The Research Centre on Zero Emission Buildings

Bjørn Petter Jelle (SINTEF and NTNTU) (today's presenter)
Arild Gustavsen (NTNU) (original maker of this lecture)
(shortened down version given here)

Bærekraftuka 2014 (Sustainability Week 2014), Trondheim, Norway, 27-31 October, 2014.

Our main objective

is 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 will encompass both residential, commercial, and public buildings.

www.zeb.no

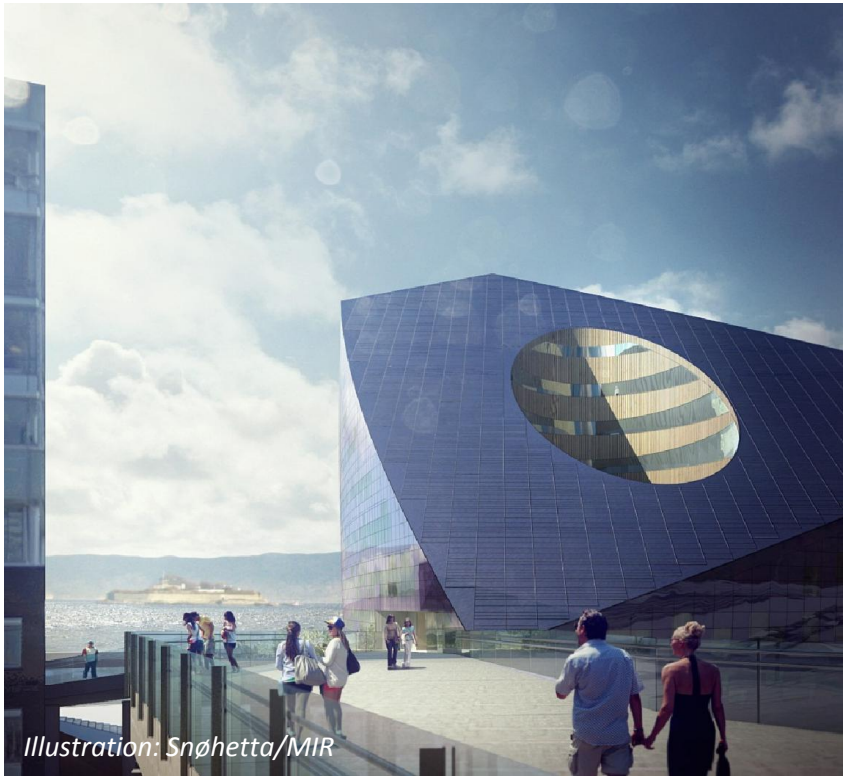
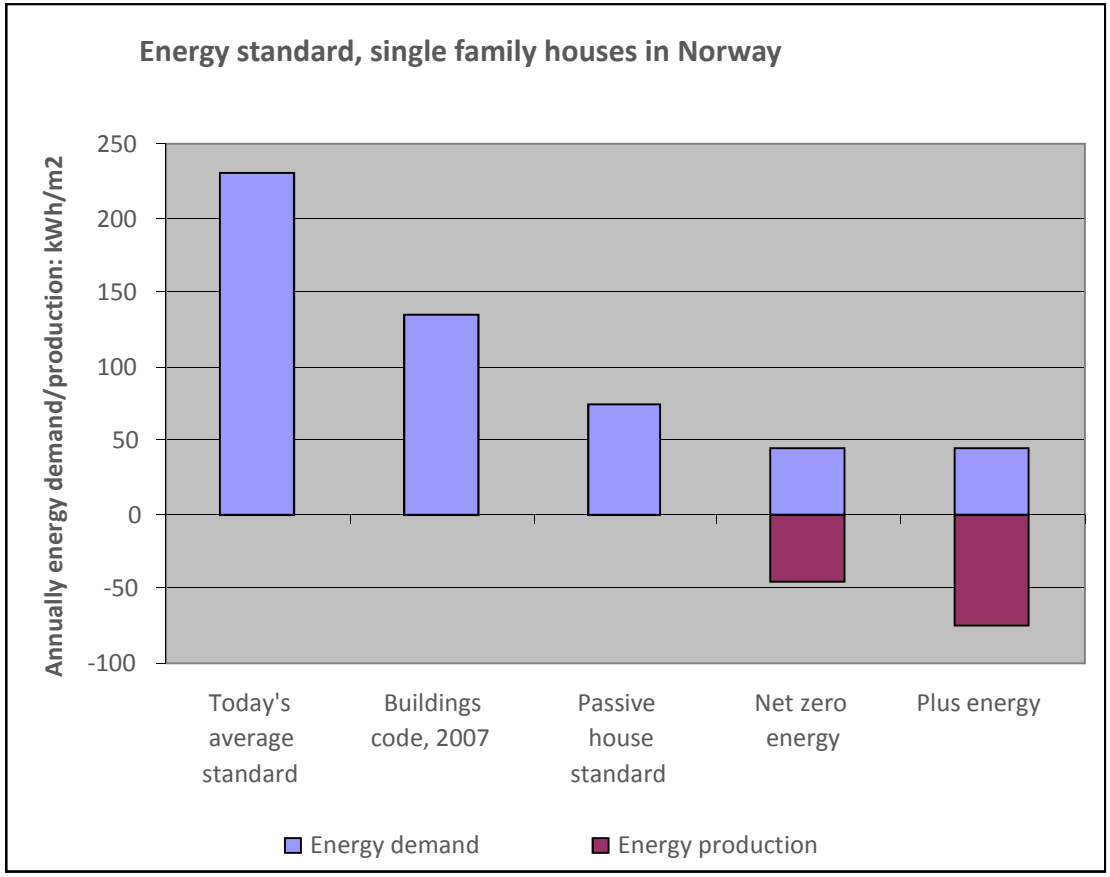


Illustration: Snøhetta/MIR

The challenge:

The main concept of a zero emission building is that renewable energy sources produced or transformed at the building site have to compensate for CO_2 emissions from operation of the building and for production, transport and demolition of all the building materials and components during the life cycle of the building.



Source: SINTEF Byggforsk

ZEB Facts

- Host institution: NTNU Faculty of Architecture and Fine Art
- Research partners: SINTEF Building and Infrastructure and SINTEF Energy Research
- Industry and public partners: 23

- Start date (contract with RCN signed): November 2009
- Total budget: ca. 290 MNOK (+ additional to research infrastructure)

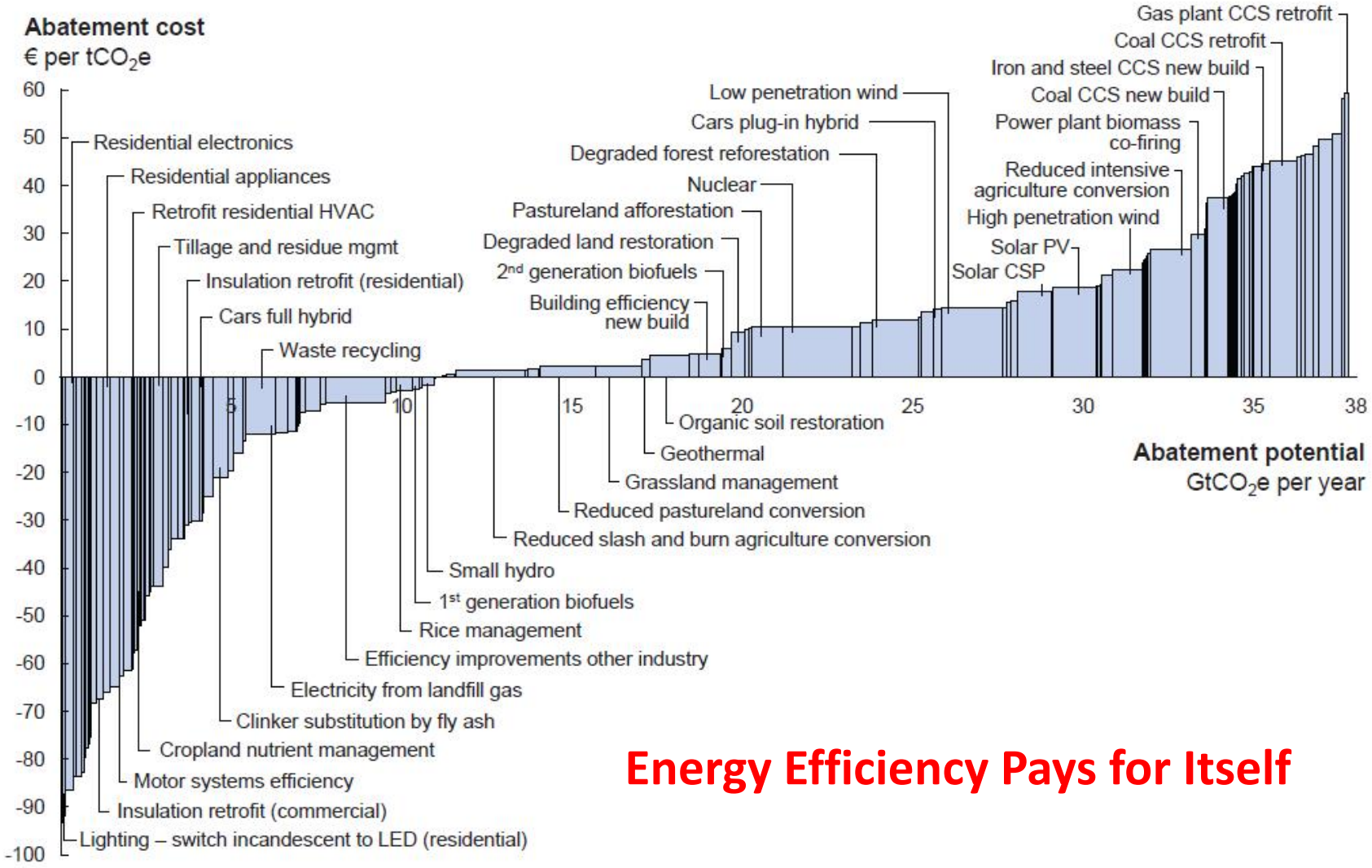
- Researchers associated with the Centre: about 25 (most part time)
- PhD candidates: 21
  - 15 is partly/directly funded by ZEB
- Post docs: 4

- Research on topics from nano material science to whole building performance (e.g. energy and CO_2), including studies on individual building technologies (e.g. building envelope and building services technologies) and user studies.

Why ZEB?

McKinsey, ”Pathways to a Low Carbon Economy. Version 2 of the Global Greenhouse Gas Abatement Cost Curve”, McKinsey & Company, 2009.

Global GHG abatement cost curve beyond business-as-usual – 2030



Energy Efficiency Pays for Itself

Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

What should be done?

Reduce the energy demand to a minimum – in new and existing buildings.

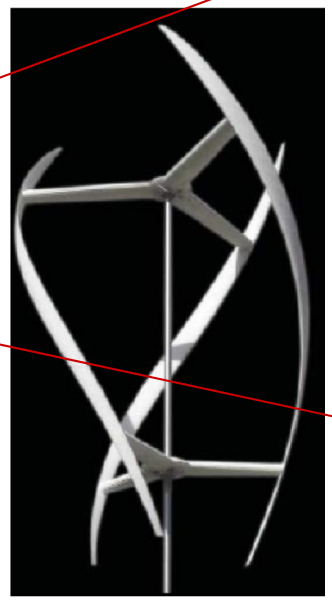
New renewable energy should be used to cover the remaining demand for heating and/or cooling.

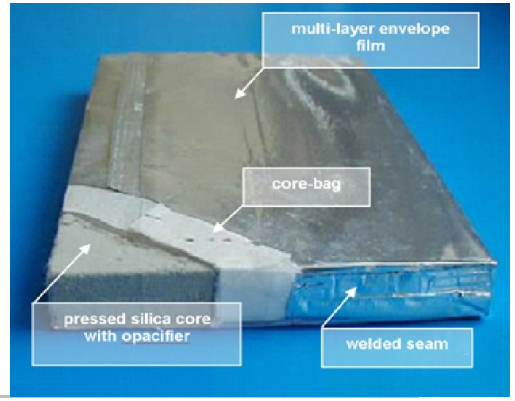
Use renewable energy to cover the demand for electricity.

Consider the usage of materials.

We have to consider the interaction between buildings and transport.

The most environmental kWh is the one that is not used.





Research Activities

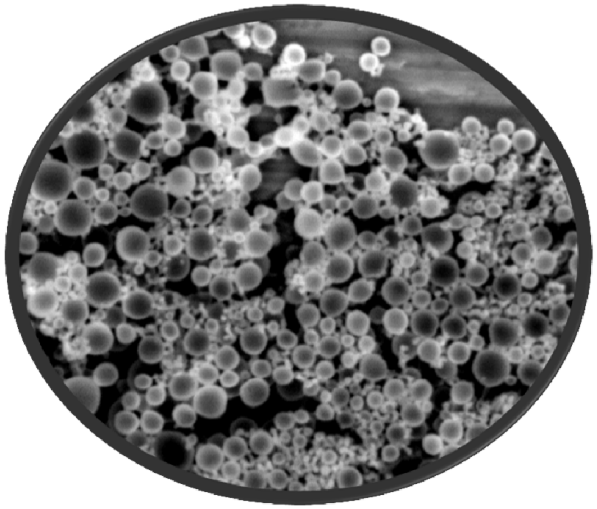
ZEB focuses its work in six areas that interact and influence each other:

- **WP1 Advanced materials technologies**
- **WP2 Climate-adapted low-energy envelope technologies**
- **WP3 Energy supply systems and services**
- **WP4 Use, operation, and implementation**
- **WP5 Concepts and strategies**
- **WP6 Pilot buildings**

WP1 Advanced materials technologies

Main goal:

Development of new and innovative materials and solutions, as well as improvements of the current state-of-the-art technologies.



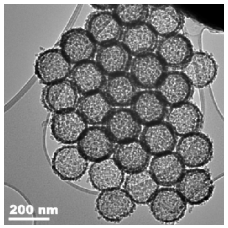
Subtasks

- New concepts
- Opaque and transparent solutions
- Controllable materials and solutions
- Energy storage solutions
- Energy converting materials and solutions

Contact: Bjørn Petter Jelle (bjorn.petter.jelle@ntnu.no)

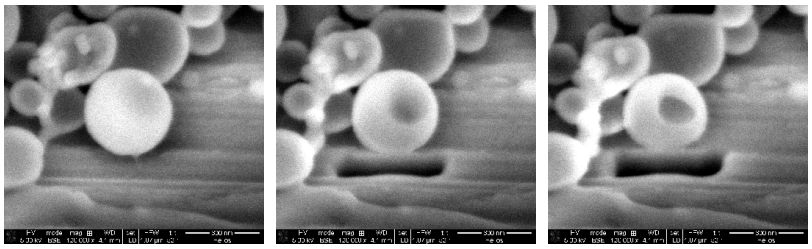
WP1 - Advanced materials technologies

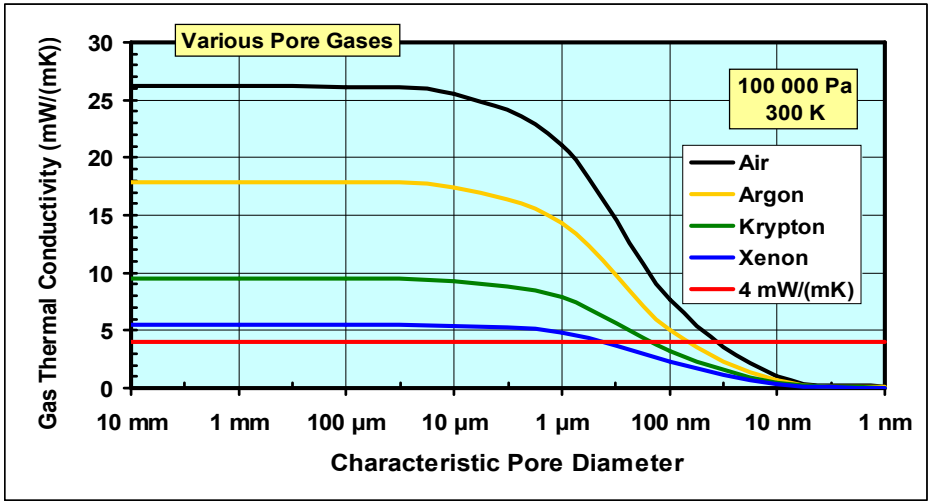
- Investigating various materials technologies for utilization in zero emission buildings
- Exploring state-of-the-art and beyond
- From theoretical concepts to tailor-making new and innovative materials
- A large focus on nano insulation materials (NIM)

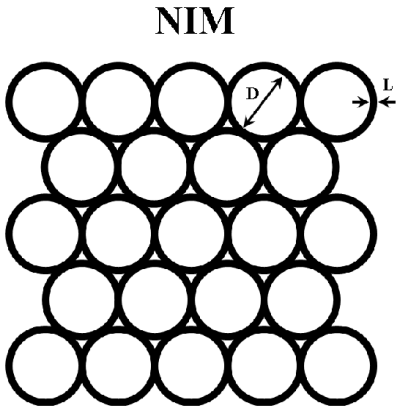


Research and development within fields like e.g.:

- Building envelope in general
- Thermal insulation
- Windows and glass

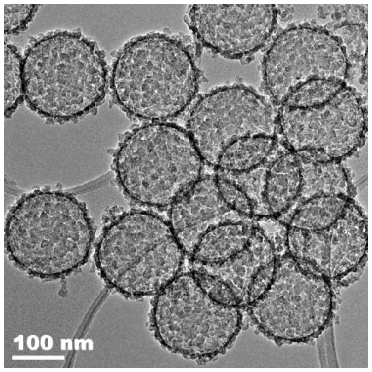






Nano insulation materials (NIM)

From theoretical concepts to development of new and innovative materials

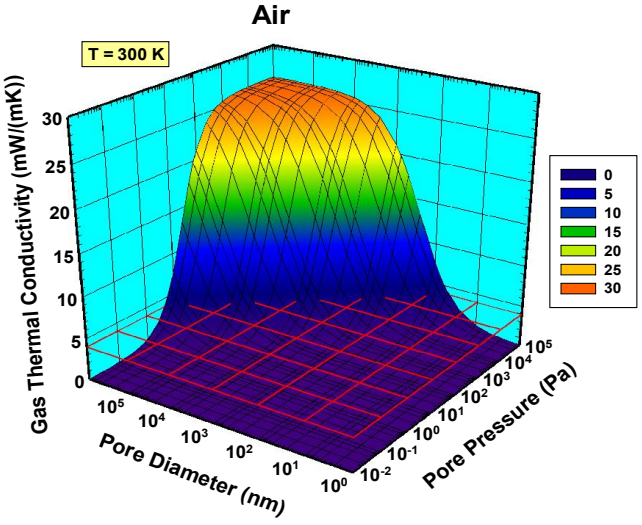


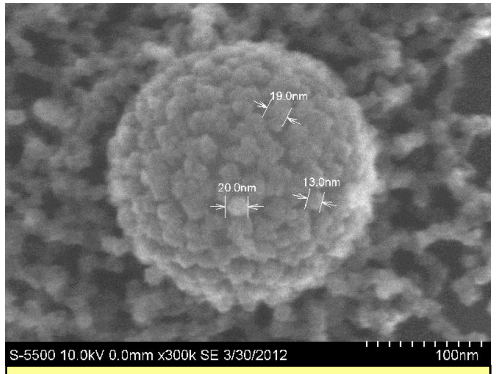
$$\lambda_{gas} = \frac{\lambda_{gas,0}}{1 + 2\beta Kn} = \frac{\lambda_{gas,0}}{1 + \frac{\sqrt{2}\beta k_B T}{\pi d^2 p \delta}}$$

$$Kn = \frac{\sigma_{mean}}{\delta} = \frac{k_B T}{\sqrt{2}\pi d^2 p \delta}$$

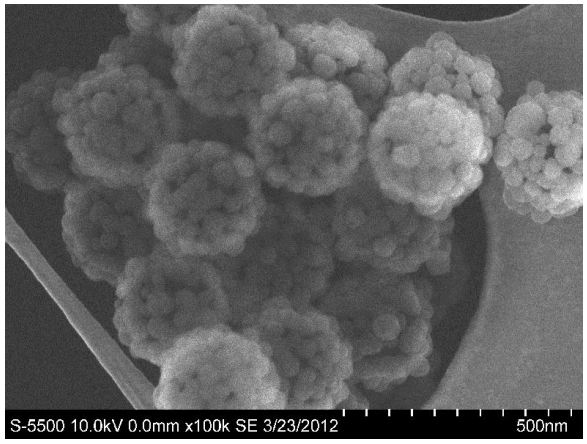
Patent application

- **Controlling:**
- **Sphere inner diameter**
- **Sphere wall thickness**





Without optimizing: So far we have reached 20 mW/(mK)



ZEB The Research Centre on Zero Emission Buildings

FME FORSKNINGS-SENTER FOR MILJØVENNLIG ENERGI

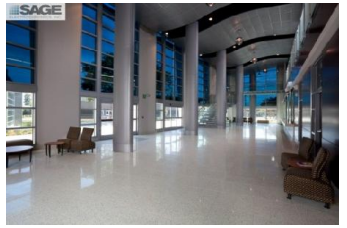
A new glass material

- A new glass material has been made:
- Reduced mass density (weight) by a factor 1.6
- Reduced thermal conductivity by a factor 5.4
- Increased solar transmittance

Various other glass and coating properties are being investigated







WP2 Climate adapted envelope technologies

Main goal:

Develop climate adapted, verified, and cost effective solutions for new and existing building envelopes (roofs, walls and floors) that will give the least possible heat loss and at the same time a reduced need for cooling.

Subtasks:

- Optimal thermal performance
- Integration of active elements in the building envelope
- Improved windows, glazing and shading
- Test- and pilot buildings follow up

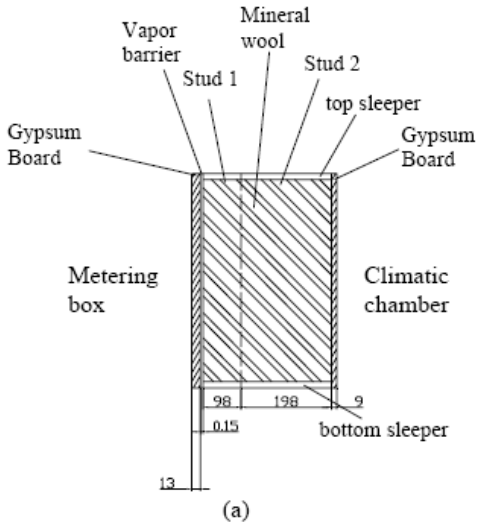

Photo: Sfære

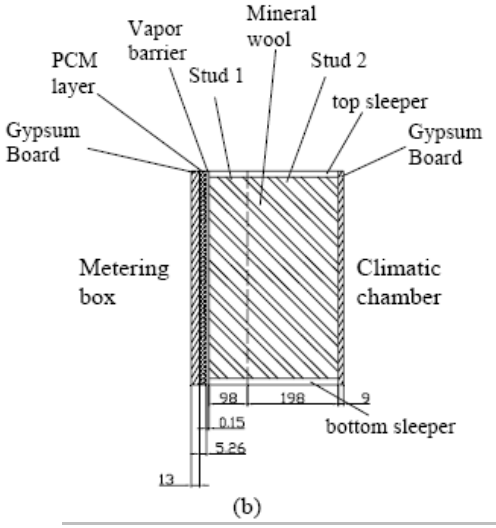
Contact: Berit Time (berit.time@sintef.no)

Development of sandwich elements with VIPs (Leca Isoblock)

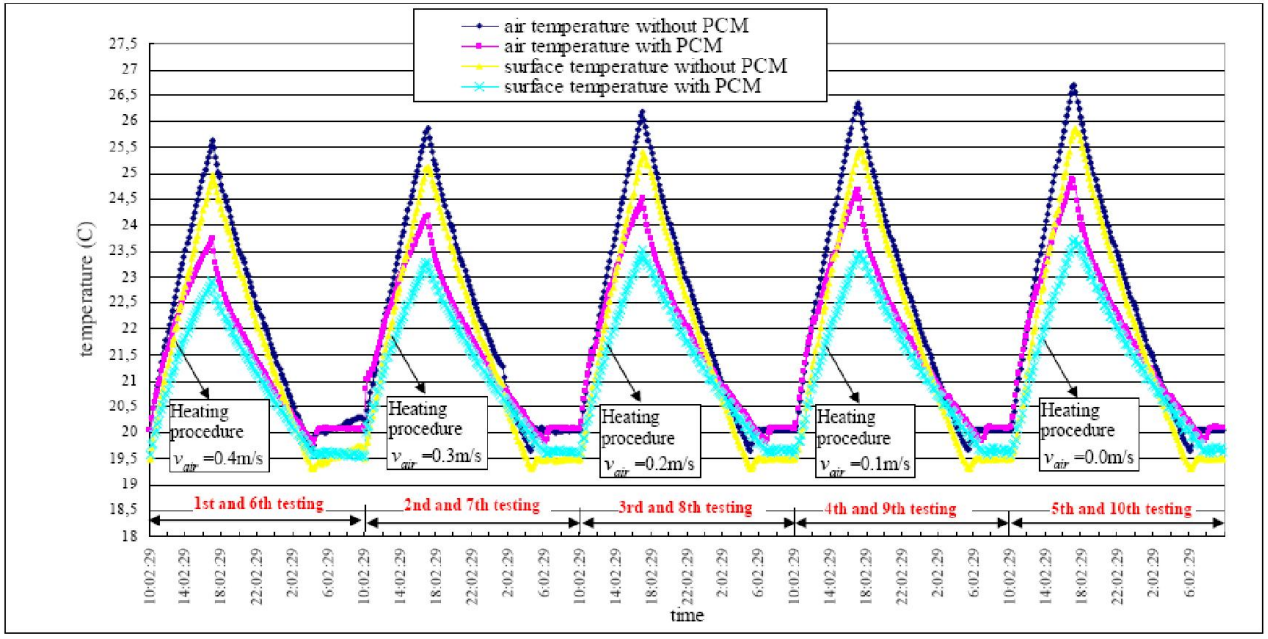
- Block built-up; Parametric study of U-value and heat loss by numerical calculations - THERM and also a 3D simulation program - Comsol Multiphysics
- Assessment of and influence of (convective) heat transport in vertical and horizontal joints for sandwich block systems
- Leca Isoblokk with VIP - Prototype developed by ZEB partner Weber (patent has been applied for)

Phase change material experiments



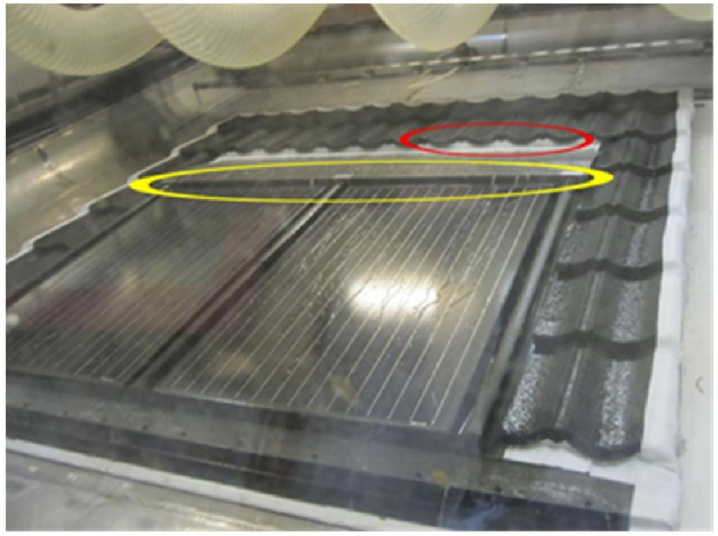


Used to validate e.g. EnergyPlus PCM models.



Wind-Driven rain exposure investigations of building integrated photovoltaics (BIPV)

- Have investigated robustness and climate performance/rain tightness of BIPV modules in a Norwegian climate
- Have proposed a test-method for testing of climate performance of BIPV



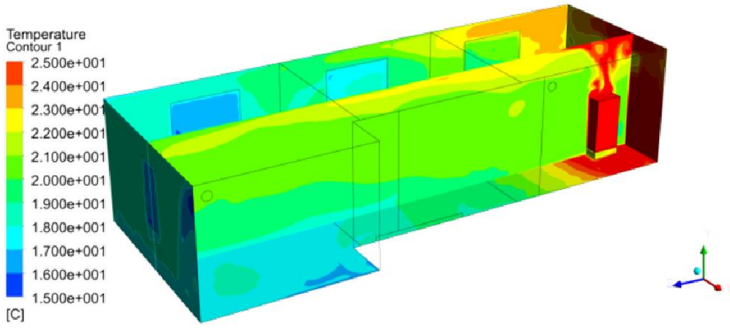
WP3 Energy supply systems and services

Main goal:

Develop new solutions for energy supply systems and building services systems with reasonable energy and indoor environment performance appropriate for zero emission buildings.

Subtasks:

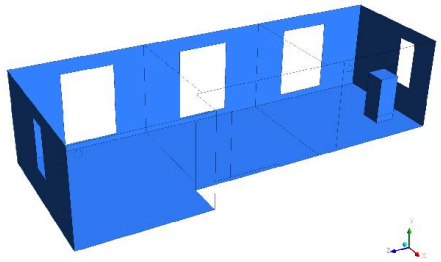
- Available technologies for renewable energy
- Interaction between user needs, energy supply, and building services
- Integration of technologies and solutions
- High performance building services
- Test and pilot buildings follow-up

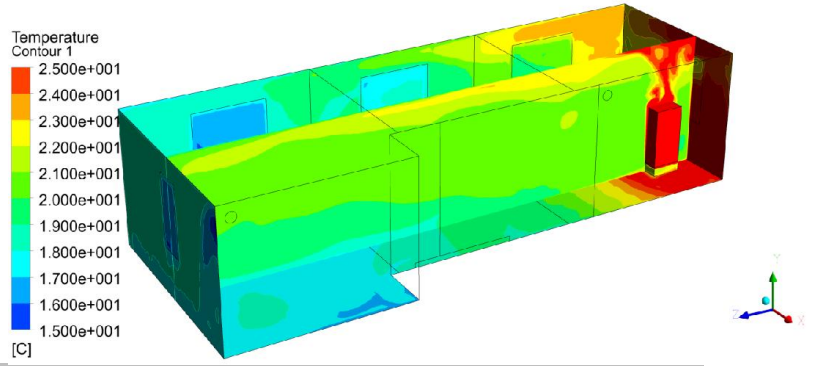


Contact: Hans Martin Mathisen (hans.m.mathisen@ntnu.no)

Effect of super-insulated envelopes on heating and cooling performance

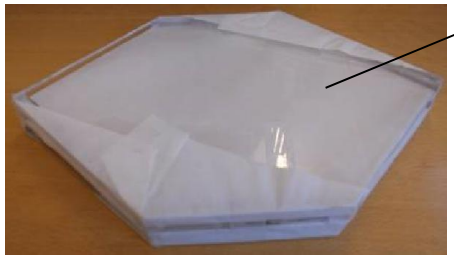
- Robust integration of the heating system for very low heating needs. Advanced simulation tools used for investigation of efficiency of HVAC systems and consequences for thermal comfort. This will lead to simplification of the heating systems.
- Test case: New concepts for wood fired furnaces - simulation study of the temperature response of a family house using downscaled wood fired furnace. Furnaces have to be downsized and equipped with power modulation facilities to be able to avoid overheating.

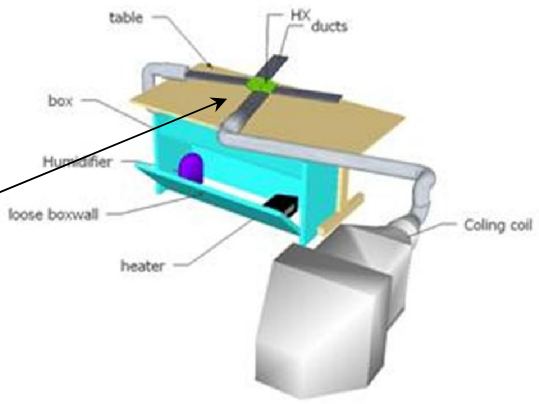




New type of a cross flow energy exchanger using membrane technology

- Hygro-thermal properties of five different membrane samples have been investigated in laboratory. Laboratory setup for testing of the membrane based energy exchanger is developed. CFD simulation study of air flow patterns in an exchanger is conducted aiming at improvement of design and efficiency.
- Recovery of moisture in addition to sensible heat will increase the overall energy efficiency of the exchanger. This will also reduce frosting problems in operation but it demand very careful design of the exchanger.





WP4 Use, operation, and implementation

Main goal:

Provide knowledge and tools which assure usability and acceptance, maintainability and efficiency, and implementation of ZEBs.

Subtasks:

- Use
- Operation
- Implementation

Contact: Thomas Berker (thomas.berker@ntnu.no)

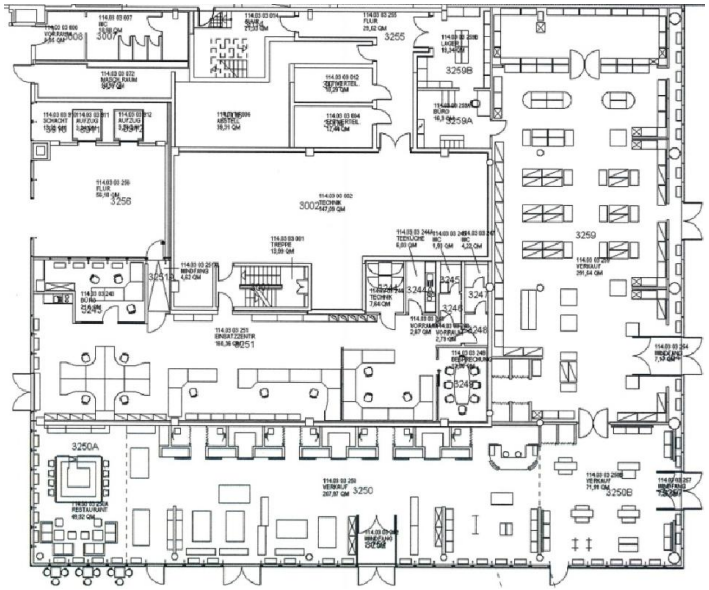
Analyses of end-use in energy efficient buildings

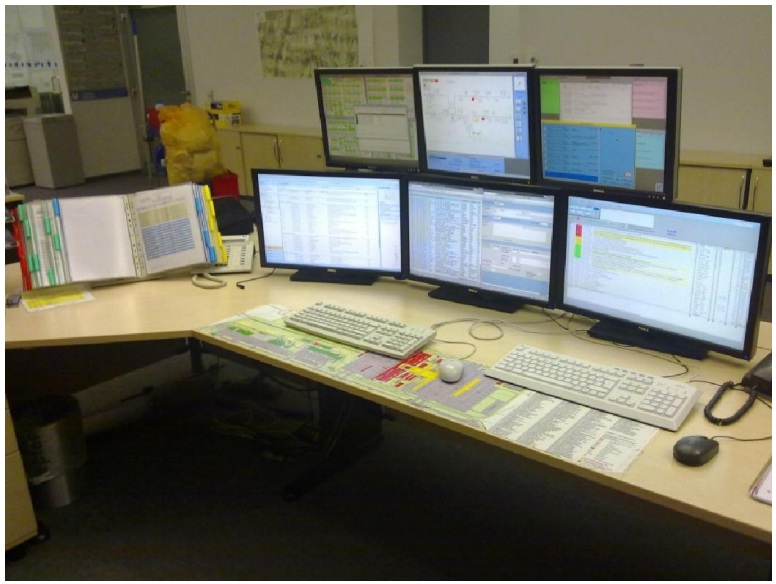
- Evaluation of new buildings with high energy ambitions
  - Bad interfaces
  - Lack of knowledge

- Unintended persistence of energy wasting behaviors (when refurbishing)
  - Deeply rooted values and attitudes
  - Negotiations within the household

ICT based operation of non-residential buildings

- Proposed improvement of existing tools (including project management)
- Demonstrated the importance of “low tech” tools (mobile phone, Excel sheets, informal ties, printout of maps)
- Has resulted in improved operation

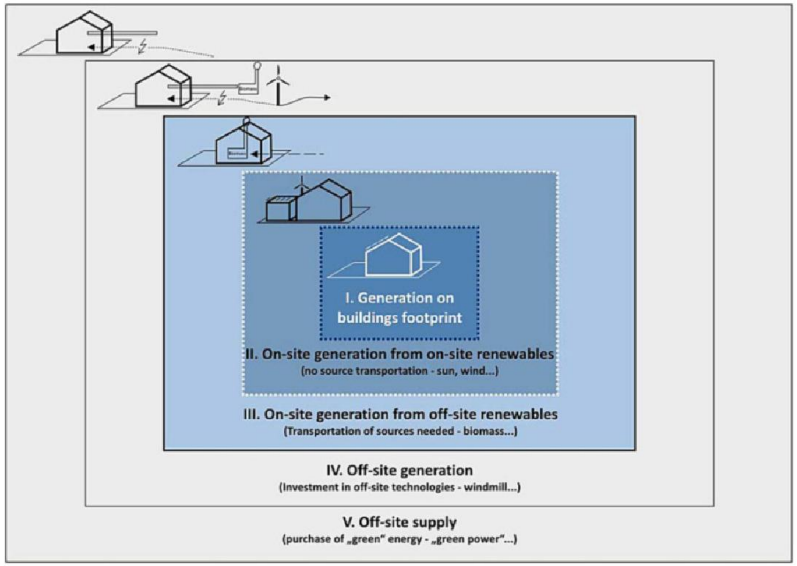




WP5 Concepts and Strategies for ZEBs

Main goal:

Develop concrete concepts for zero emission buildings which can be translated into realized pilot buildings within the time frame of the Centre.

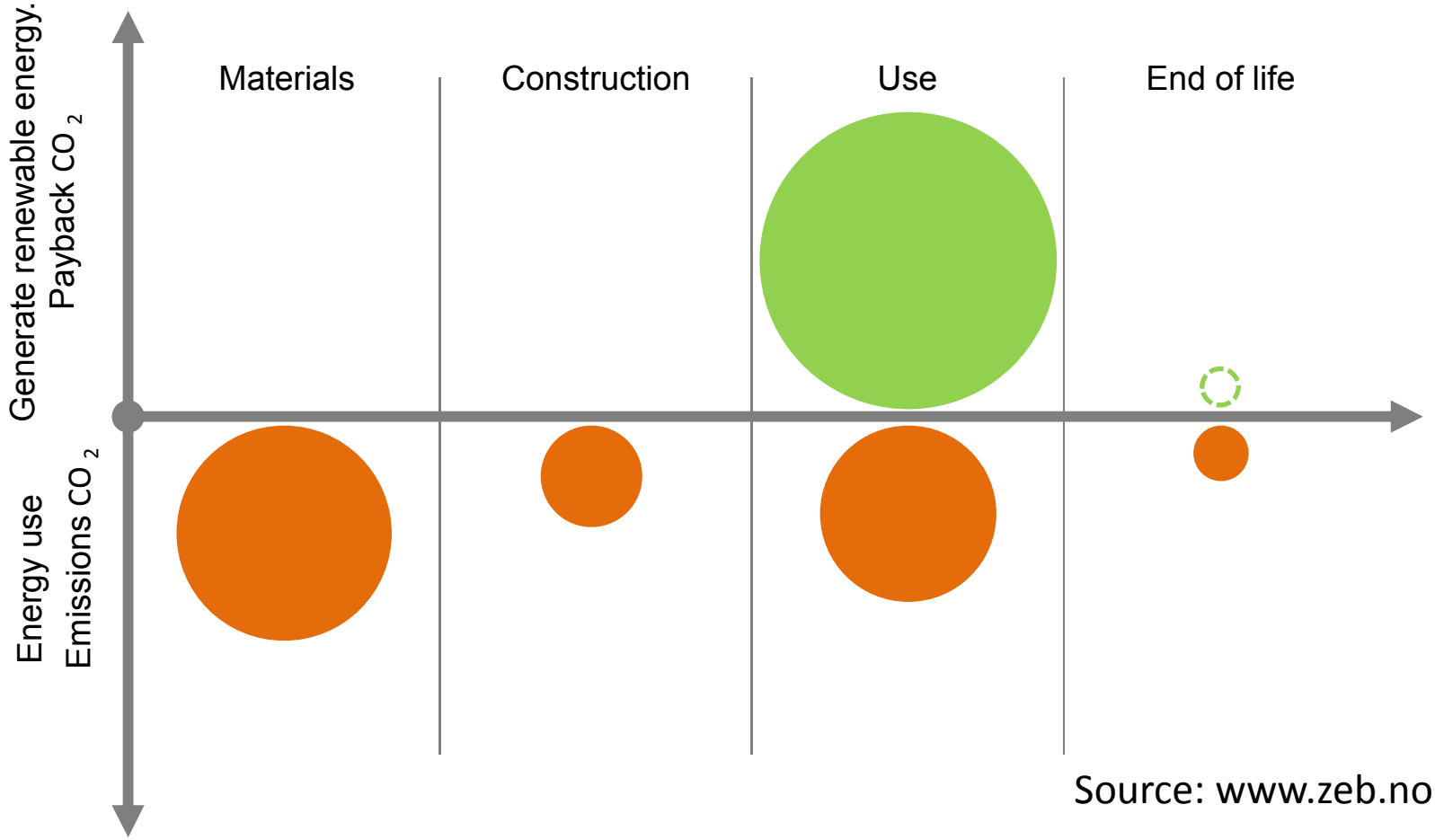


Subtasks:

- Definitions of ZEBs
- ZEB concepts
- Strategies and building processes

Contact: Birgit Risholt (birgit.risholt@sintef.no)

ZEB-Definition



Source: www.zeb.no

CO_2 emissions and embodied energy

- Embodied energy includes the energy required for manufacturing the product from raw materials, production and transport
- Embodied CO_2 emissions takes into consideration the energy source for the different components in the embodied energy

(bellona.no)

(nullutslipp.no)

(forskning.no)

WP6 Pilot buildings

Main goal:

Development of real pilot buildings

Subtasks:

- Give input to pilot building projects
- Coordinate pilot building activities in WPs

Contact: Inger Andresen (Inger.Andresen@sintef.no)

ZEB-Pilot Buildings

ZEB PILOT BUILDINGS:

1. Skarpnes, Arendal: 37 dwellings.
2. Powerhouse Kjørbo, Sandvika. Renovation of 2 office blocks.
3. Mulitkomfort, Larvik. Single family house.
4. Ådland, Bergen. 500-800 dwellings.
5. Powerhouse Brattørkaia, Trondheim. Large office building.
6. Depotbygget Haakonsvern, Bergen. Small office building.
7. ZEB Living Lab, Trondheim.

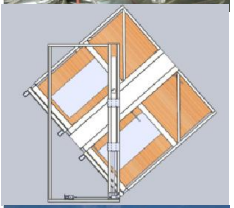
ZEB – Research Infrastructure

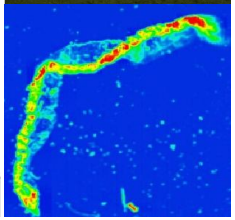
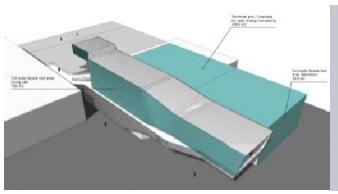
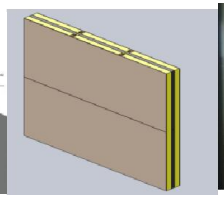
In order to achieve the vision and goals of ZEB, six laboratories are being expanded and/or developed:

- Advanced Materials Technologies Laboratory
- Climate and Building Technologies Laboratory
- Building Services Laboratory
- Full Scale Test Cell
- Living Laboratory
- Pilot Building Measurement In Situ

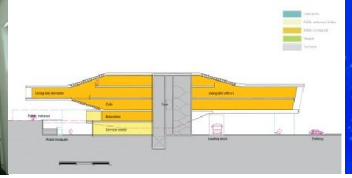




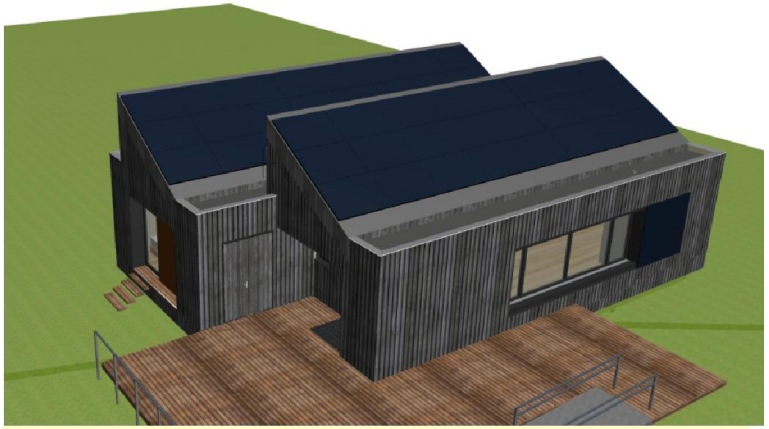


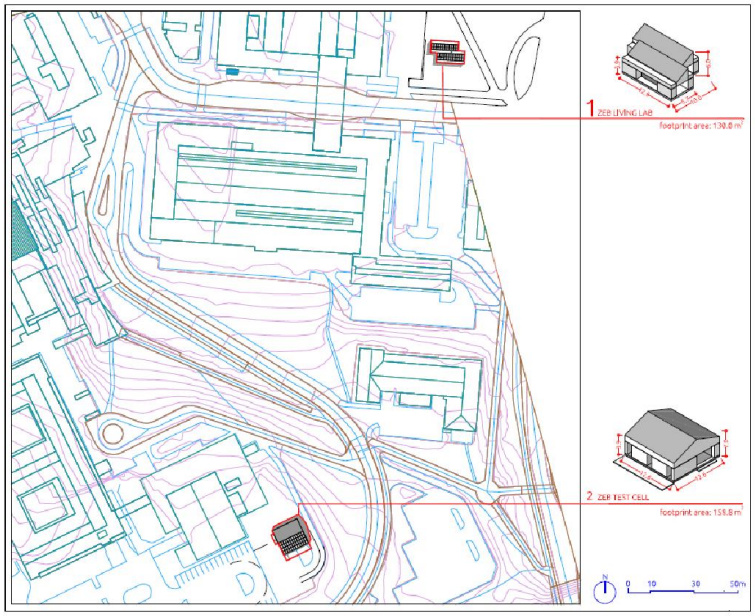




Establishment of Research Buildings at NTNU – ZEB Living Lab and ZEB Research Cells

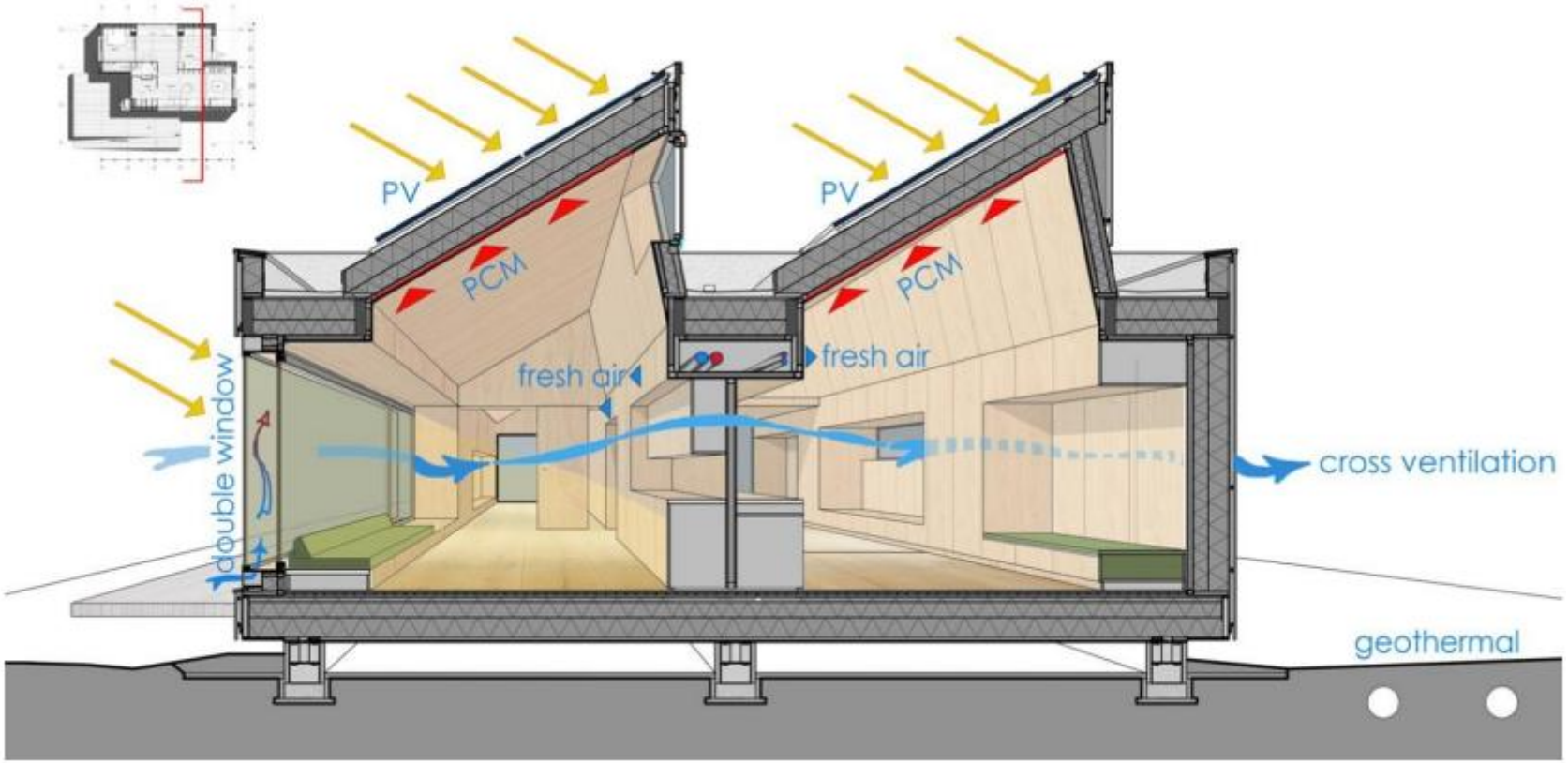


ZEB Living Lab – A dwelling for user-Technology interaction studies

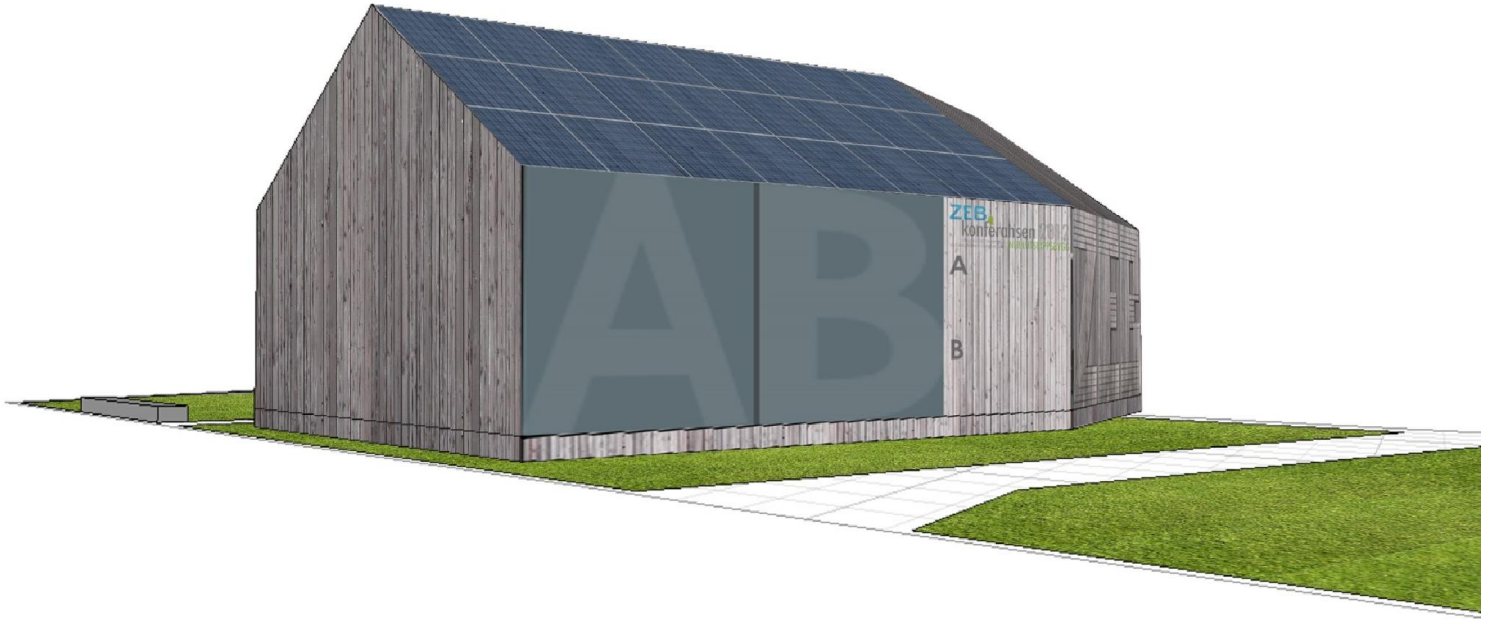


ZEB Research Cells for research and development of ZEB technologies

ZEB Living Lab



ZEB Research Cells




Zero emission buildings...
... serving humankind and nature...