Research Centre on
ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

LCA for Zero Emission Buildings

A chronology of the development of a visual, dynamic and integrated approach

Session 6 Professor Aoife Houlihan Wiberg

The Research Centre on Zero Emission Neighbourhoods in Smart Cities

Norwegian University of Science and Technology, Trondheim, Norway

The Research Council of Norway   NTNU   SINTEF

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)

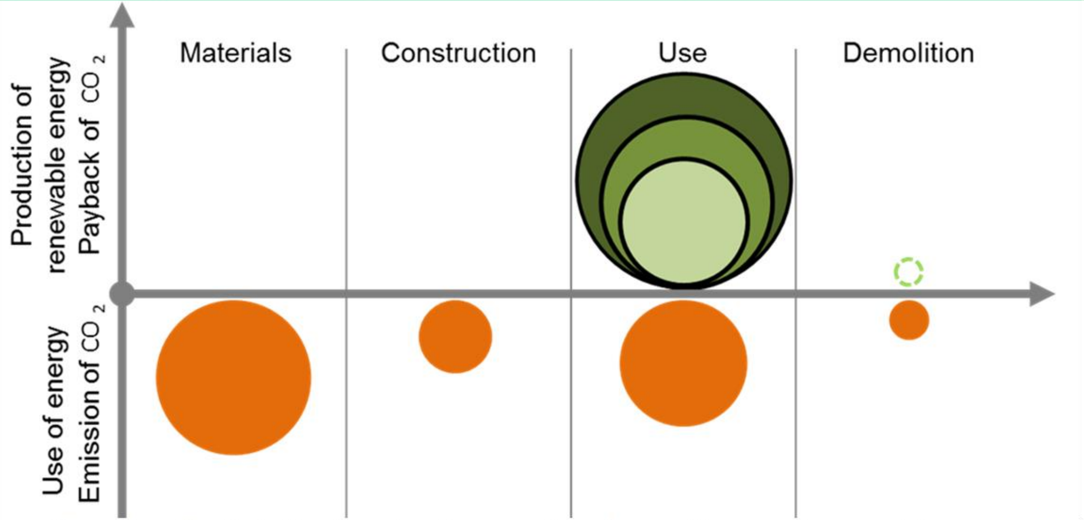


Figure 2 The illustration shows how the generation of renewable energy (green circle) may compensate for all greenhouse gas emissions from all life cycle stages of the building (red circles).

Pilot Projects

Living Lab. *Photo: Geir Mogen.*

Powerhouse Brattørkaia. *Illustration: Snøhetta/Mir.*

Visund, Haakonsvern. *Photo: Hundven Clements.*

Multikomfort. *Photo: Bo Mathisen.*

Campus Evenstad. *Photo: Leikny Havik Skjærseth.*

Powerhouse Kjørbo. *Photo: Bo Mathisen.*

Zero Village Bergen. *Illustration: Snøhetta/Mir.*

Interdisciplinary Research

WP1
Advanced materials Technologies

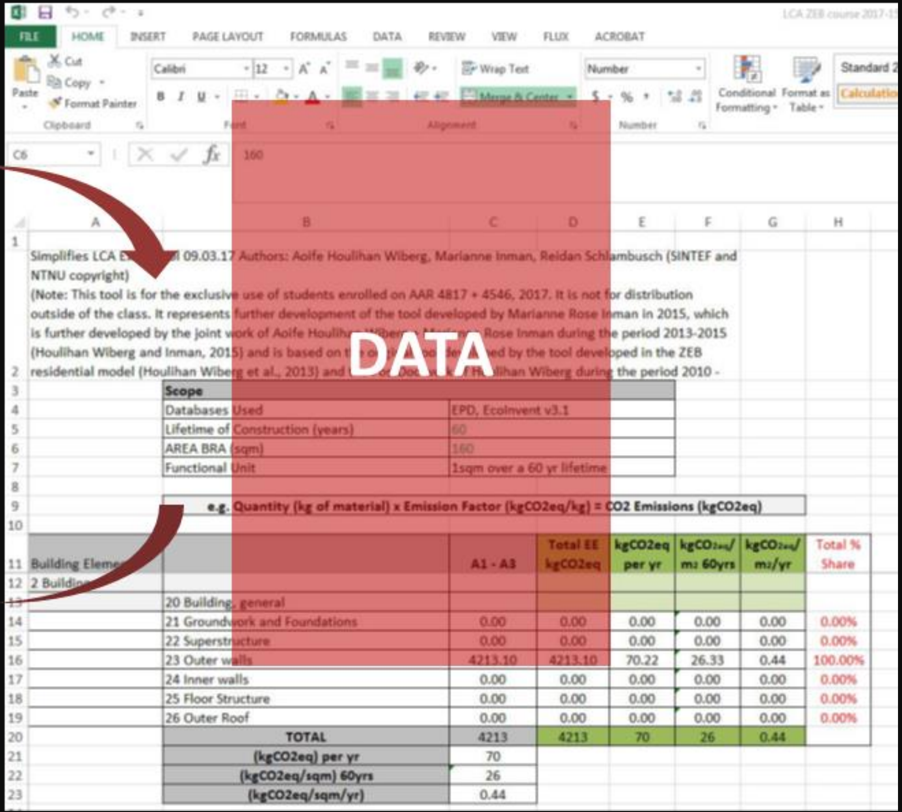
WP2
Climate-adapted low-energy envelope technologies

WP3
Energy supply systems and services

WP4
Energy efficient use and operation

WP5
Concepts and Strategies for zero emission buildings

Academic & Industry



Bridges the gap between research & design

Explorations in dynamic and parametric modelling of the ZEB Tool.

Spring 2016 & 2017

M.Sc. 2013-2015
ZEN summer intern 2014

Zorbey Tuncer

Håvard Auklend &
Mads Løkeland Slåke

Giulia Ceci

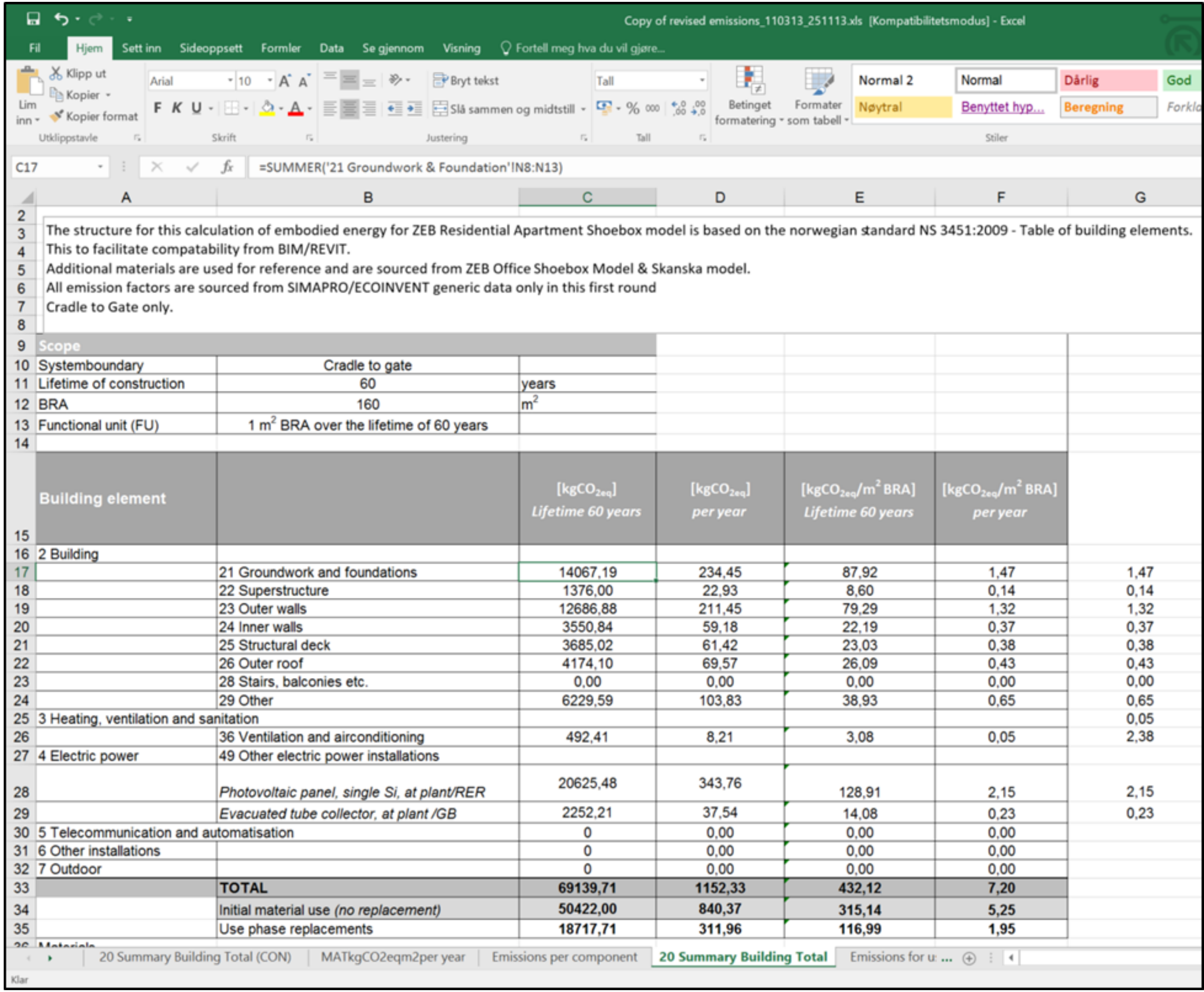
Mattia Manni

Spring 2016

Tobias Hofmeister

Spring 2016

2. The ZEB Tool Creation (2011-2014)



Copy of revised emissions_110313_251113.xls [Kompatibilitetsmodus] - Excel

C17 =SUMMER('21 Groundwork & Foundation'!N8:N13)

The structure for this calculation of embodied energy for ZEB Residential Apartment Shoebox model is based on the norwegian standard NS 3451:2009 - Table of building elements.
This to facilitate compatability from BIM/REVIT.
Additional materials are used for reference and are sourced from ZEB Office Shoebox Model & Skanska model.
All emission factors are sourced from SIMAPRO/ECOINVENT generic data only in this first round
Cradle to Gate only.

Scope		
Systemboundary	Cradle to gate	
Lifetime of construction	60	years
BRA	160	m^2
Functional unit (FU)	1 m^2 BRA over the lifetime of 60 years	

Building element		[$kgCO_{2eq}$] *Lifetime 60 years*	[$kgCO_{2eq}$] *per year*	[$kgCO_{2eq}/m^2$ BRA] *Lifetime 60 years*	[$kgCO_{2eq}/m^2$ BRA] *per year*	
2 Building						
	21 Groundwork and foundations	14067,19	234,45	87,92	1,47	1,47
	22 Superstructure	1376,00	22,93	8,60	0,14	0,14
	23 Outer walls	12686,88	211,45	79,29	1,32	1,32
	24 Inner walls	3550,84	59,18	22,19	0,37	0,37
	25 Structural deck	3685,02	61,42	23,03	0,38	0,38
	26 Outer roof	4174,10	69,57	26,09	0,43	0,43
	28 Stairs, balconies etc.	0,00	0,00	0,00	0,00	0,00
	29 Other	6229,59	103,83	38,93	0,65	0,65
3 Heating, ventilation and sanitation						0,05
	36 Ventilation and airconditioning	492,41	8,21	3,08	0,05	2,38
4 Electric power	49 Other electric power installations					
	Photovoltaic panel, single Si, at plant/RER	20625,48	343,76	128,91	2,15	2,15
	Evacuated tube collector, at plant /GB	2252,21	37,54	14,08	0,23	0,23
5 Telecommunication and automatisation		0	0,00	0,00	0,00	
6 Other installations		0	0,00	0,00	0,00	
7 Outdoor		0	0,00	0,00	0,00	
	TOTAL	**69139,71**	**1152,33**	**432,12**	**7,20**	
	Initial material use *(no replacement)*	**50422,00**	**840,37**	**315,14**	**5,25**	
	Use phase replacements	**18717,71**	**311,96**	**116,99**	**1,95**	

20 Summary Building Total (CON) | MATkgCO2eqm2per year | Emissions per component | 20 Summary Building Total | Emissions for u...

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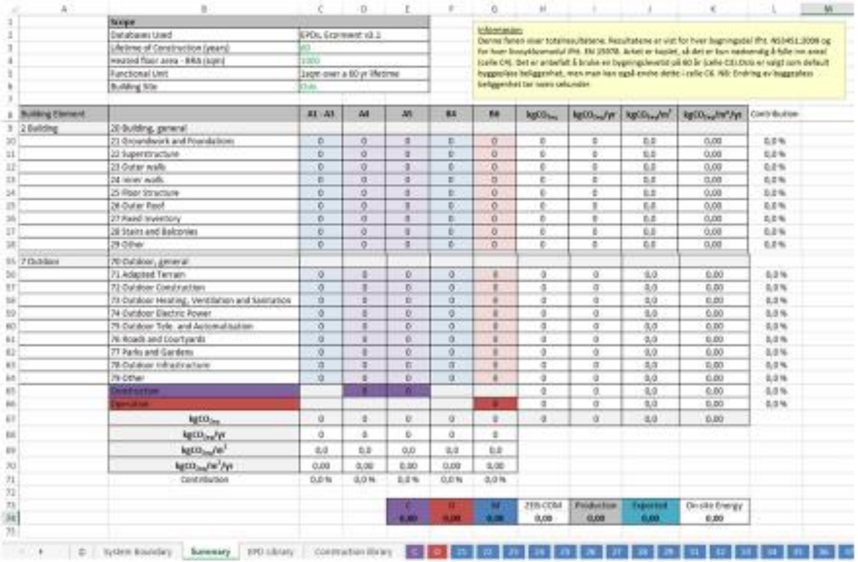
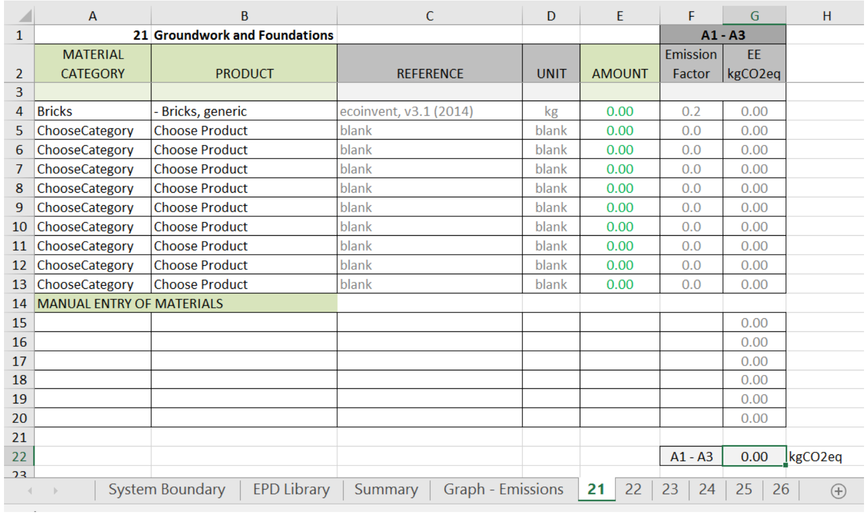
2. The ZEB Tool Development (2014-2015)





	A	B	C	D	E	F	G	H
1	21	Groundwork and Foundations				A1 - A3		
2	MATERIAL CATEGORY	PRODUCT	REFERENCE	UNIT	AMOUNT	Emission Factor	EE kgCO2eq	
3								
4	Bricks	- Bricks, generic	ecoinvent, v3.1 (2014)	kg	0.00	0.2	0.00	
5	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
6	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
7	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
8	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
9	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
10	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
11	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
12	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
13	ChooseCategory	Choose Product	blank	blank	0.00	0.0	0.00	
14	MANUAL ENTRY OF MATERIALS							
15							0.00	
16							0.00	
17							0.00	
18							0.00	
19							0.00	
20							0.00	
21								
22						A1 - A3	0.00	kgCO2eq

System Boundary | EPD Library | Summary | Graph - Emissions | 21 | 22 | 23 | 24 | 25 | 26

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2. The ZEB Tool
Further Development (2015 onwards)

ZEB Tool Authors:
Marianne Kjendseth Wiik, Reidun Dahl Schlanbusch, Aoife Houlihan Wiberg, Torhildur Kristjansdottir

Scope	
Databases Used	EPDs, EcoInvent v3.1
Lifetime of Construction (years)	60
Heated floor area - BRA (sqm)	1000
Functional Unit	1sqm over a 60 yr lifetime
Building Site	Trondheim

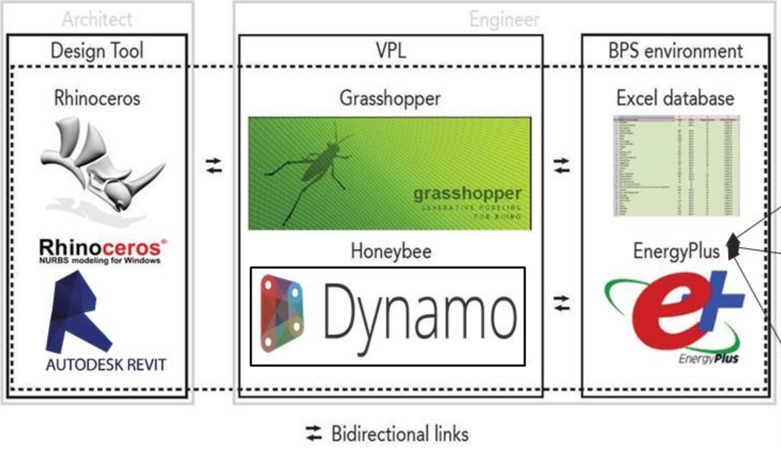
Informasjon
Denne fanen viser totalresultatene. Resultatene er vist for hver bygningsdel ifht. NS3451
for hver livssyklusmodul ifht. EN 15978. Arket er koplet, så det er kun nødvendig å fylle i
(celle C4). Det er anbefalt å bruke en bygningslevetid på 60 år (celle C3).Oslo er valgt som
byggeplass beliggenhet, men man kan også endre dette i celle C6. NB: Endring av byggep
beliggenhet tar noen sekunder.

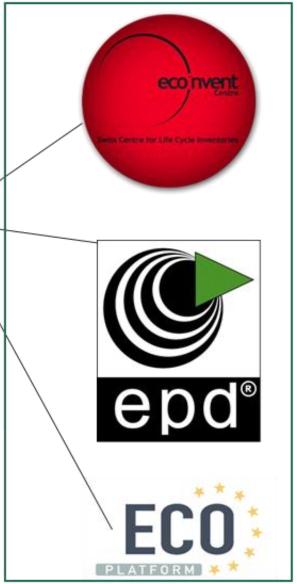
Building Element		A1 - A3	A4	A5	B4	B6	$kgCO_{2eq}$	$kgCO_{2eq}/yr$	$kgCO_{2eq}/m^2$	$kgCO_{2eq}/m^2/yr$	Contribution
2 Building	20 Building, general										
	21 Groundwork and Foundations	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	22 Superstructure	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	23 Outer walls	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	24 Inner walls	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	25 Floor Structure	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	26 Outer Roof	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	27 Fixed Inventory	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	28 Stairs and Balconies	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	29 Other	0	0	0	0	0	0	0	0.0	0.00	0.0 %
3 VVS	30 Heating, Ventilation and Sanitation, general										
	31 Sanitary	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	32 Heating	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	33 Fire Safety	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	34 Gass and Air Pressure	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	35 Process Cooling	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	36 Ventilation and Air Conditioning	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	37 Comfort Cooling	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	38 Water Treatment	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	39 Other	0	0	0	0	0	0	0	0.0	0.00	0.0 %
4 Electric Power	40 Electric Power, general										
	41 Basic Installation for Electric Power	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	42 High Voltage Power	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	43 Low Voltage Power	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	44 Lighting	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	45 Electric Heating	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	46 Standby Power	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	49 Other	0	0	0	0	0	0	0	0.0	0.00	0.0 %
5 Telecommunication	50 Telecommunication and Automation										
	51 Basic Installation for Tele. and Automation	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	52 Integrated Communication	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	53 Telephone and Paging	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	54 Alarm and Signal	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	55 Sound and Picture	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	56 Automisation	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	57 Instrumentation	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	59 Other	0	0	0	0	0	0	0	0.0	0.00	0.0 %
6 Other Installations	60 Other Installation, general										
	61 Prefabricated Unit	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	62 Passenger and Goods Transport	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	63 Transportation Facilities for Small Goods	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	64 Stage Equipment	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	65 Waste and Vaccuum-cleaning	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	66 Fixed Furniture	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	67 Loose Furniture	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	69 Other	0	0	0	0	0	0	0	0.0	0.00	0.0 %
7 Outdoor	70 Outdoor, general										
	71 Adapted Terrain	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	72 Outdoor Construction	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	73 Outdoor Heating, Ventilation and Sanitatio	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	74 Outdoor Electric Power	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	75 Outdoor Tele. and Automatisation	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	76 Roads and Courtyards	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	77 Parks and Gardens	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	78 Outdoor Infrastructure	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	79 Other	0	0	0	0	0	0	0	0.0	0.00	0.0 %
	Construction		0	0			0	0	0.0	0.00	0.0 %
	Operation					0	0	0	0.0	0.00	0.0 %
	$kgCO_{2eq}$	0	0	0	0	0	0	0	0.0	0.00	
	$kgCO_{2eq}/yr$	0	0	0	0	0					
	$kgCO_{2eq}/m^2$	0.0	0.0	0.0	0.0	0.0					
	$kgCO_{2eq}/m^2/yr$	0.00	0.00	0.00	0.00	0.00					
	Contribution	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %					

C	O	M	ZEB-COM	Production	Exported	On-site Energy	ZEB Balance
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3. A Dynamic approach to the ZEB Tool (2016)

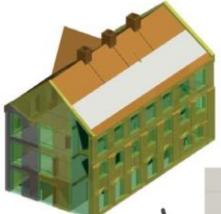
Rhino – Grasshopper – ZEB Tool

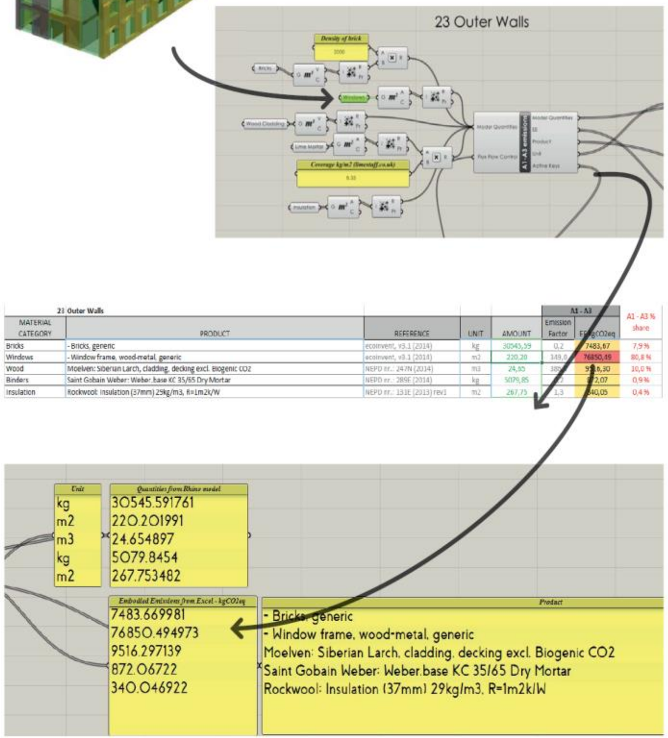




Generic & Specific Data

Integrated LCA early in design with dynamic, visual feedback

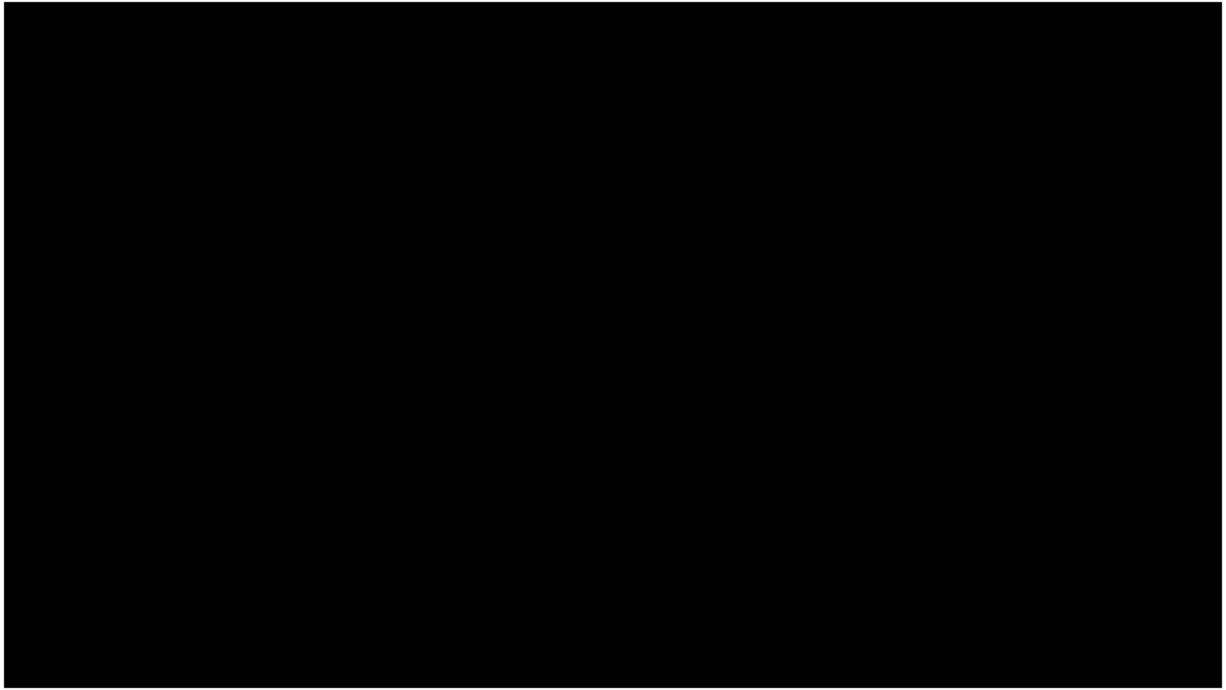




Authors: Håvard Auklend & Mads Løkeland Slåke (2016)
Supervisor: Aoife Houlihan Wiberg

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)

4. A Parametric approach to the ZEB Tool (2016)

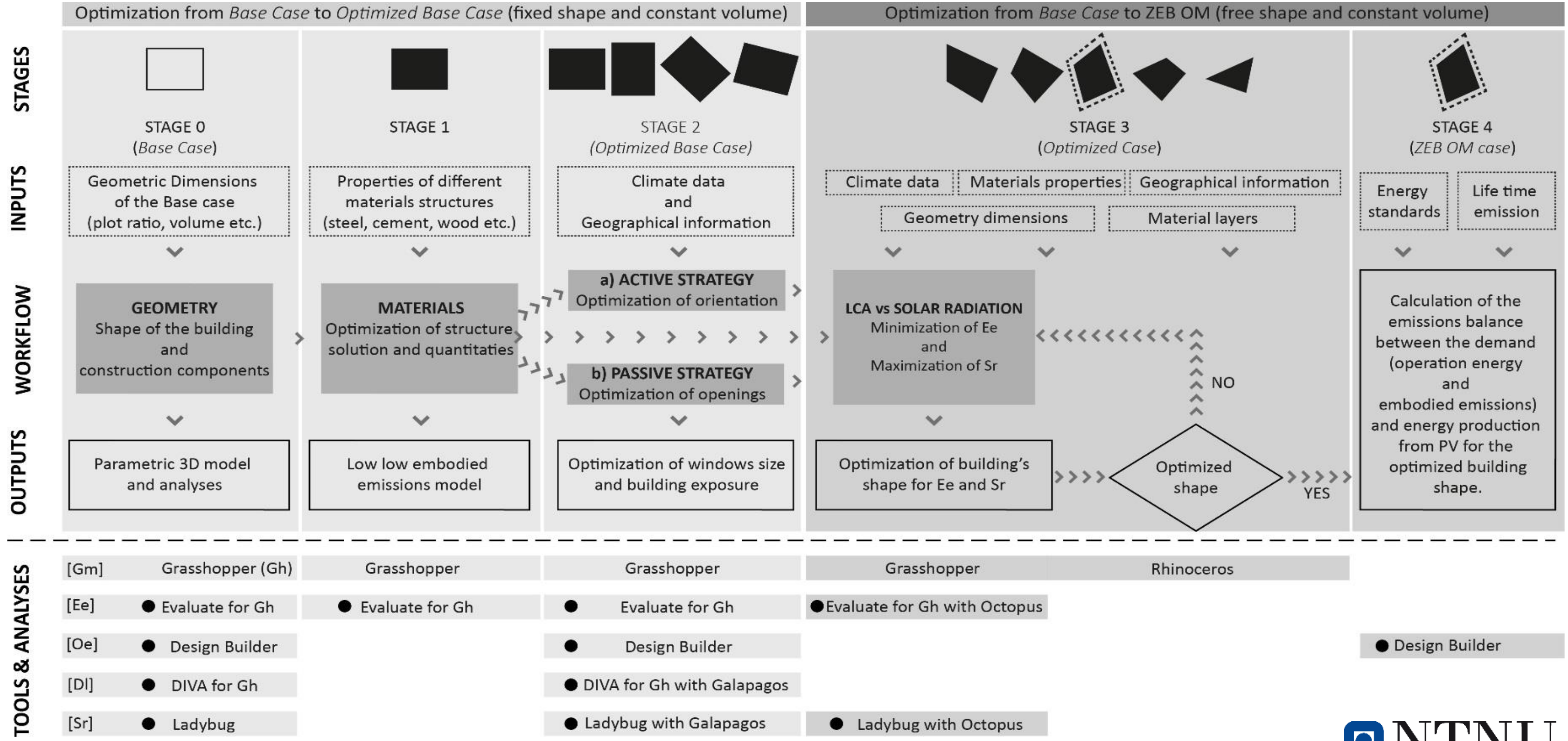
Revit – Dynamo – ZEB Tool

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

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

- 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.

Methodology | Workflow



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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?

Author Zorbey Tuncer. Supervisor Aoife Houlihan Wiberg

3. A Dashboard approach to the ZEB Tool (2017)

Revit – Flux – ZEB Tool

Source: Revit - Flux - ZEB Tool

Author: Zorbey Tuncer and Supervisor: Aoife Houlihan Wiberg, 2017)

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

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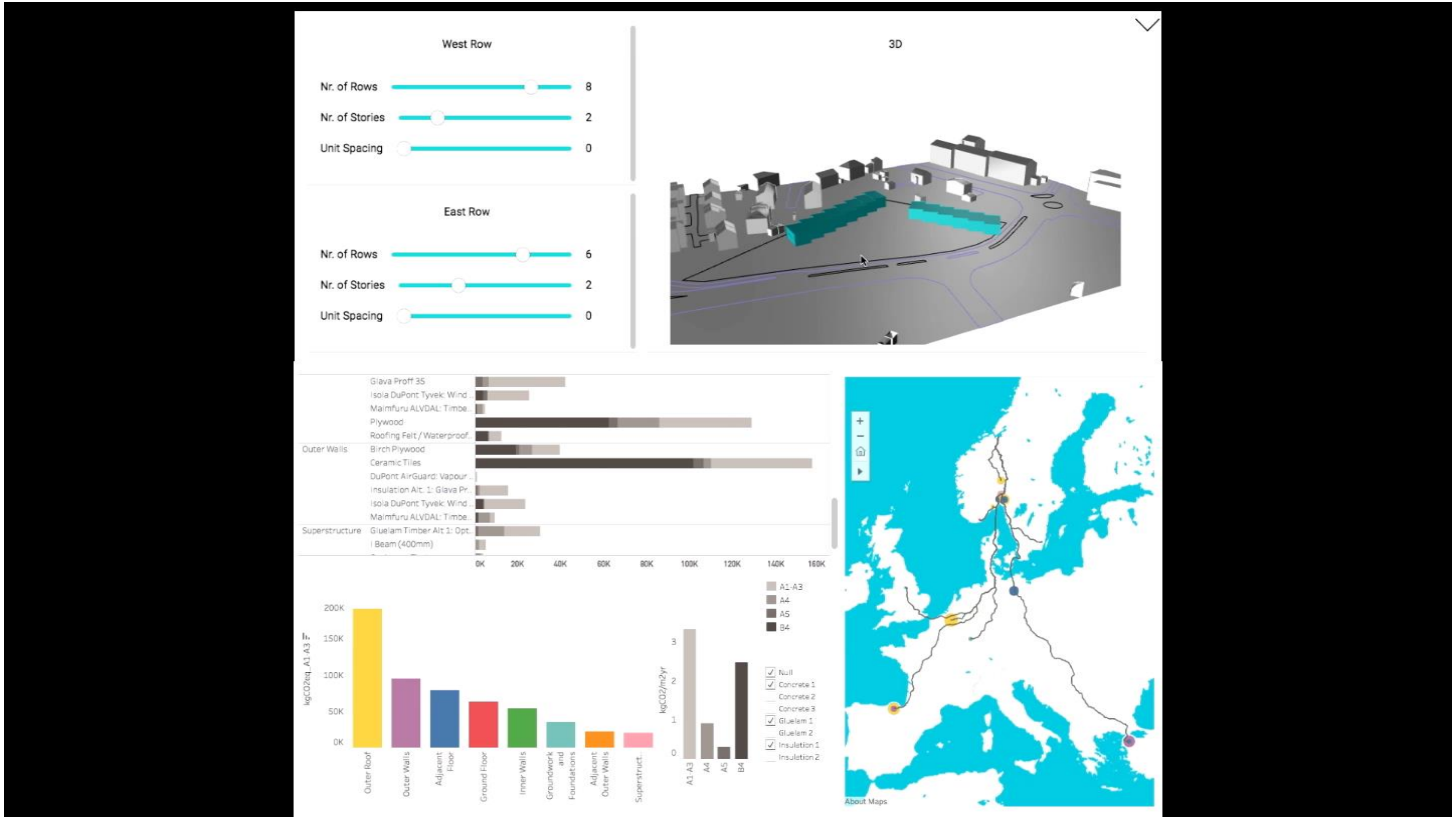
6. Visual LCA for ZEN

ZEB Emissions Visualisation *PROOF OF CONCEPT 3 Spring 2017*



Author Mads Slake & Havard Auklend. Supervisor Aoife Houlihan Wiberg

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ZERO EMISSION NEIGHBOURHOODS IN SMART CITIES

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?

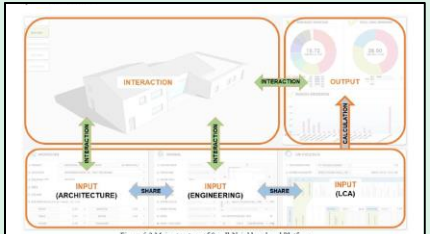
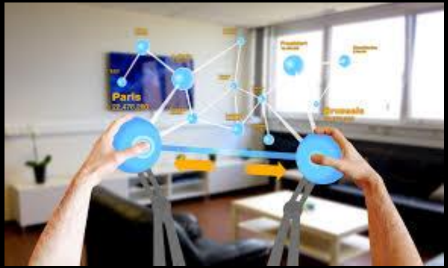


Figure 5.2 Main structure of Small-Neighbourhood Platform

Digital Innovation Immersive Environments for diverse stakeholder participation

Augmented Reality for BIM

Virtual Reality



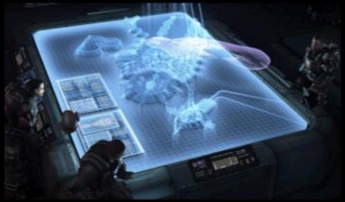
Tangible Graph Holograms

Interactive User Interface – ETH Singapore

3d Dome – California Academy of Sciences

360 Degree Spherical Projection Theatre – South Korea

Touch Table



Gaming Technology

Research Centre on ZERO EMISSION NEIGHBOURHOODS IN SMART CITIES

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway

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