The Passive House Concept

Study abstract

Jyri Nieminen,
Riikka Holopainen, Ilpo Kouhia
''Minimisation of the Energy Consumption of a Passive House Building in Cold Climates"
VTT Technical Research Centre of Finland,
VTT bulletins – research notes

PAROC®

The Passive House Concept

The purpose of a passive house is the economic minimisation of the building's need for heating energy while providing good-quality indoor air. The heat losses of the building are so low that no conventional heat distribution system is needed.

This concept is based on the principle of transferring the building's investment costs from HVAC to improving the thermal insulation of the building's exterior shell. Once a building's need for heating energy is sufficiently low, conventional heat distribution methods such as floor heating or radiators can be replaced by simpler ventilation heating system, which will also act as the heat distribution solution for the building. A different HVAC solution will affect the building's investment and lifecycle costs.

The level of thermal insulation in the structures of a passive house is higher than that of conventional buildings, its structures having been designed and constructed in a way which minimises cold bridges that reduce thermal insulation capacity. The building's exterior shell is airtight, the indoor air is draught-free and its temperature is even.

Heating Energy Requirement

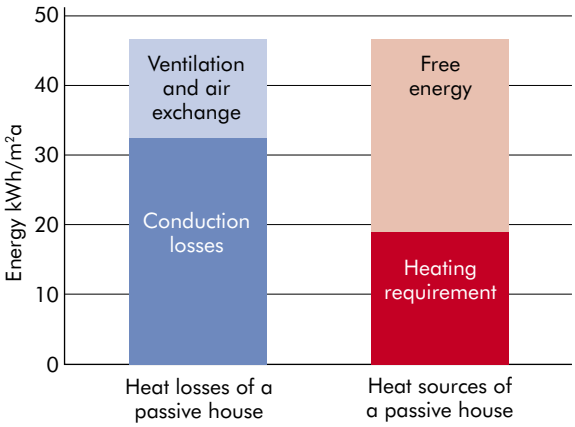
A passive house is defined based on its heating energy requirement. This definition does not concern the building's energy consumption or heating method; in a passive house, the heating energy requirement is lowered by reducing the heat losses of the exterior shell and ventilation.

The following definitions of a passive house are applied in different parts of Europe:

	Heating energy kWh/m²a	Cooling energy kWh/m²a	Primary energy kWh/m²a
South Europe	15	15	120
Central Europe	15		120
Nordic Countries	20 – 30 depending on the building's location		130 – 140

In all climates, the air leakage rate of the building is $n_{50} < 0{,}6$ 1/h.

Primary energy refers to the original energy source used in the generation of energy. However, it is currently not included in the energy efficiency analyses of buildings in Finland. Various factors have an effect on the ability to achieve the heating energy requirement specified in the definition of a passive house: the thermal insulation of the exterior shell and its parts, the air-tightness of the structures, and the annual coefficient of the efficiency of the ventilation heat recovery system. A majority of a passive house's heating energy requirement can be covered by so-called free energy, i.e. internal heat sources and solar energy. The annual coefficient of efficiency in ventilation heat recovery should be at least 75% so that the insulation of the exterior shell structures does not have to be unreasonably thick. Managing the cold bridges of structures and their joint solutions becomes a key design principle for exterior shell structures.



The energy efficiency of a Paroc Passive House pilot site was redesigned to passive level by modifying the component parameters.

A passive house utilises free energy, i.e. heat released by the occupants and appliances. Such utilisation is at its most effective when the building's thermal mass is located inside the heat insulation. However, the amount of thermal mass required is not large; the massive concrete floor of a building with lightweight structures is sufficient.

Building Design

Building a passive house is not tied to certain materials – the building's framework can be made of wood, concrete, blocks or steel as long as the thermal insulation of the structures is high enough – nor does it depend on the utilisation of solar energy. Good thermal insulation, an air-tight exterior shell, low energy windows and doors and heat recovery from ventilation exhaust air form the cornerstones of the concept. Orienting the building to the south provides energy benefits, especially during the beginning and end of the heating season in the autumn and spring. However, experience from passive houses in Central Europe shows that the concept also works rather well in northwards oriented building sites. The concept does not place any limitations on the building's location at the construction site, allowing the designer to take full consideration of the scenery.

U Values

The low energy requirement for heating of a passive house requires a thermal insulation level that is considerably higher than normal. The table below lists the target values for the thermal transmittance coefficients of the exterior shell components:

exterior wall, base floor and roof	0,06 – 0,10 W/m² K
window	0,70 – 0,90 W/m² K
fixed window	0,60 – 0,80 W/m² K
entrance door	0,40 – 0,70 W/m² K

Air Tightness

The limit value for the air leakage rate of a passive house's exterior shell has been set at n_{50} = 0.6 1/h, which must be verified through measurement. When the air leakage rate is low, the building's location and the surrounding wind conditions will have no major effect on the building's heating energy requirement.

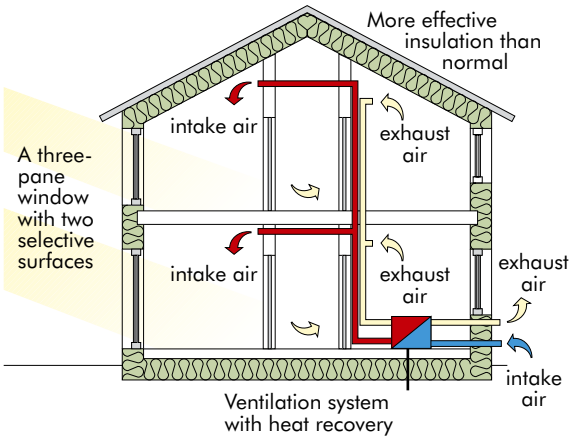
In order for the air barrier to be effective, it must be continuous and its permeability may be 1×10^{-6} m³/m² s Pa at a maximum. The seams of plastic sheeting acting as an air barrier inside the thermal insulation must be sealed, and the air barrier must be continuous over the entire area of the exterior shell. If electricity conduits are installed within the exterior walls, the use of installation spaces between the air barrier and internal cladding is recommended. The seams of window and door joints must be thermally insulated and sealed on both the exterior and internal sides.

Wind Shielding

Wind shielding protects the thermal insulation layer from cold air currents in the outside air. In principle, all thermal insulation which arrives in the form of slabs or which is sprayed or blown needs wind shielding, which may have an air permeability of 10×10^{-6} m³/m² s Pa, including seams, at a maximum. For example, wind shielding can be built from fibreboard, gypsum board or other board material with sealed seams. Wind shielding can also be attained by plastering on top of the thermal insulation layer or using mineral wool insulation with air-tight coating and sealed seams.

Ventilation Heating

A passive house is air-tight and requires a functional and correctly designed ventilation system. Improvements in energy efficiency are not sought through reductions in the ventilation volume. The target level of ventilation depends on the purpose of a room. A passive house does not require a traditional heat generation and distribution system such as radiators or floor heating. Ventilation heating is a sufficient heat distribution method.



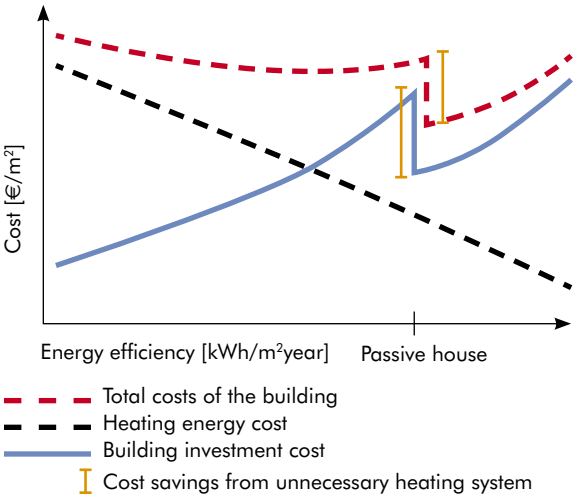
A basic diagram of the ventilation heating system of a one-family house.

There are two alternative solutions for a ventilation heating system. The intake air can be either heated in a centralised manner immediately after the ventilation machine, or room-specifically at the terminal ventilation equipment. The former alternative generates constant-temperature air for all spaces, while room-specific temperature control allows varied temperatures but requires heating the intake air either at the terminal equipment or in the ducts before the terminal equipment. Overheating may occur due to the thermal load from the Sun, even during early spring, so it must be possible to bypass heat recovery in order to avoid the need for cooling.

A high annual ventilation heat recovery coefficient (at least 75 %) can reduce the heating requirement and temperature of the intake air. The temperature of the intake air must be below 50 °C. A typical problem of ventilation heat recovery systems is their poor efficiency, caused by the need to melt the ice forming in the recovery system. One new way of improving the efficiency is to preheat the fresh air using piping with fluid circulation, located underneath or next to the building. The piping can also be used for cooling the intake air.

Lower Operating Costs

The initial investment in a passive house may be larger than that of a conventional house, but its operation and lifecycle costs are significantly lower than a conventional house.



The goal of a passive house is to minimise lifecycle costs through energy saving and simple and high-quality technology. When the heating energy requirement is low, the heat distribution system can be made simpler. This reduces both the investment costs and the lifecycle costs.

A passive house provides the developer with lower operating costs. The low energy consumption and low power required from the power grid reduce fixed energy costs and provide savings in the purchase costs of heating systems. A smaller size and power and a lower amount of heating equipment reduce service and maintenance costs.

Thermal Comfort

Thermal comfort and indoor air quality require that the intake air is mixed well with the indoor air. Mixing reduces the vertical thermal gradient in the air inside room spaces. The velocity of air from terminal equipment placed high up must be sufficiently high in order to achieve effective mixing, while in the living zone, the speed must be low, at most 0.15 to 0.20 m/s, so that the airflow does not reduce comfort.

Floor heating is justified in humid spaces to speed up the drying of the floor, but the temperature must be set lower than regular floor heating, only 1 to 3 °C above air temperature. A higher temperature may cause overheating. The vertical thermal gradient in a room space must be under 2 °C from a sitting person's ankles to his or her neck, i.e. between 0.1 m and 1.1 m. Window height should not exceed 1.8 metres unless air blowers are placed in front of them.

The thermal properties of a passive house's exterior shell are good, so the maintenance of small temperature gradients is easy and the heating period is short compared to a conventional house. A fireplace can cause overheating and reduce thermal comfort in a well-insulated house. Because the heating energy requirement of a passive house is small, the heat output of a fireplace must be low. This should be taken into consideration when selecting a fireplace.

PAROC

PAROC OY AB
Building Insulation
Neilikkatie 17, PO BOX 294
FI-01301 Vantaa, Finland
Telephone +358 46 876 8000
Telefax +358 46 876 8002
www.paroc.com

A MEMBER OF PAROC GROUP