairs and ramps		Y	1,00	N
Balustrades and handrails		Y	0,50	N
Internal doors		Y	0,50	N
Internal wall finishes		Y	0,50	N

# How credits are calculated in MAT 01

Table - 45: Percentage of BREEAM Mat 01 calculator points achieved and credits awarded (Option 1)

Percentage of BREEAM Mat 01 calculator points achieved (%) (Option 1)	Credits	
	Industrial	All other buildings
10	1	1
30	1	2
50	1	3
65	2	4
75	2	5
80	2	6
85	2 + 1 exemplary	6 + 1 exemplary



# Requirements for the LCA (RFO 2015)

## Up to six credits (option 1): Project life cycle assessment study

- 1 The project uses a life cycle assessment (LCA) tool or undertakes a building information model life cycle assessment (BIM LCA) to measure the life cycle environmental impact of the refurbishment or fit-out works.
- 2 The LCA covers new materials as relevant to the assessment parts listed in CN2.1 and indicated in the 'Materials assessment scope' section of the BREEAM International Refurbishment and Fit-out Mat 01 calculator (Part B of the tool).
- 3 The mandatory requirements identified in the 'Materials assessment tool, method and data' section of the BREEAM International Refurbishment and Fit-out Mat 01 calculator have been met.
- 4 A member of the project team completes the BREEAM International Refurbishment and Fit-out Mat 01 calculator using parts A and B and determines a score based on the robustness of the LCA tool used (Part A of the tool) and the scope of the assessment in terms of the materials specified that have been considered (Part B of the tool)
- 5 Where the design team can demonstrate how the LCA has benefited the building in terms of measuring and reducing its environmental impact. See CN2.8
- 6 Where the design team submit the LCA tool output (e.g. Building Information Model (BIM)) for assessing the building to BRE Global (via the project's appointed BREEAM Assessor) to inform future potential LCA benchmarking for BREEAM
- 7 Credits are awarded in accordance with Table - 45

*Requirement only in RFO 2015*

# LCA data detailed submission requirements

One Click LCA generates detailed submission report automatically.

An electronic data table or tables of results (suitably cross referenced) generated by the tool, submitted by the assessor to BRE Global must fulfil the following criteria:

1. Submit a total building environmental impact result for year 0 (installation only) and year 60 study periods, as follows:
  - a. To include individual results for all environmental issues or indicators that the tool or data permits, showing issue or indicators names and units used. Where issues or indicators according to BS EN 15978:2011 are available, these should be used
  - b. Include individual results for each life stage or module, e.g. stages A, B and C (see BS EN 15978:2011). Where the tool further permits, or where complete measurement of the aforementioned stages is not possible, more detail should be provided. For example, BS EN 15978:2011 modules should be used
  - c. The reporting format should be to BS EN 15978:2011 (or equivalent).
2. Results for each element as follows, to enable project team members and assessors without an IMPACT Compliant tool to check the accuracy of the model:
  - a. Element impact per issue (as above), with units
  - b. Element kg kgCO<sub>2</sub>e per life stage or module (as above)
  - c. Element quantity, with units
  - d. Element description
  - e. For each material in the element:
    - i. Installed quantities, with units
    - ii. Site wastage quantities, with units
    - iii. Replace, repair, refurbish quantities, with units
    - iv. Reuse, recycling or disposal (landfill, incineration) quantities, with units.
3. Transmitted in IFC, MS Excel or CSV file format.

# EPD logic in BREEAM (additional in Mat 01, 2016)

- BREEAM has introduced in version 2016 a reward for specifying and using products which have qualifying EPD
- One credit - Environmental product declarations (EPD)
  - Five products with EPDs are specified and purchased
- Exemplary level criteria
  - Ten products with EPDs are specified and purchased
- Additional requirements:
  - Each EPD shall be classified to one of 10 groups (Table 44) . Only two EPDs per classification group may be counted.
  - EPD certificates must be unexpired at the point of specification and be compliant with ISO 14025, ISO 21930 or EN 15804.

# The process to earn the credits for LEED

- 1. Define your baseline and your actual design strategy**
- 2. Calculate the LCA for your baseline in compliancy with LEED**
- 3. Calculate the LCA for actual design in compliancy with LEED rules**
- 4. Check if you qualify for the credit and possible exemplary credit**
- 5. Submit documentation to USGBC**



# Typical LEED v4 project scorecard

LEED Scorecard

Gold 61/110

▶ INTEGRATIVE PROCESS CREDITS

0 OF 1



▶ LOCATION & TRANSPORTATION

12 OF 18



▶ SUSTAINABLE SITES

6 OF 11



▶ WATER EFFICIENCY

6 OF 11



▶ ENERGY & ATMOSPHERE






26 OF 33



▼ MATERIAL & RESOURCES

2 OF 13



 Credit	Building life-cycle Impact reduction	0 / 5
 Credit	Building product disclosure and optimization - environmental product d...	0 / 2
 Credit	Building product disclosure and optimization - sourcing of raw materia...	0 / 2
 Credit	Building product disclosure and optimization - material Ingredients	0 / 2
 Credit	Construction and demolition waste management	2 / 2

▶ INDOOR ENVIRONMENTAL QUALITY

2 OF 16



▶ REGIONAL PRIORITY CREDITS

4 OF 4



# LEED v4: MRc1 Building life-cycle impact reduction,

## Option 4: Whole building life-cycle assessment

This is the only option available for most new buildings and it is worth 3 points and an optional exemplary point, and a regional priority (e.g. Canada, New York).

Principle of credit is to compare the proposed design against a baseline building (similar to approach used for energy efficiency prerequisite and credit).

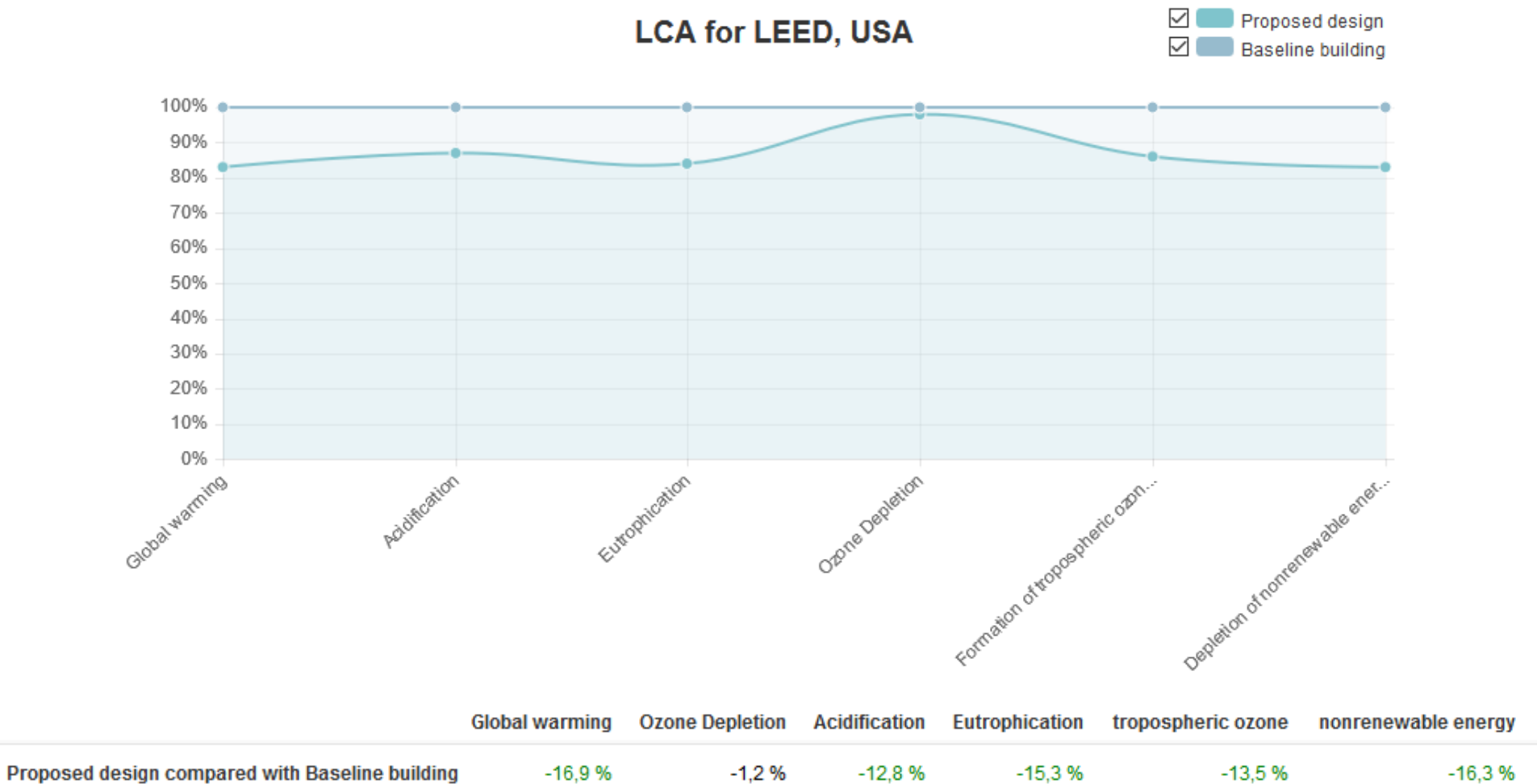
The LCA concerns the building structure and enclosure only; extending it to additional building elements will not earn additional points.

Specific requirements from LCA software point of view

- Must support the six defined impact categories
- Data sets must be compliant with ISO 14044
- Data sets must comply with CML, ReCiPe or TRACI (defined or newer versions)
- LCA scope covers life-cycle stages A1-A4, B1-B5 and C1-C4 from EN 15804

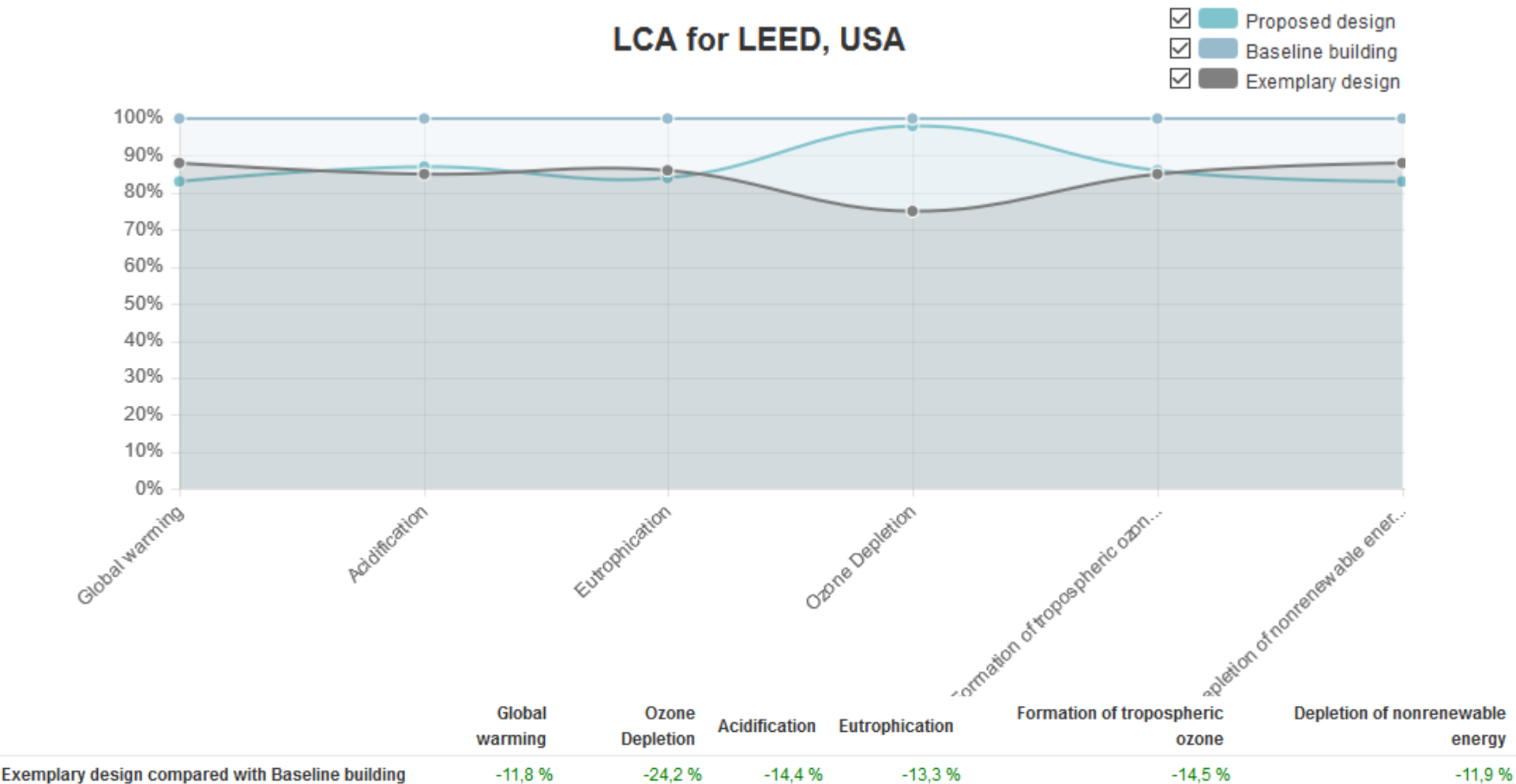
# Improvement compared to the baseline building

Demonstrate at least a 10 % reduction in global warming potential and two other impact categories vs. the baseline building. No impact may grow by more than 5%.



# Improvement compared to the baseline building

Exemplary performance: achieve any improvement over the required credit thresholds in all six impact measures; earns an additional exemplary point.

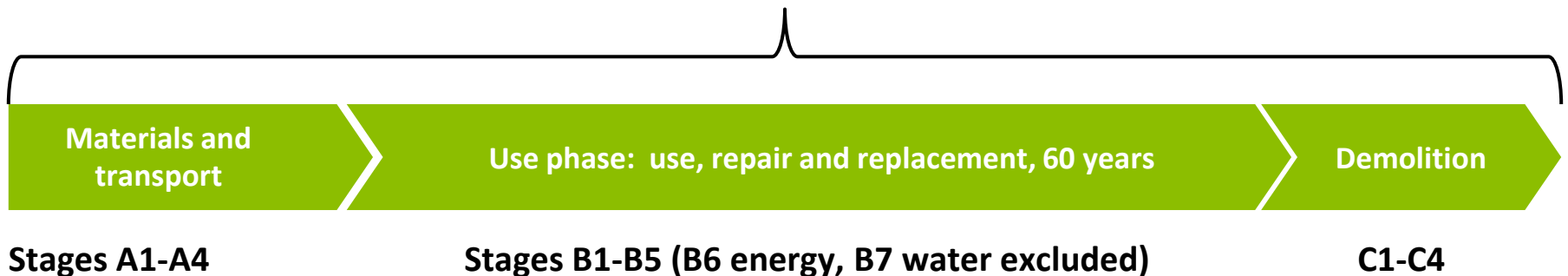




# Scope of LCA for LEED is stricly materials-focused

LEED requires the assessment to be carried over a 60 year period to account for repair and replacement of materials during the lifetime of the building. Operational energy and water are excluded from LCA as they must be same for comparability.

## Scope of LCA for LEED v4



# Formal requirements for the baseline building

Projects in the U.S. must develop the baseline using ASHRAE Standard 90.1–2010, Appendix G “Performance Rating Method”, same as for energy modelling.

The proposed design and baseline building must have same size, function, orientation, and energy performance as per EA Minimum Energy Performance.

Canadian projects may use local NECB standards.

Other international projects are expected to develop a baseline building representing typical construction for their region meeting local applicable building performance requirements.

# Four basic options for creating a baseline building

Archetype

External benchmark

Created outside design process

Created inside design process

Early design

Alternative

*Recommended*

Early design

Detailed design

Final design

Opt 1

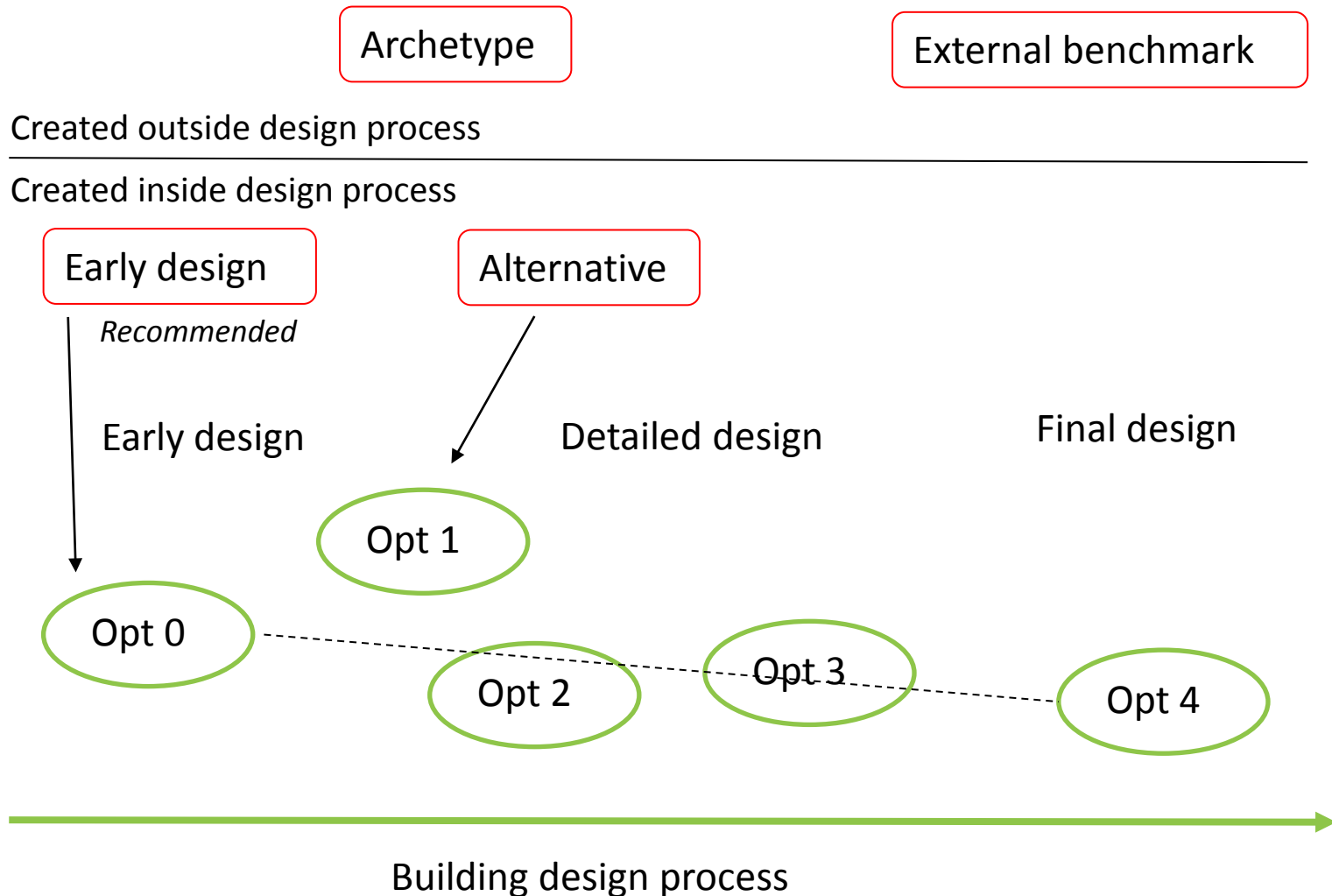
Opt 0

Opt 2

Opt 3

Opt 4

Building design process

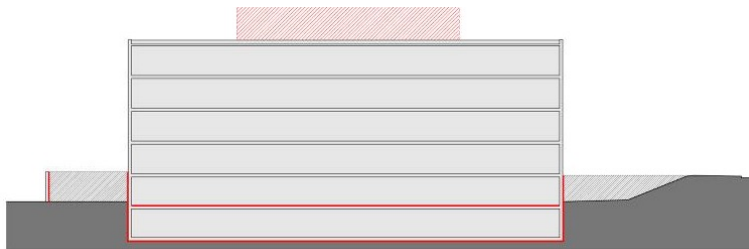


# Achieving improvements over the baseline

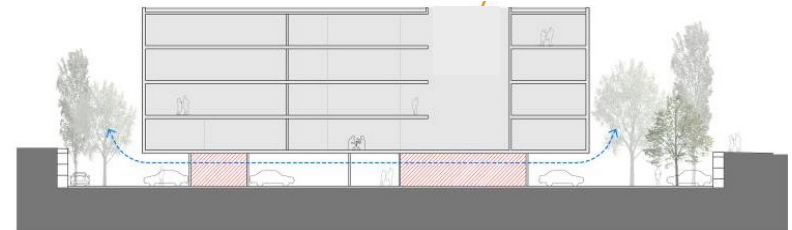
Highly efficient strategies for reducing life-cycle impacts on projects include:

- Optimizing structure to reduce material demand (e.g. designing slim floors)
- Avoiding over-specification (e.g. not all concrete needs same strength class)
- Specifying lower-impact materials (e.g. concrete using fly ash)

It is also worthwhile looking for more local supplies where major quantities of materials are involved, or looking for materials that would last the entire required life-span of the building in lieu of materials requiring replacement.



Conventional: retaining walls and floor slab in contact with the ground



Demand reduction: no retaining walls or floor slabs in contact with the ground





## Contacts

- ▶ [support@bionova.fi](mailto:support@bionova.fi)
- ▶ [eleonora.sablone@gmail.com](mailto:eleonora.sablone@gmail.com)

## Further resources

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