Proceedings of the 2006 WSEAS/IASME International Conference on Heat and Mass Transfer, Miami, Florida, USA, January 18-20, 2006 (pp33-37)

The Analysis of Costs and Reduction of Emission of Boiler House with Heat Insulated Windows

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Abstract: The article presents the possibility of reduction of emission of smoke gases from a building on the basis of building - in different heat – insulated windows and consequently protection of environment. Furthermore, economic analysis is made with a comparison of investment and savings, and the possibility of solar power exploitation and modern construction according to new directives that suggest the construction of low energy and passive houses. .

Key - Words: Heat transfer, environment, energy saving buildings, heat insulation glasses, emission of chimney gases, economic analysis

1 Introduction

The economic growth the fact that we witnessing today, and they highlight the exponential energy consumption of environmental – non-renewable resources, such as coal, oil, natural gas, nuclear fuels, etc., are limited. Since awareness of the growing emissions of SO_2, NO_x and CO_2 in the energy sector, a lot has been done in the field of research, technology, and the production of devices for the consumption of renewable energy resources (solar power, wind, water, biomass, geothermal energy, hydrogen), which are organically clean and have an important role in reducing harmful emissions. Increasing the ratio of renewable energy helps to improve the security of energy supply by reducing the EU's growing dependence on imported energy sources [1]

One of the possible solutions for our planet's protection against further destruction is the exploitation of solar energy. In order to achieve this, we need to know how and where to produce and consume this kind of energy.

This relationship has been continuously developed throughout centuries up to present. For realization of these ideas and technical solutions, EU has accepted and legislated several directives on the energy effectiveness of buildings. This is obligatory for EU members [2].

If we study the German regulative EnEV – 2002 [3], we shall discover that the energy effectiveness of a building depends on the total energy consumption for the building's operation, which is the sum consumption of energy for heating, warming the sanitary water and electricity.

2 Energy saving houses

An energy saving house is defined as a building which yearly consumes less than 80 kWh/m^2a for heating. We distinguish between the low energy house with 20 to 55 kWh/m^2a, and the passive house (PH) with 15 kWh/m^2a [4,5].

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PH has to fulfill the following conditions:

- heat transfer reduction in the non - transparent parts of the house (U < 0.15 W/m^2K ,U < 0.10 W/m^2K for houses with free space around it),
- installation of heat insulating glass (U < 0.80 W/m^2K, g ≥50%),
- proper air conditioning (n_{50P} PH ≤0.6 h^{-1}),
- ensuring air – packing,
- proper location and orientation of the building,
- proper room arrangement and ensuring proper temperatures,
- properly designed heating station connected to a solar system and heat pump,
- installation of a heat recuperation system,
- properly automated regulation system.

2.1 The energy number

Due to the drastic rises in fuel prices, it has become necessary to re-evaluate heating costs for buildings. This can be preliminary carried out by calculating the energy number, which is defined as the ratio between the annual energy consumption and the area of heated surfaces of a building.

The energy number enables the comparison of building energy consumption over different time periods, in regard to the state regulative for EU member. This is done in order to evaluate necessary energy precautions, and to compare heating costs for different fuels.

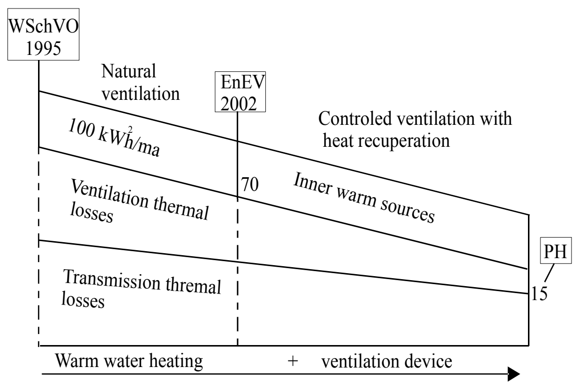


Figure 1: Energy number (regulative EnEV 2002) [3]

2.2 Fabric of buildings

A buildings fabric's which includes non-transparent and transparent surfaces (e.g. windows), has a crucial impact on heating and cooling losses. In order to reduce these losses, the EU accepted a regulative, which previously defines allowed energy consumption. This value in Slovenia is lower than 45 ÷ 40 f_0, where f_0 is the building shape factor, defined as the ratio between the whole outer surface and the whole volume of the building. Values for some other states and types of buildings are presented in table 1, where the abbreviations mean: SLO – Slovenia, G – Germany, A – Austria, LEB – low energy house, PEB – passive house.

Table 1: Equations for the calculating thermal loads [6]

Country	Q/A (kWh/m^2a)	q (W/m^2)
SLO	$45 + 40\ f_0$	$6 + 5.33\ f_0$
G	$26 + 13\ f_0$	$2.25 + 1.6\ f_0$
A	$24.55 + 81.82\ f_0$	$3.11 + 10.36\ f_0$
LEB	$13.64 + 45.45\ f_0$	$1.73 + 5.76\ f_0$
PEB	$4.1 + 13.64\ f_0$	$0.5 + 1.73\ f_0$

Figure 2 presents the dependence of specific heat loading on building shape factors.

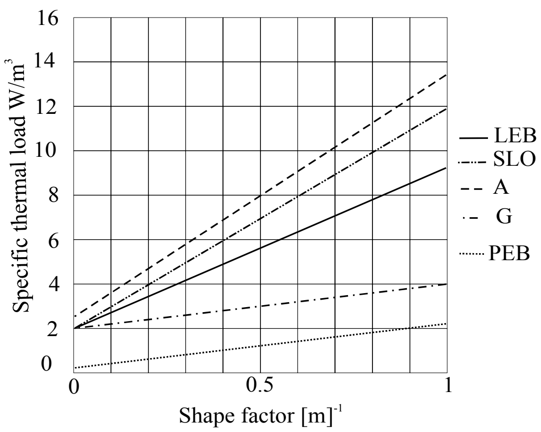


Figure 2: Specific thermal load (energy for heating) vs. building shape factor [7]

3 Insulated windows

Windows - providing natural light, ventilation and weather protection - are very important components of existing and commercial buildings, passive houses, etc.

In regard to energy balance, it can be seen that windows contribute the most to energy losses even when non-transparent parts of a building are well insulated. Therefore, the development of technical solutions for windows is directed toward heat loss reduction and search for the possibilities of using solar energy [8]. This is done by application of insulated windows, which have the following characteristics:

- multi - layer insulated windows,
- high degree of light transparency ($\tau \geq 72\%$),
- neutrality of light reflectivity and transparency (Re = 99),
- high degree of total light transparency ($g \geq 60\%$),
- low heat transfer coefficient $U < 1.3$ W/m^{2}K.

For better understanding of k – the value of reduction of heat loss at a two layer glass covered by insulation, we discover that, for a common two layer glass without insulation, about 2/3 of heat loss is due to heat radiation ($\varepsilon \sim 0.85$) only 1/3 is the result of conduction and convection in the interspaces of the window.

Covering one of two glass surfaces by insulation film reduces radiation practically to zero and any further heat loss is only due to conduction and convection.

Modern windows installed in energy saving houses, consist of two or three glass layers with inert gases such as argon, krypton, in the interspace and covered by thin layers of low emissive film on the inner surfaces.

Low energy houses have two – layer insulated windows with U = 1.1 to 1.3 W/m^{2}K, while passive houses have three layer insulated windows with U < 0.7 W/m^{2}K. This enables low temperature differences between the room and the window surfaces (Figure 3), and thus more comfortable living conditions. Furthermore, room temperature can be lowered by several degrees. Even one degree Celsius of room temperature reduction means 6% saving in fuel.

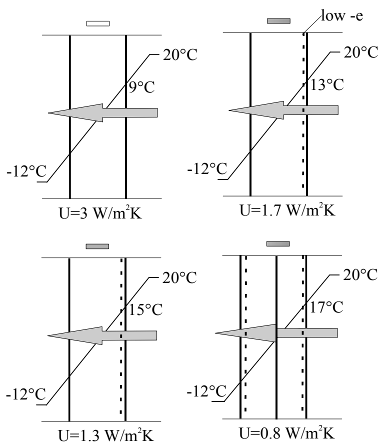


Figure 3: Heat insulated windows– the temperature of glasssurfaces

In the future, one can expect vacuum glasses with a heat transfer coefficient of 0.3 W/m^{2}K and intelligent windows with adjustable optical properties, based on thin layers

4 Economic analysis for the profitability evaluation of insulated window installations

A tipical house built in 1990, located in Maribor, was chosen for an economic analysis regarding the profitability evaluation of insulated windows installation. Surfaces of the buildings elements, heat transfer coefficient values and temperature gradients are presented in table 2 and the energy losses through the building elements in figure 4. Ventilation loss is 9100 kWh at 0.7 time air exchange.

Table 2: Typical data of house

Building element	Thermal transmission (W/m^{2}K)	Surface (m^2)	ΔT (K)
Outside wall	0.35	130	42
Floor	0.60	93	24.5
Roof	0.30	116	43.2
Double glass	3.00	29	42.4
Wooden frame	1.60	-	-

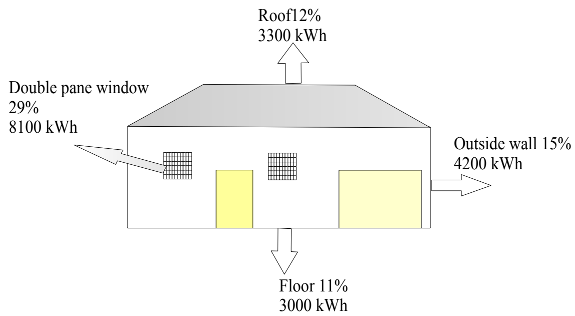
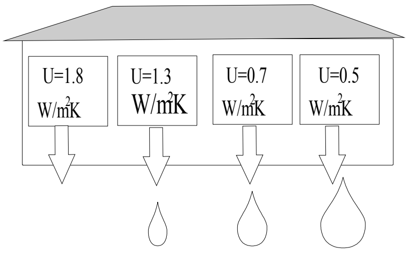


Figure 4: Heat losses and share

If we estimate the heat accumulation by solar heat gain to be 3400 kWh and heat accumulation due to inner sources to be 3400 kWh then the total annual energy consumption would be 20900 kWh. Savings due to passive solar energy consumption were not taken into account.

The installation of insulated glass (U = 1.3 W/m^{2}K) instead of the classic two – layer windows, ensures savings of 4590 kWh (where lower transparency for solar energy is already taken into account), which is 20.5% of the heating energy used over a heating season.

From the economy point of view, this value represents savings of 57.1 EUR/MWh, from 262 EUR of the total price.



Consumption (kWh/a)	17670	16310	14690	14150
Saving (kWh/a)	3230	4590	6210	6750
Saving (EUR/a)	184	262	355	385
Price of glass (EUR/m^2)	34	35	38	120
Price difference (EUR/m^2)	7	8	11	93
Returns of increased costs (1/a)	1.1	0.89	0.9	7

Figure 5: Heating energy use and recovery investment

Notice: Heat losses and savings for insulated glass (U = 0.7 W/m^{2}K) installed in PH are higher because ventilation is excluded from the calculation.

The figure presents savings in heat energy and recovery investment for different window glass:

- U = 1.7 W/m^{2}K – classic double pane window with air and covered with low emissive coat,
- U = 1.3 W/m^{2}K – double pane window with argon and covered with low emissive coat,
- U = 0.7 W/m^{2}K – triple pane window with argon and double covered with low emissive coat,
- U = 0.5 W/m^{2}K – triple pane window with krypton and double covered with low emissive coat.

4.1 Ecological and financial effects

The most polluting products of fossil fuel combustion are SO_2, NO_x and CO_2. These cause climatic disturbances on the Earth (green house effect for instance).

In order to know the values of emission coefficients for different fossil fuels, one can evaluate the emissions of polluting gases (table 3) and the emission reductions or consumption of fuels by the installation of insulated glass with higher quality (table 4).

Table 3: Fossil fuels and emissions

	SO_2 (kg/GJ)	CO_2 (kg/GJ)	NO_x (kg/GJ)	Ash emission (kg/GJ)	Ash rest (kg/GJ)	Energy value (MJ/kg)
Black coal	0.62	87.63	0.075	0.254	2.3	27.57
Brown coal	2.51	87.63	0.1	1.1	9.9	15.45
Heating oil	0.38	72.23	0.06	0.008	0	41.5
Earth gas	0.0005	50.6	0.055	0	0	34.08
City gas	0.006	50.6	0.06	0	0	17.1
Wood	0.01	87.63	0.075	0.67	4	15

Table 4: Emission of harmful gases of ash when using thermal protective run - U = 1.3 W/m^{2}K

	SO_2 (kg/GJ)	CO_2 (kg/GJ)	NO_x (kg/GJ)	Ash emission (kg)	Ash rest (kg)	Fuel saving (kg)
Black coal	10.246	1448.106	1.239	4.19741	38.008	599.39
Brown coal	41.478	1448.106	1.653	18.178	163.599	1069.59
Heating oil	6.280	1193.618	0.992	0.132	0	398.20
Earth gas	0.008	836.177	0.909	0	0	484.9
City gas	0.099	836.177	0.992	0	0	966.39
Wood	0.165	1448.106	1.239	11.072	66.101	1101.68

These calculations show that, in private houses for instance, one can save approximately 4590 kWh of heating energy per year by the installation of insulated glass (U=1.3 W/m^2K).

This is comparable to 1.1 tons of wood, 599 kg of black coal, 484 kg of natural gas, or 398 kg of oil. If the house is heated by coal, this means a reduction of SO_2 emissions by 10 kg and CO_2 emissions by 1448 kg.

Slovenia has 684,139 apartments, whit 1,965,985 permanent tenants. The living space covers 46.1 of millions m^2, which means that each tenant uses around 23.4 m^2 of living space. If we assume that 2 m^2 of window surface is needed for such living space, this means 18,047,742 MWh of heat savings or 4,728,508,483 EUR per year. These values pose a great challenge in the effort to preserve the environment and maintain the quality of air in urban environment and rational use of heat energy.

5 Conclusions

Technology for the economic use of energy, such as substantive insulation of buildings and the reduction of heat bridges, has limited influence on energy consumption. It is necessary, in addition, to apply some active elements into housing, the exploitation of solar energy, ambient heat and wasted heat. Designing such systems requires a special approach to the problem because considering the conventional energy sources as being economically and ecologically appropriate, is no longer justified.

This contribution points out how important the integration of all aspects into energy saving houses is, with special emphasis on window housing, which contribute to a substantial amount of heat loss and, consequently, to environmental pollution. Therefore, it is necessary to encourage new ways of professional thinking promoted by the political Directives of EU legislation, and to directly influence environmental standards, which are very important today.

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