Quantification and visualization of embodied impacts using Building Information Modelling

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future in process...

EXPLORING SUSTAINABILITY, PARTICIPATION AND THE BUILDING LIFE CYCLE
That’s earth.
That’s us.
what is...?
what it also is...

- **TOTAL of all sectors**
  - 0%: -82% / -79%

- **Power**
  - 0%: -99% / -93%

- **Industry**
  - 0%: -87% / -83%
  - 100%: -40% / -34%

- **Transport incl. aviation, excl. maritime**
  - 100%: -20% / -9%
  - 0%: -67% / -54%

- **Residential & services**
  - 100%: -53% / -37%
  - 0%: -91% / -88%

- **Agriculture other than CO₂**
  - 100%: -49% / -42%
  - 0%: -37% / -36%

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GHG emissions in 1990 [CO₂eq] and reductions [%] until 2030, 2050

According to the European Commission, 2012
How to integrate sustainability in the architectural design process?
“Don’t fight forces, use them.”

RICHARD BUCKMINSTER FULLER
methods.

Participatory Design Process (PDP)
Participatory Design Process (PDP)

Environmental Life Cycle Assessment (LCA)
methods.

Participatory Design Process (PDP)

Environmental Life Cycle Assessment (LCA)

Building Information Modelling (BIM)
process steps.
participatory design process.
LESEN
FEUER, FEIERN
KAFFEE
GARTEN
BESUCH, GÄSTE
TIERE
PFANZEN
WEIN
DUNGE VIELFALT
BÜCHER
DISKUSSION
VIELE SCHULE/LEHRER
WECHSEL
ENTSCHLIEßUNGEN
OFFENHEIT
KIND IN UNS
INNERE HÜTTE
PORTAL, EINGANG
KÖNNEN
SÄSCHES ANDERE KINDER
ERFASSEN
STRUKTURIERTE OBERFLÄCHEN
ABGRENZUNG
ARSEN
KÜCHE
AUSBLICK
(UN) GESTALTUNG
SELBER
KOORDINATION

GEK KÖCHEN, ESSEN, TRINKEN
WEIN LAGERN
BASTELN, WERKEN
KREATIV
GESTÜTZTE, OBST
HÖRTEIERN
FEIERN
BÜCHER, LESEN
AN PFLANZEN
POSAMMENSITZEN
GARTEN
NISCHEN
SCHWINTEICH
BIENEN, HÖCHER
SAUNA
WINTERGARTEN
WASCHKÜCHE
WASCHEN / AUFLÄUFE
GÄSTE ZIMMER + BAR
Fahrwege
STANDORT
CARSHARING
OFFIS, SATTECHi
FAHRRAD
ARBEITEN
HAUSAUFGABEN
BESPREchen
FITNESS
SILENT OFFICE
FILM, KINO
VERMIETEN

FUNCTIONS & PROGRAM.
spaces & relations.

1. ROOM OF SILENCE LIBRARY
2. GUEST ROOM
3. INDIVIDUAL FLATS
4. MULTIFUNCTIONAL SPACE
5. SECONDARY SPACES
6. COMMON GARDEN SPACE

TO PRIVATE

FROM PUBLIC
spatial concept.
co-housing
sufficient and
affordable

- small
  1-2 people
  40-65 m²

- medium
  2-3 people
  65-95 m²

- large
  3+ people
  95-130m²
idea.
What about the environment?
How do we know what’s “good”?
life cycle assessment.
Typical buildings 10-20 years old

Low-impact building current practice

"No-impact" building future?

Operational impacts

Embodyed impacts

design relevance.
building information modelling.
3D Geometry

Model
3D Geometry
4D Time
5D Cost
6D Life Cycle

Model
Schedule
Budget
Sustainability
dimensions.

3D Geometry
Model
Communication

4D Time
Schedule
Life Cycle Performance

5D Cost
Budget
Environment

6D Life Cycle
Sustainability
Design

workflow.
workflow.

PDP -> Requirements -> Design
workflow.
workflow.
workflow.

PDP → Requirements → Design → Quantities → LCA

Visualisation → Design → Impacts
workflow.
[m²] [functions] [shape]
scenario analysis.

Construction Profile

Energy Standard

Energy Mix
Total impacts of all 27 scenarios % of GWP and PEDnr benchmark

- Target value benchmark
- Fulfillment of PEDnr and GWP
- Fulfillment of PEDnr or GWP
- Neither PEDnr nor GWP

conventional oil, gas, grid EU

scenario results.
conventional oil, gas, grid EU

renewable biomass, grid AT

scenario results.
scenario results.

conventional oil, gas, grid EU

renewable biomass, grid AT

renewable HP, PV own/grid
scenario results.

conventional oil, gas, grid EU

renewable biomass, grid AT

renewable HP, PV own/grid
construction profile & energy standard

Embodied and operational impacts of scenarios 19-27 (all EM3)
% of GWP benchmark

- Target value benchmark
- Energy Standard (ES)
- Construction Profile (CP)

scenario results.
spatial concept.
Building element catalogue

<table>
<thead>
<tr>
<th>Impact</th>
<th>Quantity</th>
<th>Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWP/m²</td>
<td>m²</td>
<td>Geometry</td>
</tr>
</tbody>
</table>

External walls

- GWP/m²
- 2.1
- m²

Floor construction

- GWP/m²
- 4.1
- m²

Windows

- GWP/m²
- E3
- m²

Building element classification

- Total + Detail: C1+C2.1B+C2.2+C4.1+C4.4+E3
- Embodied impacts
- Visualization

Automation (e.g. Dynamo)
### Detailed Results

#### Share on Total (Per Element Category)

<table>
<thead>
<tr>
<th>Element Category</th>
<th>Embodied Impacts (%)</th>
<th>Element Areas (%)</th>
<th>Dominance of Element Category on Embodied Impacts [%/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation walls</td>
<td>13.7</td>
<td>31.7</td>
<td>0.43</td>
</tr>
<tr>
<td>Windows (wall/roof)</td>
<td>17.2</td>
<td>9.1</td>
<td>1.90</td>
</tr>
<tr>
<td>Roof construction</td>
<td>10.0</td>
<td>10.3</td>
<td>0.98</td>
</tr>
<tr>
<td>Floor construction</td>
<td>12.0</td>
<td>19.9</td>
<td>0.60</td>
</tr>
<tr>
<td>Ext. wall above ground</td>
<td>36.9</td>
<td>17.4</td>
<td>2.13</td>
</tr>
<tr>
<td>Foundation</td>
<td>10.2</td>
<td>11.6</td>
<td>0.87</td>
</tr>
</tbody>
</table>
Automation.

Visualization of impacts

QTO

Impacts

eBKP-H to match elements

Visual Scripting in Dynamo / Revit
1: Embodied Impacts (GWP) per building element area, [kgCO₂eq/m²]
2: Share of element category on quantified areas, [% of total m²]
3: Share of element category on total embodied impacts, [% of total GWP]
4: Dominance of element category on assessment results, [% total m² to % total GWP]

EMBODIED IMPACTS PER BUILDING ELEMENT, SHARE ON TOTAL EMBODIED IMPACTS AND AREAS. DOMINANCE ANALYSIS OF BUILDING ELEMENTS.
community.
Let's take the challenge
Let’s take the challenge

Use the tools

conclusion.
Let’s take the challenge

Use the tools

Building life cycle

conclusion.
Let’s take the challenge
Use the tools
Building life cycle
Embrace sustainability

conclusion.
Let’s take the challenge

Use the tools

Building life cycle

Embrace sustainability

Design quality matters

comclusion.
Thank you