# AN ECO-FRIENDLY LOW ENERGY HOUSE IN MARCINKOWO NEAR OLSZTYN


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## ABSTRACT

This paper presents the main features of a detached house and the experience accumulated during the first year of its use. The building is eco-friendly and energy-saving. The design takes into account such energy-related issues as heating the building, energy saving, utilisation of energy from internal sources and from the surroundings, seasonal accumulation of energy and cooling during a warm period. Environmental and health-related issues were also taken into account.


## INTRODUCTION

The major tasks that a residential building should perform include:

- providing comfortable climatic conditions for the inhabitants;
- providing beneficial ecological conditions, appropriate for the inhabitants and environment-friendly;
- achieving these goals at the lowest cost possible.

These requirements have been known for a long time, but only contemporary technology has made such solutions possible to a greater extent, at moderate investment outlays and low operational costs. Numerous designs of energy-saving and passive houses are known, in which a number of architectural solutions and energy-saving internal systems have been applied. In each specific house an individual set of technological solutions has been applied, selected based on objective and subjective criteria.

The main criteria applied in designing the building in Marcinkowo included:

1. Reducing heat loss by selecting the appropriate structure of the building.
2. Utilisation of internal heat sources and retrieval of waste heat.
3. Heat accumulation.
4. Application of unconventional energy sources.
5. Application of "smart" technical solutions to control processes and energy devices.
6. Application of materials which ensure healthy climate and are environment-friendly.

### Reducing Heat Loss

The following principles and design solutions have been applied in order to reduce heat loss:

- using materials with low heat conductivity: pressed straw was used as filling, eco-fibre – for internal surfaces, Styrofoam – for external surfaces;
- filling the unused attic space with a thick layer of eco-fibre – material made from from waste paper (newspapers) and treated with boron compounds;
- placing the warmest devices and rooms of the house (kitchen, bathroom, seasonal energy accumulator) in the central part of the building;
- the application of windows with IR low-emission coatings ensures a low value of the heat transfer coefficient (0.6 $W/(m^2K)$);
- reducing the area of external walls by the application of rounded walls, (shape index A/V = 520/700 = 0,74 $m^{-1}$ for this building)

### Internal heat sources and waste heat

Energy of various types spontaneously and easily transforms into heat. Therefore, along a chain of energy transformations, practically all the energy supplied to household appliances is ultimately transformed into heat. The value of internal heat sources, recommended by the standard PN-EN 832:2001, is 5 W per $1m^2$ of the floor of heated rooms. For smaller buildings, the total value is 5* 190 = 950 W ≈ 1 kW.

The need for air replacement is determined only by hygienic conditions. However, this necessitates the heating of the air flowing into the house during the cold period. Used air is transported outside, the process accounting for 30-60% of all the heat loss in modern buildings. The heat could be used for heating the inflowing air, but large-area heat exchangers would have to be used to this end. Owing to modern technologies, manufacturing such heat exchangers is possible. Their features include a compact design, low material consumption and low production cost. The house discussed in this paper employs a heat exchanger with the maximum air flow of 800 $m^3/h$.

### External heat sources

Solar energy has been made use of passively in windows and actively in solar collectors.

In order to ensure a higher extent of solar energy utilisation, the front wall of the building is directed southwards. Through the front windows with a total area of ca. 30 $m^2$ sunrays fall not only on the floor but – during the winter solstice – also on the opposite wall of the room. The total window area is 50 $m^2$.

Passive utilisation of solar radiation, passing through the windows in summer, may be excessive.

In consequence, external elements were made to provide shade to the windows during the summer solstice. Hence, the solar energy source is discussed not only in terms of obtaining energy, but also reducing its undesired effect during the warm season.

The north part of the building is situated on a slope. It was made of ferroconcrete covered with Styrofoam. There are no windows in it, so it can be covered with earth, thereby alleviating the temperature conditions of the northern wall in winter.

Active utilisation of solar energy by the application of solar collectors provides considerable benefits in that it makes it possible to obtain considerably high temperatures. Among the collectors with beneficial properties are pipe-vacuum collectors, as they can operate at low temperatures. Consequently, they have been applied in the building discussed in this paper.

The average annual ground temperature is close to that of the air, and the amplitude of its fluctuations decreases with depth. During the cold period, the ground temperature is higher than the temperature of the air flowing in to ventilate the rooms. Hence, during that period, the ground can be used to pre-heat the ventilation air. In order to make use of the heat in the ground, a ground heat exchanger was installed near the house. It consists of two perforated plastic pipes, 0.4 m in diameter and 9 m long, with 6 m of space between them. Between the pipes, at the depth of 1 m, there is a 60 tonne backfill of gravel. In summer, the inflowing air cools in the exchanger, but also dust and excess humidity is removed from it.

**Supplementing conventional heat sources and heaters**

In order to ensure that the building is heated during extremely cold weather, a 33 kW living-room fireplace with a water coat was installed as well as an 18 kW electric boiler.

Heaters in the floor and in the walls have been installed in the house; they work at small temperature difference. Therefore, they require low-temperature heat which is cheaper to obtain. The heat carrier is distributed only at the floor level. The wall heaters are made of thermosiphon heat pipes and placed up to the height of 1-2 m, including window sills.

## HEAT ACCUMULATOR

Accumulation of thermal energy is justified by the discrepancy between the time when natural and waste heat is available and the time of demand for heat. The discrepancies are daily and periodical in nature. In order to secure the possibility of obtaining heat from natural sources and providing heat when needed, a huge water tank is placed in the central part of the building. A seasonal heat accumulator was made from a 22 m$^3$ trailer cistern. Its vertical position and appropriate equipment ensures that temperature stratification of water can be made use of, both in supplying heat to it and in collecting the heat for use.

**Intelligent System of Controlling the Heating System**

The main task of the controlling system is to ensure the possibility of seasonal supply of the accumulator with heat at various temperatures, obtained from different sources of energy. The problem can be solved by applying a number of regulating and controlling valves, whose task is to deliver water at various temperatures to the water layers of the corresponding temperature in the accumulator. This enables supplying water of very different temperature (25-85°C) to the heating system. The wall and floor heating systems are low-temperature systems; a heat carrier at the temperature of 40-50°C is only required for the air heater. Switching on the heating of particular rooms is also regulated by the controlling system.

**Ecological Characteristics**

The house is about 70% constructed from natural materials. The skeleton is made from spruce beams. It is filled with pressed straw and covered with a layer of clay (BALES OF STRAW technology). The ceilings are largely insulated with eco-fibre, which is an environment-friendly material. Floors in residential rooms are made as wooden parquet. Wood is used as fuel in the fireplace, which is an aesthetic finishing element in the living room. The fireplace is lit mainly in order to improve the residents' well-being when they feel like basking in the light and heat radiating from the fire.

**Economic Characteristics and Summary**

Photograph of the building is shown below. By placing great emphasis on the thermal insulation, the constructor ensured that the low cost of the walls and later profits resulting from minimising the amount of fuel needed to heat the house would soon pay back the sums spent for the solar installation, heat exchangers and accumulators, electric boiler, fireplace and windows.

Fig. 1. Low energy house after completion

The cost of heating during the first year of operation amounted to ca PLN 1,500. calculations have shown that the energy consumption index for the building is close to 30 kWh/m$^2$ annually. This is totally in line with the investor's expectations. The accompanying feeling of security, comfort associated with the climatic value, lighting and acoustic qualities – all this makes the house friendly to its users. When making an investment in a house, let us choose ecology, fresh air, security and comfort, "our" comfort; it is invaluable, but it has its price.