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# Opportunities for implementation of low-energy building standards in Croatia and the resulting benefits

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Environmental Sciences Semester Thesis

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## Summary

The current situation in the Croatian residential sector shows that 80 % of the building stock is not sufficiently insulated. The main energy losses occur through walls, roof and windows and result in an annual heat energy demand of 250 kWh/m<sup>2</sup> and above. To investigate the benefits of low-energy building standards, six renovation options with low-energy standards as target were calculated for an average Croatian one-family house. It could be shown that even low-budget renovations of the house insulation result in substantial energy savings. For example, the investment of little more than one average monthly wage would lead to a reduction of the heat energy demand by approximately 100 kWh/m<sup>2</sup>. If the total Croatian building stock were refurbished in the same manner, the result would be an annual energy saving of 2.8 TWh, which corresponds to 76 % of the annual power production of the biggest Croatian coal-fueled thermal power plant TE Sisak.

## Zusammenfassung

Der aktuelle Zustand des Wohnsektors in Kroatien zeigt, dass mehr als 80 % des Gebäudebestands ungenügend isoliert ist. Die hauptsächlichsten Energieverluste geschehen durch schlecht isolierte Wände, Dächer und Fenster, was zu einem jährlichen Heizenergiebedarf von 250 kWh/m<sup>2</sup> und mehr führt. Um die Möglichkeiten und Vorteile von Niedrigenergie Gebäudestandards zu untersuchen, wurden für ein durchschnittliches kroatisches Einfamilienhaus sechs Sanierungsvarianten mit Niedrigenergie Gebäudestandards als Ziel berechnet. Es konnte gezeigt werden, dass sogar tief budgetierte Renovationen der Hausisolation in bedeutenden Energieeinsparungen resultieren. So führt zum Beispiel die Investition von wenig mehr als einem durchschnittlichen Monatslohn zu einer Reduktion des Heizenergiebedarfes um etwa 100 kWh/m<sup>2</sup>. Würde der gesamte kroatische Gebäudebestand in der gleichen Art und Weise saniert werden, könnten jährlich 2.8 TWh Energie gespart werden, was 76 % der jährlichen Leistung des grössten kroatischen Kohlekraftwerkes TE Sisak entspricht.

## Sazetak

Sadasnje stanje hrvatskog stambenog sektora pokazuje da vise od 80 % stambenog fonda ima nedovoljnu izolaciju. Glavni gubitci energije su prouzrokovani kroz lose izolirane zidove, krovove i prozore, sto rezultira u godisnjoj potrosnji energije za grijanje od 250 kWh/m<sup>2</sup> i vise. Za ispitivanje mogucnosti i prednosti koje donose niskoenergetski gradjevinski standardi, napravljen je proracun za jednu takvu prosjecnu hrvatsku obiteljsku kucu sa sest renovacijskih varianti koje uzimaju niskoenergetske standarde u obzir. Tim proracunima se pokazalo, da cak mala ulaganja u renovaciju vode k velikoj uštedi energije. Npr. investicijom od malo vise od jedne prosjecne mjesecne place za renovaciju jednog takvog objekta, uspije se smanjiti godisnja potrosnja energije za grijanje za otprilike 100 kWh/m<sup>2</sup>. Renovacijom citavog hrvatskog stambenog fonda uštedjelo bi se godisnje 2.8 TWh energije, sto odgovara 76 % snage najvece hrvatske termoelektrane TE Sisak.

# 1 Introduction

According to the International Energy Agency data (IEA 2003), Croatia imports 80 % of its total primary energy supply. An analysis of energy consumption in Croatia by the Energy Institute Hrvoje Pozar (EIHP) showed, that households take the biggest share (32 %) in the final energy consumption. Out of this share, 55 % is spent on low-temperature thermal energy as needed for heating of sanitary water and space heating (EIHP 2001). Looking at the whole residential sector from an economic point of view, it can be seen that the sector shows an annual consumption of energy which amounted up to 806 million USD in 2003 (Desnica and Sesartic 2006).

Before 1997, no government strategy and policy concerning renewable energy sources and energy efficiency existed in Croatia. Also, there were no activities at local level except for declared stances. In 1997 the EIHP initiated national energy programmes for each renewable energy source (RES) and selected areas of energy efficiency (EE) in order to establish an organised approach towards RES and EE at governmental and local level. Of special interest are hereby the programmes SUNEN (Solar Energy Utilization Programme) and KUENbuilding (which aimed to reduce the energy needs in design, constructing and using new buildings).

As could be shown by the feasibility study for the project «Croatian Solar House» (Urli et al. 2002) that is in accordance to the EU directives, it is possible for Croatian households to have a zero-energy-balance for heating and hot water generation by 2030. This goal can be reached by building of new houses in the passive standards, additional insulation of old buildings as well as intensified use of renewables, especially generation of electricity through photovoltaic solar panels.

The Croatian residential sector contains 20 % of housings which were built prior to 1950 and nearly 50 % of the total building stock was constructed prior to 1970 (Mardetko-Skoro et al. 2005). Those buildings have no thermal insulation, and together with the buildings built before 1980 it results in 80 % of the current building stock in Croatia having insufficient insulation (Borković et al. 2005).

The first technical norms on heat insulation of buildings (SL 1970) in Croatia have been enacted in 1970. The next step followed in 1980 with the norm (DZN 1987) on heating technology for buildings, which was expanded and republished in 1987. This new norm also defined the calculation methods for the heat energy demands and energy transmission coefficients. Unfortunately, not all buildings held strictly to these norms which resulted in a certain amount of them being built either to no norms at all or according to the older ones (Mardetko-Skoro et al. 2005).

Taking this into account, as well as the fact that the current laws were obsolete and Croatia's pending accession to the European Union, last year the Croatian government issued a new normative on energy standards for buildings (NN 2005). This new norm is in accord with the European directive on the energy performance of buildings (EC 2002) as well as EN 832.

Despite its big potential, the energy saving generated by renovation of old building stock has not yet been sufficiently analysed for Croatia. More emphasis was made on the benefits of buildings that are conforming to the newest energy standards. However, it is to be expected that the trend of constructing new buildings will level down in the future and consequently the refurbishment of old buildings will gain in importance.

The purpose of this semester thesis is to investigate the reduction potential in the old building stock of the Croatian residential sector with respect to energy consumption in order to

promote a sustainable development. First, by using an exemplary model building, the current situation of the old building stock is analysed and the approximative energy consumption of a building for the climatic conditions of Croatia is determined. Following the calculation of the initial situation, different renovation options with low-energy standards as targets were defined and the calculations repeated for these new settings.

## 2 Method

### 2.1 Proceeding

First, a model of an average one-family house as it is common in Croatia has been designed for the calculation purposes. Then the calculations were administered using the *CASAnova* software. Following the calculation of the initial situation with data from the current old building stock in Croatia, different renovation options with low-energy standards as targets were defined and the calculations repeated for these new settings.

The target values for the renovation options were set according to the Swiss SIA 380/1 norm and the Swiss Minergie and Minergie-P norms. The SIA 380/1 standard defines a target value for the allowed heat demand (depending on the ratio of building envelope and energy reference area) and the rules to calculate the demand for different buildings. Minergie<sup>1</sup> is a quality label for new and refurbished buildings with low-energy demand. Minergie-P is an advanced Minergie standard for passive houses, which is widely comparable to the German Passive House<sup>2</sup> standard.

### 2.2 The Model Building

To perform the calculations, a model of an average one-family house as it is common in Croatia has been designed with AutoCAD<sup>3</sup> (for detailed construction plans see Annex I). The house designed for a four person household has five rooms (one living room, four bedrooms), a kitchen combined with a dining room, a bathroom on the first floor and a toilet on the groundfloor. The attic and cellar are not heated. Some key figures of the model building are shown in Table 1.

**Table 1: Model building data.**

Item	Dimension
Energy reference area [m <sup>2</sup> ]	172.0
Heated floor area [m <sup>2</sup> ]	137.6
House air volume [m <sup>3</sup> ]	371.5
Total volume [m <sup>3</sup> ]	464.4
Width / length / storey height [m]	8.6 / 10.0 / 2.7
West façade / south façade [m <sup>2</sup> ]	46.4 / 54.0
Total window area [m <sup>2</sup> ]	30.0
Glazing area of all windows [m <sup>2</sup> ]	22.5
Fraction of frame (7 cm wide) [%]	25
Shading [%]	20
Roof inclination [degrees]	30
Roof ridge orientation	East-west

The storey height with its 2.7 m is higher than the central European average, however very common in Croatia. Generally Croatian houses have rather high rooms which allow the warm air to float up during the hot summer months. The disadvantage of this construction style is that the heat energy demand in winter is higher.

<sup>1</sup> See <http://www.minergie.com/> for details.

<sup>2</sup> See <http://www.passivhaus-institut.de/> for details.

<sup>3</sup> AutoCAD is a software for 2D-/3D computer aided design (CAD) developed by Autodesk.

## 2.3 CASAnova software

The calculations were done with the programme *CASAnova*, an educational software for calculating the heating and cooling energy demand as well as the temperature behaviour in buildings. The programme is freely available for educational purposes by the Group for Building Physics & Solar Energy in the Department of Physics at the University of Siegen.<sup>4</sup> It can be used to show the relations between building geometry, orientation, thermal insulation, glazing, solar heat gains, heating demand, heating and primary energy as well as overheating in summer.

The heating demand calculation is based on the European norm EN 832 which is also valid and used in Croatia. *CASAnova* uses building shapes of rectangular form for which in a monthly balance transmission and ventilation losses as well as solar and internal gains are calculated. Therefore it was suitable to show the results as calculated on the model building of a simple one-family house such as being common in Croatia. In addition to that, *CASAnova* also contains climate-data for Zagreb in its programme structure, which was another reason to choose it for the calculations.

To determine the number of hours during which a building is overheated, *CASAnova* uses a single-zone dynamical thermal model. Based on hourly data of the outside temperature and the solar heat gains through windows and walls, *CASAnova* calculates the usable solar heat gain as well as the transmission and ventilation losses of this zone. Together with the internal gains the balance of energy for an effective thermal mass is determined (i.e. energy losses and gains for the room-air including the heat which is stored up in an active part of the wall). According to the amount and the sign of this balance zone temperatures change with time. Finally, the number of hours is counted for which room-air temperatures exceed a comfort temperature limit given by the user.

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<sup>4</sup> Download from [http://nesal.uni-siegen.de/softlab/download/CASAnova\\_Setup.exe](http://nesal.uni-siegen.de/softlab/download/CASAnova_Setup.exe)

## 3 Results – Heat Demand Reduction for Several Renovation Options

### 3.1 Before Renovation – The Initial Situation

For the initial situation it was assumed that the house has been built before the 1970ies when the first technical norms on heat insulation of buildings (SL 1970) have been enacted. According to a recent publication (Mardetko-Skoro et al. 2005) buildings older than 50 years show an average annual consumption of 250 kWh/m<sup>2</sup> and more while at the same time they make for 20 % of all housings. Houses older than 35 years make up 50 % of the Croatian building stock and use 230 kWh/m<sup>2</sup> and up. This building stock, together with buildings constructed prior to the 1990ies has a notable impact on the Croatian energy consumption, since even after the enacting of new laws (DZN 1987) they have not always been strictly followed.

#### 3.1.1 Windows

While designing the model building it has been taken care to have more windows on the southern façade and less on the north, as it is common for Croatian architecture. The window areas on the respective directions are as shown in Table 2.

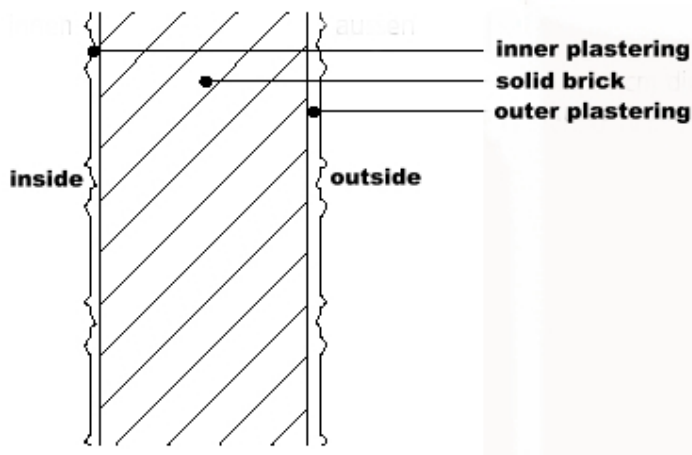
**Table 2: Window areas in percent and m<sup>2</sup> at different orientations.**

<b>Orientation</b>	<b>Fraction of wall [%]</b>	<b>Window area [m<sup>2</sup>]</b>
North	4.6	2.5
South	23.0	12.4
East	13.2	6.1
West	18.6	8.6

For the initial situation windows with double glazing but without heat-protection have been assumed. Double glazed windows are common even in older Croatian buildings, however they do not have any heat-protection. Thus the U-value (rate of heat loss through a surface) of the glassing is as high as 3.0 W/(m<sup>2</sup>K), the one of the wooden frames is 2.8 W/(m<sup>2</sup>K) and the g-value (total energy admission value) 0.8.

#### 3.1.2 Insulation

Both the interior and exterior walls have a heavy construction (bricks) with an effective heat capacity of 46.7 Wh/m<sup>3</sup>K. As already described with the windows, the U-value of the walls has been set to 1.2 W/(m<sup>2</sup>K) according to (Mardetko-Skoro et al. 2005). This corresponds to a solid brick wall without insulation as can be seen in Figure 1 on the following page.



**Figure 1: Initial situation. Solid brick wall without insulation. Modified from (Marti 2001).**

The first floor towards the non-insulated roof has an U-value of  $1.2 \text{ W}/(\text{m}^2\text{K})$  and the ground floor towards the non-heated cellar without insulation an U-value of  $1.0 \text{ W}/(\text{m}^2\text{K})$ . The door's U-value is  $2.9 \text{ W}/(\text{m}^2\text{K})$ .

The house has no air conditioning system. Since an old-fashioned building has a rather low impermeability, the air exchange rate of normal ventilation is  $1.10 \text{ l/h}$ . Indoor temperature has been set to  $20^\circ\text{C}$  and overheating occurs when the temperature rises above  $27^\circ\text{C}$ . The internal gains which stem from a four person household and average household appliances amount up to  $44 \text{ kWh}/\text{m}^2\text{a}$  i.e.  $5 \text{ W}/\text{m}^2$  according to the EN 832 and SIA norm 380.101 (SIA 1999). Since the SIA norm has been based upon the European norm EN 832 which is also respected by Croatian norms, and people and appliances generate the same amount of heat everywhere on the world, the internal gains were not calculated from scratch but extracted from already existent normative values.

### 3.1.3 Energy

All the calculations have been done for the location of Zagreb, Croatia,  $45^\circ 49' \text{N}$   $15^\circ 59' \text{E}$ . Zagreb has an annual mean temperature of  $10.6^\circ\text{C}$ , with a maximal  $20.7^\circ\text{C}$  and minimal  $0.1^\circ\text{C}$  as monthly mean values. It belongs to the building zone II according to the technical norms on heat energy conservation (NN 2005).

Natural gas is the most common energy source in Croatia for both heating and cooking since it is also much cheaper than oil fuel and electricity. Therefore the heating system of the model building has been defined as a condensing boiler, with both boiler and distribution being inside the thermal zone. The heat transfer occurs through radiators (underfloor heating has slowly started to replace the radiators only recently in new buildings) with a system temperature of  $70/55^\circ\text{C}$ .

These features and the previously mentioned features of the model building result in a heat energy demand of  $271.5 \text{ kWh}/\text{m}^2\text{a}$  and a primary energy demand for natural gas of  $283.5 \text{ kWh}/\text{m}^2\text{a}$ . The final energy demand of the household amounts to  $3751 \text{ m}^3/\text{a}$  of natural gas.

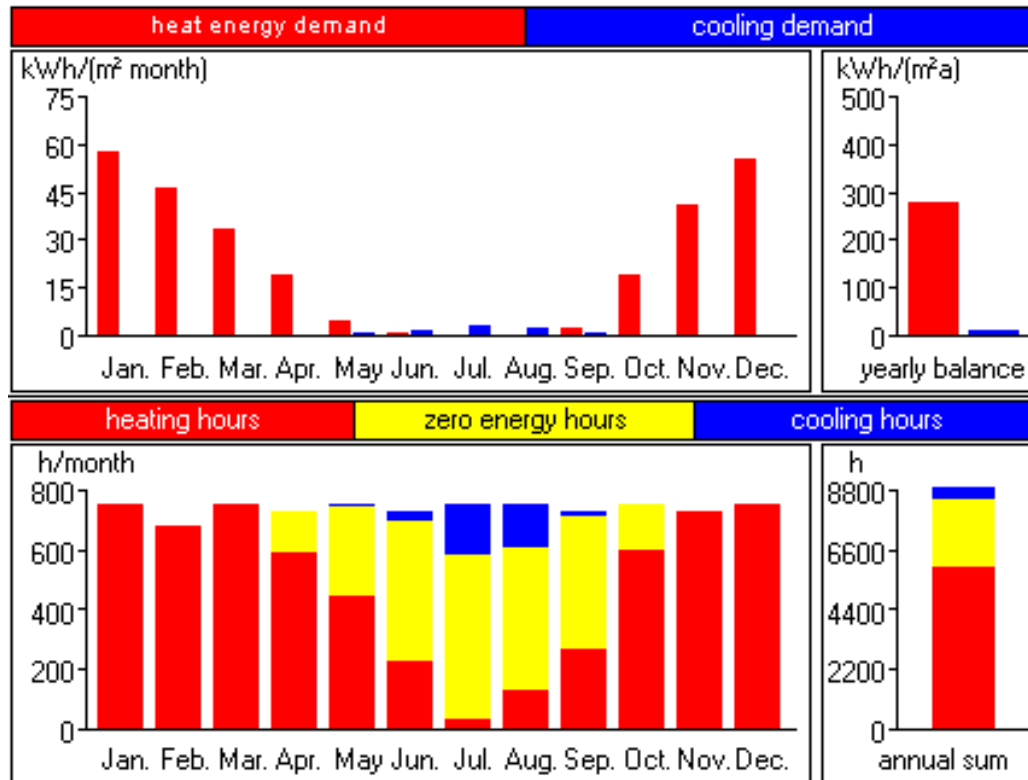


Figure 2: Yearly overview of the heat energy demand, cooling demand, heating hours and zero energy hours, as calculated for the model building.

**yearly balance:**

	absolute in kWh/a	specific in kWh/(m <sup>2</sup> a)
transmission losses:	38072	276.7
ventilation losses:	12085	87.8
usable solar gains:	8382	60.9
useable internal gains:	4412	32.1
heat energy demand:	37363	271.5

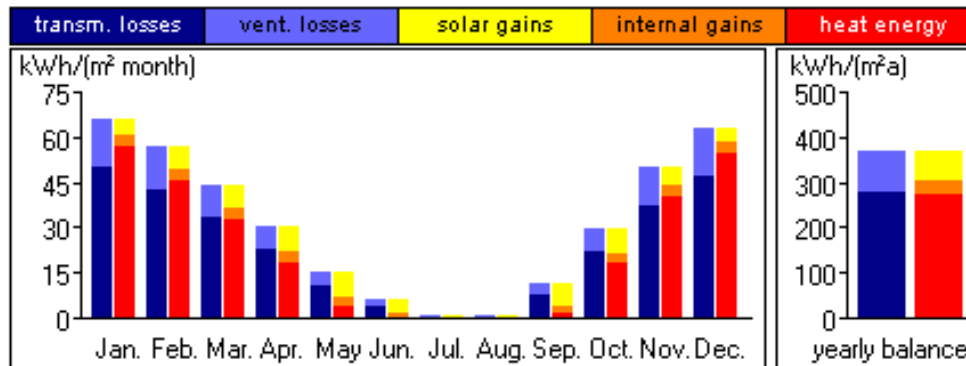
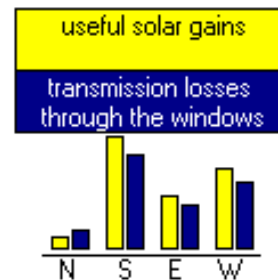


Figure 3: Yearly balance of transmission and ventilation losses, usable solar and internal gains, and heat energy demand for the model building.

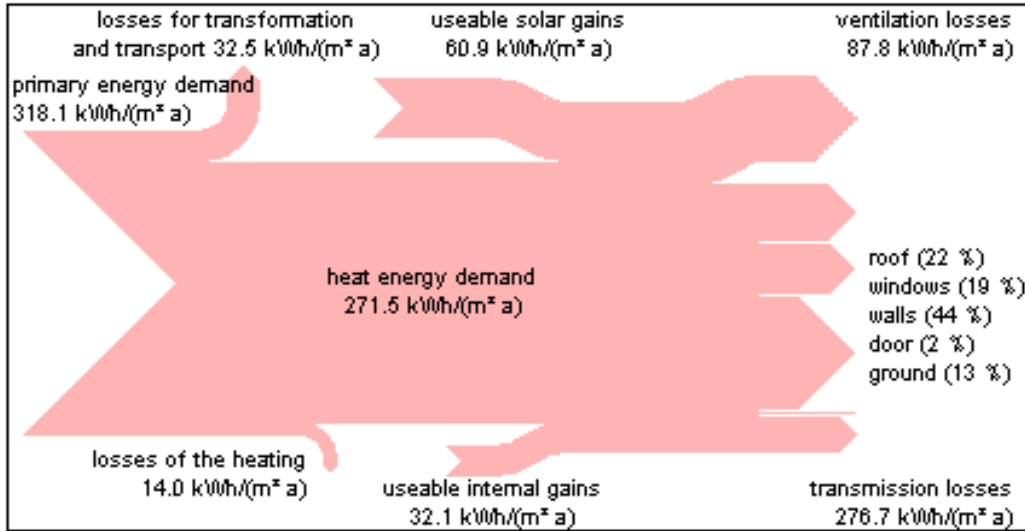


Figure 4: Energy flow (Sankey) diagram for heating.

As can be seen from the results in Figures 2 and 3, the model house correctly reflects the current situation of old Croatian buildings showing a high heat energy demand of 37363 kWh/a i.e. 271.5 kWh/m<sup>2</sup>a. Due to bad insulation which for example would let the indoor temperatures drop down to below  $-5^{\circ}\text{C}$ , the following construction leads to 279 effective heating days.

According to Figure 4, most heat is lost through walls (44 %), roof (22 %) and windows (19 %), which are offering the biggest potential for a renovation that would lead to energy savings.

## 3.2 Renovation Options

All renovation options were calculated using data for materials that are easily available in Croatia. A listing of companies whose products (insulation, windows, heating systems) were chosen, can be seen in Annex III.

### 3.2.1 Standard Options

According to (Matic 1988) the economically viable U-values for construction parts in Croatia during the late 80ies were in the same range as those described by the Swiss SIA 380/1 norm. Therefore the limit values of the SIA norm were set as the goal for the standard renovation options. To help determine the thickness of the stone wool insulation, the U-value and construction parts catalogue for refurbishments as offered by the Swiss Federal Office of Energy (Marti 2001) has been used.

In the first option only the windows were changed, in the second option the house walls get a better insulation, while the third renovation option is a combination of the first two. The fourth is a version of the third only with better windows. The other properties of the building have not been changed. The detailed calculations can be viewed in Annex II.

**Table 3: Renovation options 1 to 4. Improvement of U-values and reduction of the heat energy demand, through additional insulation (Tervol stone wool) and better windows.**

	U-value [W/(m <sup>2</sup> K)] improvement		Heat energy demand		Insulation with $\lambda = 0.40$ W/mK
	from	to	kWh/m <sup>2</sup>	%	
<b>Initial Situation</b>			271.5	100%	
<b>Option 1</b>					
New windows	$U_g = 3.0$	$U_g = 1.2$	<b>258</b>	<b>95</b>	
<b>Option 2</b>					
Cellar insulation	$U = 1.0$	$U = 0.4$	<b>121</b>	<b>44</b>	6 cm Tervol
Facade insulation	$U = 1.2$	$U = 0.3$			10 cm Tervol
Loft insulation	$U = 1.2$	$U = 0.3$			10 cm Tervol
<b>Option 3</b>					
Cellar insulation	$U = 1.0$	$U = 0.4$	<b>106</b>	<b>39</b>	6 cm Tervol
Facade insulation	$U = 1.2$	$U = 0.3$			10 cm Tervol
Loft insulation	$U = 1.2$	$U = 0.3$			10 cm Tervol
New windows	$U_g = 3.0$	$U_g = 1.2$			
<b>Option 4</b>					
Cellar insulation	$U = 1.0$	$U = 0.20$	<b>84</b>	<b>31</b>	16 cm Tervol
Facade insulation	$U = 1.2$	$U = 0.21$			16 cm Tervol
Loft insulation	$U = 1.2$	$U = 0.17$			20 cm Tervol
New windows	$U_g = 3.0$	$U_g = 1.0$			

As can be seen from the table above the exchange of windows alone, as being done in the first option, did not bring any substantial benefits at first sight. But the heat energy demand reduction by 5 % corresponds to 13.5 kWh/m<sup>2</sup> which alone would be enough to meet the heat energy demand of a passivehouse. Unfortunately, 44 % of the energy still get lost through the non-insulated walls which results in a heat energy demand of 258 kWh/m<sup>2</sup>.

In the second option, only the outer walls and floors toward the cellar and roof have been insulated, the windows were left the same. However, this time the heat energy demand could be reduced by 56 % to a mere 121 kWh/m<sup>2</sup>. The costs to achieve that by using Tervol stone wool would amount to about 700 EUR, which corresponds to 1.2 months worth of an average Croatian salary (4376 HKN in 2005 according to most recent statistical data (DZS 2006)).

The third option being a combination of the first two renovation options, lowers the heat energy demand to 109 kWh/m<sup>2</sup> which represents an improvement by 256 % in relation to the initial situation. This option accords to the SIA 380/1 limit values.

The fourth option is an improved version of the third one and corresponds to the SIA 380/1 target values. It brings a reduction of the heat energy demand by 69 %, which results in 84 kWh/m<sup>2</sup>.

Those refurbishment calculations show that already small changes and improvements in insulation can bring notable energy savings. For example, by saving 100 kWh/m<sup>2</sup> of energy per year, one would be saving 1660 litres of heating oil, respectively 1857 m<sup>3</sup> of natural gas, for this model building. Taking into account the current price of heating oil (INA 2006) with 4.82 HKN/l, the result would be an annual saving of 8000 HKN, which corresponds to 1.8 months worth of an average salary. The conclusion is, that more money goes lost for heating of a badly insulated house, than would be needed for investment in improved insulation. Even if the same calculation is done for the cheaper natural gas (~2 HKN/m<sup>3</sup>) (HERA 2004), the annual saving would still amount to 3715 HKN, which are still 80% of the monthly salary.

### 3.2.2 Renovation Goal Minergie and Minergie-P

By setting the standards even higher towards Minergie and Minergie-P (Swiss passive house standard), systems of ventilation with heat recovery will need to be installed additionally to even better insulation of walls and windows. Table 4 shows the calculation results for the 5<sup>th</sup> renovation option, where the target was to reach the Minergie standard.

**Table 4: Renovation option 5. Goal Minergie. Improvement of U-values and reduction of the heat energy demand, through additional insulation (Tervol stone wool), better windows and use of ventilation with heat recovery.**

	U-value [W/(m <sup>2</sup> K)] improvement		Heat energy demand		Insulation with $\lambda = 0.40$ W/mK
	from	to	kWh/m <sup>2</sup>	%	
<b>Initial Situation</b>			271.5	100%	
<b>Option 5</b>					
Cellar insulation	U = 1.0	U = 0.2			16 cm Tervol
Facade insulation	U = 1.2	U = 0.21			16 cm Tervol
Loft insulation	U = 1.2	U = 0.17			20 cm Tervol
New windows	U <sub>g</sub> = 3.0	U <sub>g</sub> = 1.0			
Ventilation with heat recovery	0%	80%			
			<b>24</b>	<b>9</b>	

The renovation option above represents an immense energy saving. To illustrate this further, one can look at the following comparative calculation.

The floor area of residential buildings in Croatia represented 2 840 236 m<sup>2</sup> in 2005 (DZS 2006). If an approximate 200 kWh/m<sup>2</sup> would be saved through refurbishment of each building, this would result in 5.680 TWh, respectively 20.448 PJ, of heat energy saving per year. With the total national energy import in 2004 being 318.12 PJ according to recent statistical data (DZS 2006), such refurbishment would result in a reduction of imported energy by 6.4%. If calculated for an assumed oil-only heating, Croatia would lower its annual CO<sub>2</sub> emissions by 1.5 Mio tonnes, respectively 1.2 Mio tonnes when calculated for natural gas as the sole heating energy source. The same assumption would result in the immense financial saving of 1.23 Mrd. HKN (approx. 169.6 Mio. EUR) per year due to reduced gas consumption, respectively 2.64 Mrd. HKN (approx. 363.8 Mio. EUR) per year if calculated for heating oil.

The heat energy demand for the 6<sup>th</sup> option which has the Swiss passivehouse standard as goal, seems to be extremely small with only 6 kWh/m<sup>2</sup>. But since the model object is a very compact and rather small building with a surface/volume ratio of 0.8, the results as shown in Table 5 are viable.

**Table 5: Renovation option 6. Goal Minergie-P. Improvement of U-values and reduction of the heat energy demand, through additional insulation (Tervol stone wool), better windows and use of ventilation with heat recovery.**

	U-value [W/(m <sup>2</sup> K)] improvement		Heat energy demand		Insulation with $\lambda = 0.35$ W/mK
	from	to	kWh/m <sup>2</sup>	%	
<b>Initial Situation</b>			271.5	100%	
<b>Option 6</b>					
Cellar insulation	U = 1.0	U = 0.10			30 cm Tervol
Facade insulation	U = 1.2	U = 0.11			30 cm Tervol
Loft insulation	U = 1.2	U = 0.11			30 cm Tervol
New windows	U <sub>g</sub> = 3.0	U <sub>g</sub> = 0.5			
Ventilation with heat recovery	0%	80%			
			<b>6</b>	<b>2</b>	

These six renovation options had only the reduction of the heat energy demand as their goal. To really achieve low-energy standards and to reduce emissions its also important to lower the primary energy<sup>5</sup> demand. This could be accomplished by installing a sole-water heat pump to generate warm water for heating and the household. The average temperature gradient in the north of Croatia is with 0.049 °C/m considerably above the world average (0.03 °C/m) (Jelić et al. 2000). To assist the water heating solar thermal collectors could be installed. By using geothermal and solar energy as renewable energy sources, the primary energy demand for non-renewables could be lowered.

<sup>5</sup> Primary energy is the energy embodied in natural resources that has not undergone any anthropogenic conversions or transformations.

## 4 Discussion and Conclusion

Back in the 1970ies, when the first building norms were enacted in Croatia, the country had an impressive list of scientific research programmes running in the field of renewable energies (mainly solar). About 40 000 m<sup>2</sup> solar thermal collectors for hot water generation were installed, often also combined with heat pumps. Additionally, local solar technology companies were successfully developing new technologies. (Urli et al. 2002)

However, due to political and economical circumstances the legal norms were not able to hold pace with technological development and the progress in building construction came to a stall. Today, the situation of the residential sector is not satisfactory as the households have the biggest share (32 %) in the Croatian energy consumption.

This is also reflected in the fact, that while the climate conditions of Zürich and Zagreb are very similar, the U-values for building walls in Switzerland need to be at least 0.3 W/(m<sup>2</sup>K) according to the SIA norms, while in Croatia they are only 0.8 W/(m<sup>2</sup>K) according to the most recent technical norms which have been enacted in 2005. This is a huge difference. The maximal Croatian U-value is over two and a half times worse than the Swiss one, despite the comparable climate, which results in also a two and a half times bigger energy loss.

The current state of the residential sector and the corresponding norms is harmful to Croatia's reputation, especially now that it has become an EU Candidate Country. Another proof of the overtly slow system of implementing measures concerning energy problems is the fact, that Croatia signed the Kyoto protocol in 1999 but as of today, failed to ratify it (UNFCCC 2006).

The situation is also aggravated due to many construction material and building technology manufacturers at the Croatian market, that offer lower quality products for Croatia than for the rest of Europe. On their Croatian websites and product catalogues they promote the older inefficient technologies as well as those using non-renewables. It seems as though Croatia is a market for slow selling articles, which are no longer attractive for the western European countries. For example, fuel oil radiators are promoted in Croatia while the technology for low-energy standards and use of renewable energy sources is seldom promoted or not at all. Although the better technology is easily available in Croatia as well, it is rarely advertised. That leads to customers buying the older energy consuming products and materials, which is also a setback for any efforts concerning sustainable energy policies.

Nevertheless, the previously defined renovation options show, that it is possible to save a high percentage of the heat energy demand through simple insulation measures. Moreover, the investment of little more than one average monthly wage seem justifiable for the resulting energetic gains. Even the decrease by 100 kWh/m<sup>2</sup> of heat energy demand for each building in Croatia would result in an energy saving comparable to 76 % of the annual power production of the biggest Croatian coal-fueled thermal power plant TE Sisak.

Introducing low-energy building standards would have many benefits for the Croatian society and government: a more efficient energy use and decrease in the total energy consumption, a diminished dependency on energy imports, reduction of CO<sub>2</sub> emissions and better compliance with the Kyoto protocol. The house owners on the other hand would profit from a decrease of heating bills, lower maintenance costs due to better quality of the building envelope, and finally a better comfort of living.

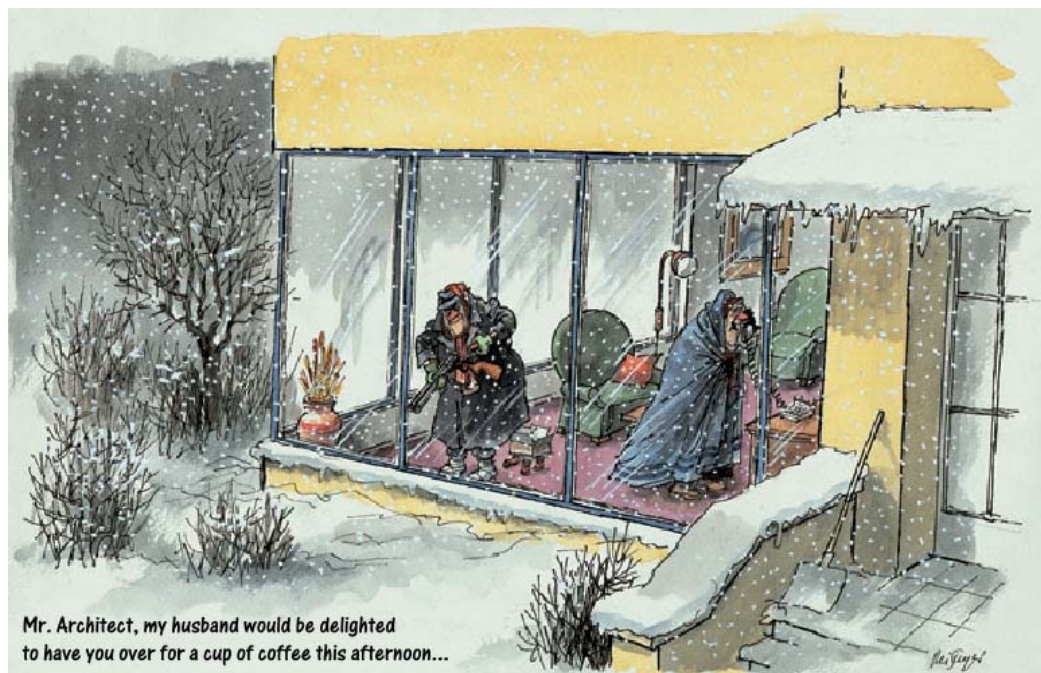
The increase of energy efficiency and a heightened use of renewable energy sources should not be regarded as a stand-alone goal, but an instrument in accomplishing economic and social targets, which would make the country more competitive, open new job opportunities

and heighten the prosperity. It is important to note that to be more efficient means to produce, live and work under the same or even better conditions, but with a lower energy consumption. When it comes to the buildings, all EU experiences show that energy efficient buildings have a by far more higher quality of living and lower maintenance costs.

Also, the results obtained in this paper show the objective feasibility (technological as well as economical) of elevating old buildings to a low-energy standard through refurbishment using resources available in Croatia. This makes low-energy building labels as a voluntary measure very interesting, which would lead to the design of a Croatian low-energy building label as the next logical step.

Such a label should be supported by the Croatian government through subsidies for citizens who decide to refurbish their house (or build a new one) according to the label's standard. The label could be defined similar to the Swiss Minergie standard, with the heat energy demand for new buildings being a maximum 80 % of the limit value of the most recent standard building norm, respectively 120 % of the limit value for refurbishments. Also, the additional investments should exceed the usual building costs by no more than 10 %, in order to be more readily accepted. These definitions are of course only viable for Switzerland (Fraefel 2003). Further research should define how they could be adapted to Croatian circumstances.

For the time being, it is advisable that through better information campaigns and subsidy grants, Croatian policy makers should support the citizens to elevate their houses on a higher low-energy standard, as far as the current legal and financial situation allows. As could be shown, also small steps can result in notable benefits, which leaves a hope that scenes like the one in the picture below will become a thing of the past.



**Figure 5: How not to insulate a building (by Otto Reisinger)**

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## Annex I – Building Plan

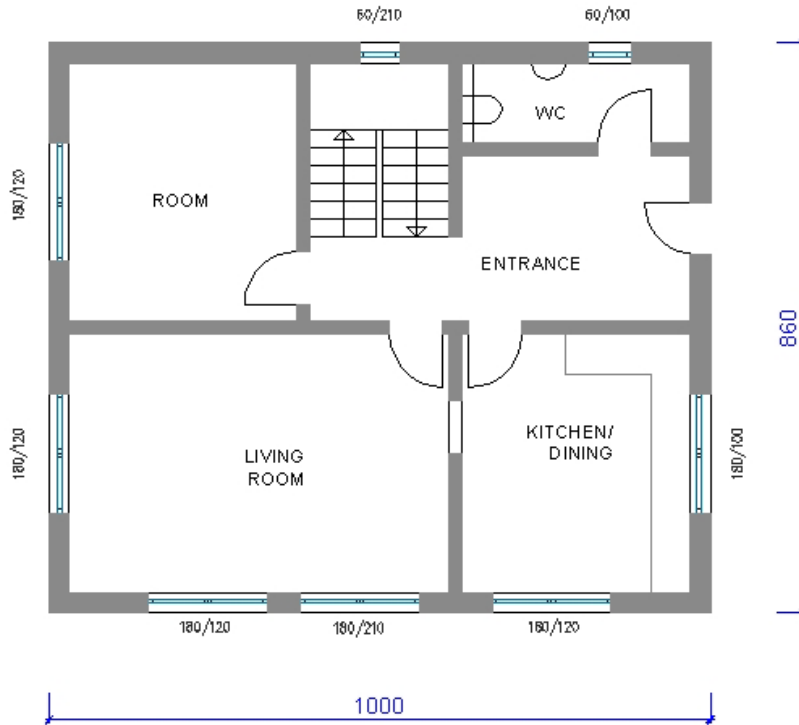


Figure a: Ground Floor

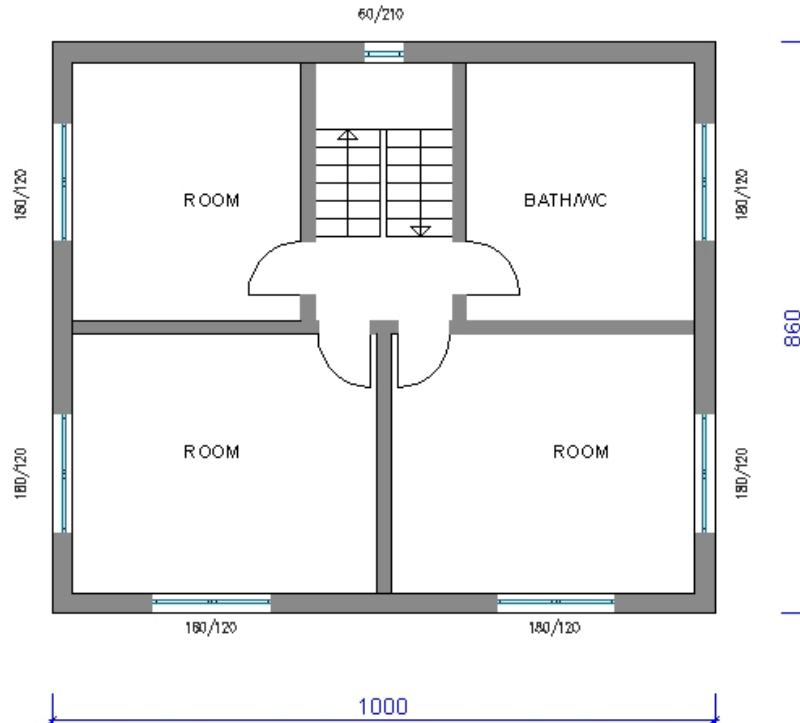
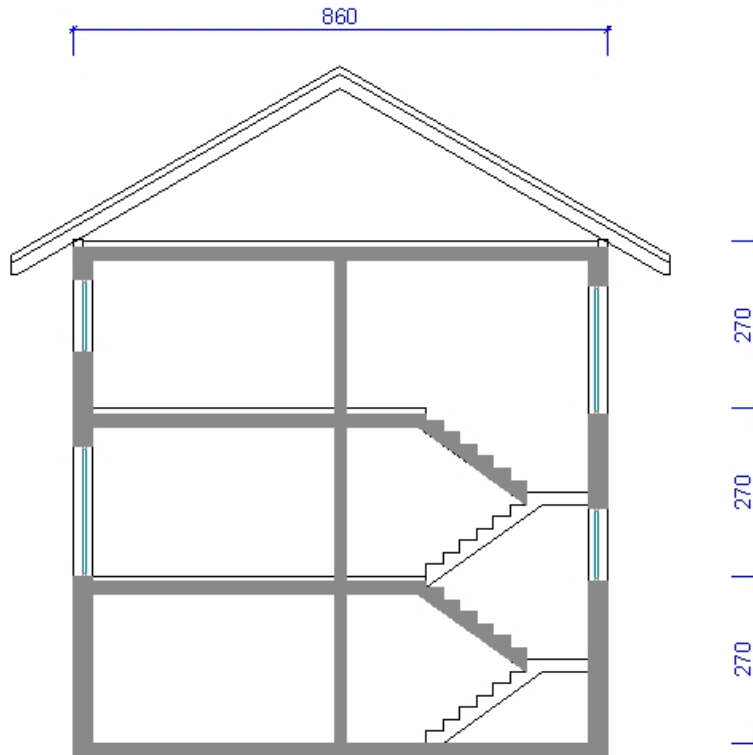
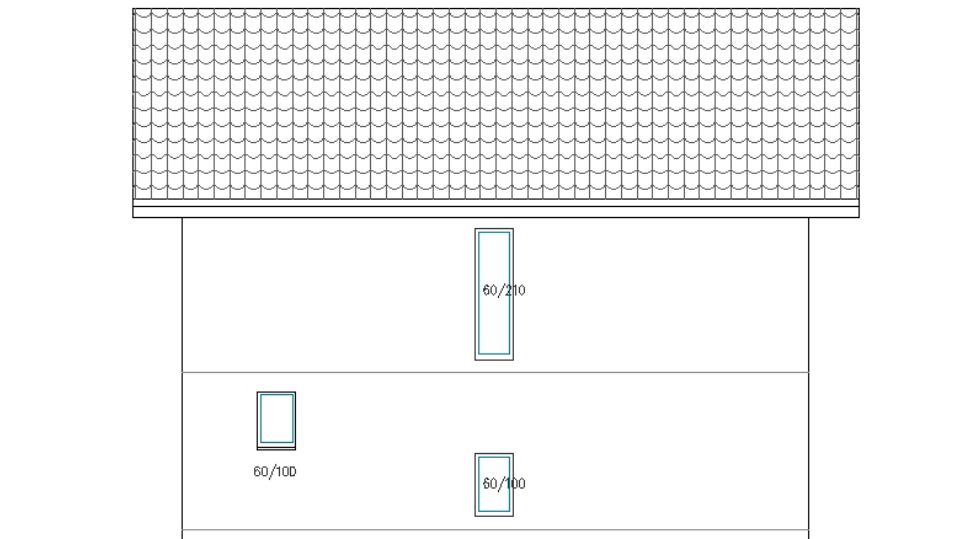


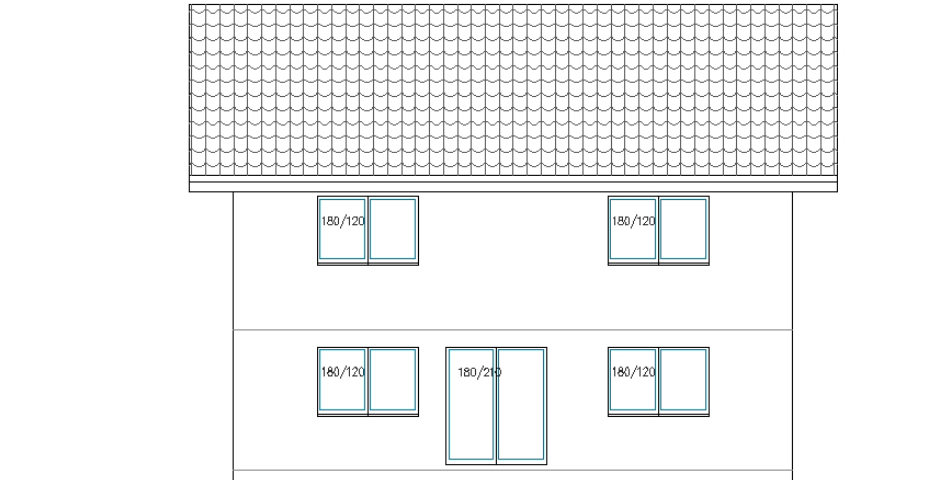
Figure b: First Floor



**Figure c: Cross Section**



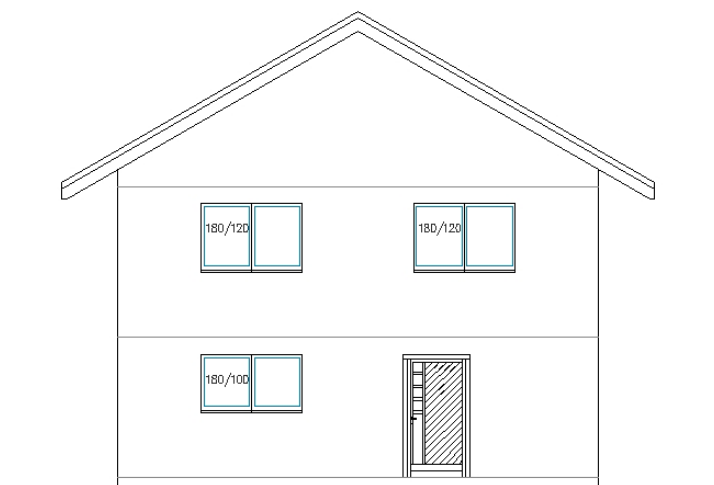
**Figure d: North Façade**



**Figure e: South Façade**



**Figure f: West Façade**



**Figure g: East Façade**

## Annex II – Calculation Datasheets

### Initial Situation of the Model Building

#### *Input: Building data*

#### Geometry:

Length of north and south facade:	10.0 m
Length of west and east facade:	8.6 m
Height (without roof):	5.4 m
Number of floors:	2
Deviation from south direction (east positiv):	0.0 °
Ground area:	86.0 m <sup>2</sup>
Useful area:	137.6 m <sup>2</sup>
Volume total:	464.4 m <sup>3</sup>
Air volume:	371.5 m <sup>3</sup>
Facade north resp. south:	54.0 m <sup>2</sup>
Facade east resp. west:	46.4 m <sup>2</sup>
Surface-to-volume value:	0.8 1/m

#### Insulation:

U values of the walls:	
north:	1.20 W/(m <sup>2</sup> K)
south:	1.20 W/(m <sup>2</sup> K)
east:	1.20 W/(m <sup>2</sup> K)
west:	1.20 W/(m <sup>2</sup> K)
Upper floor:	
Towards:	outside or non-insulated roof
U value:	1.20 W/(m <sup>2</sup> K)
Lower floor:	
Towards:	non-heated cellar (without insulation)
U value:	1.00 W/(m <sup>2</sup> K)
Door (north facade):	
Area:	2.6 m <sup>2</sup>
U value:	2.90 W/(m <sup>2</sup> K)

#### Building:

Interior temperature:	20.0 °C
Limit of overheating:	27.0 °C
Ventilation:	
Air change rate:	1.10 1/h
Heat recovery:	0 %
Internal gains:	44.0 kWh/(m <sup>2</sup> a)
Kind of indoor walls:	heavy construction
Kind of outdoor walls:	heavy construction

#### Climate:

Climate station:	Zagreb (Croatia)
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## Windows:

North:	
Windows area:	2.7 m <sup>2</sup>
Fraction of windows area at the facade:	5.0 %
Kind of windows:	double glazing
U value glazing:	3.00 W/(m <sup>2</sup> K)
U value frame:	2.80 W/(m <sup>2</sup> K)
g value glazing:	0.80
Fraction of frame:	25.0 %
Shading:	20.0 %
South:	
Window area:	12.4 m <sup>2</sup>
Fraction of windows area at the facade:	23.0 %
Kind of windows:	double glazing
U value glazing:	3.00 W/(m <sup>2</sup> K)
U value frame:	2.80 W/(m <sup>2</sup> K)
g value glazing:	0.80
Fraction of frame:	25.0 %
Shading:	20.0 %
East:	
Window area:	6.0 m <sup>2</sup>
Fraction of windows area at the facade:	13.0 %
Kind of windows:	double glazing
U value glazing:	3.00 W/(m <sup>2</sup> K)
U value frame:	2.80 W/(m <sup>2</sup> K)
g value glazing:	0.80
Fraction of frame:	25.0 %
Shading:	20.0 %
West:	
Window area:	8.8 m <sup>2</sup>
Fraction of windows area at the facade:	19.0 %
Kind of windows:	double glazing
U value glazing:	3.00 W/(m <sup>2</sup> K)
U value frame:	2.80 W/(m <sup>2</sup> K)
g value glazing:	0.80
Fraction of frame:	25.0 %
Shading:	20.0 %

## Energy:

Heating system:	condensing boiler, boiler and distribution inside the thermal zone
Heat transfer / system temperature:	radiators (outside walls), thermostatic valves (layout temperature: 1K), system temperature: 70/55°C
Source of energy:	natural gas

## *Output: Overview*

### Heat energy and cooling demand:

	Heat energy demand in kWh/m <sup>2</sup>	Cooling demand in kWh/m <sup>2</sup>
January	56.5	0.0
February	45.6	0.0
March	32.3	0.0
April	18.4	0.0
May	4.2	0.1
June	0.2	0.5
July	0.0	1.9
August	0.0	1.7
September	1.6	0.1
October	17.9	0.0
November	40.2	0.0
December	54.5	0.0
Yearly sum	271.5	4.3

### Heating and cooling hours:

	Heating hours in hours	Zero energy hours in hours	Cooling hours in hours
January	744	0	0
February	672	0	0
March	744	0	0
April	579	141	0
May	438	296	10
June	218	466	36
July	28	546	170
August	123	477	144
September	258	447	15
October	590	154	0
November	720	0	0
December	744	0	0
Sum (in hours)	5858	2527	375
Sum (in %)	66.9	28.8	4.3

## *Output: Climate and building data*

### Climate data:

	Mean temperature in °C	Maximum temperature in °C	Minimum temperature in °C
January	0.1	15.5	-14.3
February	1.2	15.2	-19.7
March	6.8	23.8	-5.4
April	10.6	28.0	-1.1
May	15.6	29.8	0.5
June	18.4	31.5	7.1
July	20.7	33.6	7.0
August	20.1	33.2	7.4
September	16.8	30.0	-0.8
October	11.2	25.2	-2.5
November	4.5	16.5	-12.0
December	1.2	14.0	-10.4
Yearly mean	10.6		

### Building data:

Mean U value:	1.31 W/(m <sup>2</sup> K)
Specific transmission losses:	487.1 W/K
Specific ventilation losses:	146.4 W/K
Sum specific losses:	633.6 W/K
Thermal inertia:	34.2 hours
Maximum heating load:	23.6 kW
Maximum specific heating load:	171.6 W
Maximum cooling load:	9.7 kW
Maximum specific cooling load:	70.2 W
Limit temperature for heating:	18.9°C
Effective heating days:	279 Tage

*Output: Heat balance*

Specific (per m<sup>2</sup> useful area):

	Transm. losses in kWh/m <sup>2</sup>	Ventil. losses in kWh/m <sup>2</sup>	Internal Gains in kWh/m <sup>2</sup>	Solar Gains in kWh/m <sup>2</sup>	Usability factor	Heat energy demand in kWh/m <sup>2</sup>
January	49.7	15.8	3.7	5.2	1.00	56.5
February	42.3	13.4	3.4	6.7	1.00	45.6
March	33.1	10.5	3.7	7.5	0.99	32.3
April	22.7	7.2	3.5	8.0	0.97	18.4
May	10.9	3.5	3.0	7.2	0.80	4.2
June	4.0	1.3	1.5	3.5	0.41	0.2
July	0.0	0.0	0.0	0.0	0.00	0.0
August	0.0	0.0	0.0	0.0	0.00	0.0
September	7.8	2.5	2.4	6.4	0.65	1.6
October	22.0	7.0	3.6	7.4	0.97	17.9
November	37.4	11.9	3.6	5.4	1.00	40.2
December	46.9	14.9	3.7	3.6	1.00	54.5
Yearly sum	276.7	87.8	32.1	60.9		271.5

Absolute (total building):

	Transm. losses in kWh	Ventil. losses in kWh <sup>2</sup>	Internal Gains in kWh	Solar Gains in kWh	Usability factor	Heat energy demand in kWh
January	6840	2171	513	718	1.00	7781
February	5818	1847	463	926	1.00	6276
March	4548	1444	509	1032	0.99	4451
April	3117	989	481	1096	0.97	2529
May	1497	475	413	986	0.80	573
June	546	173	203	487	0.41	29
July	0	0	0	0	0.00	0
August	0	0	0	0	0.00	0
September	1075	341	324	875	0.65	217
October	3028	961	497	1024	0.97	2469
November	5144	1633	496	744	1.00	5537
December	6458	2050	514	494	1.00	7501
Yearly sum	38072	12085	4412	8382		37363

*Output: Cooling balance*

Cooling demand and overheating:

	Cooling demand specific in kWh/m <sup>2</sup>	Cooling demand absolute in kWh	Mean overheating in hours/day	Cooling degree hours in Kh
January	0.0	0	0.0	0.0
February	0.0	0	0.0	0.0
March	0.0	0	0.0	0.0
April	0.0	0	0.0	0.0
May	0.1	12	0.3	2.4
June	0.5	63	1.2	22.0
July	1.9	261	5.5	201.1
August	1.7	240	4.6	185.7
September	0.1	13	0.5	3.3
October	0.0	0	0.0	0.0
November	0.0	0	0.0	0.0
December	0.0	0	0.0	0.0
Yearly sum	4.3	590		414.6

*Output: Primary and final energy demand for heating*

Energy demand of the heating system:

Heat:

Heat energy demand:	271.5 kWh/(m <sup>2</sup> a)
Losses of the heat storage:	0.0 kWh/(m <sup>2</sup> a)
Heat losses from the distribution:	2.6 kWh/(m <sup>2</sup> a)
Losses at the transmission to the rooms:	1.1 kWh/(m <sup>2</sup> a)
Expense number of heat generation:	1.03

Final energy demand natural gas:	283.5 kWh/(m <sup>2</sup> a)
Primary energy factor natural gas:	1.1
Primary energy demand natural gas:	311.8 kWh/(m <sup>2</sup> a)

Auxiliary energy (electricity):

Auxiliary energy for heat generation:	0.7 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat storage:	0.0 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat distribution:	1.4 kWh/(m <sup>2</sup> a)

Final energy demand auxiliary energy (electricity):	2.1 kWh/(m <sup>2</sup> a)
Primary energy factor electricity:	3.0
Primary energy demand auxiliary energy (electricity):	6.3 kWh/(m <sup>2</sup> a)

	Final energy demand natural gas in kWh/m <sup>2</sup>	Final energy demand electricity in kWh/m <sup>2</sup>	Final energy demand total in kWh/m <sup>2</sup>	Primary demand natural gas in kWh/m <sup>2</sup>	Primary demand electricity in kWh/m <sup>2</sup>	Primary demand total in kWh/m <sup>2</sup>
January	59.0	0.4	59.5	64.9	1.3	66.2
February	47.6	0.3	48.0	52.4	1.0	53.4
March	33.8	0.2	34.0	37.1	0.7	37.9
April	19.2	0.1	19.3	21.1	0.4	21.5
May	4.3	0.0	4.4	4.8	0.1	4.9
June	0.2	0.0	0.2	0.2	0.0	0.2
July	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0
September	1.6	0.0	1.7	1.8	0.0	1.8
October	18.7	0.1	18.9	20.6	0.4	21.0
November	42.0	0.3	42.3	46.2	0.9	47.1
December	56.9	0.4	57.3	62.6	1.3	63.9
Yearly sum	283.5	2.1	285.6	311.8	6.3	318.1

*Output: Primary and final energy demand for cooling*

Energy demand of the cooling system:

Efficiency factor of the air conditioning: 0.5 kWh cooling/ kWh electricity

energy demand	Cooling demand in kWh/m <sup>2</sup>	Final energy demand for cooling in kWh/m <sup>2</sup>	Primary in kWh/m <sup>2</sup>
January	0.0	0.0	0.0
February	0.0	0.0	0.0
March	0.0	0.0	0.0
April	0.0	0.0	0.0
May	0.1	0.2	0.5
June	0.5	0.9	2.8
July	1.9	3.8	11.4
August	1.7	3.5	10.5
September	0.1	0.2	0.6
October	0.0	0.0	0.0
November	0.0	0.0	0.0
December	0.0	0.0	0.0
Yearly sum	4.3	8.6	25.7

## Standard Renovation Options

### Option 1

*Input: Building data*

#### Windows:

##### North:

Windows area:	2.7 m <sup>2</sup>
Fraction of windows area at the facade:	5.0 %
Kind of windows:	others
U value glazing:	1.20 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.55
Fraction of frame:	25.0 %
Shading:	20.0 %

##### South:

Window area:	12.4 m <sup>2</sup>
Fraction of windows area at the facade:	23.0 %
Kind of windows:	others
U value glazing:	1.20 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.55
Fraction of frame:	25.0 %
Shading:	20.0 %

##### East:

Window area:	6.0 m <sup>2</sup>
Fraction of windows area at the facade:	13.0 %
Kind of windows:	others
U value glazing:	1.20 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.55
Fraction of frame:	25.0 %
Shading:	20.0 %

##### West:

Window area:	8.8 m <sup>2</sup>
Fraction of windows area at the facade:	19.0 %
Kind of windows:	others
U value glazing:	1.20 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.55
Fraction of frame:	25.0 %
Shading:	20.0 %

*Output: Primary and final energy demand for heating*

Energy demand of the heating system:

Heat:

Heat energy demand:	258.0 kWh/(m <sup>2</sup> a)
Losses of the heat storage:	0.0 kWh/(m <sup>2</sup> a)
Heat losses from the distribution:	2.6 kWh/(m <sup>2</sup> a)
Losses at the transmission to the rooms:	1.1 kWh/(m <sup>2</sup> a)
Expense number of heat generation:	1.03

Final energy demand natural gas:	269.6 kWh/(m <sup>2</sup> a)
Primary energy factor natural gas:	1.1
Primary energy demand natural gas:	296.5 kWh/(m <sup>2</sup> a)

Auxiliary energy (electricity):

Auxiliary energy for heat generation:	0.7 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat storage:	0.0 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat distribution:	1.4 kWh/(m <sup>2</sup> a)

Final energy demand auxiliary energy (electricity):	2.1 kWh/(m <sup>2</sup> a)
Primary energy factor electricity:	3.0
Primary energy demand auxiliary energy (electricity):	6.3 kWh/(m <sup>2</sup> a)

**Option 2**

*Input: Building data*

Insulation:

U values of the walls:

north:	0.30 W/(m <sup>2</sup> K)
south:	0.30 W/(m <sup>2</sup> K)
east:	0.30 W/(m <sup>2</sup> K)
west:	0.30 W/(m <sup>2</sup> K)

Upper floor:

Towards:	outside or non-insulated roof
U value:	0.30 W/(m <sup>2</sup> K)

Lower floor:

Towards:	non-heated cellar (without insulation)
U value:	0.40 W/(m <sup>2</sup> K)

Door (north facade):

Area:	2.6 m <sup>2</sup>
U value:	2.90 W/(m <sup>2</sup> K)

*Output: Primary and final energy demand for heating*

Energy demand of the heating system:

Heat:	
Heat energy demand:	120.7 kWh/(m <sup>2</sup> a)
Losses of the heat storage:	0.0 kWh/(m <sup>2</sup> a)
Heat losses from the distribution:	2.6 kWh/(m <sup>2</sup> a)
Losses at the transmission to the rooms:	1.1 kWh/(m <sup>2</sup> a)
Expense number of heat generation:	1.03
Final energy demand natural gas:	128.2 kWh/(m <sup>2</sup> a)
Primary energy factor natural gas:	1.1
Primary energy demand natural gas:	141.0 kWh/(m <sup>2</sup> a)
Auxiliary energy (electricity):	
Auxiliary energy for heat generation:	0.7 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat storage:	0.0 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat distribution:	1.4 kWh/(m <sup>2</sup> a)
Final energy demand auxiliary energy (electricity):	2.1 kWh/(m <sup>2</sup> a)
Primary energy factor electricity:	3.0
Primary energy demand auxiliary energy (electricity):	6.3 kWh/(m <sup>2</sup> a)

**Option 3**

*Input: Building data*

Insulation:

U values of the walls:	
north:	0.30 W/(m <sup>2</sup> K)
south:	0.30 W/(m <sup>2</sup> K)
east:	0.30 W/(m <sup>2</sup> K)
west:	0.30 W/(m <sup>2</sup> K)
Upper floor:	
Towards:	outside or non-insulated roof
U value:	0.30 W/(m <sup>2</sup> K)
Lower floor:	
Towards:	non-heated cellar (without insulation)
U value:	0.40 W/(m <sup>2</sup> K)
Door (north facade):	
Area:	2.6 m <sup>2</sup>
U value:	2.90 W/(m <sup>2</sup> K)

## Windows:

North:	
Windows area:	2.7 m <sup>2</sup>
Fraction of windows area at the facade:	5.0 %
Kind of windows:	others
U value glazing:	1.20 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.55
Fraction of frame:	25.0 %
Shading:	20.0 %
South:	
Window area:	12.4 m <sup>2</sup>
Fraction of windows area at the facade:	23.0 %
Kind of windows:	others
U value glazing:	1.20 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.55
Fraction of frame:	25.0 %
Shading:	20.0 %
East:	
Window area:	6.0 m <sup>2</sup>
Fraction of windows area at the facade:	13.0 %
Kind of windows:	others
U value glazing:	1.20 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.55
Fraction of frame:	25.0 %
Shading:	20.0 %
West:	
Window area:	8.8 m <sup>2</sup>
Fraction of windows area at the facade:	19.0 %
Kind of windows:	others
U value glazing:	1.20 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.55
Fraction of frame:	25.0 %
Shading:	20.0 %

*Output: Primary and final energy demand for heating*

Energy demand of the heating system:

Heat:	
Heat energy demand:	106.0 kWh/(m <sup>2</sup> a)
Losses of the heat storage:	0.0 kWh/(m <sup>2</sup> a)
Heat losses from the distribution:	2.6 kWh/(m <sup>2</sup> a)
Losses at the transmission to the rooms:	1.1 kWh/(m <sup>2</sup> a)
Expense number of heat generation:	1.03
Final energy demand natural gas:	113.0 kWh/(m <sup>2</sup> a)
Primary energy factor natural gas:	1.1
Primary energy demand natural gas:	124.3 kWh/(m <sup>2</sup> a)
Auxiliary energy (electricity):	
Auxiliary energy for heat generation:	0.7 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat storage:	0.0 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat distribution:	1.4 kWh/(m <sup>2</sup> a)
Final energy demand auxiliary energy (electricity):	2.1 kWh/(m <sup>2</sup> a)
Primary energy factor electricity:	3.0
Primary energy demand auxiliary energy (electricity):	6.3 kWh/(m <sup>2</sup> a)

**Option 4**

*Input: Building data*

Insulation:

U values of the walls:	
north:	0.21 W/(m <sup>2</sup> K)
south:	0.21 W/(m <sup>2</sup> K)
east:	0.21 W/(m <sup>2</sup> K)
west:	0.21 W/(m <sup>2</sup> K)
Upper floor:	
Towards:	outside or non-insulated roof
U value:	0.17 W/(m <sup>2</sup> K)
Lower floor:	
Towards:	non-heated cellar (without insulation)
U value:	0.20 W/(m <sup>2</sup> K)
Door (north facade):	
Area:	2.6 m <sup>2</sup>
U value:	2.90 W/(m <sup>2</sup> K)

## Windows:

North:	
Windows area:	2.7 m <sup>2</sup>
Fraction of windows area at the facade:	5.0 %
U value glazing:	1.00 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.52
Fraction of frame:	25.0 %
Shading:	20.0 %
South:	
Window area:	12.4 m <sup>2</sup>
Fraction of windows area at the facade:	23.0 %
U value glazing:	1.00 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.52
Fraction of frame:	25.0 %
Shading:	20.0 %
East:	
Window area:	6.0 m <sup>2</sup>
Fraction of windows area at the facade:	13.0 %
U value glazing:	1.00 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.52
Fraction of frame:	25.0 %
Shading:	20.0 %
West:	
Window area:	8.8 m <sup>2</sup>
Fraction of windows area at the facade:	19.0 %
U value glazing:	1.00 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.52
Fraction of frame:	25.0 %
Shading:	20.0 %

### *Output: Primary and final energy demand for heating*

## Energy demand of the heating system:

Heat:	
Heat energy demand:	83.9 kWh/(m <sup>2</sup> a)
Losses of the heat storage:	0.0 kWh/(m <sup>2</sup> a)
Heat losses from the distribution:	2.6 kWh/(m <sup>2</sup> a)
Losses at the transmission to the rooms:	1.1 kWh/(m <sup>2</sup> a)
Expense number of heat generation:	1.03
Final energy demand natural gas:	90.2 kWh/(m <sup>2</sup> a)
Primary energy factor natural gas:	1.1
Primary energy demand natural gas:	99.3 kWh/(m <sup>2</sup> a)
Auxiliary energy (electricity):	
Auxiliary energy for heat generation:	0.7 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat storage:	0.0 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat distribution:	1.4 kWh/(m <sup>2</sup> a)
Final energy demand auxiliary energy (electricity):	2.1 kWh/(m <sup>2</sup> a)
Primary energy factor electricity:	3.0
Primary energy demand auxiliary energy (electricity):	6.3 kWh/(m <sup>2</sup> a)

## Output 5

### *Input: Building data*

#### Insulation:

U values of the walls:	
north:	0.21 W/(m <sup>2</sup> K)
south:	0.21 W/(m <sup>2</sup> K)
east:	0.21 W/(m <sup>2</sup> K)
west:	0.21 W/(m <sup>2</sup> K)
Upper floor:	
Towards:	outside or non-insulated roof
U value:	0.17 W/(m <sup>2</sup> K)
Lower floor:	
Towards:	non-heated cellar (without insulation)
U value:	0.20 W/(m <sup>2</sup> K)
Door (north facade):	
Area:	2.6 m <sup>2</sup>
U value:	2.90 W/(m <sup>2</sup> K)

#### Building:

Ventilation:	
Air change rate:	1.10 1/h
Heat recovery:	80 %

#### Windows:

North:	
Windows area:	2.7 m <sup>2</sup>
Fraction of windows area at the facade:	5.0 %
U value glazing:	1.00 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.52
Fraction of frame:	25.0 %
Shading:	20.0 %
South:	
Window area:	12.4 m <sup>2</sup>
Fraction of windows area at the facade:	23.0 %
U value glazing:	1.00 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.52
Fraction of frame:	25.0 %
Shading:	20.0 %
East:	
Window area:	6.0 m <sup>2</sup>
Fraction of windows area at the facade:	13.0 %
U value glazing:	1.00 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.52
Fraction of frame:	25.0 %
Shading:	20.0 %
West:	
Window area:	8.8 m <sup>2</sup>
Fraction of windows area at the facade:	19.0 %
U value glazing:	1.00 W/(m <sup>2</sup> K)
U value frame:	1.50 W/(m <sup>2</sup> K)
g value glazing:	0.52
Fraction of frame:	25.0 %
Shading:	20.0 %

*Output: Primary and final energy demand for heating*

Energy demand of the heating system:

Heat:	
Heat energy demand:	24.0 kWh/(m <sup>2</sup> a)
Losses of the heat storage:	0.0 kWh/(m <sup>2</sup> a)
Heat losses from the distribution:	2.6 kWh/(m <sup>2</sup> a)
Losses at the transmission to the rooms:	1.1 kWh/(m <sup>2</sup> a)
Expense number of heat generation:	1.03
Final energy demand natural gas:	28.5 kWh/(m <sup>2</sup> a)
Primary energy factor natural gas:	1.1
Primary energy demand natural gas:	31.3 kWh/(m <sup>2</sup> a)
Auxiliary energy (electricity):	
Auxiliary energy for heat generation:	0.7 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat storage:	0.0 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat distribution:	1.4 kWh/(m <sup>2</sup> a)
Final energy demand auxiliary energy (electricity):	2.1 kWh/(m <sup>2</sup> a)
Primary energy factor electricity:	3.0
Primary energy demand auxiliary energy (electricity):	6.3 kWh/(m <sup>2</sup> a)

**Option 6**

*Input: Building data*

Insulation:

U values of the walls:	
north:	0.11 W/(m <sup>2</sup> K)
south:	0.11 W/(m <sup>2</sup> K)
east:	0.11 W/(m <sup>2</sup> K)
west:	0.11 W/(m <sup>2</sup> K)
Upper floor:	
Towards:	outside or non-insulated roof
U value:	0.11 W/(m <sup>2</sup> K)
Lower floor:	
Towards:	non-heated cellar (without insulation)
U value:	0.10 W/(m <sup>2</sup> K)
Door (north facade):	
Area:	2.6 m <sup>2</sup>
U value:	2.90 W/(m <sup>2</sup> K)

Building:

Ventilation:	
Air change rate:	1.10 1/h
Heat recovery:	80 %

Windows:

North:	
Windows area:	2.7 m <sup>2</sup>
Fraction of windows area at the facade:	5.0 %
Kind of windows:	heat protection triple glazing (U = 0.5 W/(m <sup>2</sup> K))

U value glazing:	0.50 W/(m <sup>2</sup> K)
U value frame:	0.70 W/(m <sup>2</sup> K)
g value glazing:	0.51
Fraction of frame:	25.0 %
Shading:	20.0 %
South:	
Window area:	12.4 m <sup>2</sup>
Fraction of windows area at the facade:	23.0 %
Kind of windows:	heat protection triple glazing (U = 0.5 W/(m <sup>2</sup> K))
U value glazing:	0.50 W/(m <sup>2</sup> K)
U value frame:	0.70 W/(m <sup>2</sup> K)
g value glazing:	0.51
Fraction of frame:	25.0 %
Shading:	20.0 %
East:	
Window area:	6.0 m <sup>2</sup>
Fraction of windows area at the facade:	13.0 %
Kind of windows:	heat protection triple glazing (U = 0.5 W/(m <sup>2</sup> K))
U value glazing:	0.50 W/(m <sup>2</sup> K)
U value frame:	0.70 W/(m <sup>2</sup> K)
g value glazing:	0.51
Fraction of frame:	25.0 %
Shading:	20.0 %
West:	
Window area:	8.8 m <sup>2</sup>
Fraction of windows area at the facade:	19.0 %
Kind of windows:	heat protection triple glazing (U = 0.5 W/(m <sup>2</sup> K))
U value glazing:	0.50 W/(m <sup>2</sup> K)
U value frame:	0.70 W/(m <sup>2</sup> K)
g value glazing:	0.51
Fraction of frame:	25.0 %
Shading:	20.0 %

### *Output: Primary and final energy demand for heating*

#### Energy demand of the heating system:

Heat:	
Heat energy demand:	6.3 kWh/(m <sup>2</sup> a)
Losses of the heat storage:	0.0 kWh/(m <sup>2</sup> a)
Heat losses from the distribution:	2.6 kWh/(m <sup>2</sup> a)
Losses at the transmission to the rooms:	1.1 kWh/(m <sup>2</sup> a)
Expense number of heat generation:	1.03
Final energy demand natural gas:	10.3 kWh/(m <sup>2</sup> a)
Primary energy factor natural gas:	1.1
Primary energy demand natural gas:	11.3 kWh/(m <sup>2</sup> a)
Auxiliary energy (electricity):	
Auxiliary energy for heat generation:	0.7 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat storage:	0.0 kWh/(m <sup>2</sup> a)
Auxiliary energy for heat distribution:	1.4 kWh/(m <sup>2</sup> a)
Final energy demand auxiliary energy (electricity):	2.1 kWh/(m <sup>2</sup> a)
Primary energy factor electricity:	3.0
Primary energy demand auxiliary energy (electricity):	6.3 kWh/(m <sup>2</sup> a)

## Annex III – Building Material Manufacturers

### *Insulation*

**Termika d.o.o.**  
Varaždinska 140  
HR - 42220 Novi Marof  
tel. + 385 42 40 13 00  
fax. + 385 42 61 10 30 e-  
mail: [termika@termika.hr](mailto:termika@termika.hr)  
URL: <http://www.termika.hr>

Termika is the biggest Croatian manufacturer of insulation material for buildings and industry, also being an active member of EURIMA, the European Insulation Manufacturers Association. The company is ISO 9001 and ISO 14001 certified and produces TERVOL<sup>®</sup> stone wool which complies to the DIN and Euro standards. The stone wool has a  $\lambda$  of 0.035 to 0.041 W/mK and  $\mu$  (coefficient of vapour permeability) of 1.1 to 1.3. It is easily available and the price ranges from 1 to 5 EUR/m<sup>2</sup> of insulation material.

For the following renovation options TERVOL<sup>®</sup> stone wool will be applied to insulate the outer walls, loft and floor. Alternatively, polyurethane (PU) foam or vacuum insulation panels could be used.

### *Windows*

**Veka**  
Distributor for Croatia:  
Damir Lorenz  
A. Cesarca 49  
HR – 35000 Slavonski Brod  
tel. +385 35 444726  
fax. +385 35 444699  
mail: [dlorenz@veka.com](mailto:dlorenz@veka.com)  
URL: <http://www.veka.com>

Veka is a German company specialised in the production of window and door systems. Their products are sold worldwide and are also available in Croatia. For the renovation calculations Veka's window system "TOPLINE plus" was chosen because it has a deep edge cover and with its triple insulating glazing, it obtains U-values of less than 0.8 W/(m<sup>2</sup>K). Additionally, "TOPLINE plus" is certified by the Passivhausinstitut Darmstadt (Dr. Feist) as a window system which is suitable for being used in passive houses and complies with all requirements of DIN and Euro standards.

### *Solar Thermal Collectors / Heat Pump / Ventilation with Heat Recovery*

**Viessmann d.o.o. Hrvatska**  
Dr.Luje Naletilića 29  
HR - 10020 Zagreb  
tel. + 385 1 6593 650  
fax. + 385 42 61 10 30  
e-mail: [info@viessmann.hr](mailto:info@viessmann.hr)  
URL: <http://www.viessmann.hr>

Viessmann is one of the foremost manufacturers of heating equipment in Europe, with a widespread network of distributors in Croatia. Because of their high quality products and broad availability in Croatia, Viessmann heating systems were chosen for the calculation of the renovation options.