Passive Houses for Arctic Climates

Vladyková, Petra; Rode, Carsten; Nielsen, Toke Rammer; Pedersen, Søren

Published in:
Passivhus Norden 2008

Publication date:
2008

Document Version
Early version, also known as pre-print

Citation (APA):
Vladyková, P., Rode, C., Nielsen, T. R., & Pedersen, S. (2008). Passive Houses for Arctic Climates. In Passivhus Norden 2008 Trondheim, Norway: SINTEF.

Passive Houses for Arctic Climates

Petra Vladykova, Ph.D. student,
Department of Civil Engineering, Technical University of Denmark;
pev@byg.dtu.dk

Carsten Rode, Associate Professor,
Department of Civil Engineering, Technical University of Denmark;
car@byg.dtu.dk

Toke Rammer Nielsen,
Department of Civil Engineering, Technical University of Denmark;
trn@byg.dtu.dk

Søren Pedersen,
Passivhus.dk;
sp@passivhus.dk

KEYWORDS: passive house, arctic climate, simulation analysis

SUMMARY:
The article Passive Houses for Arctic Climates introduces the new PhD project at Technical University of Denmark, which deals with the German definition of Passive House for the European climate conditions and by means of analysis tries to find an new optimum suitable for Passive Houses in more severe regions where the sources are limited and the best building energy performance is sought. The article illustrates a few examples of the sensible sensitivity analysis made by a thermal building analysis tool – Bsim, where the focus is put on the insulation thickness of wall, roof and floor, and on the window´s thermal characteristics. The analysis are made for the Low Energy house build in 2005 in Sisimiut, Greenland, where the weather is extreme and there are long periods with/without sun. Therefore the solar gains are also investigated. Furthermore the simulations are focused on Greenland (Sisimiut) and Denmark (Copenhagen) weather conditions. And the focus is put on how the Passive Houses will work and how their performance could be improved under more severe or even extreme cold climate conditions where the various technologies, energy sources and outdoor climate are very different.

1. Introduction to the project Passive Houses for Arctic Climates

To make a building a passive house as defined by Wolfgang Feist, Passivhaus Institut, its annual heat demand shall not exceed 15 kWh/m^2, its total primary energy demand shall not exceed 120 kWh/(m^2·y), and the air change by 50 Pa pressurization shall not exceed 0.6 air changes per hour. The reference area is net area and well-defined standard conditions apply. Thereby the heat can be supplied just by post-heating after a heat recovery unit the amount of fresh air that is needed to ensure satisfactory indoor air quality. The definition holds for all climates, but can in some climates be realized only by increasing the amount of thermal insulation, by using better windows, and by having a very air tight building envelope while using ventilation systems with highly efficient heat recovery units. Passive houses also take advantage of free gains such as solar heat, heat from occupants and their activities, and possibly from underground heat exchangers.

Supposedly, the Passive House should be realizable in all climates; however the arctic climates pose challenges. The insulation level would be very large, and solar gains are in some areas completely missing or much greater in the part of the year. The heat recovery systems are very often blocked by ice formation; therefore the new implementation/techniques will be needed.

The project Passive Houses for the Arctic Climates has the following **research questions**:

- Can the European definition of a Passive House make use in the Arctic countries?
- How will a European Passive House perform in Greenland?
- Could an Arctic Passive House stimulate the development of low-energy building technology in other climates?

The new definition of the Passive House for Arctic climate will be need it and the project should contribute to accomplish this goal where the building will be thermally conditioned to a satisfactory level for indoor and health environment by minimal provision of energy. Presumably the energy could be obtained from local and renewable (re)sources. The project is focused on current technologies used to achieve such a low energy building in the Europe and in the Arctic. The technologies will be adapted to the extreme climate conditions, where the low energy consumption is a main objective of the study as well as a good indoor climate in the Arctic regions.

The project uses the computational and analytical tools such as BSim, TRNSYS, and PHPP. The computations and analysis will be carried out to investigate the possible extent of reducing energy consumption for conditioning of buildings in Arctic climates, so called **the sensitivity analysis**. It will be sought to determine what it requires to meet the ambition of making building without traditional heating equipment.

Using the computational analysis the current existing low energy and Passive houses in Europe will be virtually moved to the extreme weather regions where the energy-performance analysis of the performance in such climate will be performed. The analysis will answer how the European Passive House will behave under extreme climate and what it would take to turn such a building into the Passive House according to the European Passive House definition.

The project Passive Houses for Arctic Climates is the main topic of recently started Ph.D. project at Technical University of Denmark. Through the Centre for Arctic Technology the project will contribute to the development of optimal energy design for a new dormitory building in Sisimiut (funded equally by the Villum Kann Rasmussen foundation and the A.P. Møller og Hustru Chastine Mc-Kinney Møllers Foundation) that will be build in 2008 in Sisimiut, Greenland, in particular, and for advanced Arctic buildings in general. The project will as well contribute to defining goals for Passive Houses in various climate regions.

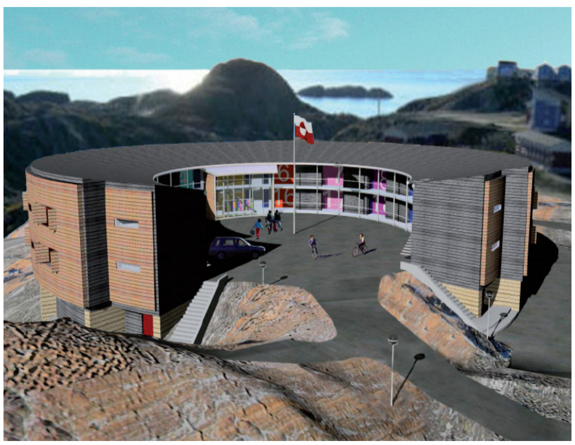

FIG 1: Dormitory building in Sisimiut, Greenland

The project will end up with the well-documented summary of technologies to adopt extreme low-energy building technologies in Arctic climates and it will give the scientific input to the new products developments for the extreme climate as well as for the innovation parts for moderate climate. The task is to come up with the definition of a Passive House in the extreme weather regions and such a definition of the well energy performing building could be in the future called **the Arctic Passive House**.

2. Introduction to the Sensitivity analysis

The article deals with **a computer based parametric study** of the building design of Low Energy House in Sisimiut, Greenland, and checks the results for energy demands. The simulations are focused on modifying of the elements step-by-step:

1. building envelope = external walls, roofs, floor slabs and windows (thermal transmittance of materials)
2. long periods with/without sun and solar radiation (solar gains)

The purpose of the article is to present a few examples of the sensitivity analysis made in BSim where the simulations are focused on the extreme climate in Greenland (extreme weather) and the long periods with/without sun. Later on the completed analysis will lead to answering the following question: What it would take to make an existing Low Energy House in Sisimiut, Greenland, from the low-energy house into the Passive House (German definition) in the Arctic climate?

Low energy building in Sisimiut, Greenland (Norling C.R. et al., 2006) has been built in 2005 by the Technical University of Denmark and Sanaartornermik Ilinniarfik (The Building and Construction School of Sisimiut) with funding from the Villum Kann Rasmussen. Sisimiut is located North of the Arctic Circle (latitude 66.96°, longitude 53.68°; heating season the whole year).

The house is approximately 200 m^2 and it is a double house with common entrance and technical room. The building envelope has increased insulation thickness and wood profiles with minimum thermal bridge effects (see TABLE 1: for the envelope thermal characteristics). The building contents lots of measuring equipments for measuring the floor heating consumption, solar collector’s production and oil burner consumption. Furthermore the house has a newly developed ventilation system with a new prototype of heat recovery unit.

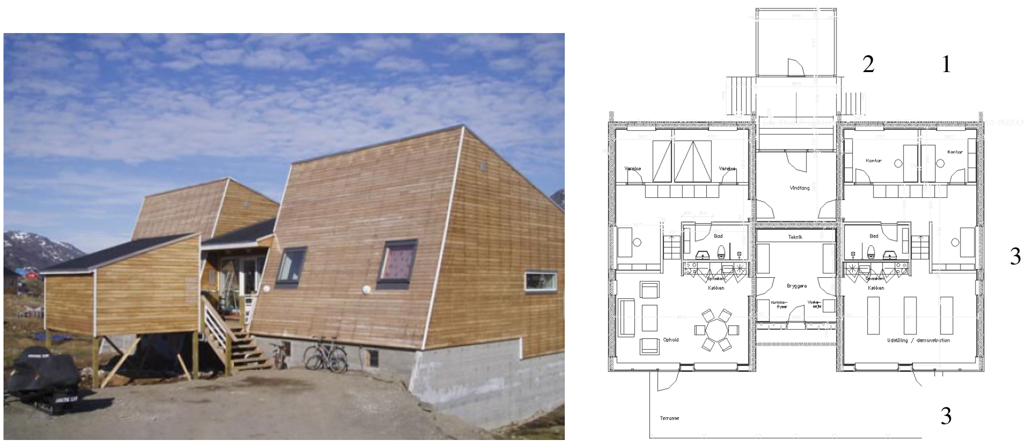

FIG 2: Low Energy House, Sisimiut, Greenland

3. The used method and BSim

Method used for the examples of the computational analysis is focusing on the building envelope (wall, roof, and floor insulation thickness, and thermal characteristics of windows). As “LEH designed” is considered the calculated U-value and insulation thickness which were designed and used for building the Low Energy house. As “LEH +10 %” is taken the variation of insulation level by 10 % (e.g. adding extra 10 % of insulation to “LEH designed”). And as LEH -10% is calculated with insulation thickness lowered by 10 % (e.g. taken out 10 % of insulation from “LEH designed”). Also the window thermal characteristic (heat transmission coefficient) has been varied the same way. For input data see TABLE1 and TABLE2. These simulations have been run under the “Sisimiut.dry” file with input date from reference year (Test Reference Year, 2004).

The simulation of LEH has been than run under the “danmark.dry” file to illustrate the energy behaviour of Greenlandic Low Energy house in Denmark (TABLE 5). Furthermore the illustration of the solar gains in LEH in Greenland is modelled in BSim software where the distributions of solar gains all over the year can be found in **Error! Reference source not found.**.

BSim (BSim, 2006) software is a computational design tool for analysis of the indoor climate, energy consumption, and daylight performance of building, developed by the Danish Building Research Institute. The system uses the common building data model with the design tools and typical building materials database (constructions, windows, and doors). The software can represent a multi-zone building with heat gains, solar radiation through windows (with shadings), internal loads, heating, cooling, photovoltaic, ventilation, and infiltration, but also transient moisture model for the whole building.

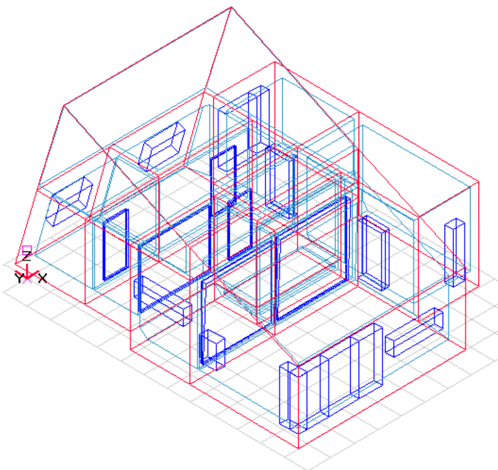

FIG 3: BSim model of Low Energy House in Sisimiut

4. Results of the examples of the sensitivity analysis

4.1 Results regarding the building envelope (wall, roof, floor, window)

TABLE 1: Construction U-values (wall, roof, and floor) and variations

Construction	Thickness [mm]	Calculated U-value [W/m²K]	Variation of insulation level **+10 % *** [mm]	Variation of insulation level **- 10 %** [mm]	Future U-value demand* [W/m²K]
External wall	**300**	0.150	**330**	**270**	0.200
External floor	**350**	0.142	**385**	**315**	0.150
External roof	**350**	0.133	**385**	**315**	0.150

*Greenlandic Building Code (Bygningsreglement, 2006)

**Designed insulation thickness 300mm plus 30 mm of extra insulation => total insulation thickness for walls is 330 mm for variation -10%.

TABLE 2: Heat transmission coefficient

Type *	U_{glass} [W/m²K]	U_w [W/m²K]	Variation of U_w **+10 % **** [W/m²K]	Variation of U_w **-10 %** [W/m²K]
1: 1+2	0.70	**1.00**	**0.90**	**1.10**
2: 2+ Vac.	0.70	**1.10**	**1.00**	**1.20**
3: 2+1	0.80	**1.10**	**1.00**	**1.20**

*placement of windows (see FIG 2)

**increasing of the window´s thermal characteristic properties by 10 %

NOTE: The following tables “Heat balance in kWh” do not include the heat balance for cooling system, people gains, and lighting energy.

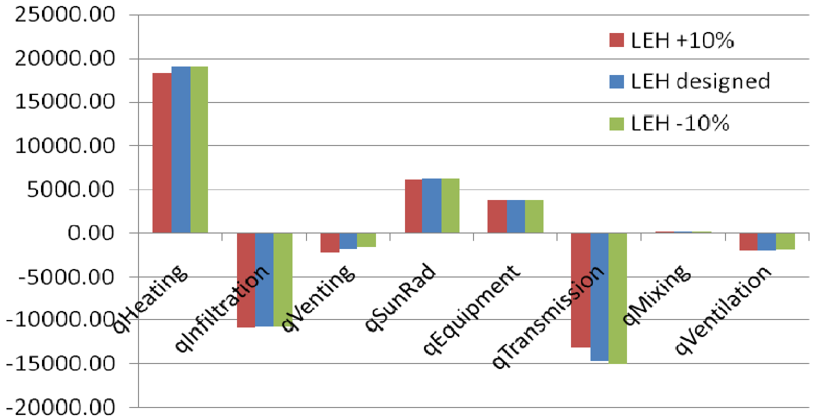

FIG 4: Heat balance in kWh for the Low Energy house placed in Sisimiut (LEH +10 %, LEH designed, LEH -10%)

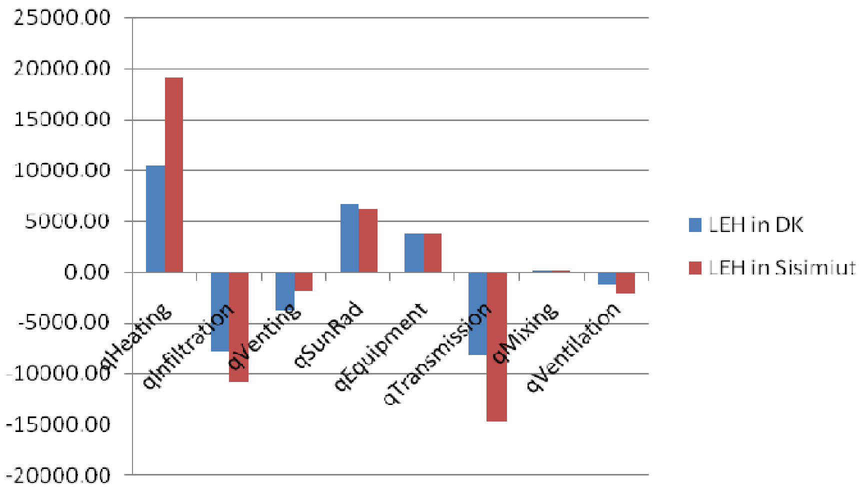

FIG 5: Heat balance in kWh for the Low Energy house placed in Denmark and Sisimiut

4.2 Results regarding the solar gains

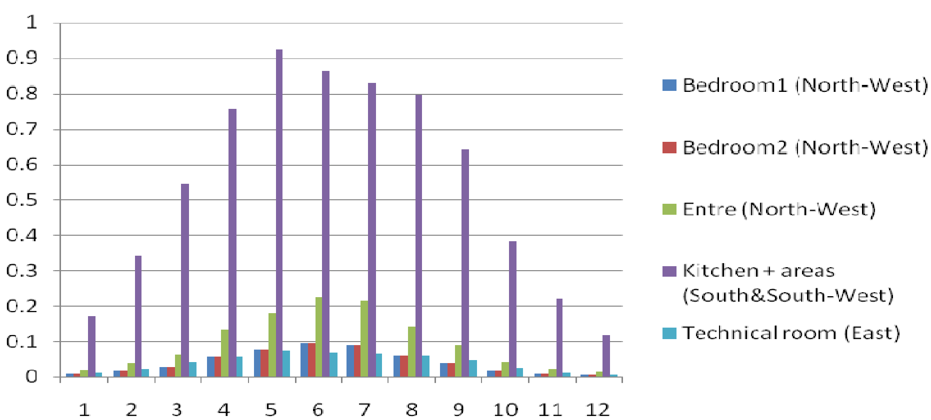

FIG 6: qSunRad for LEH designed (Sisimiut) in kW for the year period for the window area: bedroom1 & 2 = 1.40 m^2; entrance = 3.76 m^2; kitchen+areas =12.39 m^2; technical room = 1.02 m^2

5. Conclusion

This article has two main purposes: the first is to introduce the new PhD project called "Passive Houses for Arctic climates", and the latter is to show the examples of so called sensible sensitivity analysis made by a detailed thermal building analysis tool – Bsim. The focus is put on insulation thickness and thermal properties of wall, floor, roof and window.

The examples of sensitivity analysis made for Low Energy House in Sisimiut, Greenland, indicate possible ways of investigating how big the influence is when specific building components are changed, for instance increasing the insulation thickness and thermal performance of windows. The heat balance proves saving energy when increasing the thermal properties by adding extra 10 % of insulations and improving the window performance. But decreasing the thermal performance of building envelope and windows by -10 % has smaller energy savings than the increasing one. The solar gains are significantly large for South side (kitchen+areas) where the window area is 12.39 m^2 in total, which proves the optimized design of building and the best possible use of solar gains.

Furthermore analyses will investigate the influence of increasing the air-tightness of the building envelope and the performance of ventilation systems with heat recovery units. Later focus should be put also on different habitant´s customs (vapour from the cooking, etc.) and on the low humidity in Greenland.

For evaluating more specific and large-scale analysis are needed. The theoretical parametric studies of Low Energy House in Sisimiut have no validation yet and therefore the future comparison with the analysis made in PHPP and TRNSYS will be performed.

6. References

BSIM (2006), Integrated software for thermal analysis of buildings and installations. Statens Byggeforskningsinstitut, Danmark. www.bsim.dk

Bygningsreglement (2006), Ineqarnermut Attaveqarnermullu Pisortaqarfik, Namminersornerullutik Oqartussat, Grønland, ISBN 87-991296-0-4.

Feist W. (2004), First Steps: What Can be a Passive House in Your Region with Your Climate?, Passive House Institute, Darmstadt.

Norling C.R. et al. (2006), A low-energy building under arctic conditions – a case study, Research in Building Physics and Building Engineering – Fazio, Ge, Rao & Desmarais (eds), Taylor & Francis Group London, ISBN 0-415-41675-2.

Test Reference Year (2004), Sisimiut.try, ASIAQ, Nuuk, Greenland.