

Energy-efficient Buildings (Passive and Nearly Zero-energy Buildings) – Introduction

Abstract of the learning unit

In this learning unit we present the most important aspects of energy efficiency in buildings. The Energy Performance of Buildings Directive (EPBD) is explained in brief, and ways of saving energy in buildings are described. Various building strategies are presented.

Objectives

On completing this unit students are able to ...

- name measures for energy efficiency in buildings
- describe the most essential goals of the EU Directive on the energy performance of buildings
- list examples of various approaches to making buildings energy-efficient
- describe one approach to making buildings energy-efficient
- explain the most important differences between the approaches described

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1. Introduction

In the EU member states the building sector accounts for the largest individual share of energy consumed. The construction sector is a significant economic factor and will go on expanding, which will increase its energy consumption even more.

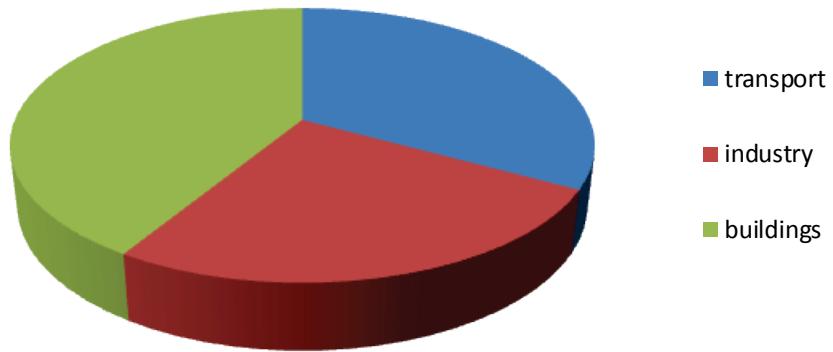


Figure 1: Energy consumption in the EU (source of data: DG Energy, 2012)

Reducing energy consumption and using energy from renewable sources in the building sector are crucial measures necessary for decreasing the European Union's dependence on energy and its greenhouse gas emissions (Directive 2010/31/EU).

2. EU Directive on the energy performance of buildings

According to the Energy Performance of Buildings Directive (EPBD), every member state must ensure that by 31 December 2020 all new buildings (for public buildings 31 December 2018 is the relevant date) comply with the so-called "**Nearly Zero-Energy Building**" standard, based on the primary energy input (= **high standards of energy efficiency and use of local sources of renewable energy**).

A nearly zero-energy building is defined as follows: "*a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby*".



Figure 2: Example of a “Nearly Zero-Energy” building with photovoltaic system on roof and solar thermal system on front façade (source: Arch Wimmer – schulze darup & partner)

Additional goals of the Buildings Directive are:

- defining a method for calculating the energy performance of buildings
- defining minimum requirements for the energy performance of buildings
- certification of the energy performance of buildings: obligatory **presentation of an energy performance certificate** for new construction, renovation, sale or rental of a building or part thereof; obligation to display the certificate in public buildings
- regular inspection of heating and air-conditioning systems with regard to energy efficiency, plus testing of heating systems more than 15 years old
- setting **cost-optimal energy performance requirements** for major renovations and for improvements in the course of major renovations

The member states have submitted their national plans, which, however, differ from each other in many aspects. For example, interpretations differ as to whether energy consumption also includes the electricity consumption of appliances such as IT or electronics, or only building-specific consumption, such as space heating, cooling, hot water or lighting.

3. How can energy be conserved in buildings?

First, we have to consider all the areas where energy is needed in a building: energy that is used for operating the building, such as for space heating, hot water, lighting, etc., probably comes to mind first. But not only these services need energy; the production of building materials, the actual process of construction, any reconstruction or renovation, and finally the demolition of a building all consume energy (this is called “grey energy”, because how much energy a material or product contains is not visible to the naked eye).

There are various ways of reducing buildings’ resource and energy consumption and thus avoiding negative effects of construction. They can be summarized under the term “sustainable building”.

Background on “sustainable building”

Sustainability in the construction sector involves constantly taking the effects to be expected from construction into account during planning and implementation. Harmful effects on the climate, the ecosystem, the economy and public health should be avoided.

Important principles and goals of sustainable building are:

- resource efficiency, in order to conserve natural resources and avoid waste and expense for raw materials, for producing and disposing of building components
- energy efficiency, in order to avoid wasting energy, energy costs and CO₂ emissions
- adapting to the users' needs, so as not to produce more than is needed, and to ensure that the buildings will be used for a long time
- adapting to the local and regional environment (e.g. the climate, the existing infrastructure or available raw materials), in order to use what is available on site, and to avoid negative effects of construction on the environment (e.g. on bodies of water, air)

The following diagram outlines possible measures available to reduce energy consumption and greenhouse gas emissions in the building sector.

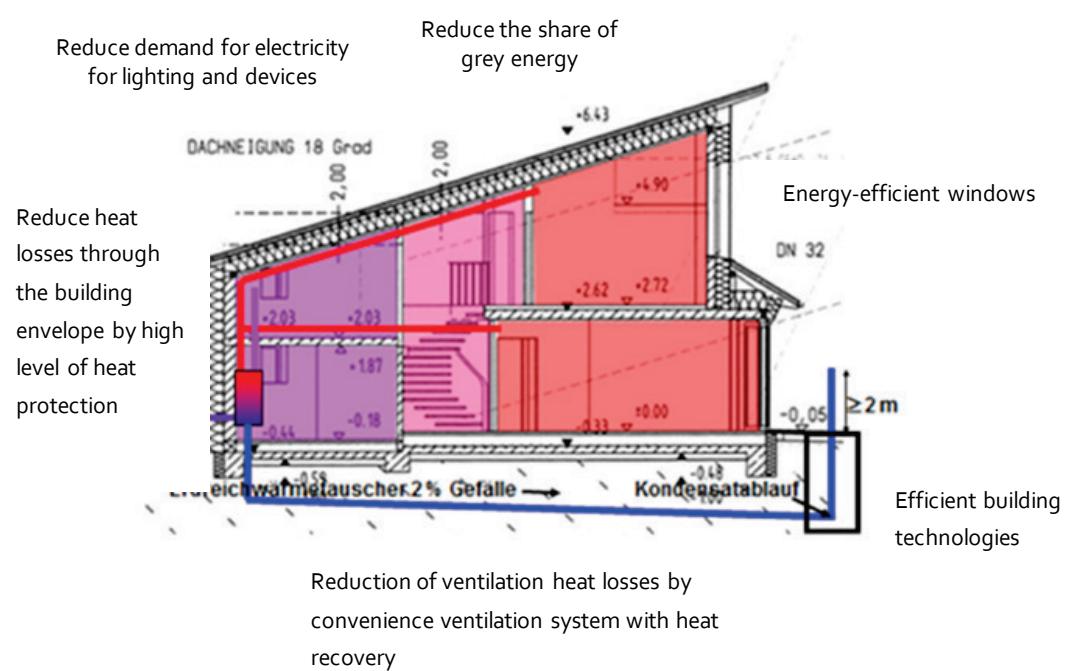


Figure 3: Measures which contribute to energy-efficiency (source: Schulze Darup, adapted)

A **high level of thermal insulation**, combined with **energy-efficient windows**, is seen as one of the most effective measures. An additional measure, e.g. for reducing heat losses by airing, is to install a **convenience ventilation system with heat recovery**. The **consumption of electricity can be reduced by using energy-saving devices**; the input of **grey energy** can be influenced by **choosing appropriate building materials**.

High level of thermal insulation



Figure 4: Floor slab with insulation layer (source: Schulze Darup)



Figure 5: Hemp insulation material (source: Christian Gahle, nova-Institut GmbH;
http://de.wikipedia.org/wiki/D%C3%A4mmstoff#/media/File:Hanfdaemmstoff_CG.jpg)

Energy-efficient windows

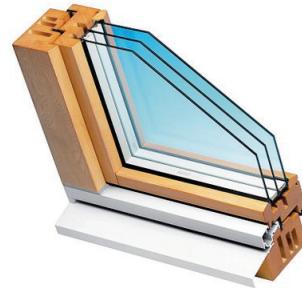


Figure 6: Passive-house window in solid timber (source: Sigg Tischlerei, Hörbranz)

Convenience ventilation system with heat recovery



Figure 7: Convenience ventilation system with heat recovery (source: Bin im Garten;
https://upload.wikimedia.org/wikipedia/commons/2/22/IFA_2010_Internationale_Funkausstellung_Berlin_104.JPG)

Table 1: Examples of measures which contribute to energy-efficiency

Background on national and international methods of certification for energy-efficient building strategies

In Europe there are a large number of specifications, voluntary standards and differing labels for energy-efficient buildings.

These definitions / quality labels / specifications use differing criteria, such as high efficiency, on-site energy, energy source, cost of emissions, grey energy, etc.

The most important international and national methods of certification and quality labels are:

- **BREEAM** (BRE Environmental Assessment Method): is the leading and most widespread method of certification for buildings. It defines the highest possible standards for best sustainable design and has in practice become a yardstick for describing a building's environmental impact (standard for best practice in sustainable building design, <http://www.breeam.org>).
- **Green Building**: is a voluntary program from the European Commission that supports owners and users of commercial buildings (private companies and state institutions) in improving energy efficiency and in introducing renewable sources of energy in their buildings (<http://re.jrc.ec.europa.eu/energyefficiency/greenbuilding/index.htm>).
- **Minergie** (Swiss label): is a voluntary building standard that enables efficient energy use and the broad application of renewable energies while at the same time improving quality of life, ensuring competitiveness and reducing environmental impact (<http://www.minergie.ch/>).
- **Leed** (Leadership in Energy and Environmental Design): is a system of classification for ecological building developed by the U.S. Green Building Council in 1998. It defines a range of standards for environmentally friendly, resource-conserving and sustainable building (<http://www.leed.net/>)

4. Building strategies

Most strategies involve a thick layer of insulation, highly efficient windows, an airtight layer and convenience ventilation with heat recovery. In many cases renewable sources of energy are utilized for covering, or at least partly covering, energy consumption.

Two short videos presenting energy-efficient buildings:

<http://www.youtube.com/watch?v=cP2Hm4rzuFI>

<https://www.youtube.com/watch?v=Prx6rJPZFIE>

Below we present three examples of building strategies. Their shared features are **minimal energy consumption** together with real comfort for residents. While the goal of **passive-house** planners is to design a building with **very low energy consumption**, designers of **net-zero-energy buildings** aim to produce **enough electricity through photovoltaics (PV)** on site to balance the building's energy account over a full year.

However, as can be seen from the following pictures, **energy efficiency is not tied to any particular architectural design**.



Figure 8 and Figure 9: on left: passive house with solarfaçade in Austria (source: Michael Paula, bmvit); on right: housing estate SunnyWatt in Switzerland, Minergie-P-Eco standard (source: kämpfen für architektur ag)

4.1 Passive house

"Passive house is no brand name and no energy concept, but a building concept open to anyone" (W. Feist, translation by author). The aim is to achieve a good overall result in terms of layout, comfort in the home and energy consumption by means of creative design and with the lowest possible investment. Never forget that the approach should result in a sustainable building that makes economic sense.



Figure 10: "Schiestlhaus" – first high-alpine passive house (source: Michael Schmid; http://commons.wikimedia.org/wiki/File:Schiestlhaus_Jul2007.jpg#/media/File:Schiestlhaus_Jul2007.jpg)

There are two main objectives in building a passive house:

1. The building should be constructed in such a way that a highly efficient building envelope results, and energy consumption is covered with renewable sources as far as possible, at maximum cost efficiency.
2. The building should offer residents real comfort in the home.

The following passive-house components form the basis for this:

- **Building envelope with high-grade insulation**
- **Windows with high-grade triple glazing and insulated frames.** Larger window openings in the south façade, smaller windows facing east and west, and very small windows facing north (or none at all)
- **Overshadowing windows to protect against overheating in summer**
- **Minimizing / eliminating thermal bridges**
- **Airtight building envelope**
- **Ventilation system with heat recovery**
- The heating system in a passive house can be a biomass stove or a heat pump
- **The annual heating energy requirement must not exceed 15 kWh/m²a**
- **Total primary energy input must not exceed 120 kWh/m²a**

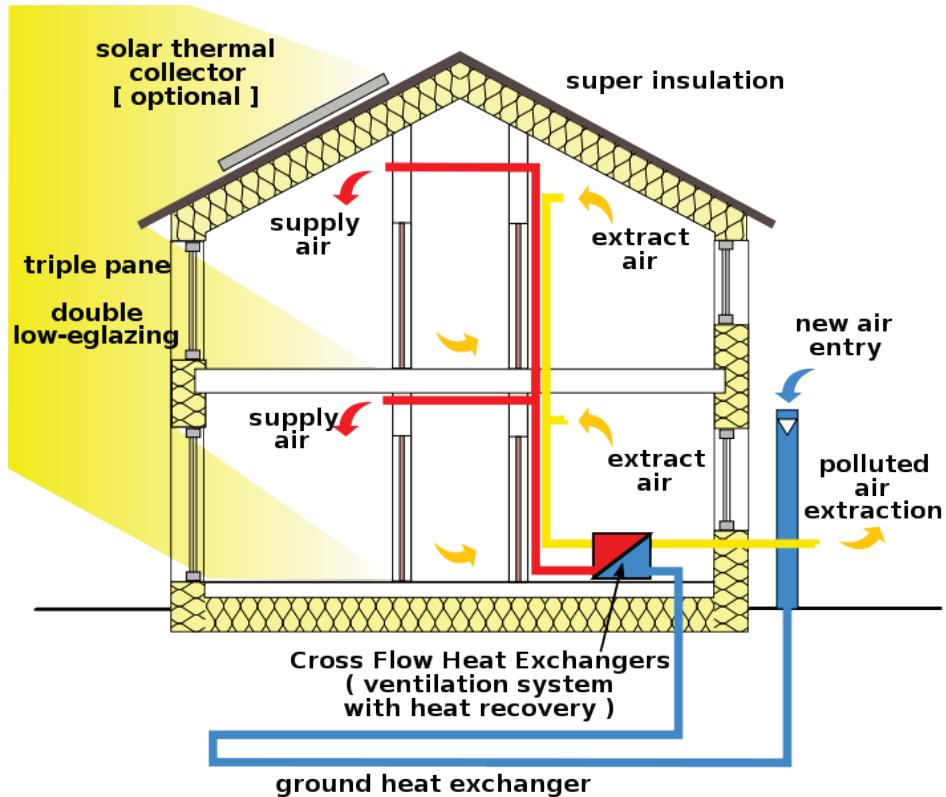


Figure 1: passive house with a supply air/extract air system with heat recovery (source: Passivhaus Institut; http://en.wikipedia.org/wiki/File:Passive_house_scheme_1.svg, adapted)

Additional aspects to be taken into account during planning are the location of the site and the orientation of the building.

4.2 Solar house

The solar-house approach is based on taking full advantage of the free energy potential provided by the sun for space heating and providing hot water.

Solar houses are **low or ultra-low-energy buildings** that cover the bulk or at least half of their annual heating energy requirement by means of a **solar thermal system**.

Here again, a **basic prerequisite** for this approach is a **building envelope that insulates really well against heat loss**.

The following components are foreseen for supplying heat:

- **Solar thermal system**
- **A fairly large solar storage unit** inside the building and/or building components made of concrete (floors) or brick centre walls to store solar heat for several days or weeks.
- **A back-up heating system** to maintain comfortable indoor temperatures even if heat in the storage unit runs low during extended periods with little sun in winter.



Figure 11: Solar house compound with solar storage unit (source: Andol; http://commons.wikimedia.org/wiki/File:Solarhauskomplex_mit_Solartank.png#/media/File:Solarhauskomplex_mit_Solartank.png)

- **Low-temperature panel heating systems**, or surfaces with **thermo-active building components**, distribute heat in line with actual needs and can be regulated individually room by room. In the case of thermo-active components, solar energy is actively stored in these on sunny days. This energy is then available to the building in the following days without solar heat gains.



Figure 12: Diagram of a solar house (source: <http://www.pink.co.at/sonnenhaus.htm>)

With the solar house, too, the site location (climate, shade from trees, neighbouring buildings, etc.) as well as the orientation of the building must be taken into account.

4.3 Minergie

Minergie is a standard for buildings in Switzerland, with three categories: **Minergie**, **Minergie-Plus** and **Minergie A**.

Comfort at home/at work is central to Minergie-standard buildings. This comfort is achieved by a high-grade building envelope, as with the approaches described above. In contrast to many other approaches, comfort here also includes the building and the technical equipment being straightforward and satisfactory to use.

Another criterion for Minergie is economic efficiency.

It is also essential to view the building as a complete system, which means that the building envelope and services (heating, ventilation and hot water processing) add up to an appropriate combination, not just a concatenation of individual components.



Figure 13: Student residence Bülachhof (Switzerland) – a large new Minergie building (source: Ikiwaner; http://de.wikipedia.org/wiki/Minergie#/media/File:Zuerich_Buelachhof.jpg)

The following comparison of Minergie-Plus and Minergie A shows which combinations are possible.

	Minergie-Plus	Minergie-A
Heat index value	30 kWh/m ² a (equivalent to 3 litres of fuel oil)	0 kWh/m ² a
Heating energy requirement	60 % of the legal requirements	90 % of the legal requirements
Airtightness of building envelope	Air changes per hour below 0.6/h at 50 pascal pressure difference	
Supply of external air	Systematic air exchange	
Auxiliary energy – heat	Is taken into account	
Domestic electricity	Best devices available	Best devices available, best lighting available
Grey energy	No requirements	Below 50 kWh/m ² a
Additional costs	At most 15%	No requirements
Comments	Minergie P is an ultra-low-energy building approach that requires a very good building envelope	Minergie A defines a zero energy or surplus-energy house. This standard can be reached only by utilizing solar energy on site.

Table 2: Excerpt from "Minergie Standards im Vergleich" (Minergie standards compared; source: http://www.minergie.ch/standard_minergie.html)

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