Thermal Protection of Residential Buildings in the Period of Energy Crisis and Its Influence on Comfort of Living

Przemyslaw Nowakowski

Wroclaw University of Technology, Department of Architecture
54-210 Wroclaw, Str Prusa 53/55, Poland
przemyslaw.nowakowski@pwr.wroc.pl

Abstract. It has been noticed within a few years now that energy prices soared all over the world. Apart from growing costs of vehicle fuels, prices of energy used in flats have risen. They take a substantial share in domestic budgets. It poses a problem mainly for residents in countries where the building industry have been using less advanced technologies. The solutions applied there refer both to conditions of the residential resources management and selection of building and decor materials. A response to the need for reducing energy consumption in residential buildings comprises successively corrected and tightened legal rules and regulations concerning thermal protection of buildings. Also, the users themselves undertake independent initiatives aimed at reduction of exploitation costs. However, the issue of improving thermal isolation of buildings is a costly venture, and profits from its implementation are noticeable only after many years. The paper will discuss technical tendencies of thermal protection of newly erected residential buildings (passive buildings, among other things) as well as the older ones, subject to so called thermal modernisation. What is more, the paper will concern the influence the buildings have on the living comfort and possibilities of counteracting negative consequences as far as influence of thermal isolation technologies on people, natural environment and a technical condition of buildings is concerned.

Keywords: residential buildings, low energy consumption, living comfort.

1 Introduction: Energy Safety and Policy for Renewable EnergyResources

One of the important challenges of a contemporary country is to ensure energetic safety. The safety implies maintaining such economy conditions which allow to meet a demand for fuel and energy at simultaneous complying with environment protection requirements. Recently, the basic factor that decides about energy delivery safety has been reliability of fuel delivery systems. However, the technology progress nowadays allows to apply solutions to a large degree independent of network systems. There are technologies among them that use renewable energy resources, which are of a particular great interest in Europe. A more general application of the technologies lets

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achieve two fundamental goals. The first one is to increase the energy safety in Europe by reducing dependence on imported fossil fuels such as petroleum, natural gas and coal. The second goal is to reduce the greenhouse gas emission, carbon dioxide in particular, resulting from the fossil fuels combustion.

In order to minimise the risk of lowering the energy safety of a country, e.g. because of interference for political reasons, technical breakdowns or strikes, fuels delivery is diversified in terms of their kinds and directions. The economic aspect of safety amounts mainly to ensuring energy carriers price accepted by consumers. In the ecological aspect, however, safety is connected with maintaining possibly an intact natural environment condition, which requires meeting appropriate standards and ecological commitments by governments. Usage of renewable energy resources and new “clean” technologies of its production is strongly promoted nowadays.

Climatic conditions do not allow for entire cutting off the human environment from energy resources. Even buildings constructed according to best technologies need to be warmed up or cooled down and lit up. Such appliances of every day use require power supply. Acquisition and combustion of the traditional energy resources such as coal, crude oil and gas negatively affect the environment. What is more, the resources are running low and will soon exhaust. Therefore, applying renewable natural energy resources is becoming a necessity on a larger scale. It will become one of major priorities of power industry development in the following years. Rational use of energy of the natural renewable origins, which mean water and wind energy, solar energy, the geothermal energy, and biomass, is one of important components of the sustainable development that brings measurable ecological, energetic and social effects.

The increase in contribution of the renewable energy resources in the fuel and energetic balance of the world observed since the 80. contributes to improvement of the energy use efficiency and saving the natural resources, improving the condition of the natural environment (mainly by reducing the carbon dioxide emission to the atmosphere and reducing the amount of the produced waste).

It has been estimated that since that time the solar energy use around the world has doubled, and the water energy has risen four times, and is still on the increase. Thus, supporting the renewable energy resources is becoming more and more serious challenge to nearly all the countries around the world, and Europe in particular, which is reflected in many EU programmes [3].

2 Heating Costs in Buildings

It has been estimated that in the European Union countries the use of energy in buildings runs at about 40% of the total energy use. In the living buildings energy is mainly used for heating and, alternatively, cooling rooms (about 60%), heating up water (about 25%) and preparing meals, lightening rooms, supplying with power the household appliances (the rest 15%). In the public utility buildings, a share of energy used for heating up and cooling rooms is similar to the energy use level in the living buildings. However, in the latter ones more energy is used for lightening systems and electrical appliances.

The amount of energy used at home depends on many factors such as a house project, a selection of materials used for its construction, residents activity and the manners of realising their living needs (the needs are connected to heating up the rooms, preparing warm water for use and lightening systems, etc.).

Elements that have a considerable influence on the heat loss include: a building heating surface, a house shape, insulating thermal partitions, materials used for a building construction, a selection of thermal insulation materials or insulation and construction materials, a rooms project and arrangement (rooms orientation according to the geographic directions), the windows number and size, constructions favourable to emerging thermal bridges, and a ventilation system.

Heating costs depend on energy and fuel prices in the world market. In the recent years, a particular price increase has been recorded as far as crude oil and gas are concerned, since the prices vary according to a current political situation around the world. Also, a general trend of increasing energy prices has been noticed, which is a consequence of a continuous development of the global economy that despite the increased energy use efficiency generates growing energy demands, particularly in dynamically developing countries such as China and India. The growing energy prices are also a result of the progressing natural resources exhaustion.

Exploitation costs constitute a great part of household expenditures. They result mainly from a considerable energy use. Growing energy prices force people to minimise the heat loss. It has been estimated that in older buildings, which do not meet requirements imposed upon modern buildings, the heating cost of one square meter may be about twice and a half higher. In order to maintain the monthly heating costs of such a building at a rational level, part of property owners withdraw from heating up rooms and thus decide on using the building in a thermal discomfort [4].

A thermomodernisation may be the measure to improve the microclimatic conditions in buildings of an old type and maintenance costs reduction. It involves introduction of changes which eliminate a considerable heat loss in buildings. Major thermomodernisation works include: windows and external doors exchange or repair, walls and roofs warming, warming the floor on the ground, improving ventilation systems, introducing appliances that use the renewable energy resources, modernisation and exchange of the heating system in a building, etc.

3 Energy Saving Living Buildings

Nowadays, the term „energy saving building" is being used more and more frequently, since the energy efficiency has become an important feature of a building, and in the next years it is going to become a requirement generally imposed on builders and users. In Germany, regulations that determine an energy-consuming potential of a building (energy used for heating up the building) have been in force since 1995. The potential is to be at the level of 50-100 kWh per a square kilometer of a house within a year. What is more, it is expected that the value will decrease to the level of 30-70 kWh/m^2a. In Switzerland, houses using energy below the level of 55 kWh/m^2 are regarded as energy-saving [4], [6]. In Poland newly erected buildings are characterised by a considerable energy consuming potential reaching 120 kWh/m^2a. Therefore, use of energy at the level of 90 kWh/m^2a may be deemed to be a bordeline value below which we can talk about an energy-saving building. However, it should be taken into account that the borderline will soon be lowered to 70 kWh/m^2a.

Growing exploitation costs, more and more strict usage requirements, and also care for the natural environment force the contemporary investors to seek new concepts and technologies of erecting buildings. It has been necessary to abandon traditional techniques and implement more energy-saving solutions. Introducing the system energy-saving solutions lead to transformation of the traditional buildings into low energy objects or so called passive houses.

The concept of a passive house emerged in Europe in Germany in the 80 of the twentieth century. In Europe, about 10 000 houses of this type have been built so far. The concept has also been implemented in objects of general use, particularly in kindergardens, schools and offices [9].

The essence of the passive building industry is maximising energy profits and minimising the heat loss. In order to meet the conditions, all external divisions and partitions must have a low coefficient of heat penetration. What is more, the external building layer has to be air-tight and provide a good protection against the heat loss. Similarly, windows carpentry has to cause a less heat loss than that standard one used so far. The blowing in and blowing out ventilation system, in turn, will decrease the heat loss connected with a building ventilation by 75-90%. What is particular about the passive buildings is the fact that the demand for heat is satisfied by thermal profits generated by the solar radiation, the heat generated by equipment and people staying in a building. Only in periods of particularly low temperatures the air blown into rooms is heated up.

The passive house standard can be regarded as a synonym of a highly energy-saving building, since it requires a very little amount of energy for heating up. The basic condition required from a house aspiring to meet this standard is its advanced energy-saving quality: a building cannot require more than 15 kWh/m^2 for heating in a year, 60% of air cannot escape from the building in an hour, which is evidence of its air-tightness.

The requirements are very high, as opposed to casual, traditional, even warmed up buildings. In a passive house, a thermal comfort is ensured by passive energy resources, unnoticed earlier. There can be only its residents, electrical appliances, the solar energy and the heat recovered from ventilation. Frequently, a building does not need an active autonomous heating system [6] , [8]. The basic manner of reaching the standards of a passive building is its highly good thermal insulation. A thick layer of insulation, however, lessens a house use surface leaving at the same external size of the building unchanged.

A good thermal insulation allow to considerably decrease energy needed for heating a house. However, the heat loss and the need to additionally heat up a house in the winter cannot be eliminated totally. In fact, each house is equipped with many waste heat sources (such as light bulbs or household appliances and multimedia), but normally the heat they generate is not sufficient. Therefore, the passive buildings can utilise the solar energy for heating. The southern walls have to have big windows then which let in more sunlight in the winter. Three-pane windows contribute to a considerable decrease in the heat loss. An optional element of a passive house is solar collectors installed on the roof, which use the solar energy for heating an entire building and heating up water for daily use. Whereas the air for ventilation is let through a ground heat exchanger, where it is slightly heated up. Then, it is heated in a recuperator, taking part of the heat from the air used and leaving the building. It allows to significantly minimise the loss of energy for ventilation. Additionally, the same convertor and recuperator may help to cool down the air taken from outside in the summer (Fig. 1).

A well designed building must comply with many very important conditions frequently excluding each other. The process of designing energy - saving buildings is complex and requires a lot of knowledge and experience. The functional arrangement and technological solutions ought to comply with the assumed low use of energy. Planning an energy-saving house, a passive one in particular, should take into consideration the following requirements: a consistent shape of a building (best if it is connected with other buildings), the main facade of the building oriented towards the south (the windows also directed towards the south should be possibly large, the northern ones, however, should be possibly small), lack of construction elements that would shade the passive house (hindering use of passive sun rays as a means to heat up the house), use Venetian blinds, roller blinds, awnings or protruding arcades (in the summer time they will protect against overheating the interior), ensure as best thermal insulation of a house construction elements as possible (usually U≤0,15 W/m2K), and a building tightness, use windows with possibly least permeability, eliminate thermal bridges, group wiring and plumbing (e.g. situating the bathroom next to, above or below the kitchen), minimise the length of wires and pipes, insulate and seal ventilation and heating ducts.

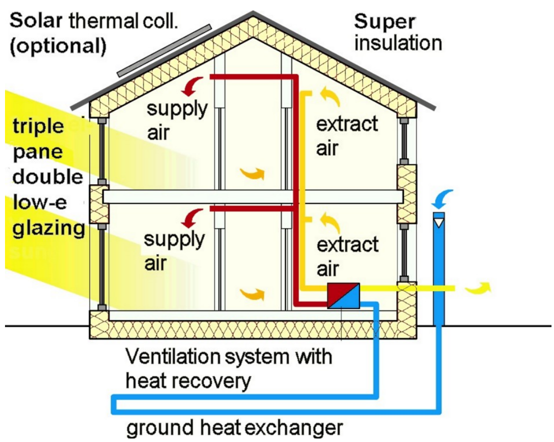

Fig. 1. Principle of a passive house operation [7]

Modern installations consist of a complicated technical system, whose efficient operation is possible only by using a computer controlled appliances. These appliances should control not only the heating and ventilation systems, but also lightening, telecommunication and protection systems. Thus, an energy-saving building will be at the same time an “intelligent” building in the future.

Additionally, an appropriate greenery design on a building plot may appear very helpful for maintaining appropriate temperatures in a passive building during an entire year (Fig. 2). Planting deciduous trees in front of the southern elevation gurantees

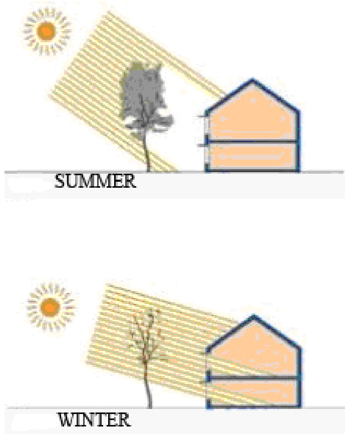

Fig. 2. Insulation of a house by deciduous trees in the summer and winter time [1]

shade in the summer season, when protection against high temperatures is very important. In the winter time, when plants lose leaves, the sun rays are coming through the unshaded windows, which is a significant source of heat in a general energetic balance of the building. From the northern side of the building, in turn, the coniferous greenery is better, since it protects the building against cold winds that cause undesirable chilling. The concept of passive buildings is at present a major proposal of erecting energy-saving buildings, which has a chance to turn out to be successful and popular in the practical application. Merely a 10 – 20 % increase of investment outlays may result in saving energy even at the level of 80 – 85 %. What is more, immeasurable ecological advantages – decreased use of dominant energy resources (coal, gas and fuel oil) – are an additional gain. Such houses, however, are still a minority in the building industry. Investors give up additional outlays, which are recouped only after 8 – 10 years, accepting at the same time increased energy use and exploitation costs [8].

4 Comfort in Rooms, Temperatures Range

In an energy-saving house, a buffer rooms arrangement is very important. It means that the same temperature does not have to be maintained in all the rooms. The temperature should be adjusted to room functions. Maintaining optimal level of temperatures in living rooms allow to save thermal energy. Reducing the temperature in several living rooms will additionally decrease use of thermal energy. Reducing the temperature by 1° C may save thermal energy even up to 6%.

In the living room and in the children's rooms there should be the temperature of 20 – 21° C, since in those places residents spend most of their time. In the bedroom even the temperature of 16 – 18° C is sufficient. The lowered temperature makes sleep better, and it is not stuffy. The bathroom should be well heated – the temperature their should remain at the level of 22 – 24° C. In the kitchen, the temperature may remain at the level of 18° C, as additional heat is generated during the cooking process. In other storage accommodation units (pantries, compartments, laundry rooms) merely the temperature of 12 – 15° C is enough, in the garage, however, maximum 4 – 8° C. Simultaneously, when determining temperatures in rooms a rule ought to be observed that the temperature difference between neighbouring rooms should not exceed 8° C. Thanks to this, relatively thin partition walls can be used, without additional thermal insulation. This principle is applied in most house projects, in which rooms arrangements is designed in such a way so it forms a buffer zone. The garage, for instance, has to adhere to household rooms (the laundry and pantry rooms) which, in turn, are to adjoin the kitchen and then with rooms [2].

5 Progress in the Energy Saving Building Industry

The contemporary technology enables introducing a full control of the heating and humidity processes in buildings. This is possible in a building maximally tight, very well insulated, equipped with automatically controlled central heating appliances and mechanical ventilation with heat recycling. Windows in such a building are used for lightening the house interior with daylight and are mostly not designed to be open. Automatic appliances provided with sensors of external and internal temperature control ventilation and heating systems. This basic system can easily be further developed and improved by connecting with a system of solar collectors, and also by a system of roller blinds, curtains and shutters regulated automatically depending on the temperature outside and insulation conditions.

Complying with the severe requirements in the energy-saving building industry, the passive one in particular, requires applying specific building materials and installation systems. Following the normative recommendations cause then considerable limitations in selection of materials for thermal insulation and manners of ventilation, limiting them to mechanical blowing in and blowing out ventilation.

As materials for thermal insulation foamed polystyrene and more seldom mineral wool are recommended and generally propagated. They are, in fact, characterized by a high coefficient of thermal insulation, however, their influence on the chemical microclimate of the interior and on the natural environment is harmful. Production of those materials is energy consuming, their use is connected to emission of substances harmful to the surrounding area (e.g. styrol from polystyrene or tiny fibres from glass wool). Additionally, as utilised materials they are not biodegradable and require special storage. A favourable alternative to the mentioned insulation materials may be mats made of cork, ground cellulose, wood fibres and sheep wool, etc. In spite of the fact that the materials have slightly worse insulation qualities and are more expensive, they are at least neutral to people's health, and they are biodegradable. Therefore, they are ecological.

Long-term usage of the mechanical blowing in and blowing out ventilation and lack of an appropriate supervision (which may particularly occur in detached houses) may cause a significant contamination of ducts and specific components such as filters, ventilators, etc. A contaminated mechanical ventilation may cause spraying dust, saprophytes and pathogenic bacteria [1], [5]. The mechanical ventilation has to be propelled by electric energy and be subject to control and cleaning. This, in turn, increases real exploitation costs of a house, which are not always appropriately calculated at the design stage.

6 Summary

The contemporary energy crisis and growing costs of houses maintenance result from multiple international conflicts, monopolization of traditional resources supplies and growing demand for them. Interest in the natural renewable resources is still passive. The potential of local resources is too little used. It is average energy consumers who suffer consequences of an ineffective energy policy of particular countries in the form of continually growing house exploitation costs.

Apart from a necessary diversification of energy resources, directions and forms, modern building systems whose application cause measurable energy use should be propagated. Therefore, the aim should be to convert the present building model into the energy-saving and ecological building industry, adjusted to the sustainable development principles, which means not threatening people and the natural environment. It refers first of all to materials whose production does not require considerable resources and energy outlays, materials that in the building and use of a house will not affect harmfully the living organisms, and materials which after pulling down a building may be reused. It involves installation systems and appliances for removing rubbish and waste in a way that enables their cleaning, utilization and recycling.

It requires introduction of new solutions, technologies and materials, and also change of designers' attitude as well as change of habits of house users. It is a process that will take place within many years and the changes will occur gradually.

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