From Zero Emission Buildings (ZEB) to Zero Emission Neighbourhoods (ZEN)
A Norwegian Approach

Symposium on the Changing Face of ZNE and Responsible Grid Citizenship
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Global Impact of Buildings

Buildings account for

- 32% of total global final energy use
- 19% of energy-related greenhouse gas (GHG) emissions (including electricity-related)\(^1\)

Improving the energy performance of the building stock and developing zero emission building concepts are critical to avoid increase in energy use and GHG emissions.

The primary objective of NZEBs is to mitigate climate change and to help EU transition to zero carbon economy by 2050.

- NZEBs have very high energy performance and low energy required comes from renewable sources.

- According to European Parliament all new buildings within the European Union should be nearly Zero Energy Buildings by the end of 2020. All new public buildings must be nearly zero energy by 2018.

- EU countries have to draw up national plans to increase number of NZEBs.

Energy Efficiency Requirements in Norway

- Todays average: TEK'10
- TEK'17 "Passive house" TEK'17
- TEK'20 Nearly Zero Energy (?)
- TEK'25 Zero Energy (?)

Energy Use for Operation
Renewable Energy Production

kWh/m² each year

(ZEB, 2016)
Goals:

- To contribute to the reduction of greenhouse gas emissions nationally and internationally as well as to a more effective use of energy and a higher production of renewable energy

- Increased innovation and value creation in the participating public institutions and private businesses, as well as, in the Norwegian society in general
The Vision of the ZEN Centre

Sustainable neighbourhoods with zero greenhouse gas emissions
Norwegian Definitions of ZEB and ZEN
Zero Emission Buildings and Neighbourhoods

Zero emission building and neighbourhood concepts consider GHG emissions in a life cycle perspective and will result in

- Reduction of GHG emission
- Energy efficient buildings
- New local renewable energy production
- Reduction of material and energy use
- Use of environmental friendly materials
- Reuse of materials and solutions

(ZEB, 2016)
What is a Net Zero Energy Building and Zero Emission Building?

**Net Zero Energy Building**
A 'net zero energy building' (net ZEB) produces the same amount of energy from renewable sources (e.g. PV, solar thermal collectors) as the energy needed for its operation. (ZEB, 2016)

**Net Zero Emission Building**
In a 'zero emission building', the balance is measured in terms of associated greenhouse gas equivalent emissions during the lifetime of a building instead of on direct energy demand and generation. (ZEB, 2016)
The emissions from renewable production must balance or compensate emissions from, not only operation, but also during the life cycle of the building. (ZEB, 2016)
ZEB Ambition Levels

- Energy use for heating, cooling, ventilation, hot water and lighting
- Energy use for equipment/plug loads
- Greenhouse gas emissions are calculated as kg CO2-equivalents per m² heated floor area per year (distributed over a 60 years life time) (ZEB, 2016)
What factors affect the ZEB Balance?
Emission factor for grid mix & country production of materials... This has particular relevance for emissions calculations of future Zero Emission buildings in Norway due to the cross border trade of electricity with the European Grid.

(ZEB, 2016)
A failure to consider a year on year improvement in electricity will result in an over estimation of the total GHG emissions of electricity by as much as 270% between now and 2050.

Source. Different scenarios of annual CO2eq emissions factors (gCO$_{2\text{eq}}$/kWh) for the next 60 years (Georges, Houlihan Wiberg et al., 2015)
Choice of grid mix $\text{CO}_2\text{eq}$ factor

Annual $\text{CO}_2\text{eq}$ emissions and offset from PV for the different $\text{CO}_2\text{eq}$ factors for the electricity (Georges and Houlihan Wiberg et al., 2015)
The importance of considering Embodied Emissions
60 to 70% ratio embodied emissions compared to emissions from operation.

Total embodied emissions, use-stage emissions from net electricity delivered, CO2eq(use) and electricity exports, CO2e(export), per square metre of heated floor area for the eight buildings. (Kristjansdottir et al., 2017)
Key drivers for Material Emissions

(Houlihan Wiberg et al., 2015)
Net Zero emission Building (ZEB)
ZEB Centre + Pilots
The ZEB Research Centre in numbers

Host: The Norwegian University of Science and Technology (NTNU)

- 2009-2017
- 37m USD
- 24 PhD candidates and 5 postdocs (more in assoc. projects)
- 25 Researchers in associated projects
The ZEB Centre Industrial Partners

22 public & industry partners

2 research partners
ZEB Main Objective

To develop competitive products and solutions for existing and new buildings that will lead to market penetration of buildings with zero greenhouse gas emissions related to their production, operation, and demolition. The centre encompass both residential, commercial, and public buildings. (www.zeb.no)
ZEB Research Activities

ZEB focuses its work in areas that interact and influence each other:

**WP1** Advanced materials technologies
**WP2** Climate adapted low energy envelope technologies
**WP3** Energy supply systems and services
**WP4** Use, operation and implementation
**WP5** Concepts, strategies and demo buildings

**Laboratories**

- VIP Leca Isoblock
- Nano insulated material
- Membrane Heat Exchanger
- ZEB Living Lab
- ZEB Demo buildings

**ZEB Definition**
<table>
<thead>
<tr>
<th>Pilot Building</th>
<th>Type of Building</th>
<th>Built area</th>
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<tbody>
<tr>
<td>1. Skarpnes, Arendal</td>
<td>5 new houses</td>
<td>5 x 154 m²</td>
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<tr>
<td>2. Powerhouse Kjørbo, Sandvika</td>
<td>Renovation of two offices</td>
<td>5 000 m²</td>
</tr>
<tr>
<td>3. ZEB Pilot House, Larvik</td>
<td>New demonstration house</td>
<td>200 m²</td>
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<tr>
<td>4. Zero Village Ådland, Bergen</td>
<td>720 new dwellings</td>
<td>80 000 m²</td>
</tr>
<tr>
<td>5. Visund, Haakonsvern Bergen</td>
<td>New office building</td>
<td>2 000 m²</td>
</tr>
<tr>
<td>6. Powerhouse Brattøra, Trondheim</td>
<td>New office building</td>
<td>14 000 m²</td>
</tr>
<tr>
<td>7. ZEB Living Lab, Trondheim</td>
<td>New research dwelling</td>
<td>100 m²</td>
</tr>
<tr>
<td>8. Heimdal VGS, Trondheim</td>
<td>New upper secondary school</td>
<td>18 000 + 8 000 m²</td>
</tr>
<tr>
<td>9. Campus Evenstad</td>
<td>New offices</td>
<td>1 100 m²</td>
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</table>
Important Outcome of the ZEB Pilot Buildings

• Verification of calculations i.e. indoor climate, energy, emissions

• Testing of new materials, building assemblies and façade solutions

• Verification of technical installations i.e. heating, lighting and energy supply i.e. pv, solar thermal

• Demonstration and testing of integrated solutions for the whole building

• Transfer of knowledge to the Norwegian building industry
Net Zero emission neighbourhoods (ZEN)
ZEN Centre + Pilots
The ZEN Research Centre in numbers

Host: The Norwegian University of Science and Technology (NTNU)

- 2017-2024
- 47m USD
- 20 PhD candidates and 5 postdocs (more in assoc. projects)
The ZEN Centre Industrial Partners

<table>
<thead>
<tr>
<th>11 public partners</th>
<th>21 industry partners</th>
<th>2 research partners</th>
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<td>BERGEN KOMMUNE</td>
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<td>Caverion</td>
<td>SINTEF</td>
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<td>BÆRUM KOMMUNE</td>
<td>CIVITAS</td>
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<td>ELVERUM KOMMUNE</td>
<td>ELVERUM YKST</td>
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<td>Vogtspor</td>
<td>EnergiNorge</td>
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<td>Oslo kommune</td>
<td>Future Built</td>
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<td>Statsbygg</td>
<td>Hunton</td>
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<td>Steinkjer kommune</td>
<td>Moewen</td>
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<td>Trondheim kommune</td>
<td>Multiconsult</td>
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<td>Trøndelag fylkeskommune</td>
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<td>HNK Norge as</td>
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Work packages in the ZEN Research Centre:

WP1 Analytical framework for design and planning of ZEN

WP2 Policy measures, innovation and business models

WP3 Responsive and energy efficient buildings

WP4 Energy flexible neighbourhoods

WP5 Local energy system optimization within a larger system

WP6 Pilot projects and living labs
What is a zero emission neighbourhood (ZEN)?

A zero emission neighbourhood aims to reduce its direct and indirect greenhouse gas emissions towards zero within its life cycle.

The neighbourhood should focus on the following:

- Plan, design and operate buildings and associated infrastructure components towards zero life cycle greenhouse gas emissions;
- Become highly energy efficient and powered by a high share of new renewable energy in the neighbourhood energy supply system;
- Manage energy flows (within and between buildings) and exchanges with the surrounding energy system in a smart and flexible way;
What is a zero emission neighbourhood (ZEN)?

- Promote sustainable transport patterns and smart mobility systems;
- Plan, design and operate with respect to economic sustainability, by minimizing total life cycle costs and life cycle system costs;
- Plan and locate amenities in the neighbourhood to provide good spatial qualities and stimulate sustainable behavior;
- The development of the area is characterized by innovative processes based on new forms of cooperation between the involved partners, leading to innovative solutions.

Further reading: https://fmezen.no/what-is-a-zen
ZEN pilot projects

Ambition to realize at least 7 pilot projects for ZEN pilots in Norway.

- **innovation hubs** for *co-creation* between researchers and building professionals, property developers, municipalities, energy companies, building owners, and users;

- **living labs** to verify, *document* and *optimize* the real-life performance of the solutions developed in the ZEN Centre;

- **lighthouse projects** to *learn, inspire, and disseminate* ZEN-related knowledge.
Net Zero emission neighbourhoods (ZEN)
ZEN Centre + Pilots
ZEN pilot projects

Bodø: Airport area
Steinkjer: Residential area
Trondheim: Knowledge Axis (NTNU Campus & Sluppen)
Evenstad: Campus
Elverum: Ydalir
Bergen: Zero Village Bergen
Oslo: Furuset
Bærum: Oksenøya, Fornebu

30 000 m² > 1 million
How to bridge the gap between research and design?
ZEB Tool Development
Design Decision Making
(Digital and Analogue)
Further development of an integrated LCA model with visual feedback

(Houlihan Wiberg et al., 2016)
During Spring 2016, the *Emissions as Design Drivers* course in the *M.Sc. Sustainable Architecture*, Havard and Mads linked the Revit model with the ZEB excel tool using dynamo plugin.

Håvard Auklend & Mads Løkeland Slåke, 2016
Supervisor. A Houlihan Wiberg
ZEB Emissions Visualisation PROOF OF CONCEPT 2 Spring 2017
Authors Zorbey Tuncer and Supervisor Aoife Houlihan Wiberg

Copyright@ Tobias Hofmeister and Aoife Houlihan Wiberg (2017)
Visual LCA in ZENs Stage 2 Development Spring 2017
Authors Havard Auklend, Mads Slake and supervisor Aoife Houlihan Wiberg

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How to bridge the gap between research and design?

ZEN Toolbox Development
Goal:

1. Develop definitions, targets and benchmarking for ZEN, based on customised indicators and data (quantitative + qualitative)

2. Develop life cycle analysis methodology for energy and emissions at neighbourhood scale

3. Develop a citizen-centred architectural and urban toolbox for design and planning of ZEN, including visualisation for decision support.
How to move between scales from materials to neighbourhood & increased ZEN KPI’s?

- **Neighbourhood Climatic & GIS**
- **Building User & BIM**
- **Materials Details**
- **Diverse Media**

*(Houlihan Wiberg, 2017)*
Knowledge building to develop a Dashboard for ZEN
CIVAL facilitates the usage of ICT-based research infrastructure at the FCL, specifically Value Lab Asia, for research, education and communication. Image: CIVAL, 2016
Immersive Virtual Environments to improve stakeholder participation

Northrop Grumman TouchTable (MIT Media Lab)

360 degree Immersive Environment (Korea)

Tangible graph hologram

Gaming Technology

Augmented and Virtual Reality

(Houlihan Wiberg, 2017)
Realizing zero emission neighborhoods

**Possibilities**

- Optimization of energy use and renewable energy production (reducing mismatch between production and use) should be easier with larger systems and several building typologies and uses.
- Focusing on neighborhoods instead of individual buildings, makes sure emissions related to infrastructure (e.g. grids and technologies for water, sewage, waste, mobility) also are considered.
- Installation of new renewable energy technologies will be easier when considering a neighborhood than individual buildings.
- Neighborhoods and urban areas are more suitable for implementing integrated innovative solutions in direct connection to citizens.
- The neighborhood scale is very efficient in climate resilient and zero emission design interventions as it makes use of the benefits provided by the buildings layout and the natural and technical elements of the complete setting.
Realizing zero emission neighborhoods

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<tr>
<th>Challenges</th>
<th>Different ZEN ambitions</th>
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<tbody>
<tr>
<td>[Image: ZEB Pilot House Larvik - demonstration home]</td>
<td>On Building, services and infrastructure from users, owners, developers</td>
</tr>
<tr>
<td>Solutions for sharing (thermal) energy resources not always in place</td>
<td></td>
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<tr>
<td>Tools (and emission data) for planning of zero emission neighborhoods are still hard to find</td>
<td></td>
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<tr>
<td>Technical and legal standardization is needed at all steps</td>
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<tr>
<td>Regulatory barriers for energy exchange between end-users</td>
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Thank you for your attention.

https://fmezen.no
@ZENcentre
FME ZEN (page)

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