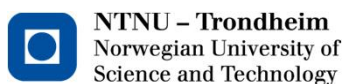


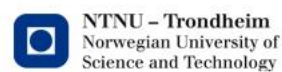
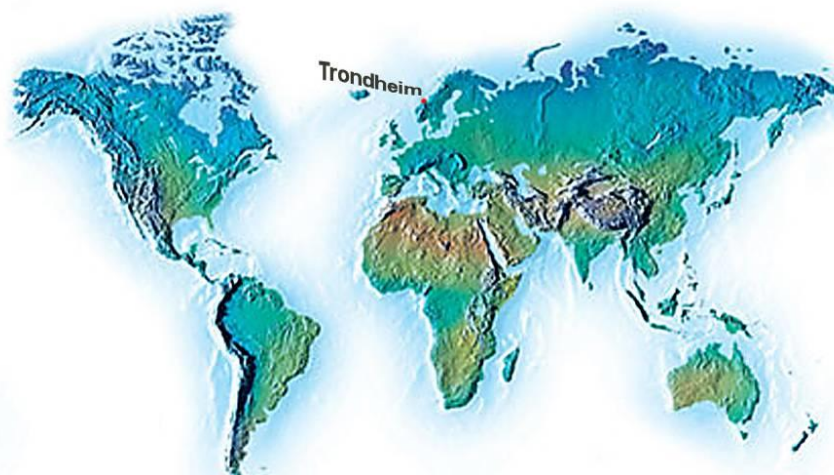


**The Research Centre on  
Zero Emission Buildings**

**Arild Gustavsen**, Professor NTNU  
Director The Research Centre on Zero Emission Buildings



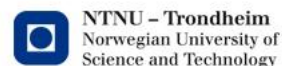
2



3

## NTNU – An international university

- Main focus: Europe, China, international mobility, international research training
- About 350 MoUs related to international cooperation for research and education
- 10 % of NTNU's students are foreign nationals
- 30 % of NTNU's PhD candidates are international
- 25 % of NTNU's academic staff is international



[www.ntnu.no](http://www.ntnu.no)

4

## NTNU key figures (2012)

**49** departments in **7** faculties

NTNU University Library

NTNU University Museum

**11 865** student applications with NTNU as first choice

**22 349** registered students, **7752** admitted in 2012

**3 326** Bachelor and Master degrees awarded

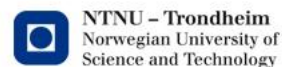
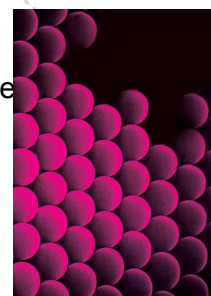
**374** doctoral degrees awarded (36 % women)

**4 972** person-years

**3 009** employed in education and research; **629** full professors

**EUR 714 mill.** budget

**585 000 m<sup>2</sup>** of owned and rented premises



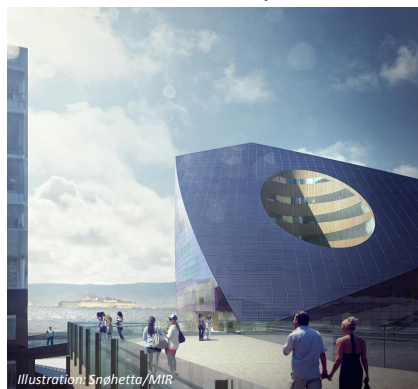
[www.ntnu.no](http://www.ntnu.no)

## The Zero Emission Building Centre's 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](http://www.zeb.no)



## Zero Emission Buildings Centre Facts

- Host institution:  
Norwegian University of Science and Technology (NTNU)
- Research partners:  
SINTEF Building and Infrastructure and SINTEF Energy Research
- Industry and public partners: 22
- Researchers associated with the Centre: About 25 (some part time)
- PhD candidates: 21
  - 3-5 expected to complete during 2013
  - 13 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<sub>2</sub>), including studies on individual building technologies (e.g. building envelope and building services technologies) and user studies.



## Partners in the Centre

- **Users (the reference group)**
- **Contractors**
- **Producers of materials and products for the building industry**
- **Consultants, architects**
- **Trade organizations**
- **Property managers**
- **Public administration**
- **University and research institutions**
- **The Research Council**

Skanska  
Caverion  
Weber  
Isola  
Glava  
Protan  
Hydro Aluminium/Sapa  
NorDan  
Velux  
DuPont  
Brødrene Dahl  
Multiconsult  
Shohetta  
ByBo  
Entra Eiendom  
Forsvarsbygg  
Statsbygg  
Enova  
Husbanken  
Direktoratet for byggkvalitet  
Byggenæringens landsforening  
Norsk Teknologi  
NTNU  
SINTEF, SINTEF Energiforskning  
Norges forskningsråd



## Other institutions cooperating with the Centre

### International partners

- VTT (Finland)
- Chalmers (Sweden)
- Fraunhofer (Germany)
- TNO (The Netherlands)
- LBNL (USA)
- MIT (USA)
- University of Strathclyde (Scotland)
- Tsinghua University (China)

### Other new

- Politecnico di Torino
- Shanghai JiaoTong University
- EMPA

### Reference group

- Lavenergiprogrammet
- NBBL
- NVE
- Forbrukerrådet
- EcoBox
- Driftsforum
- Arkitektbedriftene



## Zero energy/emission buildings (ZEBs) in international policy documents

**USA:** «... to achieve our strategic goal of net-zero energy buildings ...»

**UK:** «... The objective of the proposal is to set a timetable for moving towards zero carbon development as a contribution to meeting UK target to reduce carbon emissions ...»

**Canada:** «The Equilibrium House Initiative aims ...»

**Netherlands:** «In the Netherlands, the government and the construction sector aim at achieving energy neutral new construction in 2020.»

**Germany:** «Zero emission buildings are the long-term objective»

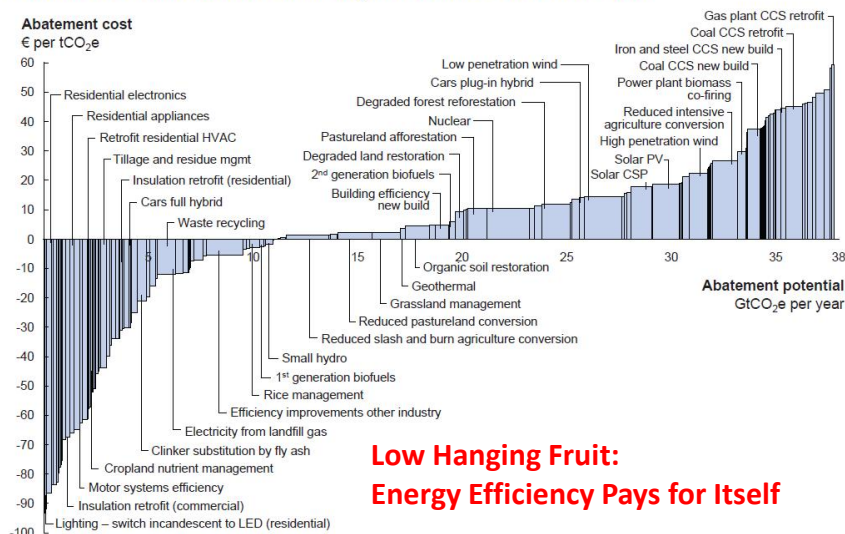
**Norway:** «All new buildings should be nearly zero energy buildings before 2020.»



## Why Zero Emission Buildings?

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

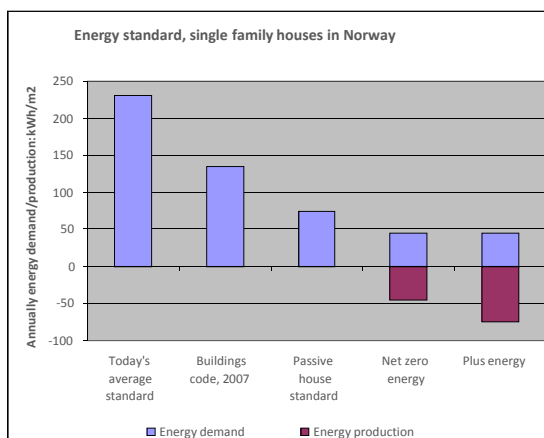
### Global GHG abatement cost curve beyond business-as-usual – 2030



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO<sub>2</sub>e 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

## Zero Emission Buildings - 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<sub>2</sub> 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



## The research activities

ZEB focuses its work in five 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 pilot buildings



## Some Research and Development Examples



**NIM** Nano insulation materials (NIM)

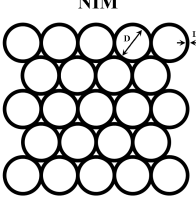
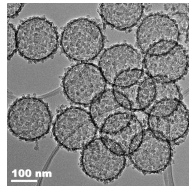
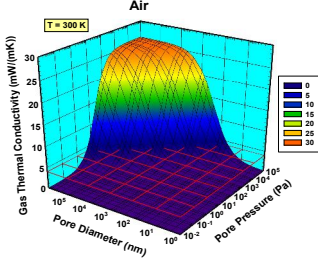
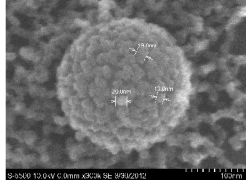
**From theoretical concepts to development of new and innovative materials**

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

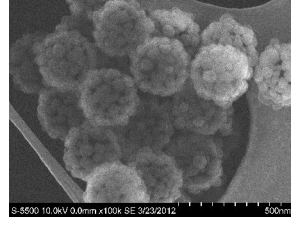
$$\text{Kn} = \frac{\sigma_{\text{mean}}}{\delta} = \frac{k_B T}{\sqrt{2\pi} d^2 p \delta}$$

**Patent application**

- Controlling:
- Sphere inner diameter
- Sphere wall thickness

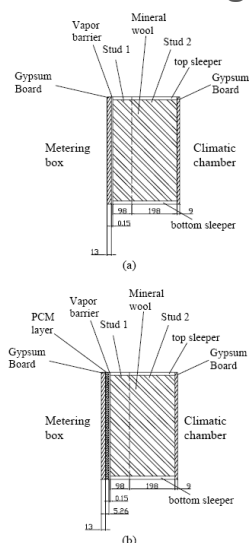





**Without optimizing: So far we have reached 20 mW/(mK)**

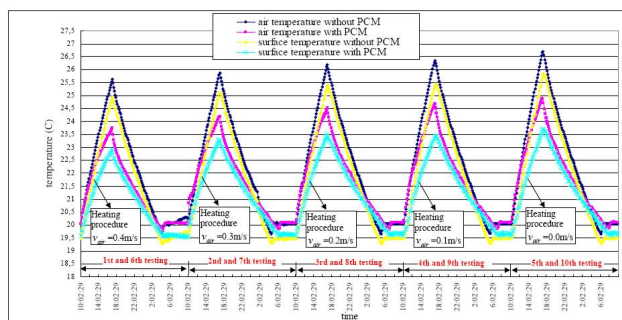





## Phase change material experiments



Used to validate e.g. EnergyPlus PCM models.



**ZEB** The Research Centre on Zero Emission Buildings

**FEM** CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

## 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



**ZEB** The Research Centre on Zero Emission Buildings

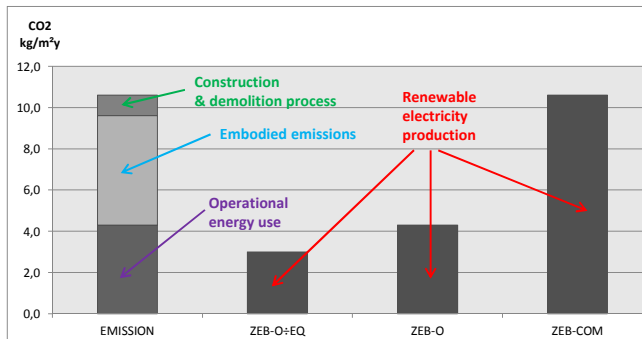
**FEM** CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH



## ZEB-Definition

ZEB-DEFINITION:

1. Ambition level
2. Rules for calculation
3. System boundaries
4. CO2-factors
5. Energy quality
6. Mismatch production and demand
7. Minimum requirement energy efficiency
8. Requirement indoor climate
9. Verification in use



ZEB-O+EQ: Balancing operational energy use exclusive equipment.

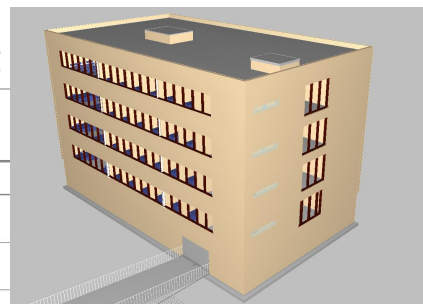
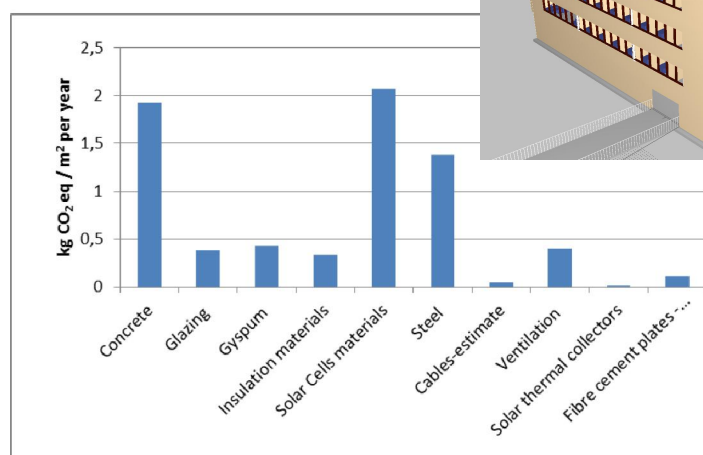
ZEB-O: Balancing operational energy use inclusive equipment.

ZEB-COM: Balancing operational energy, embodied emissions, construction and demolition processes

*The main concept of a zero emission building is that renewable energy sources produced or transformed at the building site have to compensate for CO2 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.*



## Concept work – Office building



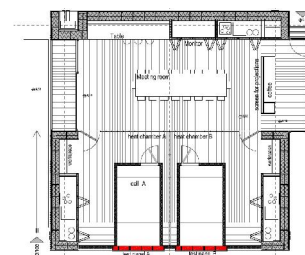
## ZEB-Pilot Buildings

### ZEB PILOT BUILDINGS:

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



## Establishment of laboratories and test buildings – “Living Lab” and “Test Cell”



Thank you for your attention

Contact: [Arild.Gustavsen@ntnu.no](mailto:Arild.Gustavsen@ntnu.no)

