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Environmental Impact of Improving Energy Efficiency of Buildings

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ABSTRACT

Around 40% of total energy consumption is in household use, some 70% of this number is due to heating/cooling. In this time of great price increases of energy sources, global warming and greenhouse effect, energy efficiency and sustainable construction along with the possibility of using renewable energy sources are becoming a priority when contemporary construction and the energy industry are considered. A fundamental principle of improving energy efficiency of buildings is to optimize the thermal insulation of the external building envelope and to reduce the thermal bridging. Low energy houses are a great step forward in achieving this goal. This paper investigates the potential for energy and CO_2 emissions reduction when a passive house space heating standard of 15 kWh/m^2 is applied to new built houses in Croatia. The calculations are based on a computer model representing national standards and the best European practice in the passive house construction.

INTRODUCTION

The term "Energy Efficiency" implies the efficient use of energy in all of the final energy consumption sectors like industry, transport, service industry, agriculture and residential buildings. It is important to say that the energy efficiency should not be regarded as energy savings, because savings always involves certain sacrifice while the efficient use of energy can never violate the conditions of work and life. Furthermore, improving the efficiency of energy consumption does not only imply the application of technical solutions. In fact, no matter how effective it is, technology can lose its properties when it is not handled in the most efficient way possible. Therefore, it can be said that the energy efficiency is primarily a matter of awareness and the willingness to change habits, than it is a matter of complex technical solutions. Only after the level of awareness about the need for efficient use of energy is developed, does a consumer need to be directed to the use of new technical measures for reducing energy consumption. Implementation of these measures is then decided based on their profitability, price, and energy efficiency respectively.

Nowadays, in the age of increased energy prices and emission excesses, the efficient use of energy is becoming more and more important. It is no longer solely an environmental consideration, but also a financial one.
The improved efficiency will result in reduced energy consumption, and this is directly related to reduction in energy production. It can be said that every conserved kWh of energy

means less amount of pollutant gasses in the atmosphere. Therefore, more efficient energy use raises the quality of the environment, thus contributing to the global efforts to prevent climate change. On the other hand, the limitation of conventional energy sources and uncertain energy supply affect its price. It is clear that the reduced energy consumption, due to its more efficient use, brings proportional financial savings. [Bukarica, 2008.]

ENERGY USE

Some 40% of annual energy consumption in the European Union (EU) countries is used in buildings (Figure 1).

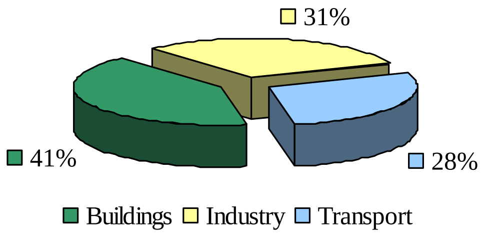


Fig. 1: Annual energy consumption by sectors [Hrs Borković, 2005]

In Croatia, the largest share of energy consumption in residential buildings is for space heating (50 to 60 %), then for the process of hot water preparation (15 to 20 %), lighting and appliances (12 to 15 %) and finally cooking (12 to 15 %) (Figure 2). It could be concluded that in residential buildings, energy consumption for heating purposes takes 80 to 90 % of the total energy needs of a building.

In non-residential buildings, the largest share of energy consumption is for space heating (50 to 55 %), followed by lighting (12 to 15 %), preparation of hot water (8 to 10 %), cooking (about 5 %), space cooling (about 4 %) and for other needs - equipment, devices, electrical facilities, air conditioning and other (15 to 20 %), (Figure 3).

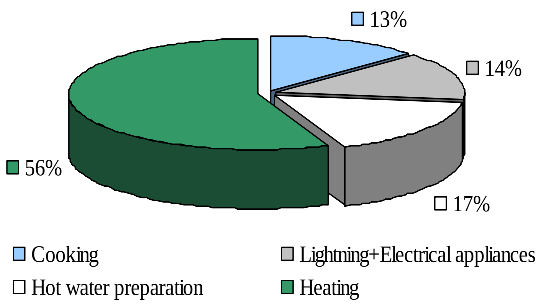


Fig. 2: Energy consumption in residential buildings of Croatia [Hrs Borković, 2008]

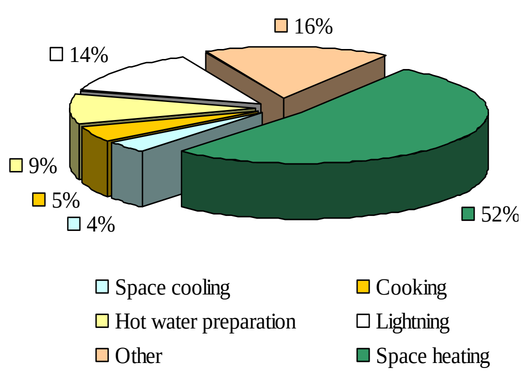


Fig. 3: Energy consumption in non-residential buildings of Croatia [Hrs Borković, 2008]

Existing buildings are representative of the vast potential for energetic and economic savings, all because of the fact that there are a considerable number of buildings with insufficient thermal insulation. Therefore, the EU countries have decided to implement plans for improving energy efficiency in their energy strategies and to develop a legal framework for the realization of these plans. The Republic of Croatia, as the EU accession candidate country, is in the process of harmonizing its legislation with the EU directives and fulfilling the accepted obligations. For example, 83 % of buildings in Croatia have the heating energy consumption from 150 kWh/m^2 up to 200 kWh/m^2. Figure 4 is a plot showing CO_2 emission, Gross Domestic Product (GDP), total energy consumption and an electric energy production change in Croatia during the period from 1998 – 2003 with the baseline being the year 1998. It can be seen that all the parameters specified on Figure 4 increased from 12 – 20 % during this period of time.

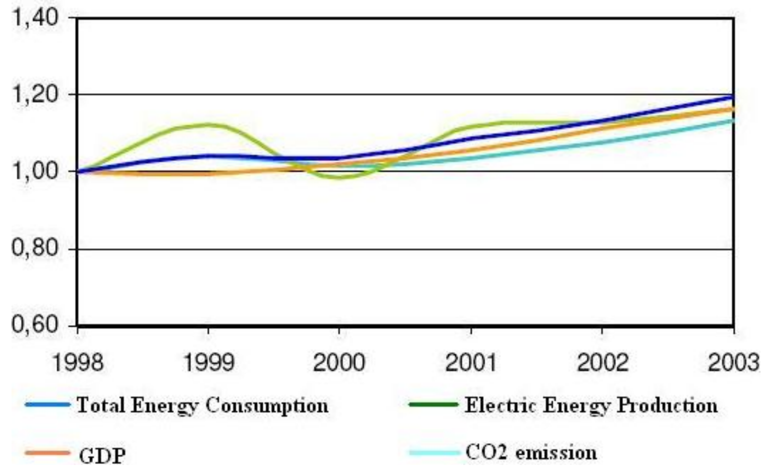


Fig. 4: Relative Change of: Total Energy Consumption, Electric Energy Production, GDP and CO_2 Emission [Jelavić, 2006]

Also, in the period from 2008 to 2012, the Republic of Croatia has to meet the requirements of Kyoto Protocol which are, to reduce the CO_2 emission by 5 % from the 1990 level. Bearing in mind the fact that Croatia has a GDP that is 58 % smaller than the current EU countries (EU 27) and plans to achieve the level of an EU 27 country in near future, a question has to be asked. Is it possible to increase the GDP without increasing the CO_2 emission? The answer is simple. The annual energy consumption in the building sector must be reduced to offset the energy consumption increases in industry and transportation, thus keeping the total energy consumption at the same level.

From all of the above, it is obvious that buildings are one of the biggest energy consumers and have a great impact on the environment and economy. Therefore, the energy efficiency, sustainable construction and the use of renewable energy sources are becoming priorities of contemporary construction process.

More and more building professionals have recognized the Passive House approach as the sensible way forward. The general definition of the Passive House is a limited heating energy demand of around 15 kWh/m^2 of treated floor area for heating and around 120 kWh$_{primary}$/m^2 treated floor area for space heating, domestic hot water (DHW) and all other electrical equipment combined. To meet this criterion, the Passive House concept focuses first and foremost on reducing the energy demand of a building which consequently directs the attention to high efficiency of energy use. The next priority lies in the use of passive (solar) techniques. After high efficiency has been obtained with all forms of energy use in the building, on-site renewable energy sources can be applied to meet the highly reduced demand of the residence [Strom, 2006].

This paper investigates the potential for space heating energy and CO_2 emission reduction regarding the most common form of housing in Croatia and the increase of thermal insulation layer.

METHODOLOGY

The tool used in this study is a computer based model, developed by the Institute IGH according to the Technical regulations about thermal energy savings and thermal protection in buildings (2005). The model was used to predict the space heating energy consumption and CO_2 emission of housing with the typical floor area of 80 m^2 located in Zagreb area. Using this model, CO_2 emission was determined regarding the energy source used for space heating in a typical housing located in the continental area of Croatia. For this purpose, conversion factors found in Table 1 were used.

Table 1: Conversion factors by the unit of effective heat [Hrs Borković, 2008]

Energy Source	**Conversion factor ($kgCO_2/kWh$)**
Electricity	0,383
Natural gas	0,236
LNG	0,264
Brown coal	0,446
Oil	0,332
Public heating - Zagreb	0,257
Boiler house - Croatian average	0,300

It has been assumed that residential buildings with 1 or 2 apartments are in fact family houses. According to this assumption there are 932 000 family houses in Croatia which is 65 % of the total number of residential buildings in Croatia [Census 2001]. With the predicted rise of 1.6 % in the year 2010, the number of family houses in Croatia will be 1 066 000. If 83 % of them have insufficient thermal insulation, this comes to approximately 885 000 family houses. Using this data, three scenarios representing different levels of the thermal insulation increase in family houses are presented. The scenarios are representing the energy and CO_2 emission saving potentials (Table 2).

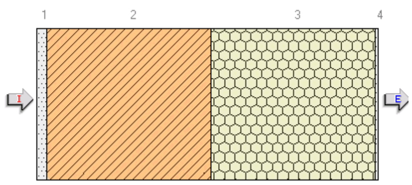
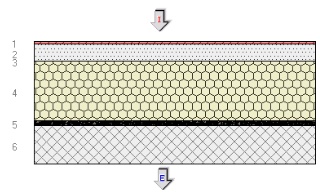
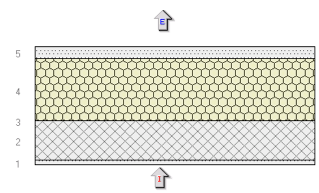
Table 2: Scenarios of improving energy efficiency of family houses

Application	Percentage of houses with increased thermal insulation (%)	Number of houses
Low	10	88 500
Medium	50	442 500
High	75	663 750

CALCULATION RESULTS

In the model, a typical house has been assumed with only a ground floor, without a basement and with an unheated attic, while all of the useful floor area of the house was heated. All structural elements of the building were composite, consisting of most common materials that are being used in Croatia. It has to be said that the structural parts and finishing surfaces were kept constant in all cases, only insulation thickness varied (Table 3).

Table 3: Layers of each structural element

OUTER WALL	FLOOR ON THE GROUND	CEILING
		
1. Plaster 2 cm 2. Building block 30 cm 3. Rock wool 4. Polymer plaster 0,5 cm	1. Wood 1,5 cm 2. Concrete slab 7 cm 3. Polyethylene 4. Rock wool 5. Waterproofing 6. Concrete slab 16 cm	1. Plaster 1 cm 2. Concrete slab 16 cm 3. Polyethylene 4. Rock wool 5. Concrete slab 5 cm

Thermal transmittance, the U-value of outer walls, ceiling and floor structures of the house are given in Figure 5, all depending on the insulation thickness.

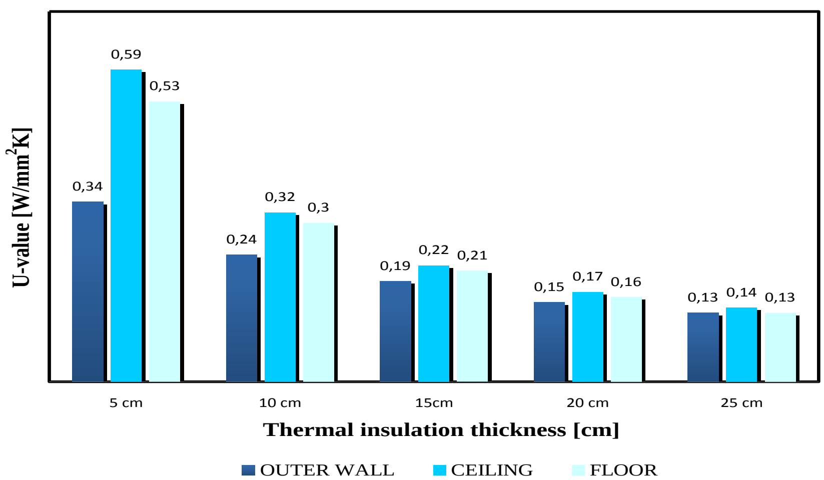


Fig. 5: Thermal transmittance for structural elements

Windows and doors are chosen with the U_w = 1,1 W/m^{2}K because it has been assumed that the old ones will be replaced with new ones as a first step of the energy efficiency improvement process. Air exchange has been resolved with air-condition devices contrary to current practice, when air exchange is resolved by opening the windows.

Using the described model, annual heat demand for heating by unit of useful floor area of the building (Q_h'') for all thermal insulation levels is calculated [Technical regulations, 2005], Table 4.

Table 4: Annual heat demand for heating by unit and total useful floor area

Thermal insulation level	Annual heat demand for heating by unit of useful floor area Q_h'' (kWh/m^{2}a)	Annual heat demand for heating by total area (kWh/a)
Insufficient	200,00	16 000
5 cm	78,35	6 268
10 cm	49,25	3 940
15 cm	39,01	3 121
20 cm	31,96	2 557
25 cm	28,95	2 316

Energy Saving Potential. The change of required energy for space heating depending on the thermal insulation level, and consequently the reduction of the required energy are presented at Figure 6. All calculations have been made regarding the insufficient thermal insulation level and energy improvement scenarios.

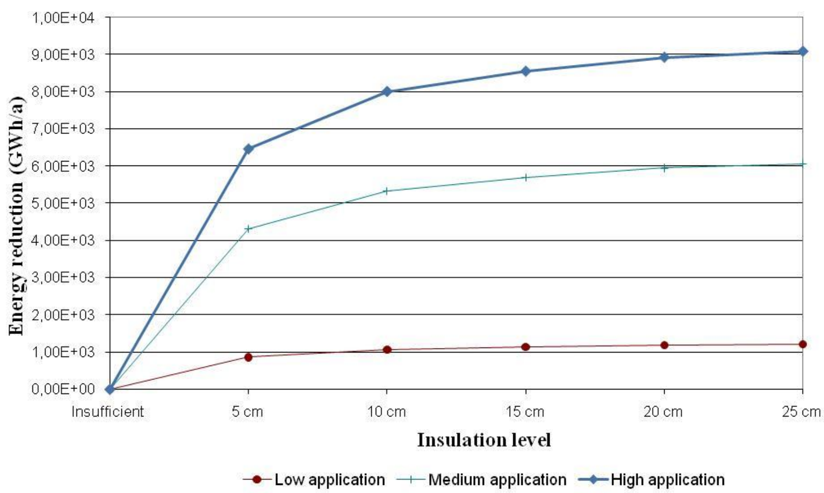


Fig. 6: Energy reduction, regarding the insulation level

CO_2 Emission Results. Annual CO_2 emission of a single building regarding the energy source could be calculated when annual heat demand for space heating by total useful floor area is gained, (Table 5 and Figure 7). The results have been calculated by multiplying the annual heat demand for heating by total area (table 4) with conversion factors by unit of effective heat that are being used in Croatia. CO_2 emission is presented for different energy sources, regarding the thermal insulation level.

Table 5: CO_2 emission for 80 m^2 typical Croatian housing

Energy Source / Insulation Level	CO_2 emission ($kgCO_2/a$)						
	Electricity	Natural gas	LNG	Brown coal	Oil	Public heating-Zagreb	Boiler house
Insufficient	6128	3776	4224	7136	5312	4112	4800
5 cm	2401	1479	1655	2796	2081	1611	1880
10 cm	1509	930	1040	1757	1308	1013	1182
15 cm	1195	737	824	1392	1036	802	936
20 cm	979	603	675	1140	849	657	767
25 cm	887	547	611	1033	769	595	695

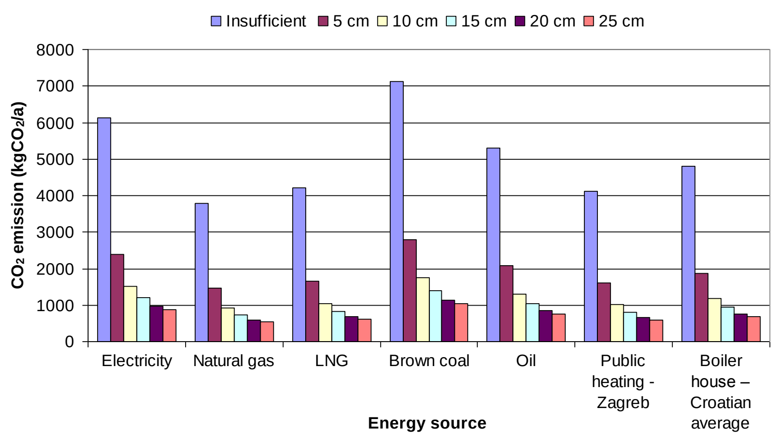


Fig. 7: Annual CO_2 emission of a single building

From Table 5, it is evident that out of the conventional energy sources, natural gas is the most environmentally friendly, while brown coal should be used as little as possible. Applying these potential energy and CO_2 emission saving rates to three scenarios of the energy efficiency improvement defined before, the following results have been calculated, Figures 8 - 10.

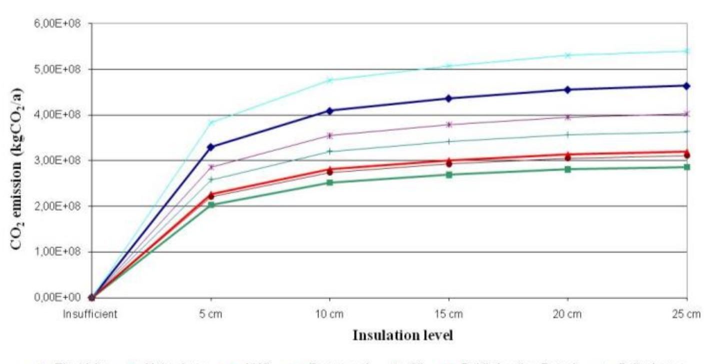


Fig. 8: CO_2 reduction – Low application scenario

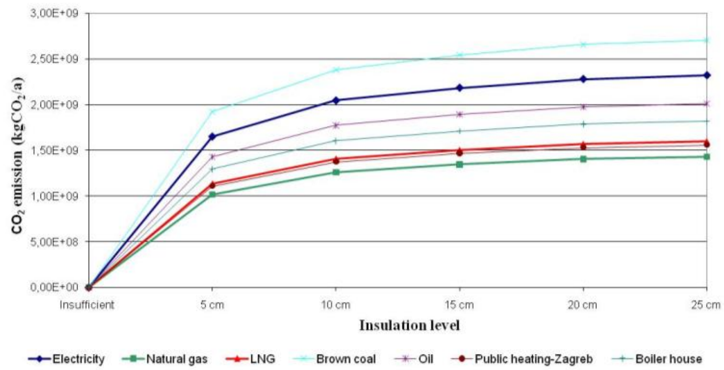


Fig. 9: CO_2 reduction – Medium application scenario

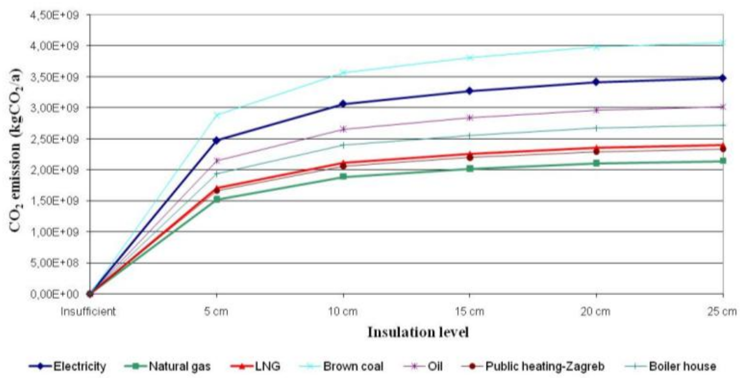


Fig. 10: CO_2 reduction – High application scenario

From Figures 8-10, the potential of CO_2 emission reduction from all energy sources is evident. If thermal insulation thickness is increased, it logically follows that CO_2 emission is reduced to some extent. In Figure 11, the percentage of CO_2 emission after the increase of thermal insulation levels by 5, 10, 15 and 20 cm are presented. All results are given with regard to the initial insulation level, before the increase.

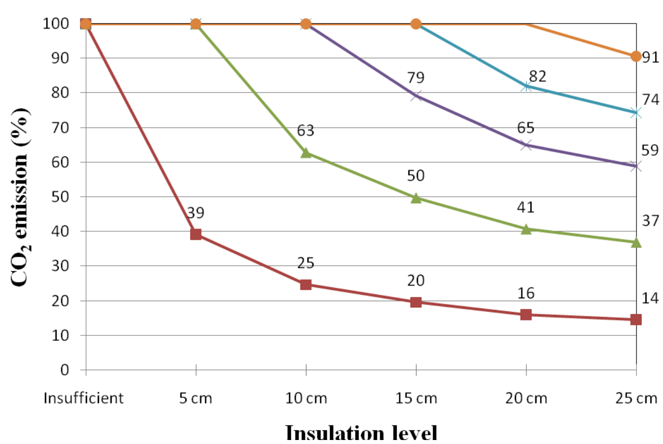


Fig. 11: CO_2 reduction, regarding the initial insulation level

CONCLUSIONS

In recent years, Croatia has tightened up its regulations concerning the energy performance of buildings, as a result of the EU directives and harmonization of legislation with environmental, energy and building performance issues. The engineering EU directive 2002/91/EC, "Energy Performance of Buildings Directive" [EPBD, 2002] is the most important one. With Croatia still lagging behind its Kyoto Protocol requirements and the need of "more emissions" to develop its economy, it is an ideal time for the application of energy efficiency in buildings, following the EPBD directive. This will require the improvement of the thermal insulation level of the existing residential and non-residential buildings and building more energy efficient new buildings. In this paper, clear indications of the advantages of the thermal insulation increase are given. This is only a basic analysis and further steps will be needed to take into account the energy used for space cooling, appliances, lighting and all other possible energy gains. Among the energy sources used, the renewable energy sources should be considered, not only in energy strategy of Croatia but also individually. Measures presented in this paper will reduce non-renewable energy demand, increase the comfort conditions for people and, after some initial investment, become cost effective. The biggest obstacle to achieve presented goals is public awareness.

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