Low energy buildings –

the basis for realizing the strategy for independency of fossil fuels in 2050

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Introduction

The problems for users of fossil fuels:

- Security of supply
- Environmental impact
- Economy

The solution:

Replace fossil fuels by

1. Energy savings
2. Renewable energy

Buildings and energy

- Buildings are the biggest energy user (40%)

- Buildings offers the cheapest solutions
 for energy savings and renewable energy

EU Policy on energy and buildings

EPBD recast:

All new buildings in the EU as from December 2020 (2018 for public buildings) will have to be **nearly zero energy buildings**

the ***nearly zero or very low amount of energy required should to*** a very significant level be covered by energy from renewable source

Roadmap
for no fossil fuels in buildings by 2050

- Solutions: New nearly zero energy buildings from 2020

  Energy retrofitting of all existing buildings by 2050

  Renewable energy supply by 2050
- Challenge: Integrate and optimize solutions

  Innovate and implement

Energy performance requirements in the Danish Building Code

For dwellings:

- 2010: $E < (52{,}5+1650/A)\ kWh/m^2$ pr.year.
- 2015: $E < (30 + 1000/A)\ kWh/m^2$ pr year
- 2020: $E < 20\ kWh/m^2$ pr. year

E: Energy use for heating of rooms and DHW, electrical energy for pumps and fans including energy factors for heating (1, 0.8, 0.6) and electrical energy (2.5, 2.5, 1.8)

Strategies for development of low energy buildings

- Option 1: Experience based development

- Option 2: Research based development

Experiences: DTU 1979:
Low energy houses with 5000 kWh/year

Experiences: DTU 1979: Low energy houses with 5000 kWh/year

Results:

- Tested in simulated use and real use
- Energy performance as expected

- But were not implented in the Building Code

Passive Houses in Vejle in 2008
Big windows to the south

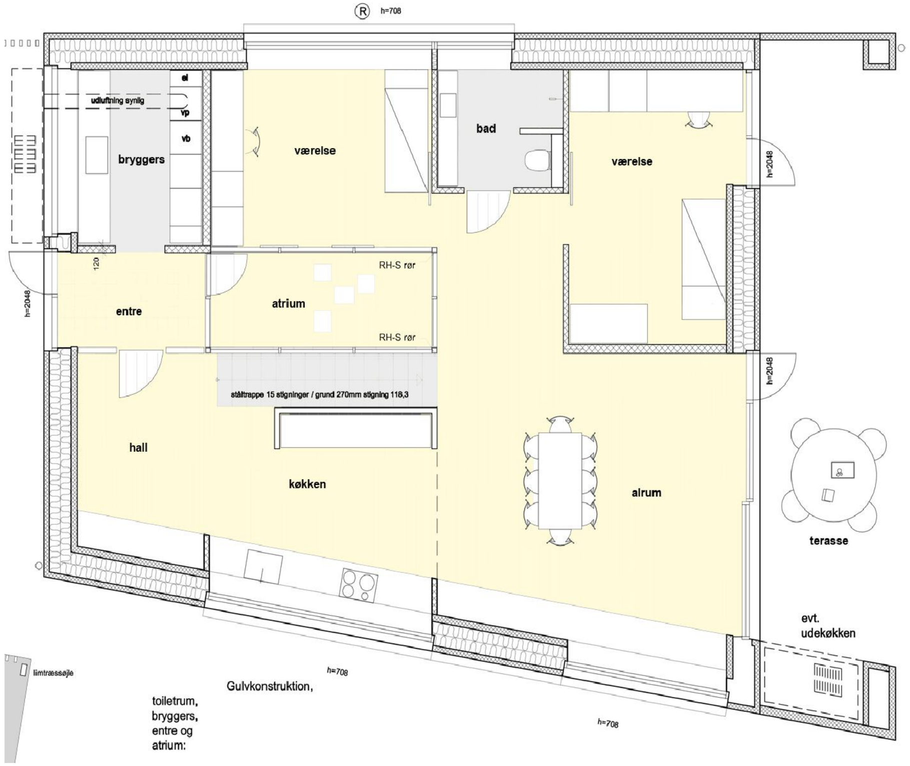







Passive Houses in Vejle in 2008

Big windows to the south



Passive Houses in Vejle in 2008 - Experiences

- Problems with overheating due to the big windows to the south
- Problems with ’underheating’ due to the ventilation based heating system with heat pumps
- Design guidelines for windows not correct
- Simulation of energy and indoor environment performance must be on room basis

Nearly zero energy house (25kWh/m^2) Type house - but need to be optimized

Experience based development

- The building sector needs to develop much better buildings before 2020
- May be based on an experience based development but that will lead to:
- many bad experiences
- non-optimised solutions

Research based development of nearly zero energy buildings

Clear objectives: Develop low energy buildings as an element of the general sustainable energy solution that:

- Use no fossil fuels
- Have a good indoor environment
- Have an optimised lifecycle cost
- Can be produced in sufficient numbers to realize the vision of a fossil fuel independant society in 2050

Challenge and opportunity for the building sector

- **Industry** — **Energy efficient products**
- Consultants — Integrated design focused on energy performance
- Constructors — Build low energy buildings as standard solutions
- Managers — Continous commissioning

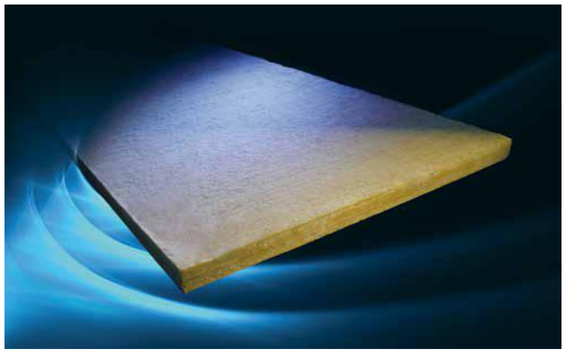
Development of high performance products

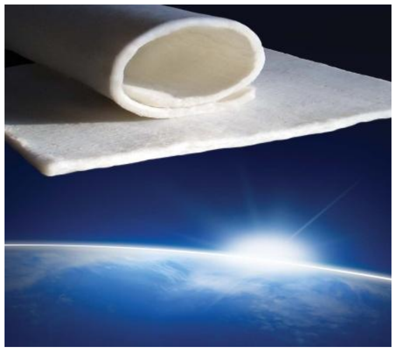
Products with improved energy performance:

- Building envelope based on
  - Insulation materials with lower termal conductivity
  - Insulation materials in larger thicknesses
- Windows
- Ventilation systems
- Space- and DHW- heating systems
- Lighting system

Insulation with lower thermal conductivity, λ

- Conventional insulation $\lambda = 37$ mW/mK
- EPS with graphite : $\lambda = 31$ mW/mK
- Stonewool with aerogel: $\lambda = 19$ mW/mK
- Aerogel $\lambda = 14$ mW/mK
- Vacuum panels $\lambda = 5$ mW/mK





Insulation in larger thicknesses

Steel and plywood wall
Clad with Gypsum plates and plywood
Insulation thickness: high

Sandwich panel of thin fibrereinforced concrete
2x 3 cm
Insulation thickness: high

Insulated building envelope

Insulation Thickness	Thermal conduc. λ	U-value	Insulation price
m	mW/mK	W/m^2K	Euro/m^2
0,5	35	0,07	33
0,6	35	0,06	40
0,5	**31**	0,06	**46**
0,33	19	0,04	? higher
0,23	14	0,03	? higher

U-values of 0,06 are realistic in 2020

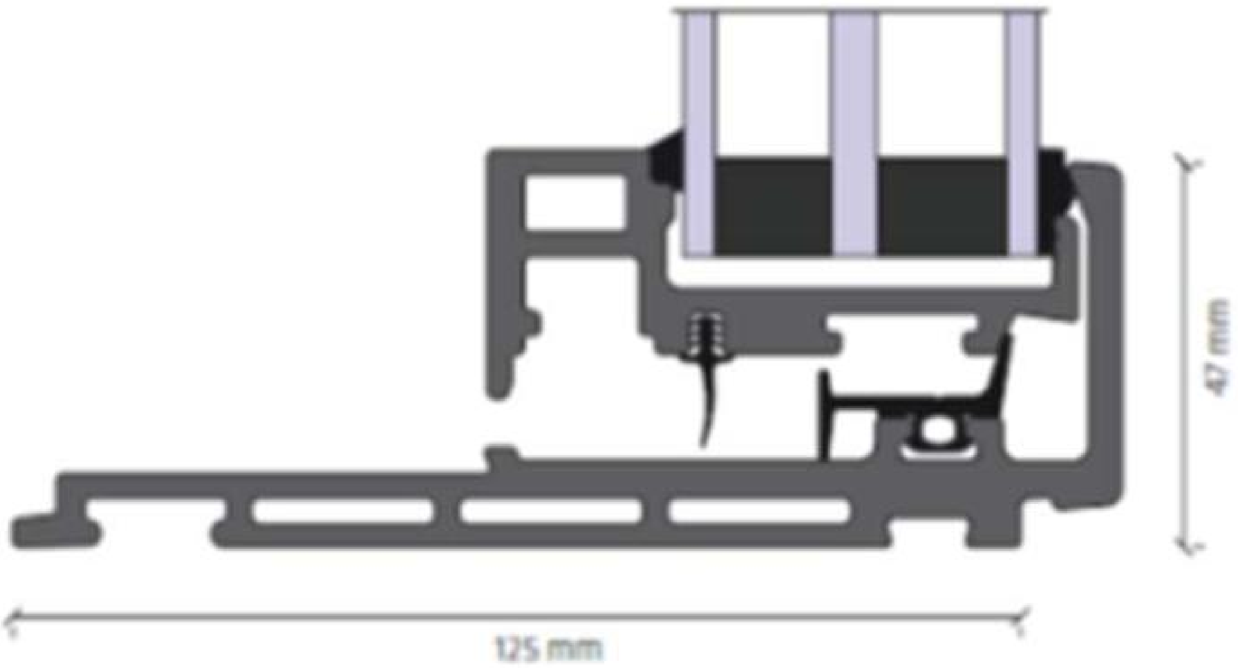
Windows

- Energy performance of windows:
  - Heat loss - smaller
  - Solar gain – larger but controllable
  - Day light – larger but controllable
- Net energy gain for short heating season:

  E = 116 g -74 U
- Need for improved glazing units and profiles

Windows with improved profiles

Improvements: Slim and insulating



Windows

	Type of window	b (mm)	U (W/m^2K)	g (%)	E (kWh/m^2)
1	Reference: Typical wood window With a double low–e glazing	95	1,35	45	-48
2	Typical passive house window	125	0,8	33	-21
3	Best on Danish market composite window With triple low iron and low-e glazing	47	0,78	53	+4
4	Type 3 with expected improvements	40	0,6	56	+20
8	Coupled window with night insulating shutter (day/night)	20	1,0/0,2	62/0	+34

Ventilation systems

- Improved energy performances:
  - Heating: highly efficient heat recovery
  - Cooling: Venting to cool air and constructions.
  - Electrical energy for fan: Lower pressure drop
  - Control: Demand controlled ventilation
- Mechanical ventilation
- Ducts and units with low pressure drop

Energy use for fans in ventilation systems for office buildings in 2020: $300 J/m^3$ or $3 kWh/m^2$

Space- and DHW- heating systems

Low temperature space heating systems:

- Floor heating at 24 C self controlling
- Radiators with supply temperatures of 50C
- Predictive control based on weather forecasts

DHW heating:

- Flat plate heat exchanger at 45C
- Storage tank and heat exchanger at 45C
- Principle: no legionella bacteria problem with small volumes of DHW (less than 3 l)

Space- and DHW- heat supply systems

- Low temperature district heating (50C / 20C)

- Heat pump systems

Low temperature district heating based on renewable energy

District heating for low energy buildings requires:

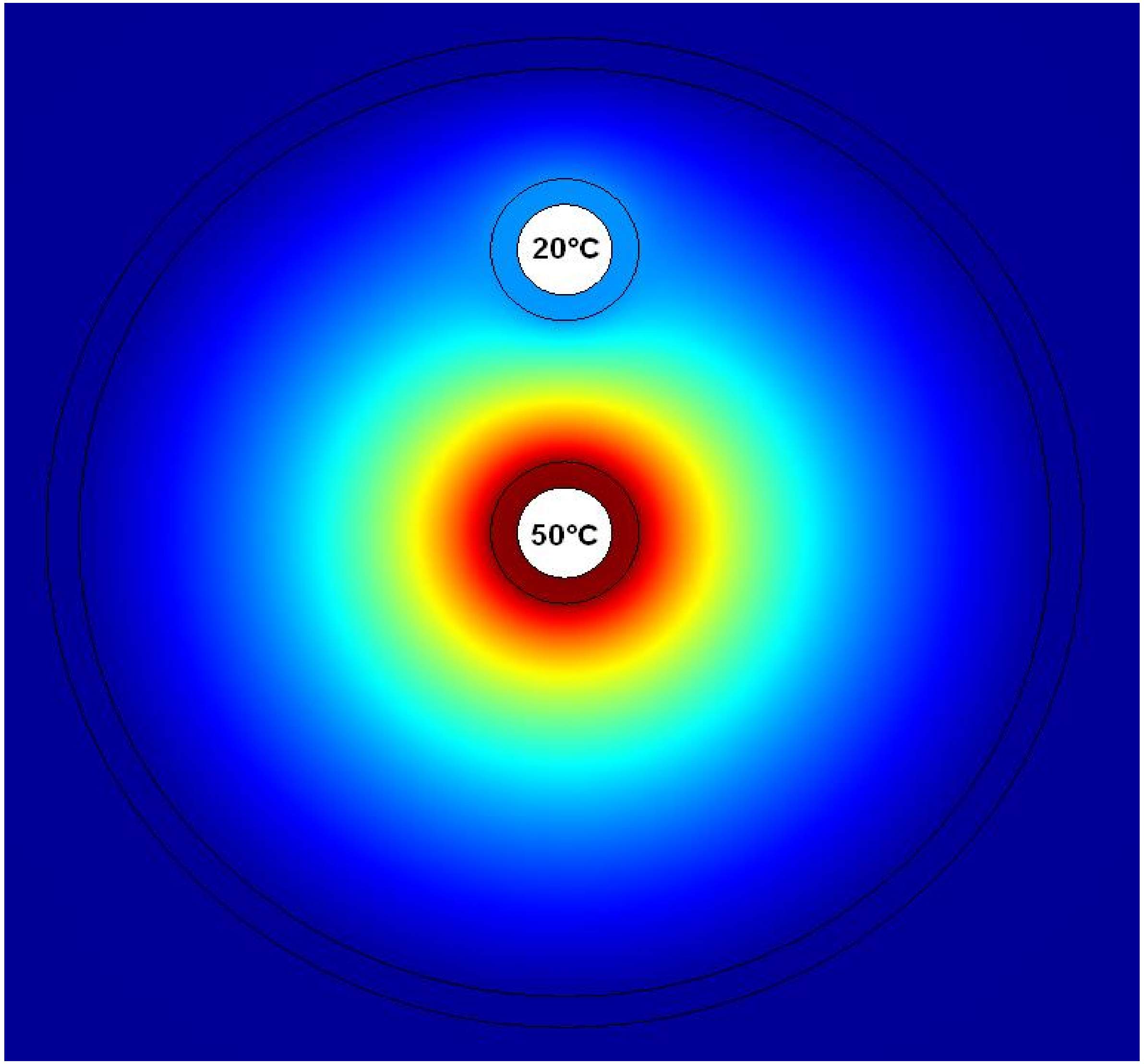
- Reduction of heat loss from pipes by:
  - Low temperature
  - Twinpipes with small pipes and thick insulation

District heating based on non-fossil fuel requires:

- Low temperature

Low temperature district heating based on renewable energy

Supply temp. 50C
Return temp. 20C
Heat loss 3 W/m
Heat loss 15%

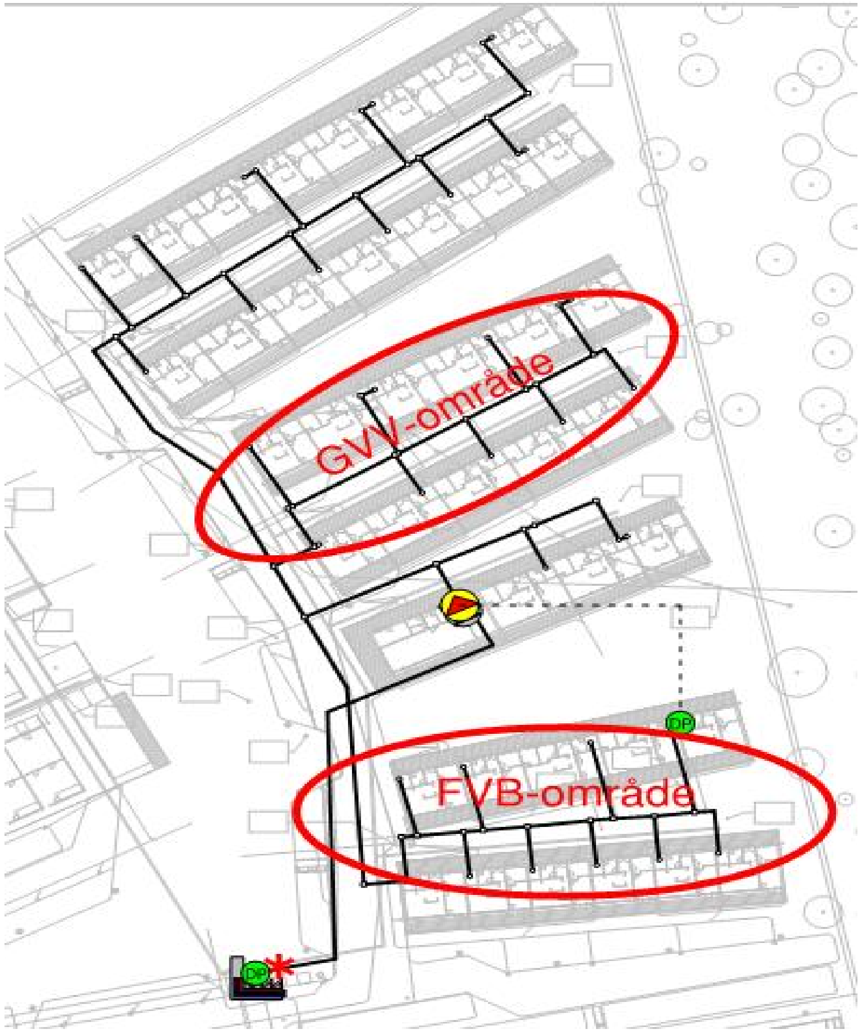


Low temperature district heating

System in full scale test in Lystrup in Århus in two version:

GVV: based on flat plate heat exchangers and no storage of DHW

FVB: Based on storage of district heating water for limiting the power from DHW



Low temperature district heating

Results of test in low energy houses in Århus:

- Domestic hot water supply temperature at 45C accepted by users
- Space heating OK
- Heat exchanger works with only 3 C temp. diff.
- Heat loss of network about 15% as planned

Heat pump based on electricity from renewable energy

- Low temperature for heating and domestic hot water improves efficiency
- Storage of heat from heat pump in system water may be useful for solving mis matching of production of heat and use of heat.
- Heat from ground source better than air in cold winthers

Potential energy efficient products in 2020

- Insulation of building envelope: U < 0.06 W/m^2K
- Windows: U < 0.6 W/m^2K , g > 55% . Ref: A_{window}
- Ventilation with heat recovery (90%)
- Venting and night ventilation
- Solar shading
- Natural cooling
- Energy efficient elec. light, fans, pumps, boilers
- Energy efficient electrical equipment
- Solar heating of domestic hot water
- District heating based on waste, geothermal, solar
- Heat pumps based on renewable electricity

Challenge and opportunity for the building sector

• Industry	Energy efficient products:
• **Consultants**	**Integrated design focused on energy performance**
• Constructors	Build low energy buildings as standard solutions
• Managers	Continous commissioning

Integrated design of low energy buildings

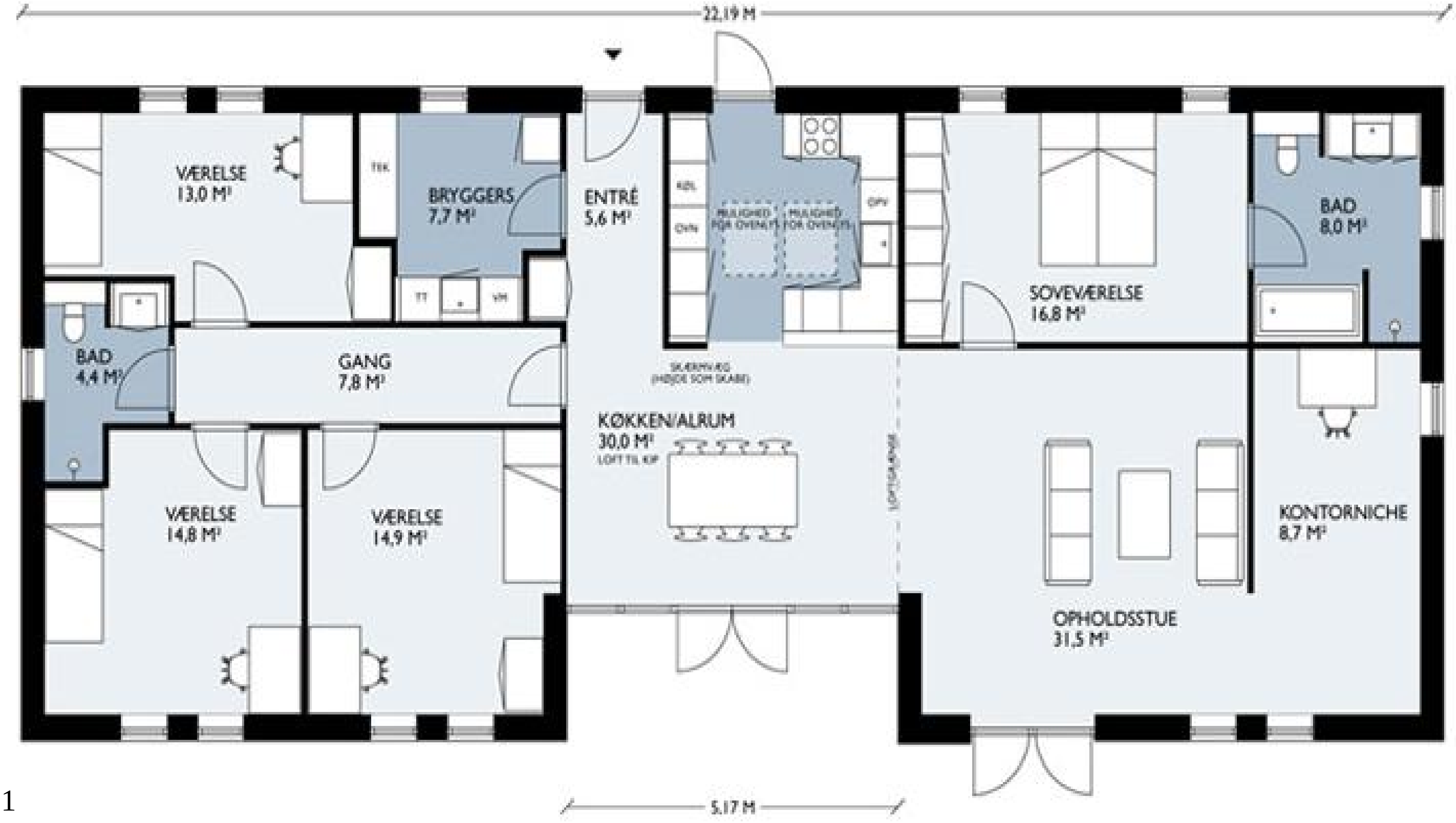
- Single family houses may be designed following a guideline with focus on window sizes and orientation

- Large buildings may be designed in a design group based on an integrated design method with simulation based support on energy performance

Guideline for design of new low energy dwellings

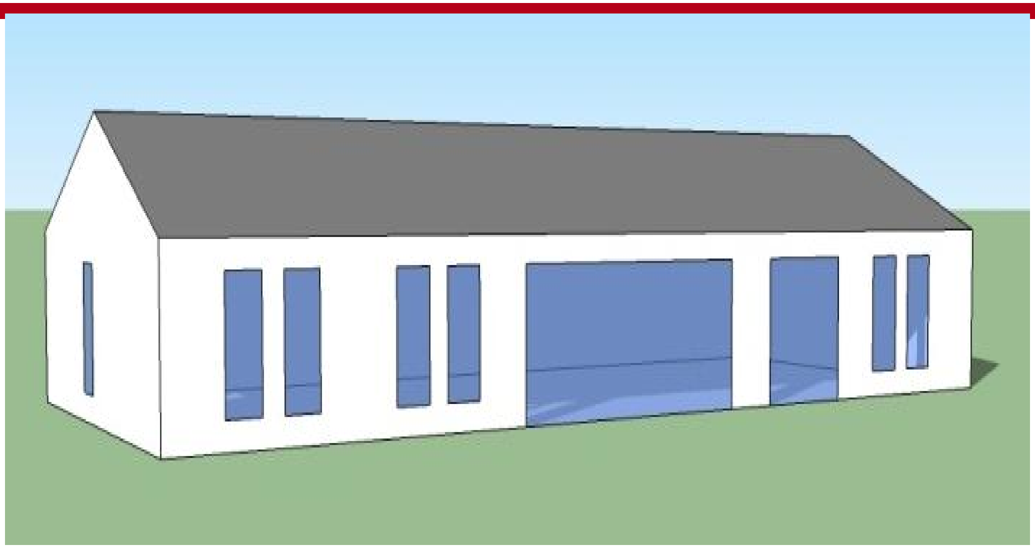
- Determine the minimum window size in all rooms with regard to daylight
- Calculate the maximum window size in each room with regard to overheating
- Calculate energy consumption in each of the rooms for the different window sizes
- Choose a window size for each of the rooms based on results in previous steps
- Document the energy consumption and indoor environment for the final window design in the dwelling

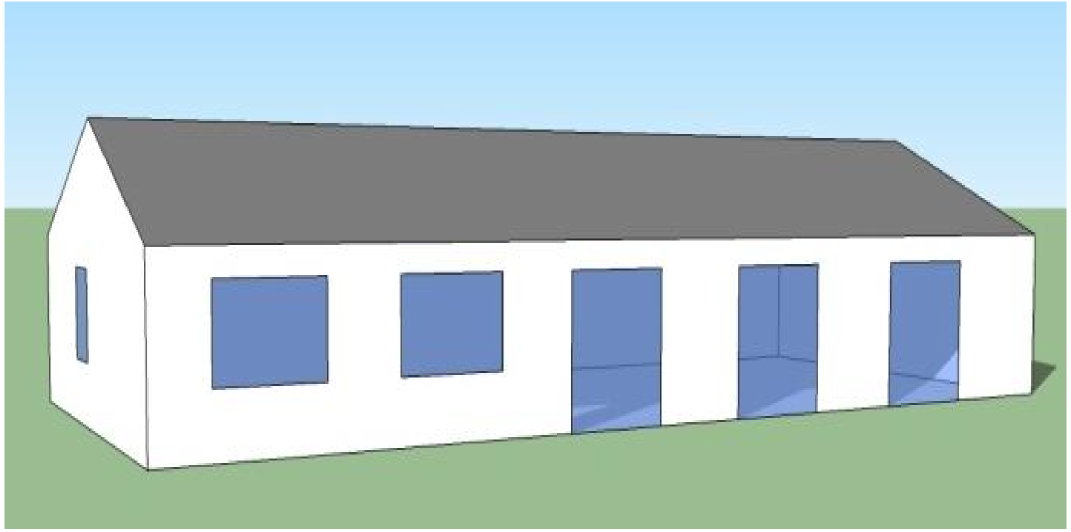
Example



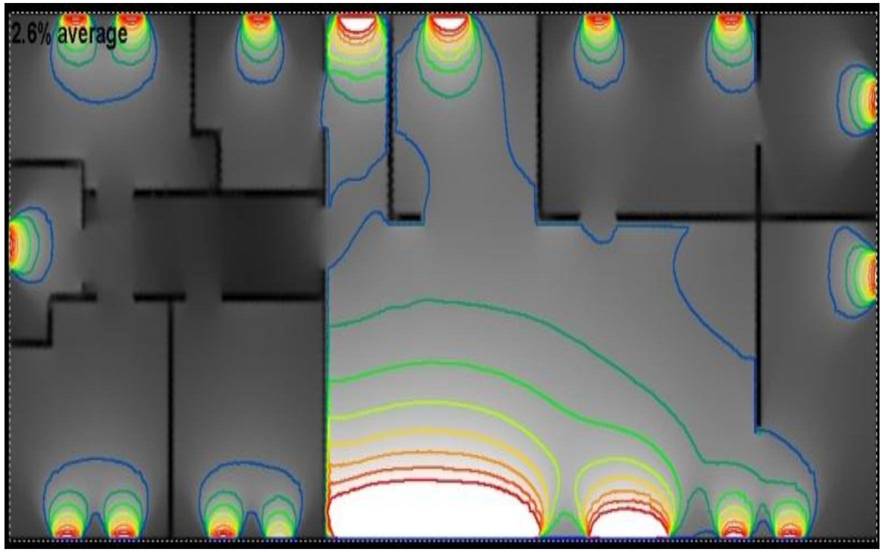
22,19 M
VÆRELSE
13,0 M²
TEK
BRYGGERS
7,7 M²
ENTRÉ
5,6 M²
KØL
OVN
OPV
BAD
8,0 M²
SOVEVÆRELSE
16,8 M²
BAD
4,4 M²
GANG
7,8 M²
KØKKEN/ALRUM
30,0 M²
VÆRELSE
14,8 M²
VÆRELSE
14,9 M²
KONTORNICHE
8,7 M²
OPHOLDSSTUE
31,5 M²
5,17 M

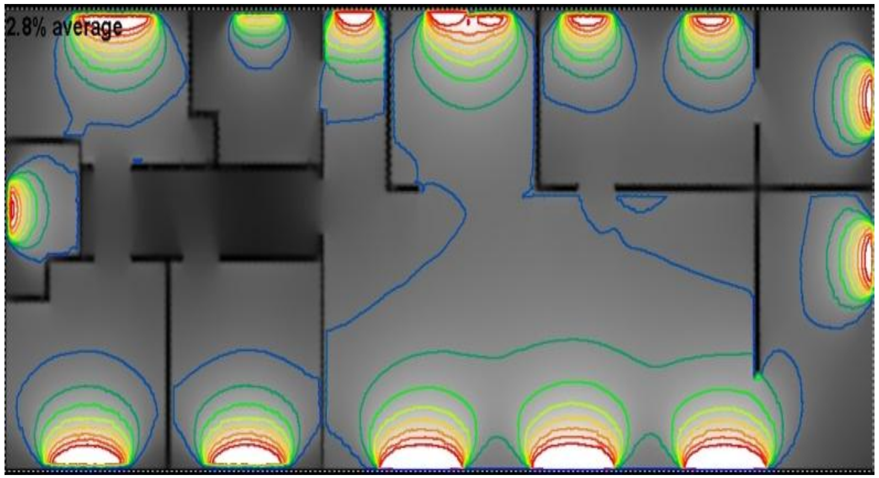
Example: Changing windows because of dark north oriented rooms and overheating





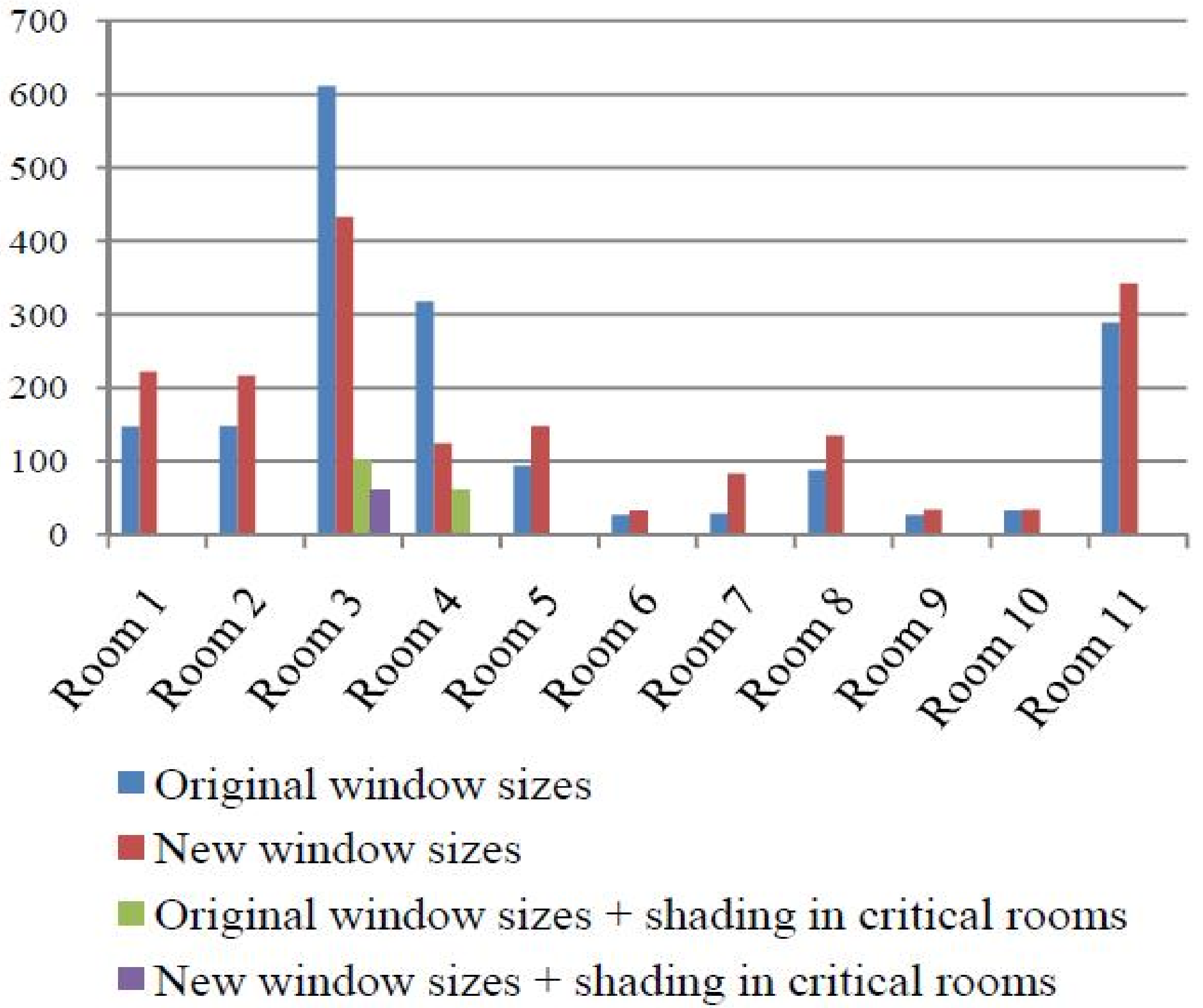
Example: Improved daylight by change of window to more uniformly in all orientations





Example: Rendering of daylight in living room before and after window change

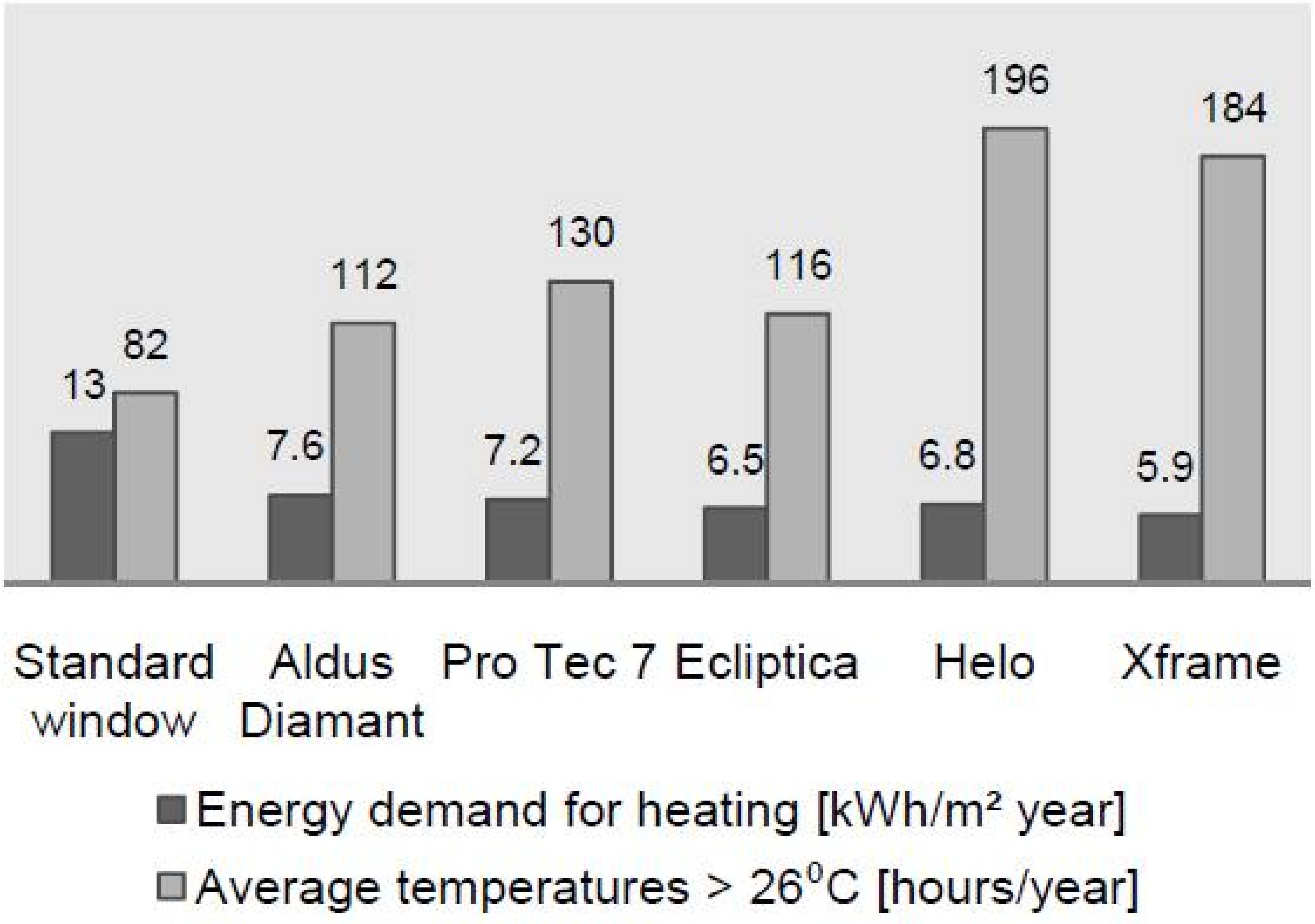
Example: Investigation of sum of hours with overheating in all rooms



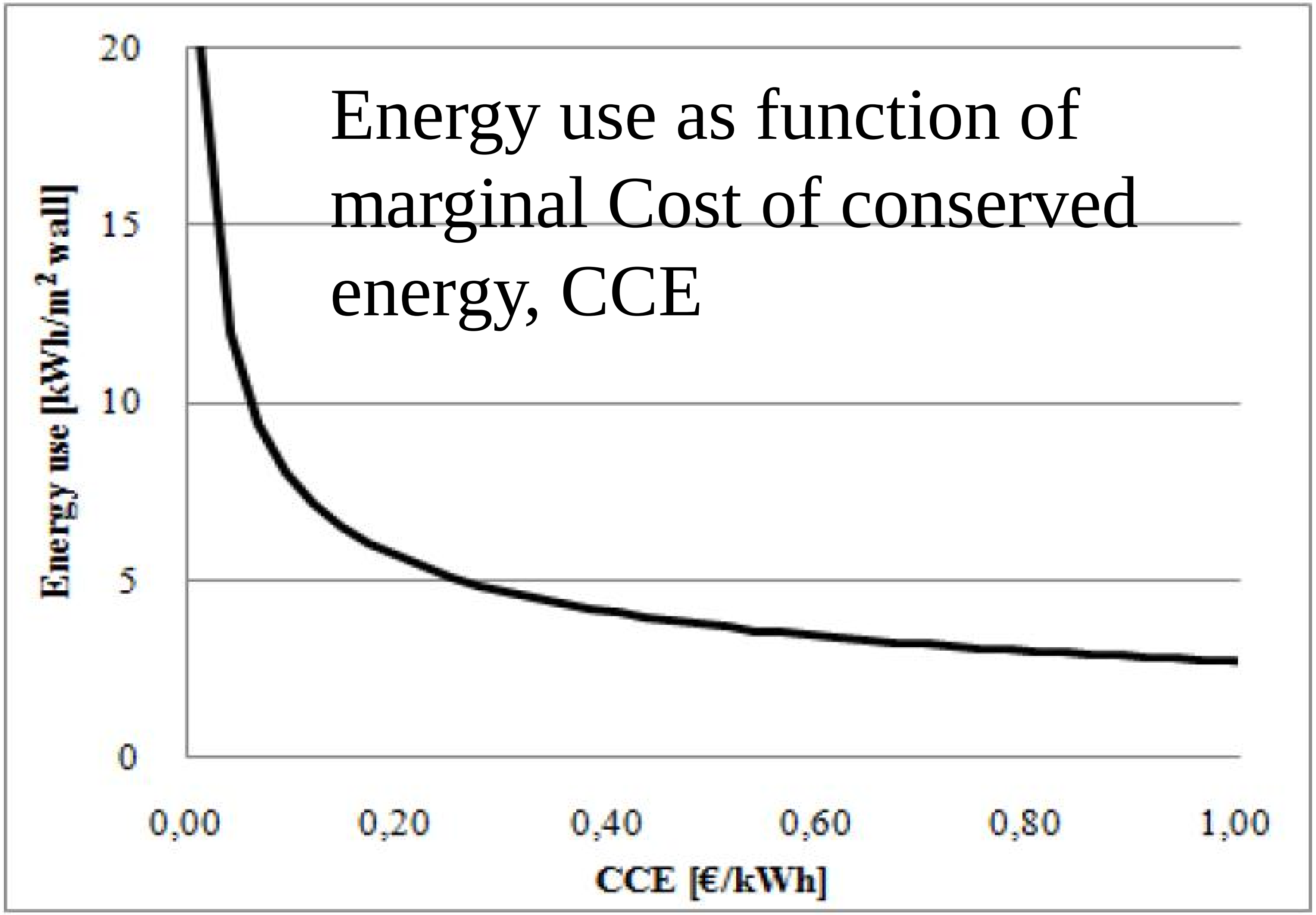
Example: investigation of which window is best.

Manufacturer	Type	Glazing	Frame	E_{ref} (kWh/m^2)	$E_{ref\ 2020}$ (kWh/m^2)
Rationel	ALDUS Diamant	Low iron triple energy glazing	Alumium/wood	+5	-15
PROTEC	Pro Tec 7	Triple energy glazing	GRP/wood	+10	-12
Skjern Vinduer	Ecliptica	Triple glazing with Argon filling	GRP/ wood	+12	-9
Velfac	Helo	Low iron triple glazing with Argon filling	Helo fibres (82% glas, 18% PUR)	+29	-1
HansenProfiles	Xframe	Low iron triple glazing with Argon filling	GRP	+33	+3

Example: Investigation of Energy use and overheating for different window products



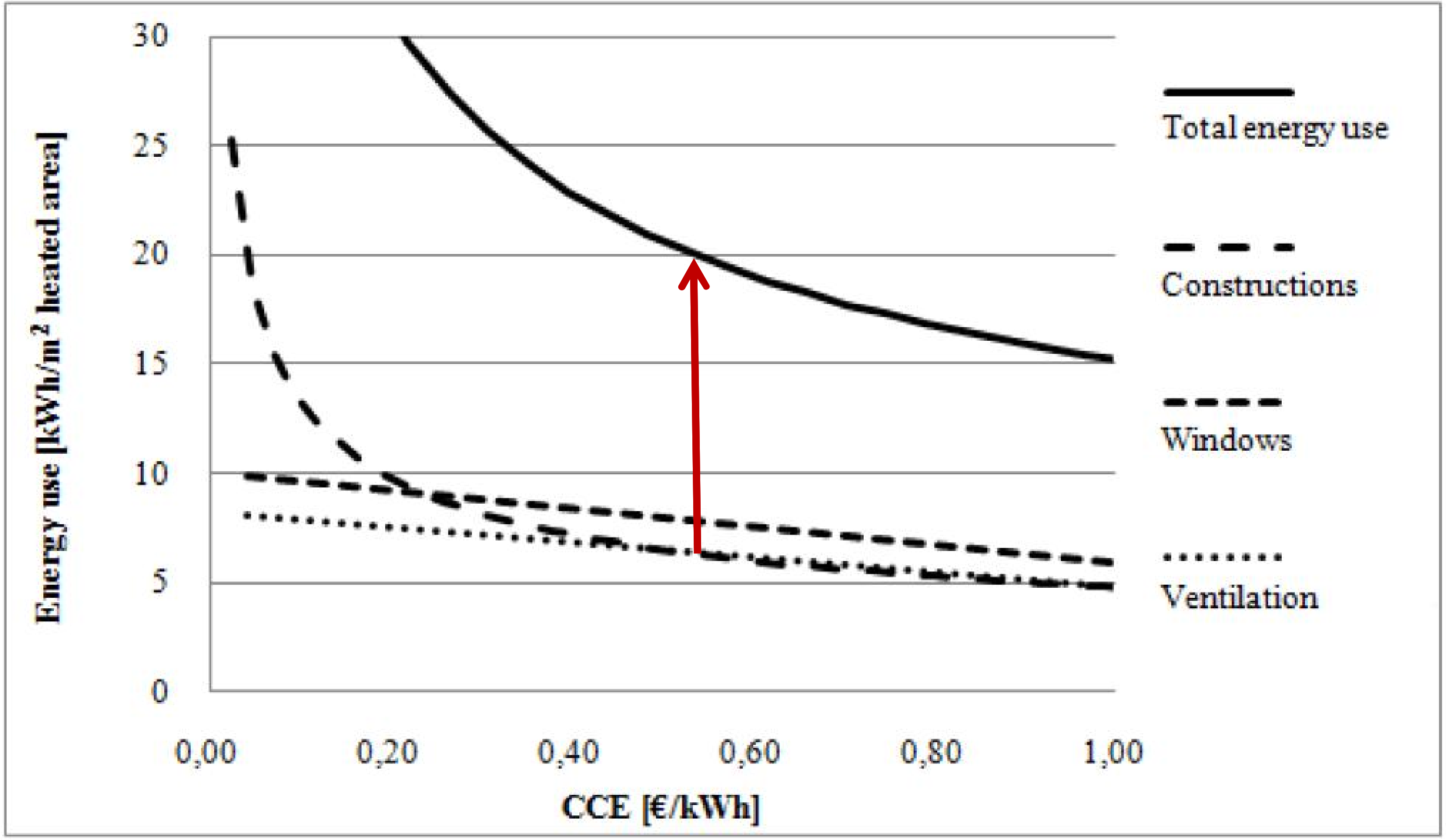
Economical optimisation



Economical optimisation based on CCE on each building part

- General product data for floors, walls and roofs windows and ventilation systems: the energy use per unit size is expressed as a function of the marginal Cost of Conserved Energy
- Geometry of specific building used to present the product data for the building per area of the building
- Products with same CCE with a sum of energy use according to requirements are used as the optimal solution

Economical optimisation – use products with same CCE with a total energy use as required



Integrated design method with simulation based support on energy performance

- The contribution of the building parts to the energy use of the building are based on simplified component models according to EN 13790 (Energy performance calculation methods)
- Only used for making a starting point for further optimisation based on room models
- But it gives overview of the use of energy and the cost of the building

Indoor Environ-ment

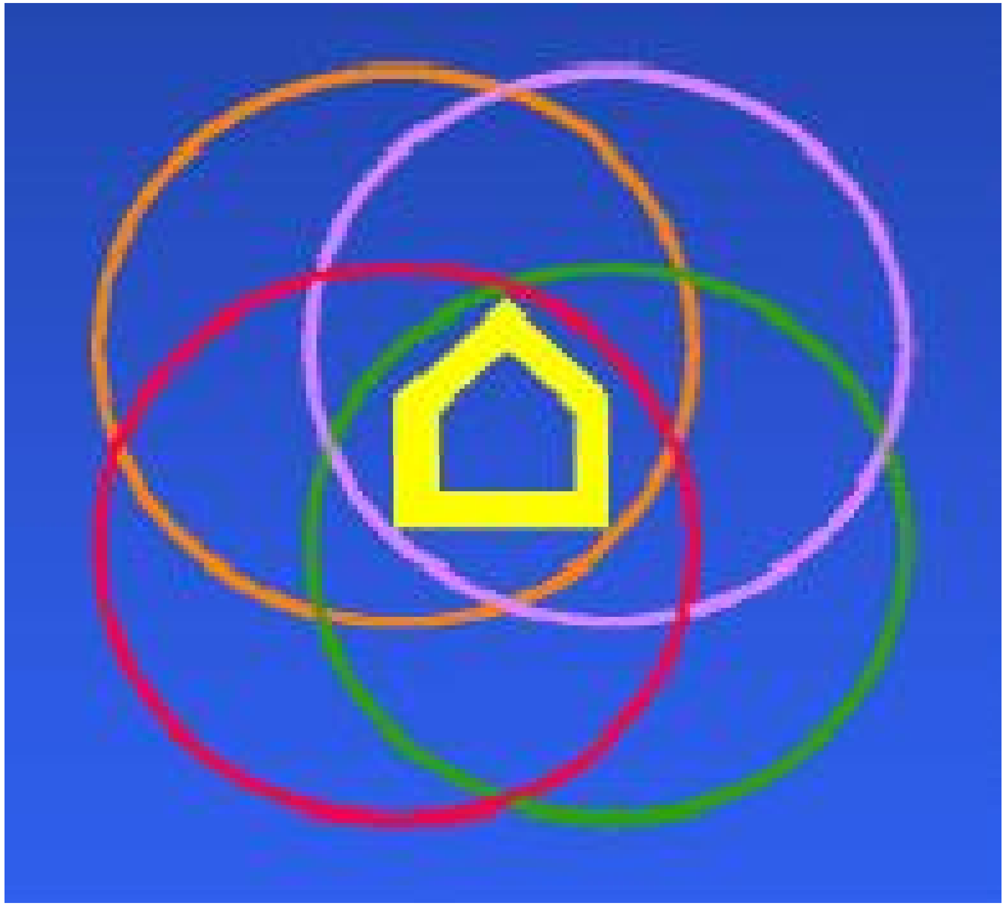
Energy use

Total Economy

Optimi-sation

Integrated design method with simulation based support on energy performance

Performance Requirements



Space of Solutions

Design proposals

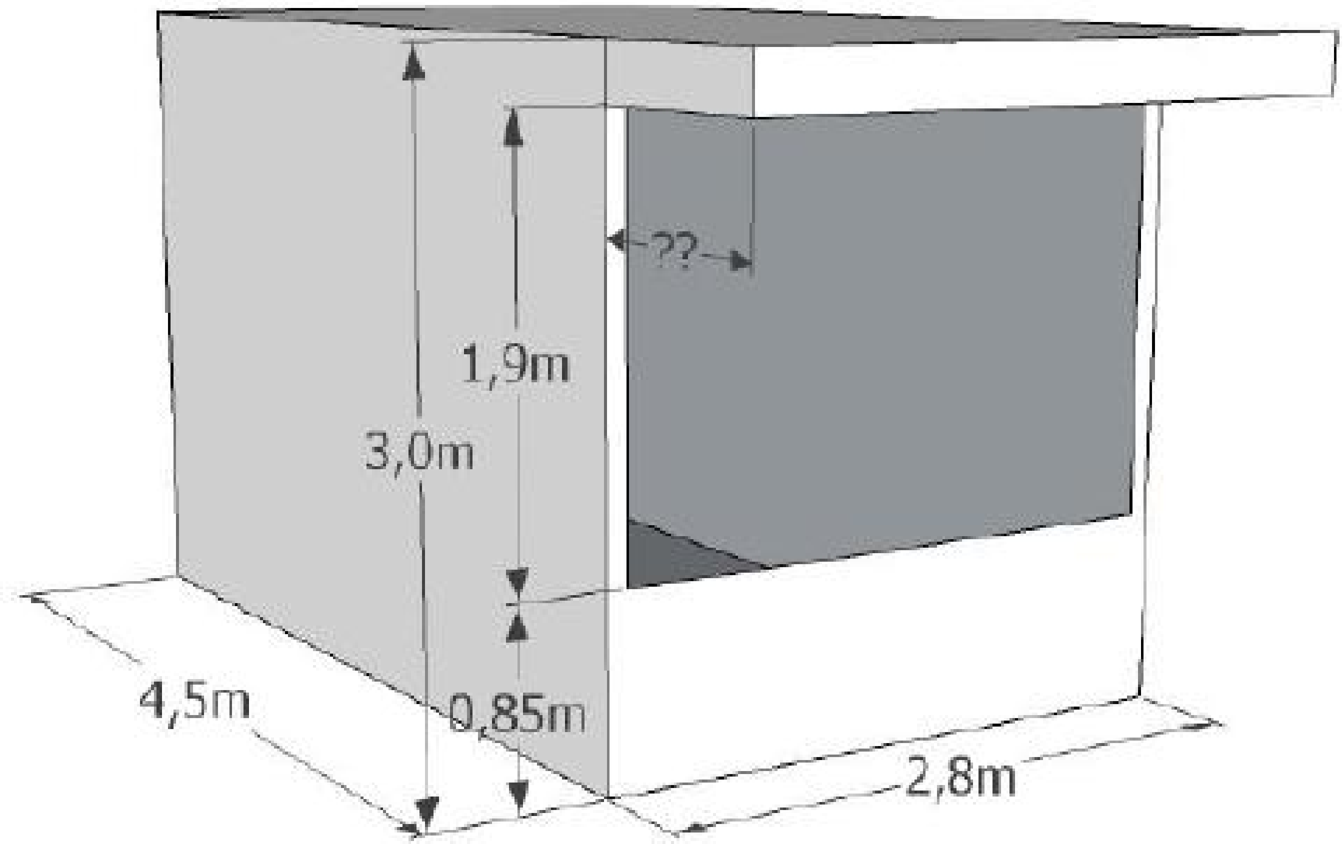
Optimisation

Decission

Integrated design method with simulation based support on energy performance - Example

1-person office

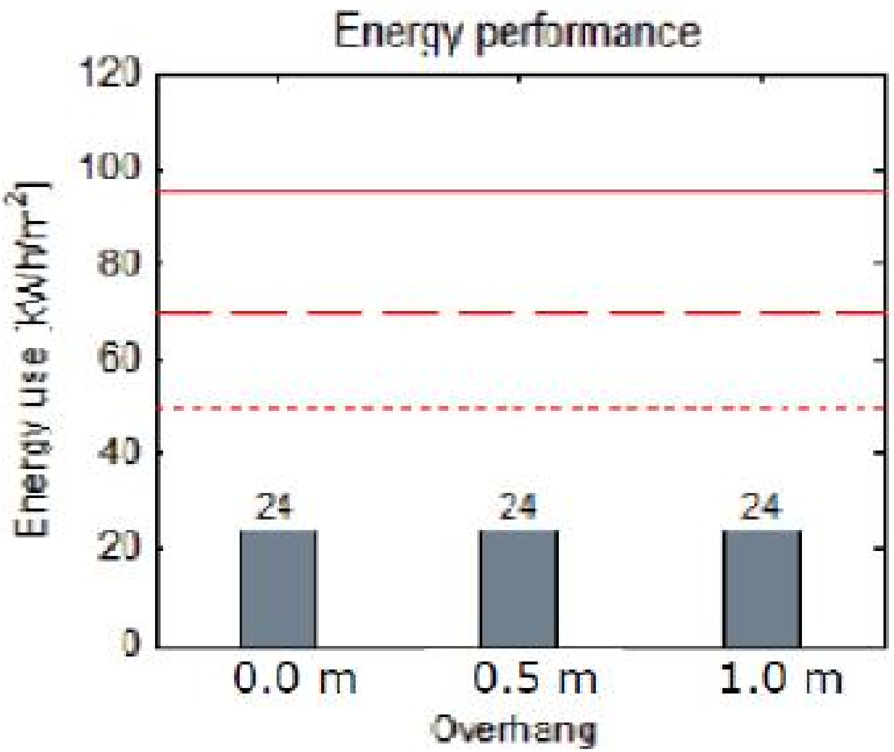
How does an overhang affect performance?

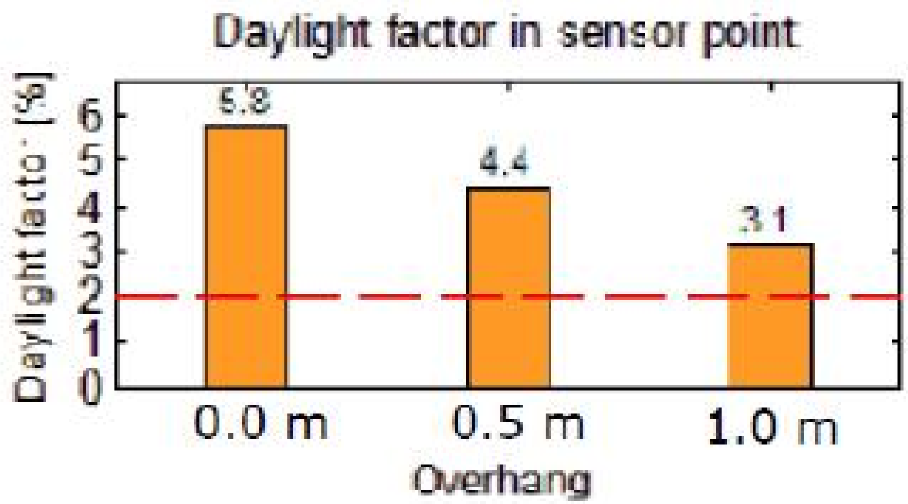


Integrated design method with simulation based support on energy performance - Example

Parameter variation of overhang

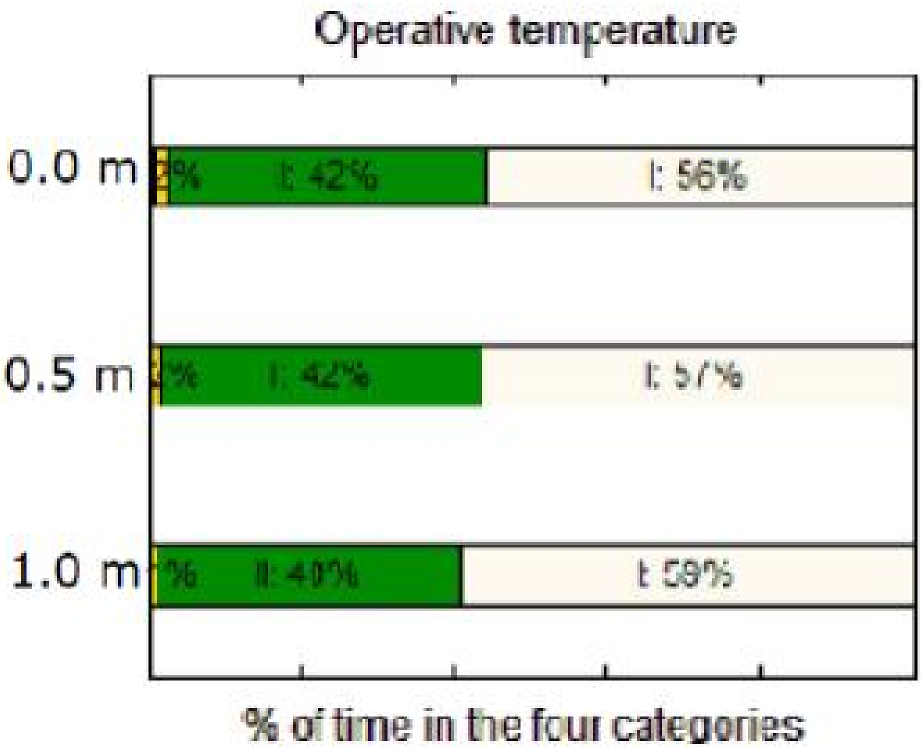
South-facing office

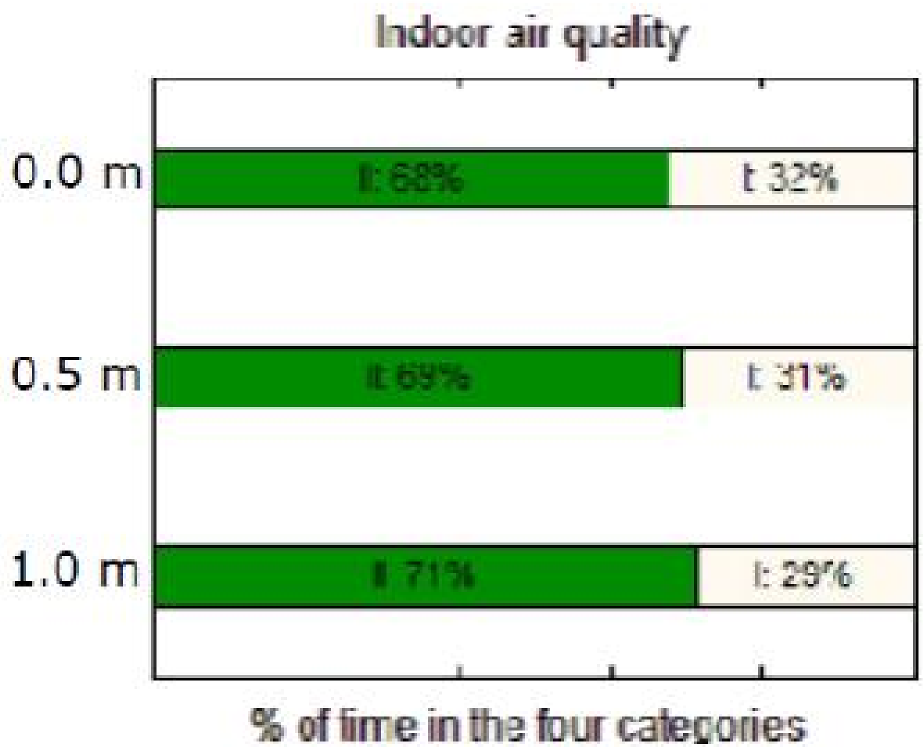




	Daylight Autonomy	Solar Shading
Variation 1:	0.87	0.47
Reference:	0.85	0.45
Variation 2:	0.83	0.43

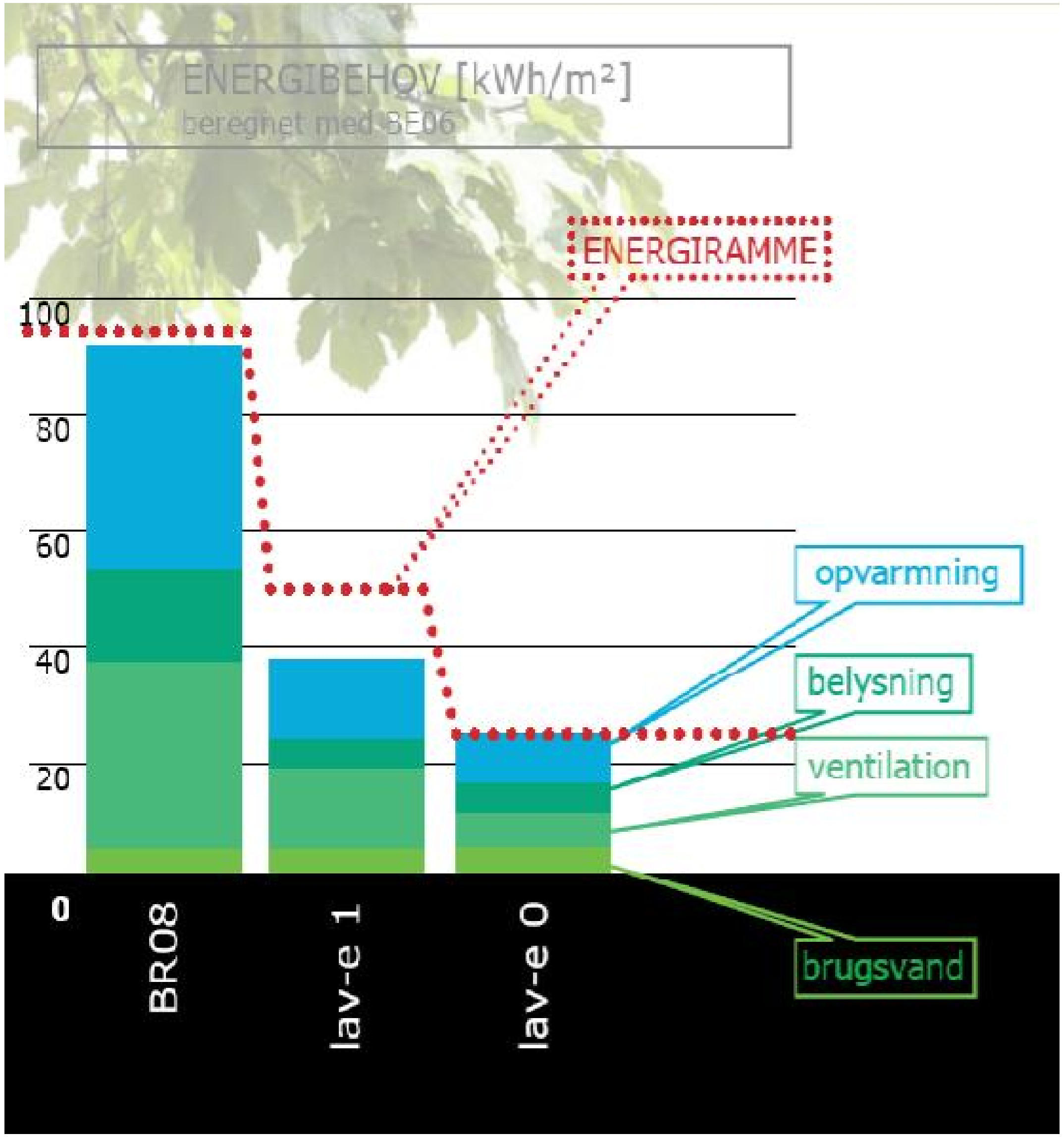
Integrated design method with simulation based support on energy performance - Example

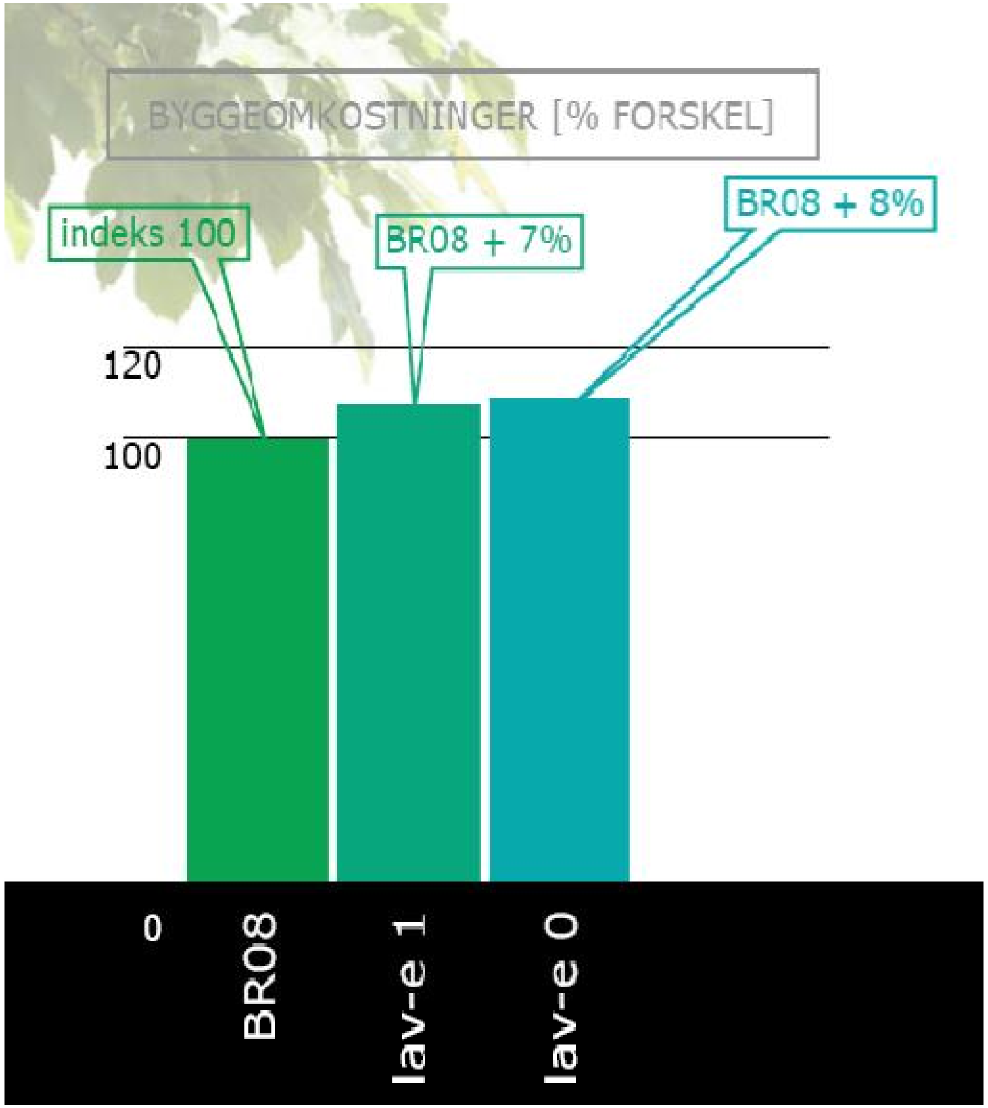




Office Building: (25kWh/m^2)
Designed in an integrated design proces

Energy reduction by factor 4
Extra cost of 8%





Challenge and opportunity for the building sector

- Industry — Energy efficient products:
- Consultants — Integrated design focused on energy performance
- **Constructors — Build low energy buildings as standard solutions**
- **Managers — Continous commissioning**

Construction of low energy buildings as standard solutions

- The construction of low energy buildings can be made at marginal higher cost than standard buildings based on the conditions:
  - Availability of products with improved performance as standard products
  - Optimised design of the building
  - Low energy buildings required by the building code
  - Research and innovation programmes that provide test, demonstration and documentation of the new optimised solutions

Continous Commissioning of the performance of buildings

- The performance of low energy buildings with respect to indoor environment, energy use and durability is more critical than for ordinary buildings
- May be solved by:
  - detailed measurements of performance
  - Simulation of expected performance for actual use and weather
  - Comparison and servicing on daily basis

Contribution from universities to the sector by research and education

Universities may perform research and educate engineers and architects that can contribute to:

- The development and optimization of integrated sustainable solutions for buildings and the built environment

Conclusions

- The EPBD requirements in 2020 of nearly zero energy buildings with no use of fossil fuels
- can be accomplished by combining
- low energy buildings
- with
- renewable energy via low temperature district heating in cities and suburbs and via heat pumps for low density settlements

Conclusions

- The very big and quick change of the energy performance of buildings is a challenge for the building sector but
- it can be solved by improving the methods of
- product developments as well as the methods of designing, constructing and operating buildings by including simulation based analysis and optimisation as well as durability

Conclusions

- The building sector may be transformed from an experience based sector to
- a knowledge and research based sector with
- high quality sustainable products and
- very good business

Thank you for your attention