LCA for Zero Emission Buildings
A chronology of the development of a visual, dynamic and integrated approach

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Net Zero Emission Building

A 'net zero emission building' (net ZEB), the balance is measured in terms of associated GHG emissions during the lifetime of a building instead of just energy demand and generation (ZEB, 2016)

**Pilot Projects**

- Living Lab. Photo: Geir Mogren.
- Powerhouse Brattkava. Illustration: Snøhetta/Mir.
- Visund, Haakonsvern. Photo: Hundvåen Clements.
- Multikomfort. Photo: Bo Mathiassen.
- Campus Evenstad. Photo: Lecky Havik Sjøvold.
- Powerhouse Kjerbo. Photo: Bo Mathiassen.
- Zero Village Bergen. Illustration: Snøhetta/Mir.

**Interdisciplinary Research**

- **WP1** Advanced materials Technologies
- **WP2** Climate-adapted low-energy envelope technologies
- **WP3** Energy supply systems and services
- **WP4** Energy efficient use and operation
- **WP5** Concepts and Strategies for zero emission buildings

**Figure 2**

The illustration shows how the generation of renewable energy (green circle) may compensate for all greenhouse gas emissions from all life cycle stages of the building (red circles).
Early Design
Decision Making
*(Digital and Analogue)*

Bridges the gap between research & design
Explorations in dynamic and parametric modelling of the ZEB Tool.

Zorbey Tuncer

Spring 2016 & 2017

Håvard Auklend & Mads Løkeland Slåke

M.Sc. 2013-2015
ZEN summer intern 2014

Giulia Ceci

Mattia Manni

Spring 2016

Tobias Hofmeister

Spring 2016
2. The ZEB Tool Creation (2011-2014)

<table>
<thead>
<tr>
<th>Building element</th>
<th>[kgCO₂eq] Lifetime 60 years</th>
<th>[kgCO₂eq] per year</th>
<th>[kgCO₂eq/m² BRA] Lifetime 60 years</th>
<th>[kgCO₂eq/m² BRA] per year</th>
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<tbody>
<tr>
<td>21 Groundwork and foundations</td>
<td>14067.19</td>
<td>234.45</td>
<td>87.92</td>
<td>1.47</td>
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<tr>
<td>22 Superstructure</td>
<td>1378.00</td>
<td>22.79</td>
<td>0.70</td>
<td>0.14</td>
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<tr>
<td>23 Outer walls</td>
<td>12368.08</td>
<td>211.45</td>
<td>79.29</td>
<td>1.32</td>
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<tr>
<td>24 Inner walls</td>
<td>3550.84</td>
<td>59.18</td>
<td>22.19</td>
<td>0.37</td>
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<tr>
<td>25 Structural deck</td>
<td>3685.02</td>
<td>61.42</td>
<td>23.03</td>
<td>0.38</td>
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<tr>
<td>26 Outer roof</td>
<td>4174.10</td>
<td>69.57</td>
<td>26.09</td>
<td>0.43</td>
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<tr>
<td>28 Stairs, balconies etc</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>29 Other</td>
<td>6228.59</td>
<td>103.83</td>
<td>38.93</td>
<td>0.65</td>
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<tr>
<td>36 Ventilation and airconditioning</td>
<td>492.41</td>
<td>8.21</td>
<td>3.08</td>
<td>0.05</td>
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<td>49 Other electric power installations</td>
<td>20625.48</td>
<td>343.76</td>
<td>128.91</td>
<td>2.15</td>
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<tr>
<td>Photovoltaic panel, single Sl. at plant</td>
<td>2252.21</td>
<td>37.56</td>
<td>14.08</td>
<td>0.23</td>
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<tr>
<td>Evacuated tube collector, at plant</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>5 Telecommunication and automation</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>6 Other installations</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>27 Outdoor</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>TOTAL</td>
<td>69139.71</td>
<td>1152.33</td>
<td>432.12</td>
<td>7.20</td>
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<tr>
<td>Initial material use (no replacement)</td>
<td>50422.00</td>
<td>840.37</td>
<td>315.14</td>
<td>5.25</td>
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<tr>
<td>Use phase replacements</td>
<td>18717.71</td>
<td>311.96</td>
<td>116.99</td>
<td>1.95</td>
</tr>
</tbody>
</table>
2. The ZEB Tool
Further Development (2015 onwards)

ZEB Tool Authors:
Marianne Kjendseth Wiik, Reidun Dahl Schlanbusch, Aoife Houlihan Wiberg, Torhildur Kristjansdottir
3. A Dynamic approach to the ZEB Tool (2016)
Rhino – Grasshopper – ZEB Tool

Integrated LCA early in design with dynamic, visual feedback
3. A Dynamic approach to the ZEB Tool (2016)
Revit – Dynamo – ZEB Tool

Source: Revit - Dynamo - ZEB Tool
Author: Tobias Hofmeister and Supervisor: Aoife Houlihan Wiberg, 2016)
Revit – Dynamo – ZEB Tool

Parametric design to minimize the embodied emissions of a ZEB building in Oslo, Norway

- Applying parametric design principles to ZEBs planning.
- Integrating environmental analyses (i.e. solar radiation, daylighting factor) with life cycle assessment into a unique algorithm.
- Allowing the single family house pilot project to achieve the ambition level ZEB-OM according to the guidelines defined by ZEB Research Center in Trondheim.
- Generating a workflow for conducting multi-objective optimization in order to orienting the planning from the early stages of the design process.

Giulia Ceci, UniPG | Author
Mattia Manni, UniPG | Author
Aoife Houlihan Wiberg, NTNU | Supervisor
Umberto Berardi, UniPG | Supervisor
Gabriele Lobaccaro, NTNU | Co-supervisor
Methodology | Workflow

**Optimization from Base Case to Optimized Base Case (fixed shape and constant volume)**

**STAGES**
- **STAGE 0** (Base Case)
  - Geometric Dimensions of the Base case (plot ratio, volume etc.)
- **STAGE 1** (Optimized Base Case)
  - Properties of different materials structures (steel, cement, wood etc.)
- **STAGE 2** (Optimized Base Case)
  - Climate data and Geographical information

**INPUTS**
- GEOMETRY
  - Shape of the building and construction components

**WORKFLOW**
- **PARAMETRIC 3D model and analyses**
- **LOW LOW embodied emissions model**
- **Optimization of windows size and building exposure**
- **a) ACTIVE STRATEGY**
  - Optimization of orientation
- **b) PASSIVE STRATEGY**
  - Optimization of openings

**OUTPUTS**
- **[Gm]** Grasshopper (Gh)
- **[Ee]** Evaluate for Gh
- **[Oe]** Design Builder
- **[Di]** DIVA for Gh
- **[Sr]** Ladybug

**TOOLS & ANALYSES**
- Grasshopper
- Grasshopper
- Grasshopper
- Grasshopper
- Rhinoceros
- Grasshopper with Octopus
- Design Builder
- DIVA for Gh with Galapagos
- Ladybug with Galapagos
- Ladybug with Octopus

**Optimization from Base Case to ZEB OM (free shape and constant volume)**

**STAGE 3** (Optimized Case)
- Climate data
- Materials properties
- Geographical information
- Geometry dimensions
- Material layers
- LCA vs SOLAR RADIATION
  - Minimization of Ee and Maximization of Sr

**STAGE 4** (ZEB OM case)
- Calculation of the emissions balance between the demand (operation energy and embodied emissions) and energy production from PV for the optimized building shape.
- Energy standards
- Life time emission

**[NTNU]**
5. A Dashboard approach to the ZEB Tool
ZEB Emissions Visualisation PROOF OF CONCEPT 2 Spring 2016

Research Questions

RQ 01
Is it possible to establish a seamless connection between a Building Information Modelling software and a customizable database usable by non/experts?

RQ 02
Can visualisation and the dashboard facilitate better understanding of embodied emissions associated with material selection for various decision makers during the early design phase of a building?

RQ 03
Is it possible to involve different stakeholders in a shared platform that be used collectively and simultaneously?
3. A Dashboard approach to the ZEB Tool (2017)
Revit – Flux – ZEB Tool

Source: Revit - Flux - ZEB Tool
6. Visual LCA for ZEN
ZEB Emissions Visualisation  PROOF OF CONCEPT 3 Spring 2017

Research Questions

RQ 01
How can visualisation and LCA be combined to realise material associated greenhouse gas emissions as preliminary design driver in Zero Emission Neighbourhoods?

RQ 02
What defines the difference in material use on building- and neighbourhood scale, and how does it affect the material associated greenhouse gas emissions?

RQ 03
An integrated platform: How to deal with interactions between various scales?

Author Mads Slake & Havard Auklend. Supervisor Aoife Houlihan Wiberg

NTNU
6. Visual LCA for ZEN

ZEB Emissions Visualisation  PROOF OF CONCEPT 3 Spring 2017

Author Mads Slake & Havard Auklend. Supervisor Aoife Houlihan Wiberg
Further Work

• Generate new knowledge in how emerging immersive technologies, such as, AR&VR can be adapted and integrated with our existing dynamic science-based method for GHG emissions, to provide user friendly, interactive feedback on quantitative performance, as well as, qualitative parameters in the design of sustainable and healthy buildings of the future.

• How can these new methods/tools be used to improve communication and participation from diverse stakeholders?

• How can intelligent visualization and immersive environment methods improve environmental performance feedback in the design process and increase uptake in design practice and improve stakeholder participation?
Digital Innovation: Immersive Environments for diverse stakeholder participation

- Augmented Reality for BIM
- Virtual Reality
- Tangible Graph Holograms
- Interactive User Interface – ETH Singapore
- 3D Dome – California Academy of Sciences
- 360 Degree Spherical Projection Theatre – South Korea
- Gaming Technology
Thank you for your attention.

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