Energy and Environmental Performance of New and Future Buildings

Danvik Dagen, 2014

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Content

- Low and zero energy and emission buildings over life cycles - experiences and challenges related to zero emission pilot and concept studies.
- Ongoing pilot-studies
- Study of indoor air quality of typical low energy buildings in Norway

The research centre on Zero Emission Buildings

- Research center for Zero Emission Buildings (ZEB) in Norway.
- Develop products and solutions for buildings that have zero emissions of greenhouse gases related to production, operation and demolition

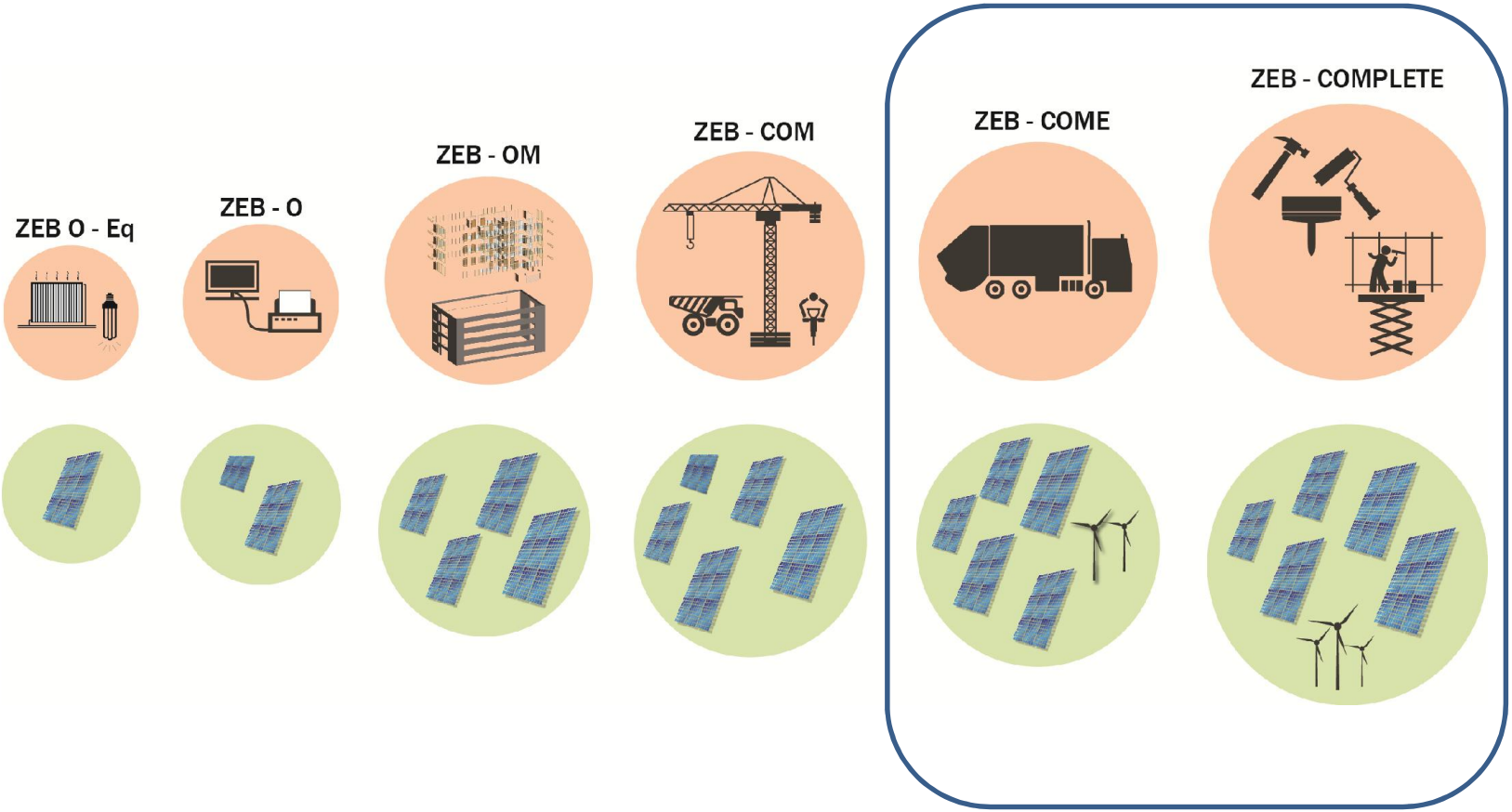
Illustration: Snøhetta

Norwegian ZEB- definition levels

ZEB-COM	ZEB-ambition level , where emissions from construction, operational energy use and material use are compensated for with renewable energy on site
ZEB-OM	ZEB-ambition level , where emissions from operational energy use and material use are compensated for with renewable energy on site
ZEB-O	ZEB-ambition level , where emissions from operational energy use are compensated for with renewable energy on site
ZEB-O÷EQ	ZEB-ambition level , where emissions from energy use in operations minus energy use for equipment (PCs, projectors etc.) are compensated for with renewable energy on site

Source, Dokka et.al, 2013

Norwegian ZEB- definition levels – further work



Source, ZEB, 2013

ZEB Office Concept Study – Goal and Team

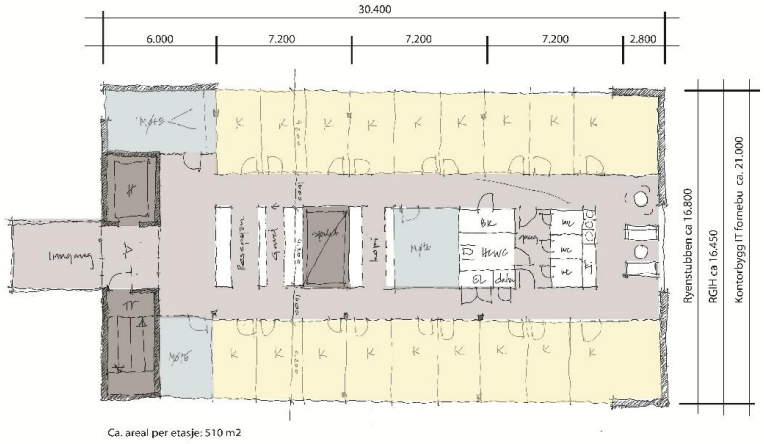
- Goal to gain insight into the current challenges and status for achieving a Zero Emission Office Building in Norway
- Use the concept model to test out different approaches and methods
- Full report available at www.zeb.no
- Interdisciplinary co-operation – team

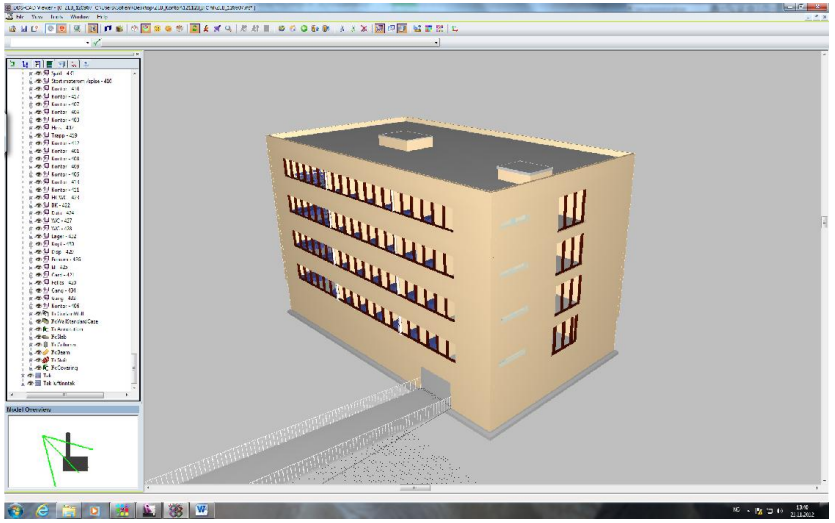
Tor Helge Dokka, Torhildur Kristjansdottir, Berit Time, Sofie Mellegård,
Matthias Haase and Jens Tønnesen

A zero emission concept analysis of an office building

ZEB The Research Centre on Zero Emission Buildings FME FORSKNINGS-SENTER FOR MILJØVENNLIG ENERGI

Building – BIM

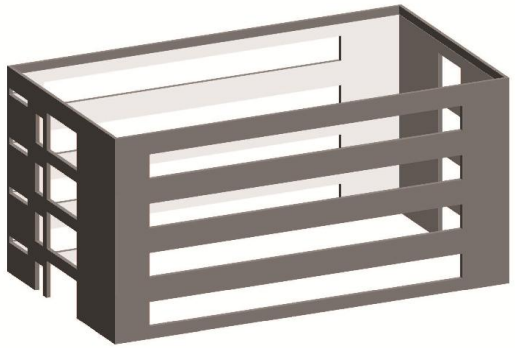


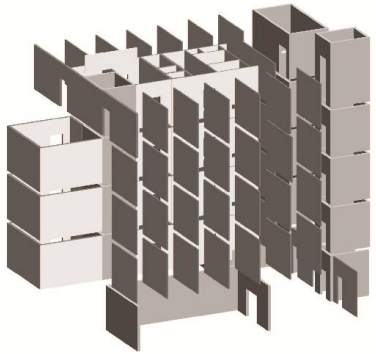


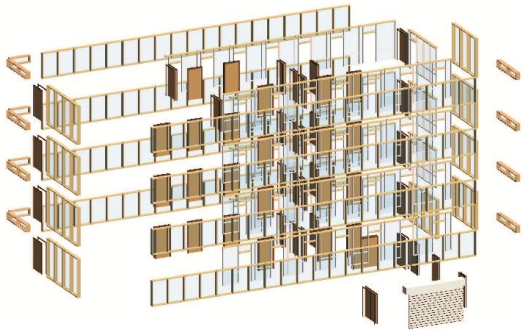
- Sketch based on Norwegian regulation on technical requirements for construction
- Optimal width, flexible floor plan, technical grid, continuous ceiling, frequent changes over time
- Heated floor area 1980 m^2, four-story building + cellar/parking
- Mix of office cells and open landscape, meeting rooms, common spaces, cellar, technical rooms etc.
- BIM – Revit (Autodesk, 2011)

Building – BIM – inventory for material take-outs

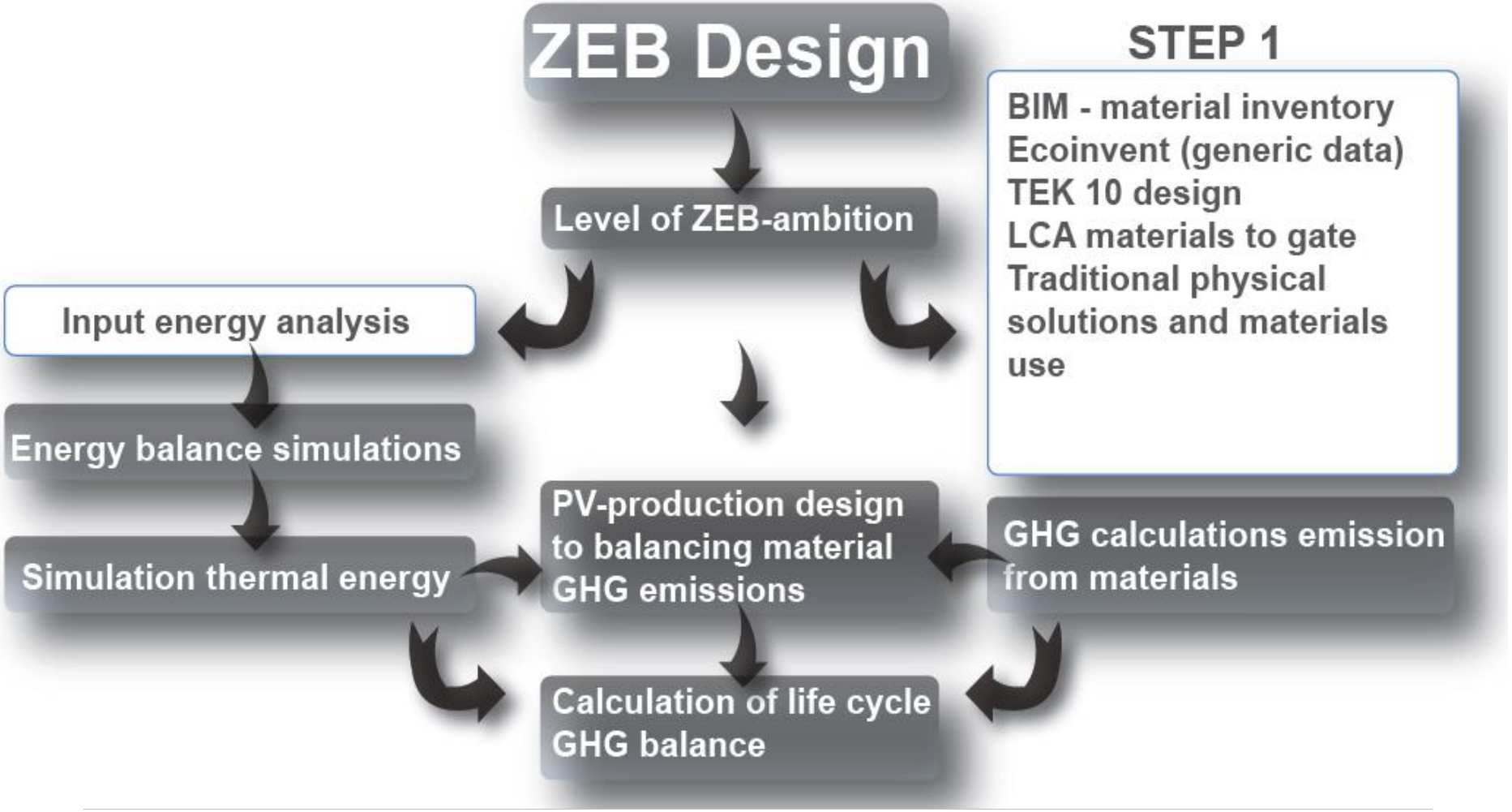
Type	LEVEL	MATERIAL TYI	NAME	AREA m2	VOLUME m3	LENGTH	WIDTH
V1_dB37	1	Systemvegg	Insulation mineral wool	13	0,91	4100	166
V1_dB37	1	Systemvegg	Insulation mineral wool	13	0,91	4100	166
V1_dB37	1	Systemvegg	Insulation mineral wool	13	0,91	4100	166
V1_dB37	1	Systemvegg	Insulation mineral wool	13	0,93	4200	166
V1_dB37	1	Systemvegg	Insulation mineral wool	13	0,92	4150	166
V1_dB37	1	Systemvegg	Insulation mineral wool	13	0,92	4150	166
V1_dB37	1	Systemvegg	Insulation mineral wool	13	0,92	4150	166
V1_dB37	1	Systemvegg	Insulation mineral wool	13	0,91	4100	166
V1_dB37	1	Systemvegg	Insulation mineral wool	15	1,02	5234	166







ZEB-concept work – office building - approach



Material emission calculations

- Goal: estimate material (CO_2 eq)emissions in the building materials and technical equipment
- The functional unit used in the analysis is 1 m^2 of heated floor area in the office building over an estimated life time of 60 years.
- Traditional building materials (glass wool insulation, hollow core slab structures, timber framed outer wall)
- Database for material emissions Ecoinvent version 2.2.
- Life cycle simulation tool: SimaPro (version 7.3) tool from Prè consultants
- Table of building elements NS 3451:2009
- Technical equipment included – based on estimates from ZEB pilot buildings (ventilation, electric cabling and energy producing units)

Boundaries, A1-A3 and B4 based on EN 15978:2011

A1-3			A4-5		B1-7					C1-4				Supplementary information beyond the building life cycle. D
PRODUCT STAGE			CONSTRUCTION		**USE STAGE**					END OF LIFE				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D
Raw material supply	**Transport**	**Manufacturing**	Transport	Construction installation process	Use	Maintenance	Repair	**Replacement**	Refurbishment	De -construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling potential

EN 15978:2011

Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method

Energy concept and calculations

Very low energy demand:

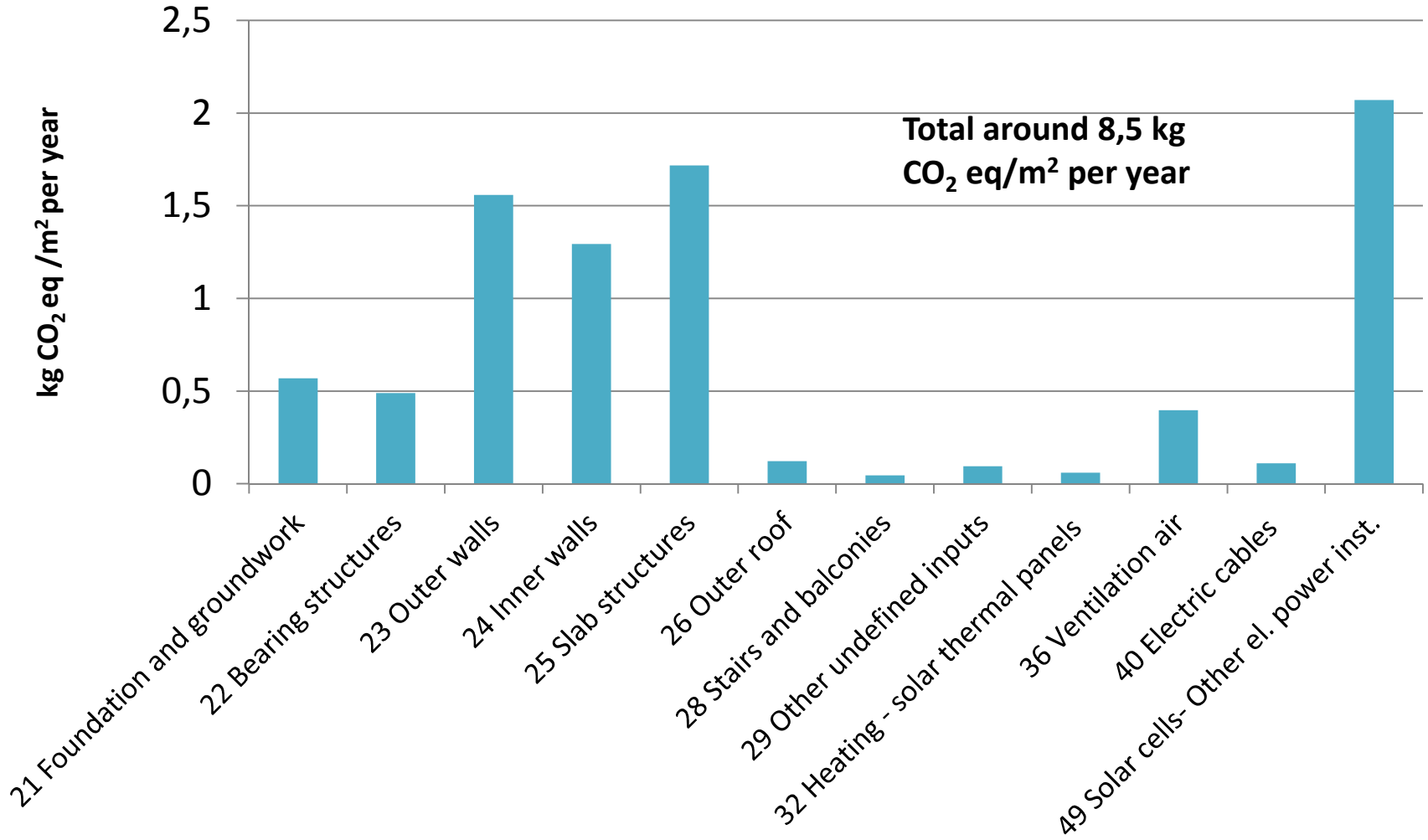
- Norwegian passive house standard NS3701:2010
- Energy efficient building envelope
- U-values:
  - Timer framed outer wall – 0.12 [W/m2K] (350 mm insulation thickness)
  - Roof – 0.09 [W/m2K] (450 mm insulation thickness)
  - Floor against cellar 0.11 [W/m2K] (350 mm insulation thickness)
  - Windows 0.75 [W/m2K]

Energy supply:

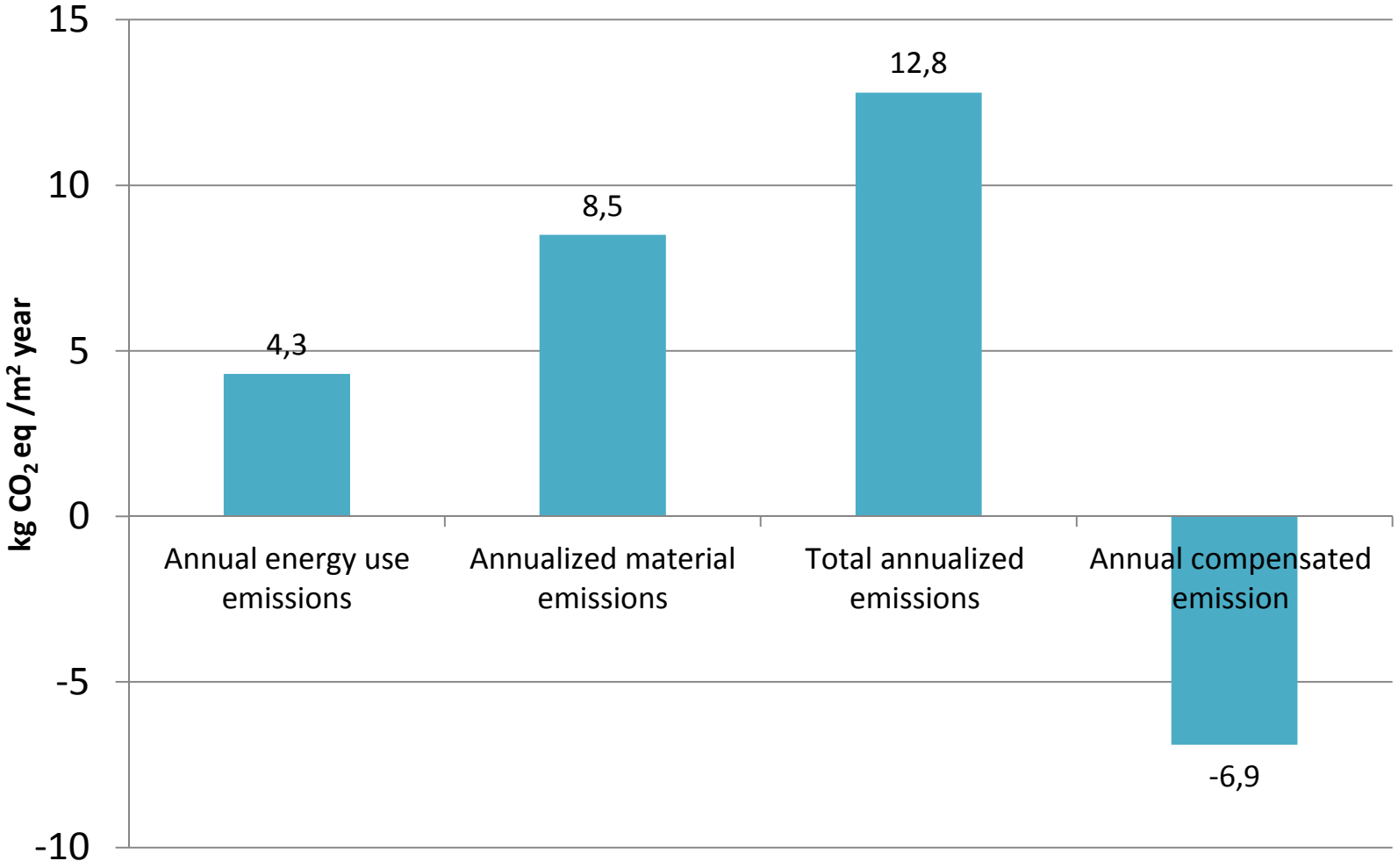
- Heat pump
- Solar thermal panels and solar electric panels
- Renewable electrical energy on site: 675 m^2 solar cells on roof and south façade of the building model
- Simulation energy performance – SIMIEN version 5.011 (SIMIEN, 2012)
- Simulation solar thermal system/heat pump – PolySun (Polysun, 2012)
- Performance PV-systems – PV-syst (Pv-syst, 2012)

Source: Dokka et. al. (2013)

Results – embodied emission – total and distribution



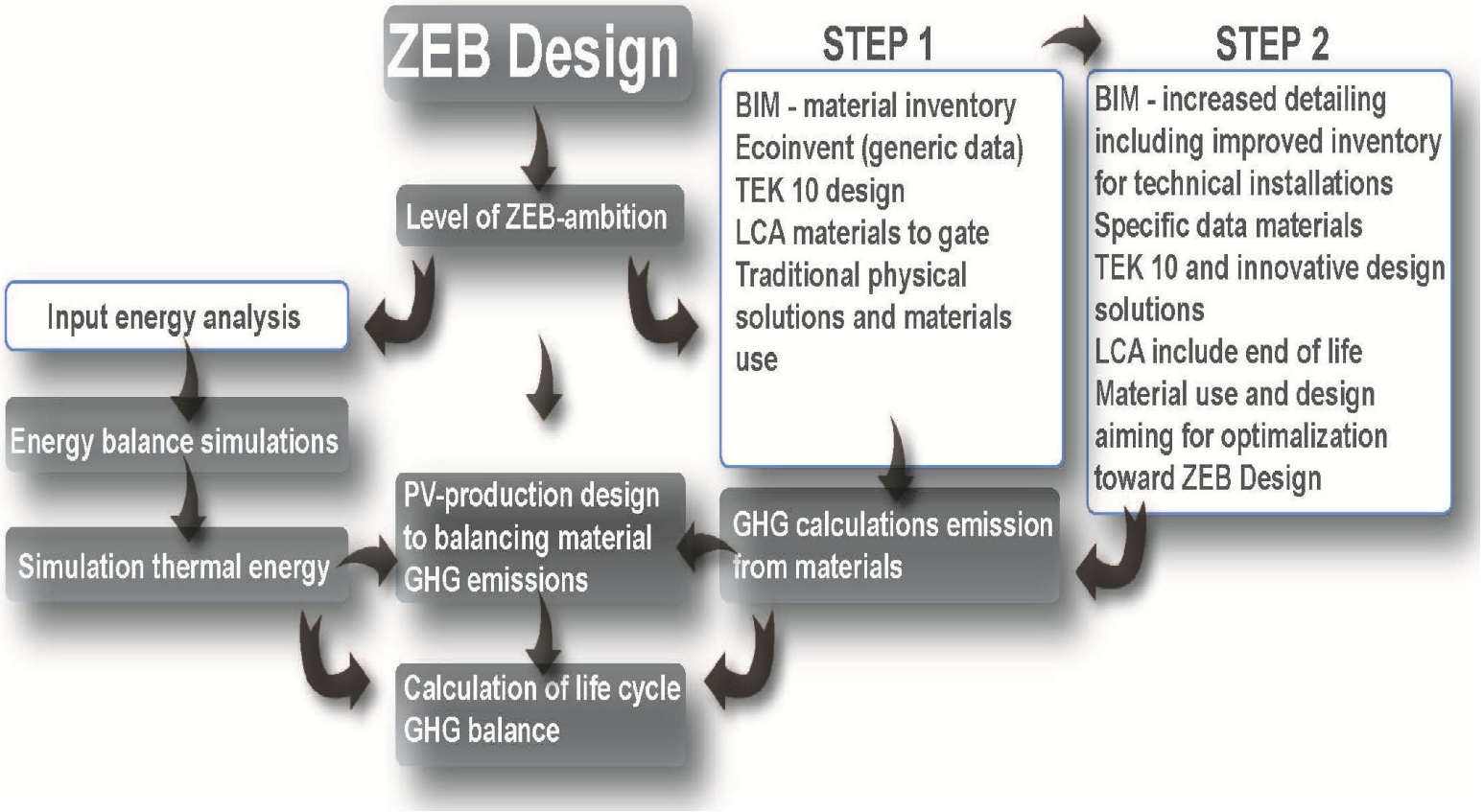
Results combined – from first phase



Results

- Material emissions are higher then operational emissions over the estimated service lifetime
  - 8,5 kg CO2 eq/m2 year material emissions (67 %)
  - 4,3 kg CO2 eq/m2 year operational emissions (33 %)
  - Total 12,7 kg CO2 eq/m2
- Renewable energy offsets around 50 % of the total emissions
- ZEB-ambition level ZEB-O is achieved
- ZEB-ambition level ZEB-OM is not achieved with the current approach
- Using BIM simplifies the Life cycle inventory phase

ZEB-concept work – office building – further work



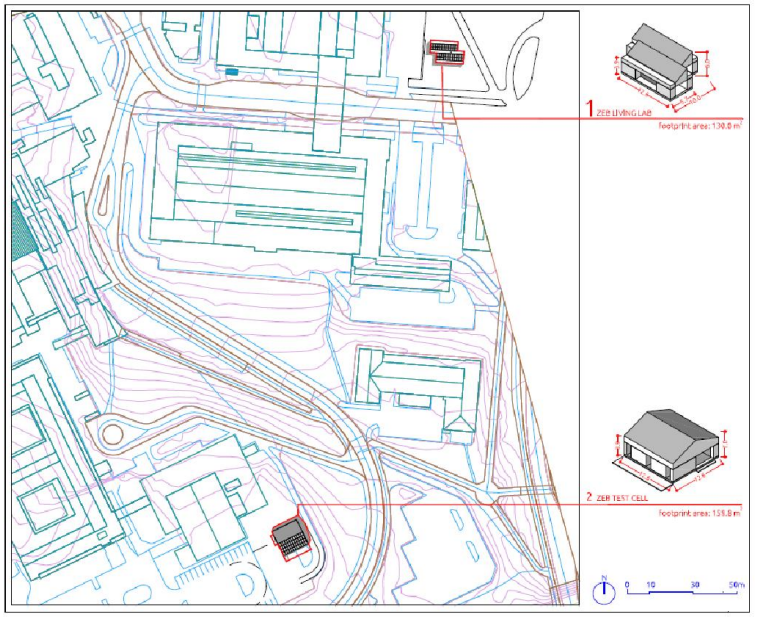
ZEB-Pilot Buildings

ZEB PILOT BUILDINGS:

1. Skarpnes Arendal: 37 dwellings, ZEB-O.
2. Powerhouse #2 – Sandvika. Renovation of 2 office blocks to Plus energy.
3. Mulitkomfort-Larvik: Single family house, ZEB-COM.
4. Ådland: 500 dwellings, ZEB-O.
5. Powerhouse # 1 – Trondheim. Large office building, Plus energy.
6. Depotbygget Haakonsvern – Bergen. Small office building, ZEB-O÷EQ.
7. ZEB Living Lab

Establishment of Test Buildings at NTNU – ZEB Living Lab and Test Cell

ZEB Living Lab



ZEB Test Cell

Study of indoor climate

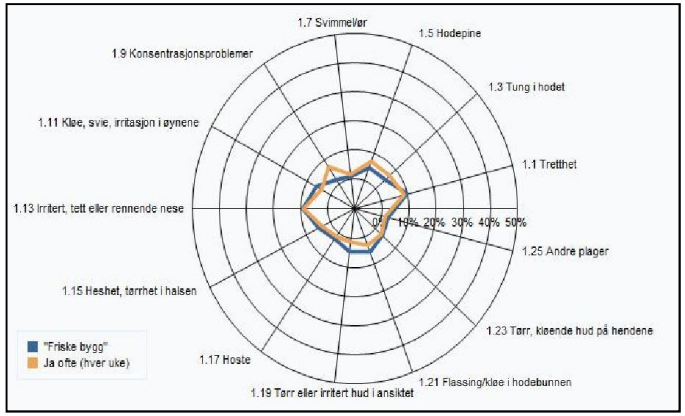
- User Survey (using Örebroskjema – *Örebro schedule*)
- Interviews
- Existing reports (interviews and surveys conducted at Fjell nursery and Marienlyst elementary school)
- http://www.regjeringen.no/upload/KMD/BOBY/Civitas_passivhus_lavenergi_yrkesbygg.pdf.

	Har du i løpet av de siste 3 måndene vært plaget av en eller flere av de undernevnte faktorene på din arbeidsplass				
		Ja, ofte	Ja, iblant	Nei, aldri	Vet ikke
	2.1 Draught				
	2.2 Too hot				
	2.3 Too uneven (alternating) temperature				
	2.4 Too cold				
	2.5 Stuffy and "poor" air				
	2.6 Dry air				
	2.7 Unpleasant odors				
	2.8 Static electricity tiny shocks				
	2.9 Tobacco smoke from others				
	2.10 Noise				
	2.11 Lighting: to low or glare				
	2.12 Dust or dirt				
	2.13 Other indoor climate aspects other than mentioned above				

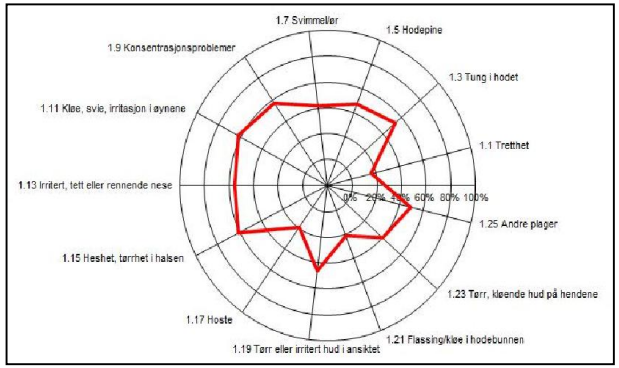
If yes: do you think they are related to your workplace conditions

The survey

Symptom frequency (56 av 120 invited)

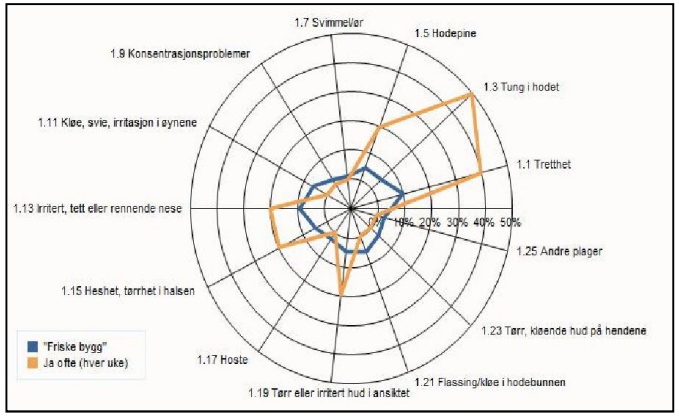


Related to the workplace conditions?

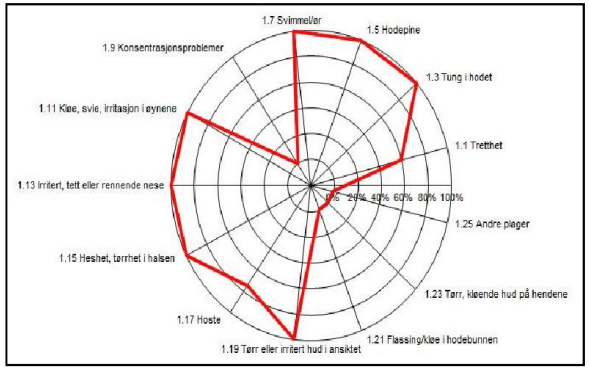


A very good functioning building!

Symptom frequency (5 av 26 invited)

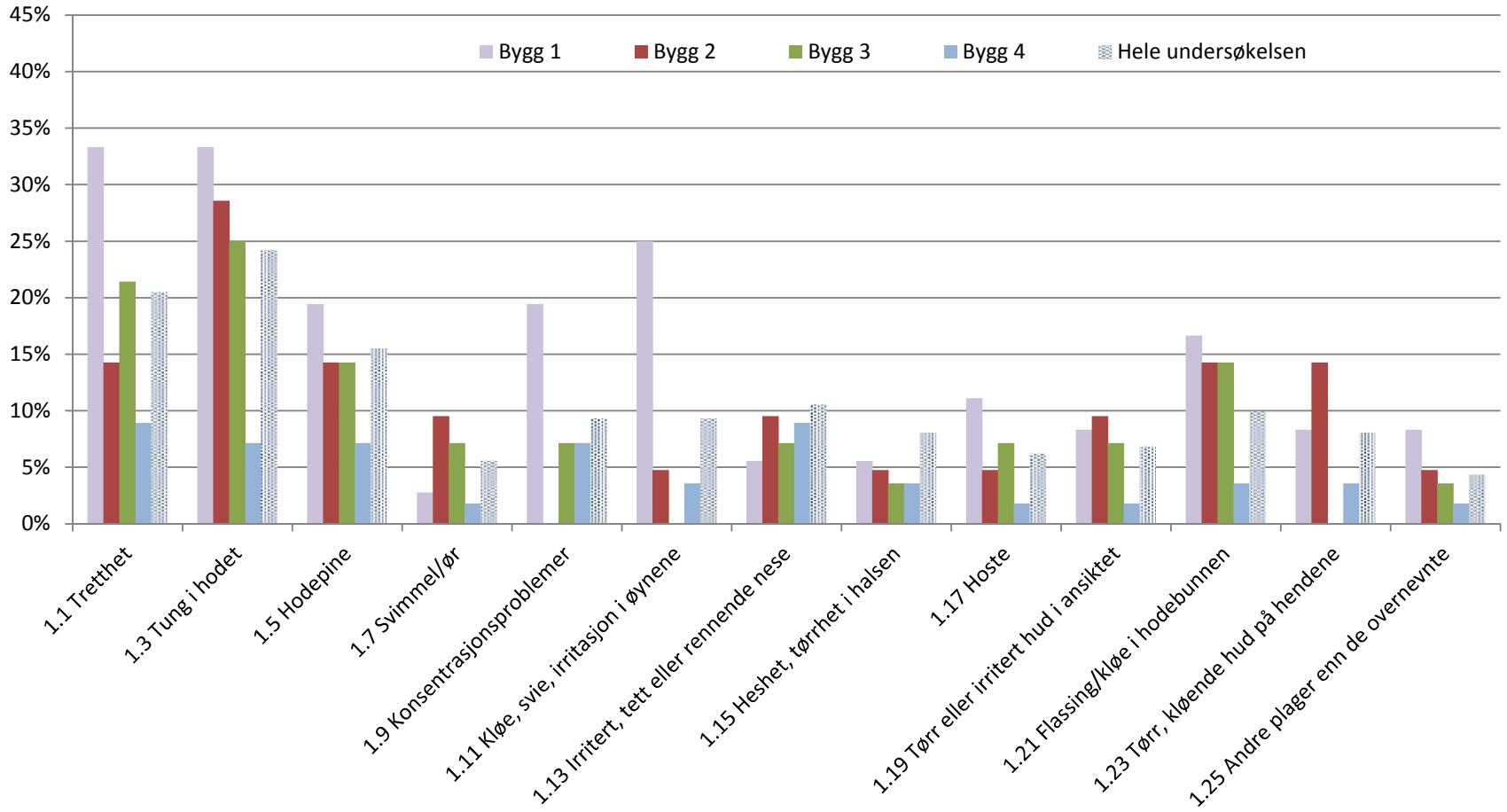


Related to the workplace conditions?



Some have complaints - should be monitored. Hard to say anything about the building!

Major differences between the buildings



Results from literature

- Problems with acoustics, pressure differences, air quality (by interruptions in ventilation systems)
- Individual rooms are too cold
- Group rooms with insufficient daylight
- Cold floors in the toddler department

Interviews – examples of findings

- **User:** bright and nice building with good indoor air quality. Normal or fewer complaints compared with other studies.

Although:

- The air in educational buildings in the core of the building is perceived as close, and these rooms are also experienced as too hot.
- Periodically classrooms and group-rooms in the building is perceived as too cold.
- Problems related to high pressure differences (doors are hard to open).

- **Operator:** Project planning, product and workmanship associated with the VAV system, inadequate commissioning. This has led to imbalance, large internal pressure differences, and unnecessarily high air flow when there are people present.

Methodical incorrect, but worth mentioning:

Upon inspection of the building an employee mentioned that he had not been sick since the school opened in 2010, while he previously experienced significant health problems and frequent sick leave. He also reported that "the time when students had to go home because of headaches is over".

In summary, indoor climate

- **Surveys and interviews reveal significant differences between buildings.**
- **Many possible causes of poor indoor air quality**
  Possible energy-related reasons:

- Compact building composition without adequate daylighting
- No possibilities for window ventilation (opening windows)
- Complex and sometimes inadequate operational systems
- Insufficient heating "reveals" lack of attention during the design phase
- Development and management toward buildings with low heating demand can cause complaints of it being "cold" (but it is beneficial for the air quality)

- **The energy-related causes are not specific to passive / low energy buildings**

Recommendations, indoor climate

- Systematic surveys amongst users in non-residential buildings
- Further development of user surveys for easier handling and more precise results that can be used in facility management
- Clarification and monitoring of regulatory requirements (daylight, windows that can be opened)
- Guidelines to simplify startup period and justifying new VAV systems

Available publications

Project reports

www.zeb.no

A zero emission concept analysis of an office building

A zero emission concept analysis of a single family house

Energy and Buildings - *A net zero emission concept analysis of a single-family house, 2014*

Report (in Norwegian) Brukerundersøkelse om innemiljø på Marienlyst skole. Evaluation of indoor environment quality at Marienlyst School, 2012.

Report (in Norwegian) - Indoor environment and energy consumption, examination of selected buildings and input methods to uncover relationships. February, 2013