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SCIENCE DIRECT
Energy and Buildings 35 (2003) 1077–1084
ENERGY and BUILDINGS
www.elsevier.com/locate/enbuild

Renewable energy for passive house heating
Part I. Building description

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Abstract

A passive house is a cost-efficient building that can manage throughout the heating period, due to its specific construction design, with more than 10 times less heat energy than the same building designed to standards presently applicable across Europe. Its extended thermal insulation and enhanced air-tightness removes the need for temperatures higher than 50 °C. This makes renewable energy sources particularly suitable for heating, cooling and domestic hot water production. Modeling of renewable energy usage for space heating requires as a preliminary stage the detailed description of the building structure, of the HVAC equipment and of the internal heat sources. This paper shows the main data used to model the thermal behavior of a passive house. Details about Pirmasens Passive House (Rhineland Palatinate, Germany) are given, as for example, the internal heat sources, including electric appliances, heat and humidity released by human bodies, thermal internal facilities as hot and cold water pipes. All these are quantified by using statistically derived data. A detailed time schedule for a standard German family with two adults and two children was prepared. It takes into account the national celebrations, vacation and weekends among others.

Keywords: Sustainable building technology; Energy efficiency; Renewable energy; Passive house

1. Introduction

In regards to the threatening climate changes, the German government decided a cut of the greenhouse gas emissions by 25% by the year 2005. A large contribution could be made in the field of space heating since about 40% of the end-energy demand in Germany is devoted to space heating and domestic hot water production. Passive buildings—which are equipped with an extended heat insulation skin and energy saving HVAC equipment and which are proposed at a justifiable cost—are promising candidates for the new generation of environmental friendly buildings. To stress this point, we remind that the current average heat load in Germany is about 150 kWh/m^2 per year. The space heat load mainly depends on the heat losses of the building. It results of the sum of the transmission and ventilation heat losses as well as of the internal and passive solar gains.

In the 1980s, the low-energy house standard arose after the oil crises, with a space heat load around 75 kWh/m^2 per year. Following this trend of energy-saving, the first “passive house” (PH) was built in Germany in the year 1992. The goal was to meet a heat load below 15 kWh/m^2 per year [1] by using standard construction materials and technologies. A couple of year measurements showed that the goal was achieved with additional costs of about only 5% upper the costs of the same implementation but according to the building regulation then. Up to now over 1000 passive house units have been built throughout Germany and this amount sensibly doubles every year.

The term “passive house” refers to a construction standard. Passive houses are buildings that assure a comfortable indoor climate during summer and winter without needing any conventional heating or cooling system. The standard has been named “passive house” because the passive heat input-delivered externally by solar irradiation through the windows and provided internally by the heat emission of appliances and occupants is essentially enough to keep the building at comfortable indoor temperature throughout the

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0378-7788/$ – see front matter
doi:10.1016/j.enbuild.2003.10.001

heating period. Details about passive houses in Germany were presented previously in [2].

In two companion papers we propose a model to evaluate the contribution of renewable energy sources to meet the heating demand of a three-zone passive house. The three zones refer each to an area with quite similar indoor features (in terms of temperature and humidity), namely to: (1) the kitchen, (2) the bathroom and (3) the remaining rooms of the house. As a case study, the model was applied to the Pirmasens Passive House (Rhineland Palatinate, Germany). In this paper, we present a way of describing the structure of the passive house. The components and operation of the ventilation–heating system is also presented. The companion paper [3] (later on referred as paper II) describes the time-dependent models used to evaluate the thermal heat demand and the operation of the ventilation–heating system. Some preliminary results are also presented there.

2. Description of Pirmasens PH

As explained below, several principles are followed in order to reach the very restrictive space heating load requirements of a passive house (referring to the German Passivhaus prescriptions). In a passive house, the heat bridges and losses are technically cut to a minimum. This is reached with the aid of an outer skin with an overall heat transfer coefficient of only about 0.1 W/m^2. In order to reduce heat losses by conduction, the building shell insulation is extended (30 cm corresponds to the lone insulation layer, commonly consisting of expanded polystyrene. This figure is only given as an example and varies accordingly to the average air temperature difference between inside and outside the building, i.e. the geographical location of the building).

Solar heat gain is increased by aligning the main building front to south and equipping the front with high solar transmittance glazing. The northern front is equipped with small windows to provide the required amount of sunlight into the north rooms such as the kitchen or the entrance.

Heat losses by ventilation are strongly reduced by improving the air tightness of the building. This one is measured under pressure test by putting the building under inflation of 50 Pa and measuring the hourly air change rate. This should be $<60\%$ of the inside house volume per hour. A ventilation system with high efficiency heat recovery is usually foreseen in order to provide the necessary amount of fresh breath air. From all these measures, it results that the space heating in a passive house can be entirely assured through the ventilation system by heating the supply air. A passive house stands out for its draught and odor free atmosphere. Since radiators are no more required and windows are well insulated, there exists no more hot and cold surfaces. The entire room has uniform surface temperature what provides a cozy room climate.

The domestic hot water turns out to be the major energy consumer in a passive house (with 50–80% of the total heat demand). As an illustration, note that the German energy saving ordinance (EnEV) recommends for computational purposes to assign 12 kWh/m^2 per year net heat demand for domestic hot water production [4]. On the other hand, the latent and sensible heat from the kitchen (cooking and washing up) and from the bathroom (bathing) are partially

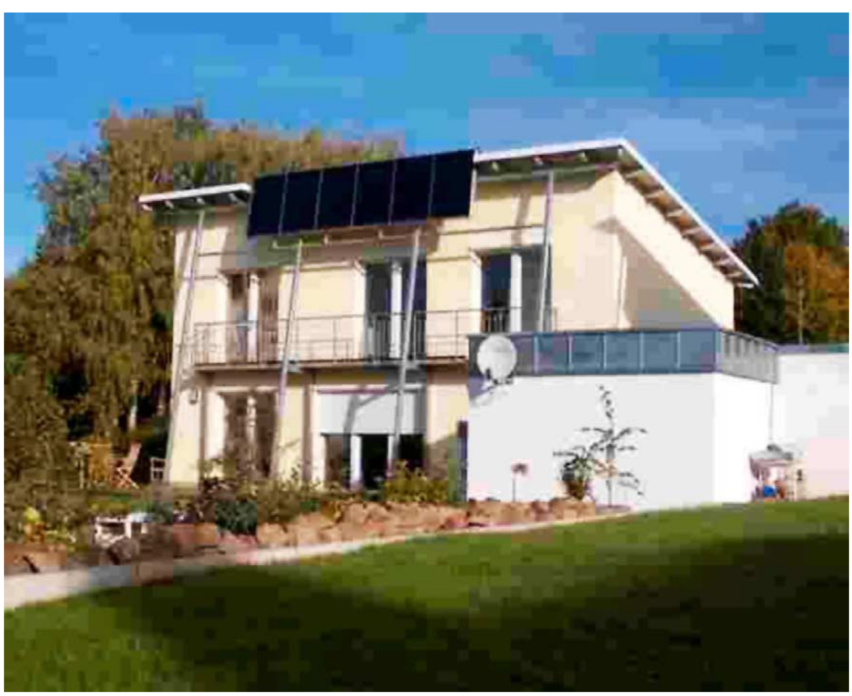

Fig. 1. South view of Pirmasens Passive House (photograph by courtesy of Arch. Volker Wilhelm).