SIMTERM

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17th Symposium on Thermal Science and Engineering of Serbia

Sokobanja, Serbia, October 20–23, 2015

University of Niš, Faculty of Mechanical Engineering in Niš
Society of Thermal Engineers of Serbia

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Contents

Model of Energy efficient and Sustainable design through Conceptual architectural-urban design of an Eco Green Village in Belgrade

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Abstract: This paper is based on the project of Conceptual architectural-urban design of an Eco green village composed of MILD[1] objects that was done for the purpose of participation in an Open anonymous single-stage competition organized by City Municipality of Savski venac in Belgrade[2]. The subject of the paper is Conceptual design of Eco green village on the territory of Municipality of Savski venac done by team of authors: Krstić H., Spasić Đorđević S., Ranđelović D., Vasov M., Gocić M. The aim of the paper is to show, through particular example (in this case conceptual project) that it is possible to design sustainable residential objects that are able to decrease energy consumption, provide more comfortable living to the residents and, at the same time, are affordable. Most of the people think that houses that have lower impact on the environment are usually more expensive. This research shows that this is not a rule. During the design process, numerous analyses have been carried out, which will be discussed in more detail in the paper. Also, there will be presented some of the solutions planned for the purpose of energy efficiency such as use of solar panels, green roofs, Trombe wall, advantage of proper orientation, reduction of motor traffic etc. It is important to emphasize that this Conceptual arch.-urban project is just one possible variant that aims to promote a model of housing that provides a better quality of life and involves a healthy indoor and outdoor environment. Methods used in the paper are following: analysis, synthesis, comparison, description, classification, model. For the creation of 3D model it was used computer program 3D Studio Max and for renderings' editing - PhotoShop CS6. All thermic calculations, heat losses and gains, are carried out in computer program KnaufTERM.

Key words: *energy efficient construction, eco village, conceptual architectural urban design, model of energy efficient design, sustainable architecture*

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1.0 Introduction

This paper presents Conceptual urban-architectural design of Eco green village in Belgrade, designed by the above mentioned team of authors. The Conceptual urban-architectural design of Eco green village was created in the framework of Competition announced by City council of Municipality of *Savski venac* in Belgrade. Main theme of the Competition is to research specific architectural ideas for residential units sustainable in construction and exploitation, which have low impact on environment and are cheaper than conventional. One of the Competition's goals is to demonstrate that construction of financially affordable residential buildings with low environmental impact is also possible in the region of South-eastern Europe.

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[1] Abbreviation of: Modular, Intelligent, Low cost, Do it yourself
[2] Competition was completed in February 2014. The conceptual architectural and urban design presented in this paper participated in competition and was exposed at the exhibition held in *Mikser house* after completion of competition.

The place predicted for conceptual design of the village is located in the south part of Municipality of *Savski venac*, on the very border with Municipality of *Vozdovac*. Location is defined by *Borska* Street, near the intersection with *Crnotravska* Street[3]. In Master plan of Belgrade this location is provided for housing, so it was suitable for this project. Boundaries of the location are shown in the figure 1 to the left. In the figure 1 to the right is shown photo of the location downloaded from the *www.googlemaps.com*. Although this specific location indubitably has a great influence on the design process, additional goal of this competition is to design residential buildings and the whole village that can be adjusted to other locations in Serbia.

Figure 1. Location boundaries and photo of the location

The project task is composed of two parts – specific and additional. Specific project task is to develop the model of residential units that can be constructed under low price and at the same time can provide appropriate solutions for ecological and social challenges in present and future. Additional task is to design Eco green village, residential complex that unifies those residential units.

The task demands minimum two types of residential units: for individual and multistory housing, with maximum high up to 4 levels. Units of each type must contain essential residential functions (sleeping, food preparation, sanitary facilities and common space) and each unit must have approach to open space – balcony or garden. Total number of units has to be between 100 and 200, while the number of each type is left to the decision of architects. It is recommended that residential units should be 40-90 m^2 in size, which is based on preliminary examination of the market. But this was not obligatory. Also, houses should not be the same. They should have possibility of customization to the users' needs and their way of life. When it comes to content, the only obligatory purpose is habitation. Other contents are optional.

There is an intention that inhabitants of Eco green village should use bikes or go on foot within the complex. For the connection to the city, they should use public transport as much as it is possible. For that reason, it is necessary to provide enough parking lots for bicycles. Minimum number of parking lots for cars is 0.7 per residential unit, according to requirements of Master plan of Belgrade.

Aiming to further reduction of negative village impact on the environment, project task emphasizes the use of passive design (orientation, natural or artificial shading, terrain configuration, reduction of total outer house surface, greening…). [1]

On the basis of these requirements, as well as analyses of micro and macro location[4], it is possible to approach to the design process with further investigations of potentials and restrictions.

2.0. Design approach

This chapter shows architects' approach as well as analyses of factors that led to final solution.

2.1. Functional contents

Location of the Eco green village is near the large number of public contents and "social knots". Therefore, it was firstly made an analyse of functional contents on the micro and macro location, in order to avoid duplication of functional contents for future inhabitants that are already available to them. This

[3] The location in Borska Street is public property, formally within the military complex.
[4]Climate, traffic, functional contents on the location and wider.

primary refers to existing kindergarten, elementary school, market, sports and recreation center, which are located in neighborhood. In this regard, on the project's location are planned contents that are mainly related to residential facilities, with accompanying contents like open common spaces for recreation and relaxation of future inhabitants, their socialization and gathering, children's play and similar activities. Shops, cafes, post office, bank, pharmacy, supermarket and other facilities necessary for quality functioning of entire complex are also planned.

2.2. Concept, function and shaping

Complex is primarily designed for young married couples and young families. All residential units are subordinated to them and their needs. There are two types of housing in the complex: multistory buildings and individual houses. The idea is to phisicaly separate these two types and create two different zones. But these zones should be, at the same time, related and should function as one union. In figure 2 is showen site plan, where these zones can be recognized. In figure 3 is shown 3D model of Eco green village with disposition of objects on the location.

Figure 2. Site plan of Eco green village

The main design concept is expressed with the following thesis:

- Clear separation of two housing types - individual and multistory. This contributes to better positioning of objects. Multistory buildings have more levels and are higher, so they are positioned in the way that do not disturb insolation of lower objects - individual houses. They are placed parallel to *Kraljica Ana* Street, occupying the north-west part of the complex. They block north and allow opening towards south. Number of floors decreases going from north to south – from 4 floor, 3, 2 to one floor. (Fig 2).
- Individual houses are distributed radial. The reason for radial distribution is related to idea of implementation of bike traffic inside the complex and creating easier moving paths in the space, which will be more discussed in further text. Regardless of radial distribution, every house follows favorable orientation. In order to use maximum of the sun rays, each house opens to the south.
- Residential units are flexible and modular. They have the possibility to adjust to users and their needs (possibility of unification two or more units, vertically extension etc.).
- Existing greenery should be kept in the biggest percentage.
- Common central zone, designed for all inhabitants, is placed in the central spot of the complex. Common space is used for recreation, relaxing time, children's games and other relaxing activities.
- Water area is designed as very important element for microclimates improvement.

- Green roofs are placed on the top of each building. They, in a way, compensate green area that was confiscated from the nature for the construction site.
- Clear differentiation of all types of traffic is also introduced trough the project. Motor traffic is reduced to a minimum, while bike traffic and pedestrian traffic are favored. In this way emission of harmful emanations at the site is decreased.
- For construction are used natural materials. They are ecological, healthy for the environment and have possibility to be recycled.
- Paving is combined together with grass and allows permeating of natural and constructed areas.
- LED lighting is used on the whole area.
- Waste disposal is in differentiated containers for recycling.

Figure 3. 3D model of objects' disposition in Eco green village

Multistorey buildings, total of three, are located in the north-west part of the complex, parallel to *Kraljica Ana* Street. This position fits the maximal use of space, while does not distort the beneficial use of natural factors on site, first of all, in terms of "liberation" and "opening" the south orientation in organizing individual residential buildings – houses, which height is smaller than the projected height of buildings for collective housing. Buildings are marked as A, B and C (fig. 2). All the buildings are typical and adaptive (flexible) to different functional and organizational possibilities and construction conditions. The basic structural module used in the design of the building is 7,50x5,00m raster. By compatible multiplication of the module, building can be expanded or reduced, depending on the needs, thus enabling the construction in phases[5].

Each building is compound of three parts: ground floor and two parts of different number of floors. So, the buildig, at the same time, has 1 floor, 3 floors and four floors. Ground floor combines the whole building and facilitates shops (along street side), pantries and garage (in the middle) and apartments oriented towards south. These ground floor apartments are specific, because they are greatly independent of the rest of the building. In some way, they can be better described as some type of transition between multistory and individual housing. They have their own large-space gardens, where are located entrances to the apartments.

Figure 4. Garden on the top of the garage

[5]This concept offers the possibility to construct depending on economic conditions and planned budget. Buildings don't have to be built at the same time. They can be build in different time intervals without discontinuity.

Other floors are designed as galleries. This design approach enables larger comfort. Each apartment has front and back yard, which is achieved whit galleries. Front yard is on gallery oriented toward north-west, while back yard has south-east orientation and is actually organized as terrace. Between building's parts of different number of levels, on the top of the garage, is placed common garden. This common garden has low and medium green vegetation, walking paths and mobiliard (fig. 4). Other roofs are also green. Idea with green roofs was to reimburse the nature everything that was taken from it. This way, buildings become part of the nature. Flats on the galleries are typical and organized in the frame of above mentioned module. In figure 5 is shown section through the building, for a better overview. It clearly shows different number of floor in the building. Symbols in the picture illustrate insolation and ventilation in the building.

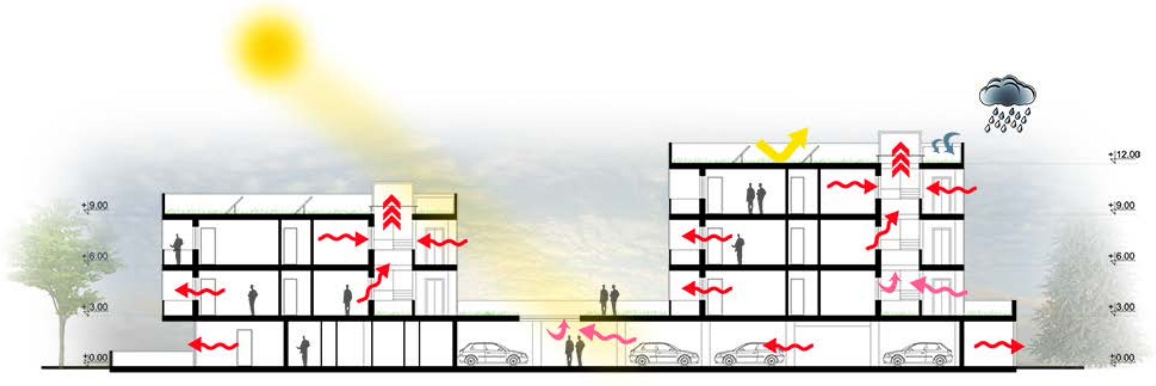


Figure 5. Section of the multistory building

Individual housing is organized through free-standing houses, radially distributed on the rest of the location. Individual free-standing houses provide maximum comfort and privacy, so they are chosen rather than double houses and houses in a row. Radial distribution follows bicycle and pedestrian path which connects contents in the complex and unifies them. This kind of houses' disposition didn't break the comfort in the terms of favourable orientation, because houses follow south side, following at the same time radial disposition.

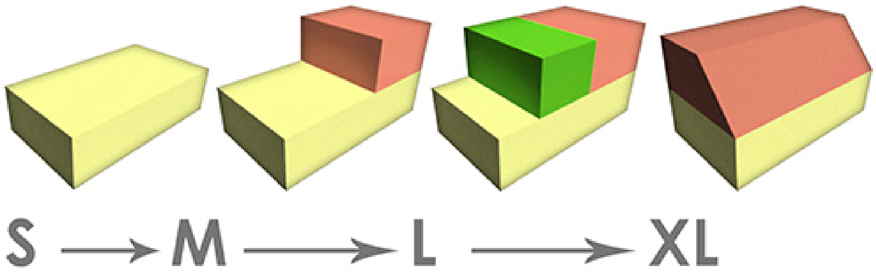


Figure 6. Types of houses

Designed MILD homes have the possibility to be adjusted to the users' taste and their way of life. This concept is schematically schowen in the figure 6. The basic house type is marked as S house. This house is designed to meet all the needs of inhabitants and is designed for a young couple who is just planning to expand the family. With the expansion of the number of users, the need for surface also grows, and the house S can be rebuilt in the house M. So, as the family expands, so expand and housing units. In one moment, if house M becomes too small for the family, it can be rebuild in house L. For the biggest comfort, it is designed XL house.

Figure 7. 3D model of XL house

For the explanation of applied principles of green desgn in further text it is chosen XL house (figure 7).

2.3. **Traffic inside the complex**

The main idea is to reduce motor traffic on the location to a minimum. Inside the complex are favored bicycles and pedestrian traffic, and for the connection with the city – public transportation[6]. Operating a motor vehicle ends at the entrance to the complex of new eco-village (fig. 8 to the left). All residents of the complex park their vehicles in garages that are located on the ground floor of multistory buildings and which are common to all residents[7]. Garages are placed right next to the access road, in order to avoid the use of cars inside the complex. Residents continue their way to the houses or apartment on foot (fig. 8 in the middle) or by bicycles (fig. 8 to the right).

Figure 8. Schemes of motor, pedestrian and bicycle traffic

Navigating through the site is maximally subjected to pedestrians. Therefore are designed many pedestrian paths, that connect contents on the location and enable undisturbed and easy movement through the space. The network of bicycle paths also cover the complex evenly. It follows the most frequent pedestrian lines. On the adequate spots along bicycles' paths are placed points with parked bicycles. Those bicycles are common to all residents in the complex and can be taken from the parking by inserting ID card on the automat near parking. Every resident has its own ID card and the number of bikes is sufficient to meet needs of all the residents. Shape and disposition of paths follows radial objects' arrangement.

[6]The entire territory of the Municipality of *Savski venac* is covered with network of public transportation. In the near of the proposed location, there are many lines of public transport (through *Borska* Street and *Crnotravska* Street). Part of *Borska* Street belongs to the outer ring of Belgrade's highway, which facilitates access to the site.

[7]Envisaged number of parking places is 144, or 0.88 per housing unit, which meets the capacity prescribed by Master plan, of 0.7parking places per housing unit.

3.0. Contribution to energy efficiency

Thermal, acoustic, hygienic and visual comfort are key elements of pleasant stay in an closed space. Appropriate thermal insulation of facility, quality glazing of desired surfaces of doors and windows and their correct dimensioning and orientation, as well as adequate choice of heating system, ventilation, lighting and their optimal regulation on the basis of smart houses are elements that can contribute to higher level of comfor in inner space. [2]

Figure 9. Schematic display of applied elements that contribute to energy efficiency in the house on the example of XL house

Elements that contribute to better comfort and higher energy efficiency in objects are presented on the model of house of XL type (figure 9). They are:

1. Transparent paving that combines the grassy area with a material. That enables easy moving of water and air around the paving material.

2.Green roofs with a system for collecting rainwater. There are many ecological advantages in using this system like: regulation of biodiversity, improvement of microclimate, retention of dust, retention of rainwater, noise reduction, regulation of air quality and temperature. In addition to environmental aspects, which are directly related to human health, the green roof has also an aesthetically outrank, as well as economic advantages. It turns out that green roofs are significantly more durable than other roofs, so that the initial investment for their construction can be far more returned through durability and savings in consumption of energy for heating and cooling of the building. On the green roof is also installed system for rainwater collecting with lot of advantages like: increased efficiency of surface, reduced dependence of the water from the water network, underground infiltration system and collection system (valuable space is not taken up), water purification and very low maintenance requirements. The system works in the way that rainwater from the roof is filtered and collected in modular tanks or so called infiltration blocks. The water can then be used as technical water, such as water for watering the garden or can be redirected with an overflow pipe to infiltration reservoir and then back into the ground. [3]

3.Use of natural material for construction – wood (with an insulation value of R50-60). Constructive elements from wood used in the project are strong, durable, practical for construction and are coated with protective layer against fire and insects.

4. Usage greenery on the facade of the building, like for example ivy over canopies. The chosen greenery is appropriate for our climatic conditions – protects from insolation during summer and allows sun reys to get into the house through glass surfaces in winter, increasing in that way solar gains. During hot summer months, greenery creates shadow on the south facade and helps passive cooling of inner space. That largely decreases energy consumption and total costs for building functioning.

5. Deciduous trees around the building, that creates shadow in summer, while in winter, when leaves fall down, allows the sun light to penetrate deep into the house, helping with natural heating of the building (fig. 10).

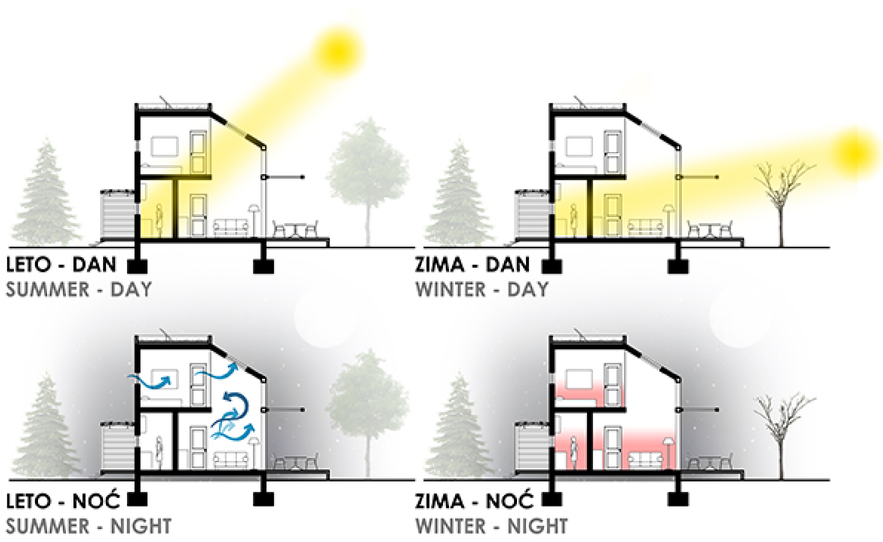


Figure 10. Bioclimatic schemes of building functioning

6. Solar panels as a support system for central heating. They are able to cover 30% to 40% of energy needed for heating during winter.Apart from this energy savings, this system can cover up to 80% of hot water needs during the whole year. Solar panels are complement to central heating. In addition to saving energy during the winter, combined solar water heater provide hot water for domestic use, in the interim and summer periods for bathing, kitchen and washing machine. Working principle: solar collectors placed on the roof surface absorb heat during sunshine hours. The absorbed heat is transported by pump and stored in large storage solar water heater. From the storage tank, heat is transferred to other rooms through the central heating system. The solar system is also the perfect solution for under floor heating.
7. Installation of sunshaders to prevent overheating of rooms in summer, as well as preventing from disturbing visual comfort. Angle of sunshaders is designed for our climate conditions, in order to maximize solar gain in the winter, and to protect us from solar influence in summer
8. The possibility of growing fruit and vegetables in the backyard. Fruit trees create a pleasant setting for a stay in the garden. It also allows the household to product fresh fruit.

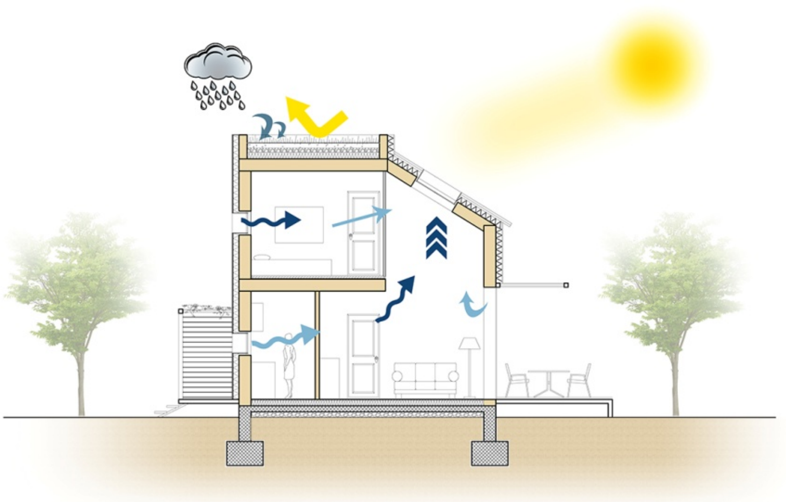


Figure 11. Scheme of natural ventilation in the house

9. Trombe wall, as one of the systems of passive absorption of thermal solar energy. The wall is made of a material that can act as a thermal mass (stone with granite cladding). It consists of a dark colored wall of high thermal mass facing the sun, with glazing spaced in front to leave a small air space[8]. It is set on the south side. Between the wall and the well-insulated glass surfaces is air space. In the winter period, the

[8] http://sustainabilityworkshop.autodesk.com/buildings/trombe-wall-and-attached-sunspace

system behaves as a sort of heat source. During the day the sun rays go through the glass surfaces and heat wall, which emits heat into the interior of the room during night.

10. Operable windows/passive cooling. Operable windows allow cross-ventilation for the ventilation of the interior space. This strategy improves the air quality and reduce energy consumption. In all the facilities it is possible to make natural ventilation, which prevents from syndrome of sick building (fig. 11). Natural ventilation is ventilation in which the air changes due to a difference in pressure without the use of mechanical and other similar devices. Its advantage is the low investment costs, easy maintenance and low speed air flow. In this way is achieved the air comfort and provided sufficient quantity of clean air. Used materials do not affect the reduction of air quality, there are no harmful fumes dangerous for human health. Natural ventilation achieve the requirement of air comfort - provide the required amount of fresh air. [4]

11. Preventing light pollution and energy saving for lighting in complex. Light pollution appears as unnecessary light, unwanted glare that disturbs night activities and the light that shines directly or is reflected in the direction of the sky. The use of adequate lamps that emit light only below the horizontal plane passing through the plane of the radiation lamps can prevent the spread of light in unwanted directions.Planned lamps have within themselves photovoltaic panels which collect solar energy during day and then transform it into the light.

5.0. Conclusions

By using passive systems explained in the paper, energy requirements are decreased up to 70%. Designed individual houses with different technical characteristics combined, are getting closer to low-energy houses, with low construction price. Materials that are used in project have very good performances and at the same time are not expensive. By integral concept of design and use of traditional and modern materials, it is given an effort to achieve higher standard in residential housing in terms of ecology and environmental protection. Primary material used in construction are wood panels – modern solution created with prefabricated cross wise bonded panels – CLT (Cross Laminated Timber), which do not contain adhesives based on a phenol-formaldehyde.

The calculations carried out in the program KnaufTerm have led to results that are shown in Table 1. Energy class of facilities is C, which is quite good result. However, by further optimization of buildings in terms of HVAC systems (applying heat pumps, cogeneration energy systems, etc.) is very likely to achieve the B energy class of designed buildings. A significant impact on energy savings represents a good insulation of the house, the walls, roof and attic.

The initial idea involves the construction of modular homes. Use of simple basic automation contributes to the possibility that individuals can build their future homes themselves, and can be able to make changes at various levels. Not only can move, add or remove modules, they also may change the details on the exterior facade panels, which greatly affects the characteristics of these objects.This allows the houses to "live" and change according to users' needs and seasonal changes.

One of the most important aspects when it comes to construction is the price. Prices per square meter of residential space (in individual houses and multistory buildings) go from 563,78 e/m^2 to 654 e/m^2, which is shown in Table 2. It is important to emphasize that use of some of the passive systems initially rises the price for construction, but initial investment in a very short period pays back through energy savings.

On the example of Conceptual urban-architectural design of Eco green village, this paper aims to show that it is possible in Serbia to build affordable housing, which are eco-friendly, healthy for residents and environment.

Description	Building type					
	S	M	L	XL	A	B
Net area of the heated part of the buildingA_f[m^2]	59,86	85,82	105,70	105,54	821,37	511,08
The volume of the building envelope V [m^3]	292,32	397,71	488,43	467,90	4.000,78	2962,11
Form factorf_0[m^{-1}]	0,95	1,06	0,81	0,81	0,66	0,54
Transmission lossesH_T[W/K]	5.776,22	10.534,61	8.089,90	7.644,89	63.195,56	34.632,77

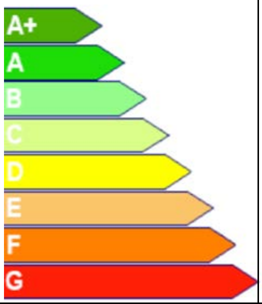
The volume of heated space $V_e[m^3]$	171,72	231,71	284,47	315,10	2.217,69	1.379,92
Sealing of windows	good	good	good	good	good	good
Number ofair changesn$[h^{-1}]$	0,5	0,5	0,5	0,5	0,5	0,5
Ventilation lossesH_v[W/K]	1.713,63	2.312,28	2.838,78	3.144,45	22.130,77	13.770,50
Total lossesH [W/K]	7.489,85	12.846,89	10.928,68	10.789,42	85.326,33	48.403,27
Specific annual energy use for heating $Q_{H,an}$ $[kWh/m^2a]$	50,14	49,20	42,26	45,96	39,74	41,75
Energy class			$Q_{H,nh}$$[kWh/m^2]$ <=10 <=17 <=33 <=65 <=98 <=130 <=163 >163			

Table 1. Calculation of energy class

	Price of construction $[€/m^2]$	Total costs [€]
Individual house S type	621,78	37.219,95
Individual house M type	574,89	49.337,47
Individual house L type	563,78	59.399,47
Individual house XL type	573,41	60.517,37
Apartmenttype I	654	25.957,26
Apartmenttype II	654	37.421,88
Apartmenttype III	654	53.085,18

Table 2. Prices

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