# Using a budget approach for decision-support in the design process

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# Environment-related questions during the design process

"This building is responsible for a Global Warming Potential of 1'002'500 kg $CO_2$-equivalent over the next 50 years"

# Environment-related questions during the design process

1. Is is good ?

2. Is it enough?

3. How can we improve the environmental performance of the building through material and construction design choices?

# Top down approach

1 t $CO_2$-e per capita and year

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1 t $CO_2$-e per capita and year

↓

36% attributed to housing

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1 t $CO_2$-e per capita and year

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360 kg $CO_2$-e per capita and year

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360 kg $CO_2$-e per capita and year

↓

SIA 2040 scenarios

# Top down approach

1 t $CO_2$-e per capita and year

↓

36% attributed to housing

↓

360 kg $CO_2$-e per capita and year

↓

SIA 2040 scenarios

↙

Embodied 270 kg $CO_2$-e/(c·a)

# Top down approach

1 t $CO_2$-e per capita and year

↓

36% attributed to housing

↓

360 kg $CO_2$-e per capita and year

↓

SIA 2040 scenarios

↙ ↘

Embodied 270 kg $CO_2$-e/(c·a) | Operational 90 kg $CO_2$-e/(c·a)

# Top down approach

## 18 people are supposed to live inside…

| | GWP [kg $CO_2$-e/a] |
|---|---|
| Embodied | 4860 |
| Operation | 1620 |
| **Total** | **6480** |

# Top down approach

## Top-down benchmark

| | GWP [kg $CO_2$-e/a] |
|---|---|
| Embodied | 4860 |
| Operation | 1620 |
| **Total** | **6480** |

## Actual building

| | GWP [kg $CO_2$-e/a] |
|---|---|
| Embodied | 5518 |
| Operation | 2073 |
| **Total** | **7591** |

# Top down approach

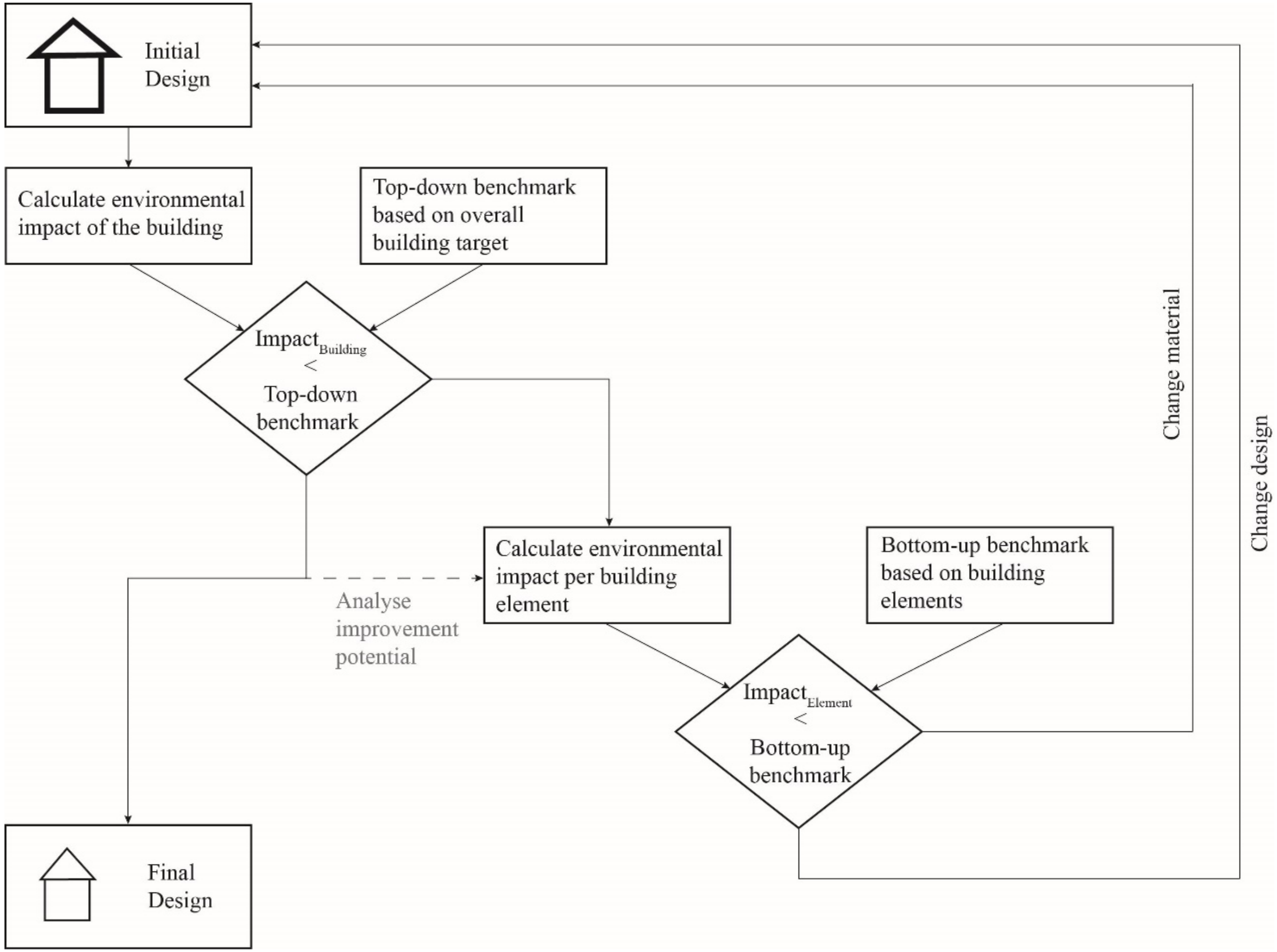
## Top-down benchmark

| | GWP [kg $CO_2$-e/a] |
|---|---|
| Embodied | 4860 |
| Operation | 1620 |
| **Total** | **6480** |

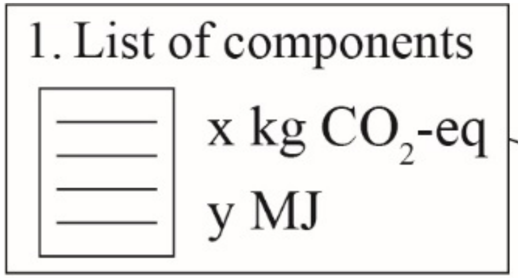
## Actual building

| | | GWP [kg $CO_2$-e/a] |
|---|---|---|
| Embodied | | 5518 |
| Operation | | 2073 |
| **Total** | **+15%** | **7591** |

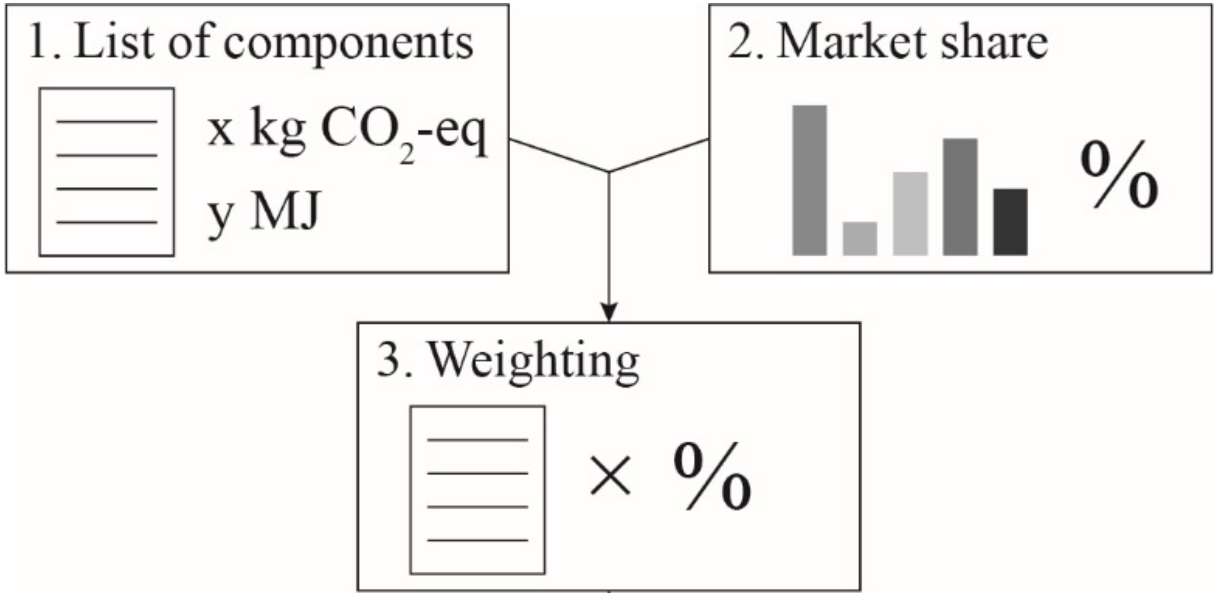
# Method


Initial Design
Calculate environmental impact of the building
Top-down benchmark based on overall building target
Impact Building < Top-down benchmark
Calculate environmental impact per building element
Bottom-up benchmark based on building elements
Analyse improvement potential
Impact Element < Bottom-up benchmark
Change material
Change design
Final Design

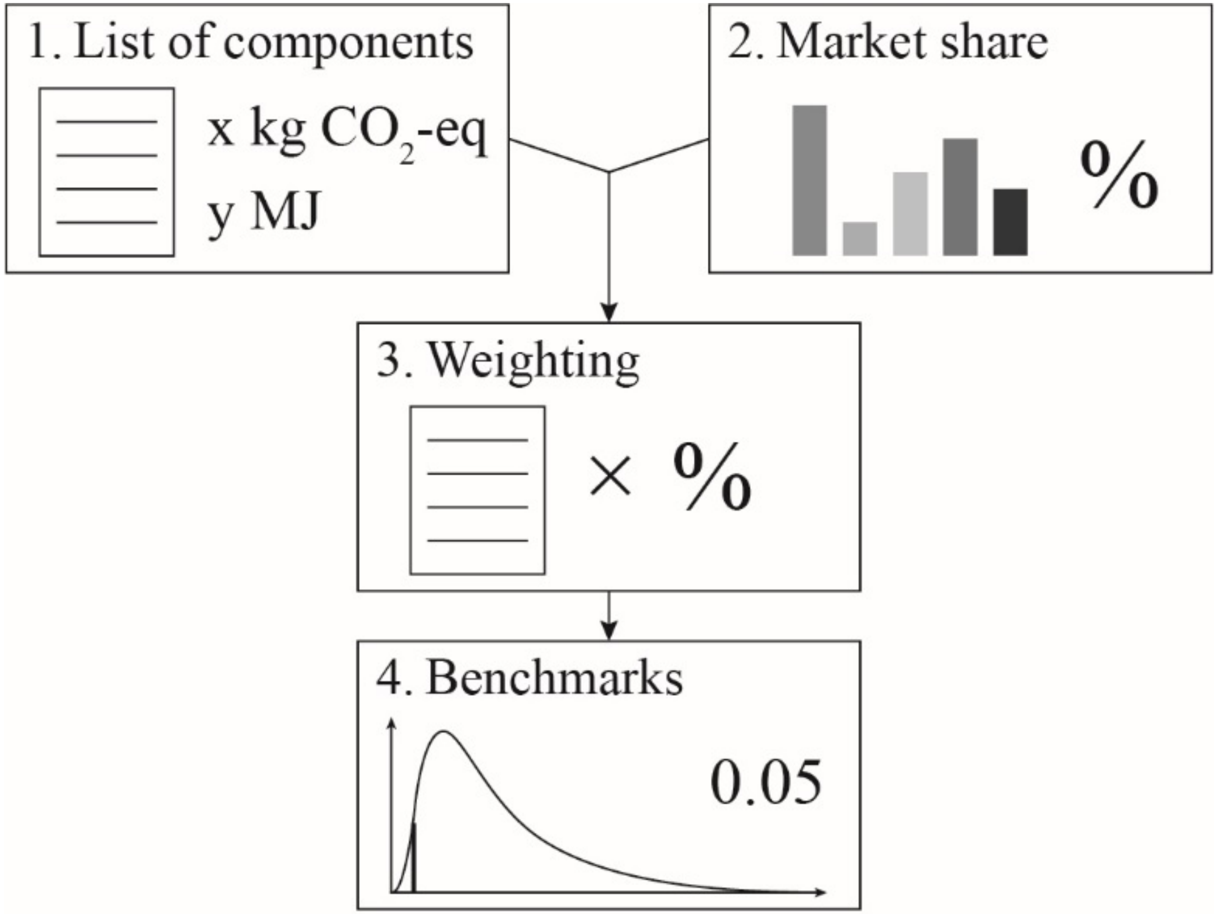
# Bottom up approach



# Bottom up approach



# Bottom up approach



# Bottom up approach

BAUTEILKATALOG.CH

HOME | INFORMATIONEN | FUNKTIONEN | MY BAUTEILKATALOG.CH | KATALOGE

ANSICHT | BEURTEILUNGSGRÖSSE | AUSGABE | BAUTEILSUCHE | BERECHNEN | ZURÜCKSETZEN | QS

| | |
|---|---|
| **E2.2** | **Aussenwärmedämmung** |
| **MB2032_042** | **Wärmeverbundsystem, WD Aussenputz** |
| **Ausführung** | **Steinwolle, ρ 100 [kg/m3], d 0.18 m, λ 0.04 W/mK** |
| **Beschrieb** | |
| **Bauteiltyp** | |
| **Graue Energie** MJ/m² a, KBOB/eco-bau/IPB Version: 2018-in Bearbeitung | **15.12** |

| Nr. | Material / Schicht | Schichtdicke | Lambda | Amortisationszeit | Masse | Erstellung | | Entsorgung | | Total pro Jahr | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | m | W/mK | a | kg/m² | MJ/m² | % | MJ/m² | % | MJ/m² a | % |
| | Kunststoffmörtel | 0.002 | 0.8 | 30 | 3.2 | 75.71 | 17% | 0.36 | 7% | 2.54 | 17% |
| | Steinwolle, ρ 100 [kg/m3] | 0.18 | 0.04 | 30 | 18.0 | 269.44 | 60% | 4.39 | 79% | 9.13 | 60% |
| | Kunststoffmörtel | 0.002 | 0.8 | 30 | 3.2 | 75.71 | 17% | 0.36 | 7% | 2.54 | 17% |
| | Polyester (UP) glasfaserverstärkt | 0 | 0.19 | 30 | 0.2 | 12.09 | 3% | 0.07 | 1% | 0.41 | 3% |
| | Kunststoffputz | 0.002 | 0.7 | 30 | 3.0 | 15.23 | 3% | 0.34 | 6% | 0.52 | 3% |
| | | | | | 28 | 448.17 | 99% | 5.53 | 1% | 15.12 | 100% |

*Bauteilkatalog.ch*


*Wüest & Partner AG*

# Bottom up approach

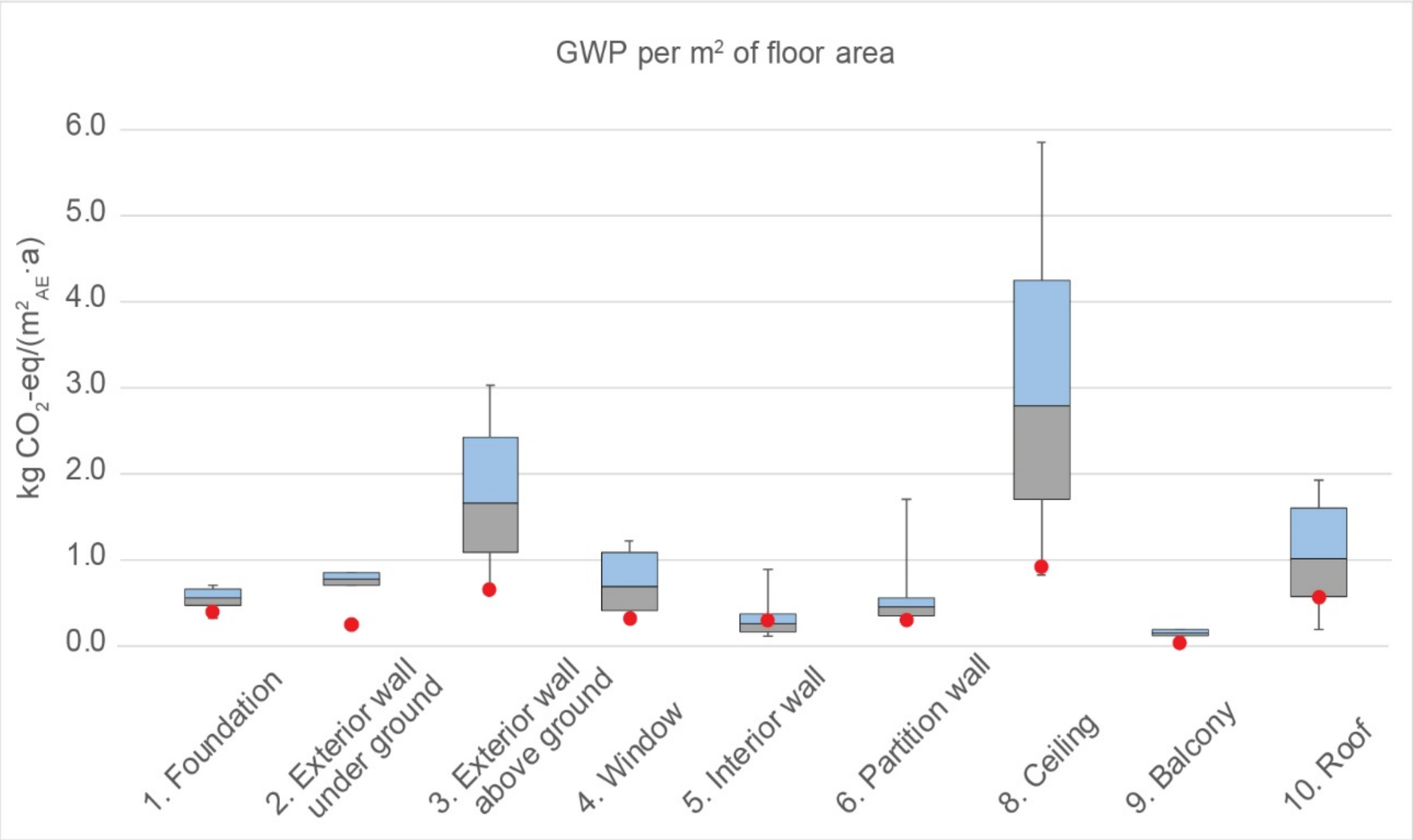
Minimum, maximum, weighted mean and target values (0.05 quantile) for GWP for the building elements.

| Building element | Sample size | Reference unit | GWP [kg $CO_2$-e/(unit·a)] | | | |
|---|---|---|---|---|---|---|
| | | | Min. | W. mean | Max. | Target (0.05) |
| 1. Base slab | 80 | $m^2_{element}$ | 1.32 | 2.23 | 2.82 | 1.87 |
| 2. Exterior walls underground | 3 | $m^2_{element}$ | 3.52 | 3.72 | 3.87 | 3.35 |
| 3. Exterior walls aboveground | 404 | $m^2_{element}$ | 0.82 | 2.11 | 3.82 | 1.37 |
| 4. Windows | 16 | $m^2_{element}$ | 1.49 | 3.16 | 5.57 | 1.85 |
| 5. Interior walls | 35 | $m^2_{element}$ | 0.59 | 1.28 | 4.46 | 0.82 |
| 6. Partition walls | 30 | $m^2_{element}$ | 0.58 | 1.05 | 3.97 | 0.83 |
| 7. Columns | 7 | piece | 1.29 | 6.04 | 11.76 | 1.91 |
| 8. Ceilings | 1260 | $m^2_{element}$ | 0.66 | 2.24 | 4.69 | 1.37 |
| 9. Balconies | 4 | $m^2_{element}$ | 1.2 | 1.48 | 1.76 | 1.13 |
| 10. Roof | 273 | $m^2_{element}$ | 0.79 | 4.05 | 7.71 | 2.32 |
| 11. Technical equipment[a] | 29 | $m^2_{AE}$ | 1.18 | – | 3.36 | 1.18* |

[a] Due to a small number of solutions in the building component catalogue, no benchmark is calculated, but the minimum is used. The target value is the sum of minimum values for electric equipment, heat generation, heat distribution and delivery, ventilation equipment and water (sanitary) equipment of residential buildings.

# Potential to improve construction/material selection

| Architectural element | GWP [kg $CO_2$-eq/($m^2$·a)] 0.05 | min | actual |
|---|---|---|---|
| 1. Base plate / foundation | 304 | 301 | 383 |
| 2. Exterior wall under ground | 614 | 644 | 241 |
| 3. Exterior wall above ground | 1295 | 592 | 619 |
| 4. Window | 372 | 298 | 298 |
| 5. Interior wall | 154 | 108 | 285 |
| 6. Partition wall | 326 | 226 | 278 |
| 7. Column | 0 | 0 | 0 |
| 8. Ceiling | 1558 | 749 | 903 |
| 9. Balcony | 102 | 108 | 42 |
| 10. Roof | 529 | 181 | 538 |
| 11. Technical equipment* | 939 | 939 | 1222 |
| Sum | 6193 | 4145 | 4809 |
| **/ AE** | **6.8** | **4.5** | **5.3** |



- «Is good good enough?»

- Target values for embodied according to SIA 2040 / 1 t CO2 per capita society

| $A_E$ per person | PEnr [$MJ/(m^2_{AE} \cdot a)$] | GWP [$kg\ CO_2\text{-}eq/(m^2_{AE} \cdot a)$] |
|---|---|---|
| 60 $m^2$ | 27.0 | 4.5 |

- Case study results

| | 0.05 | min | actual |
|---|---|---|---|
| GWP [$kg\ CO_2\text{-}eq/(m^2 \cdot a)$] | 6.8 | 4.5 | **5.3** |
| PEnr [$MJ/(m^2 \cdot a)$] | 83.3 | 62.1 | **82.6** |

- «Is good good enough?»

- Target values for embodied according to SIA 2040 / 1 t CO2 per capita society

| $A_E$ per person | PEnr [$MJ/(m^2_{AE}\cdot a)$] | GWP [kg $CO_2$-eq/($m^2_{AE}\cdot a$)] |
|---|---|---|
| 60 $m^2$ | 27.0 | 4.5 |
| 45 $m^2$ | 36.0 | 6.0 |

- Case study results

| | **0.05** | **min** | **actual** |
|---|---|---|---|
| **GWP [kg $CO_2$-eq/($m^2\cdot a$)]** | 6.8 | 4.5 | **5.3** |
| **PEnr [$MJ/(m^2\cdot a)$]** | 83.3 | 62.1 | **82.6** |

# Problem statement and goal

- LCA results are difficult to interpret for designers and clients
- Current benchmarks on building level cannot indicate improvement potential
- Benchmarks on element level are needed
- Database with LCA results for many buildings on element level is missing (big data)

# Conclusion

- Method works well for elements with more than 10 standard components
- Limitations regarding innovative constructive solutions
- Market share approach can be used as long as wide building LCA database is not available

- Application in other national contexts
- Integration in building LCA tools for the design phase

# ”Top-down or bottom-up?” – How environmental benchmarks can support the design process

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## Top-down or bottom-up? – How environmental benchmarks can support the design process

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ABSTRACT

Buildings are responsible for a large share of greenhouse gas (GHG) emissions. The use of Life Cycle Assessment (LCA) during the design phase can help to improve the environmental performance of buildings. However, designers and clients find it difficult to set environmental performance targets and interpret the results obtained through LCA in order to improve the building design. Therefore, reference values or benchmarks are needed. Current available LCA-based benchmarks have mostly been developed for certification systems on whole building level and do not provide design guidance on material or element level. To close this gap, this paper introduces an alternative approach that supports the design process by providing guidance and encouraging to improve the environmental performance. The aim of this approach is to support exploiting the optimization potential particularly regarding the embodied GHG emissions related to the manufacturing of construction products and to the construction, maintenance and demolition of the building. The concept consists in combining top-down benchmarks per capita derived from the capacity of the global eco system with bottom-up reference values for building components that are defined based on a statistical best-in-class approach (top 5%) using the market share of different construction products. Benchmarks for GHG emissions for new residential buildings in Switzerland are discussed. The results of applying the dual benchmark approach to a case study show that it can facilitate the use of LCA-based tools for design support and promote the optimization of the building-related environmental performance.

https://doi.org/10.1016/j.buildenv.2019.02.026

# “If less is more, maybe nothing is everything.”


Sce: Nichols, S. 2019. 22 propositions for Re-materializing construction. LafarageHolcim Foundation

**Place Léon Aucoc, Bordeaux, Lacaton & Vassal, 1996.**