Energy-conscious architecture – a student's scientific work

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The highest level of a student's scientific work is manifested in participation in the activities of a scientific student circle. The decision made by a student to engage in scientific work requires not only a high level of interest but also a good subject.

In the second year of my university studies I became interested in the topic of energy-conscious architecture. This issue, which is becoming of vital importance today, appeared to be significant to me as early as 2003. My interest in renewable sources of energy is rooted in my secondary school studies, where I received very sound education in science subjects. I had the opportunity with some of my classmates to learn about renewable sources of energy in the framework of a European Commission Socrates Lingua-E project between March and July 2000. Part of the project was a visit to Hungary by students of the Liceo Scientifico Alfano da Termoli, our partner institution in Italy. They learnt about methods of using different sources of energy such as nuclear power, wind energy and biomass in this country. After their visit a group of Hungarian students travelled to Italy to find out about the use of renewable energy there. We visited a wind farm, a solar power plant and a hydroelectric power plant there. At the end of the program participating students were required to write an article on a topic of their choice to be published in the bilingual (English-Hungarian) volume called Harmony with nature – many coloured energy. [1] My article was titled - Solar energy in the household. In my article after a brief overview of the components of solar radiation and the advantages of using solar energy there were examples for different ways of utilising solar energy in the household for space heating, water heating and generating electricity as well as in environmentally friendly vehicles.

After this experience I set out to deepen my knowledge on the topic. I was keen to find answers to the questions: what are the ways of energy-conscious building design and how is it possible to use renewable energy resources in buildings?

First of all I had to clarify the basic principles. If a building design is energy-conscious, it has a specific purpose. Choosing the appropriate building geometry is important, as non-compact building shapes may result in the development of thermal bridges. Other important considerations include the orientation of the building and the surface to volume ratio. The design of a building is environment friendly if its entire life-cycle is taken into consideration, which means calculating the environmental impact of a specific building from extracting raw materials to be used in building construction through to the demolition of the building. German building standards include the passive house standard. The different standards are specified on the basis of the annual energy consumption of buildings. There are low-energy houses and there are passive houses. The annual energy consumption of a passive house does not exceed 15 kWh/m2/year. [2] A book by dr. András Zöld titled Energiatudatos építészet (Energy-conscious architecture) helped me to learn a lot about the topic.

Having become aware of the basic concepts and different uses of renewable sources of energy (passive, hybrid, active) I had to decide what kind of building I was going to design. My idea was designing a building where different solutions were taken advantage of and where the implementation of these solutions were relatively simple.

For the non-professional, everyday person it may be surprising to hear that the energy consumption for buildings related services accounts for 45% of a country's total energy consumption. The energy requirement for buildings is increasing with the higher demand for air conditioners due to global warming. In a poorly designed building vast quantities of energy are consumed for heating and lighting, with a heavy reliance on artificial sources. If the process of building design is energy conscious from the very beginning, the use of artificial sources can be minimised, thus the key word is "prevention", i.e. purposeful planning of a building.

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The next step of my work was to look at traditional solutions of energy conscious building construction. People living in different climatic regions and having access to different building materials have always strived to take advantage of energy efficient solutions. Examples include Eskimo igloos, earth-bermed, partially underground buildings, adobe houses and traditional peasant houses with sheltered verandas. This is what we call climate-conscious building design, where people aim at putting the building materials available to the most efficient use, adjusting to specific climatic conditions.

Figure 1 Traditional peasant house with veranda

Conservatories, sunspaces attached to buildings have great importance. They supply pre-heated air for ventilation. In rural architecture there is a great variety of building types, one example for such architecture is the traditional peasant house with a veranda. In city architecture with frontages forming a continuous building line, traditionally rooms overlook the street. Energy efficiency is not among the main considerations in this case. Energy-conscious design can be very varied. The shape of such buildings depends on their function, their size and the climate.

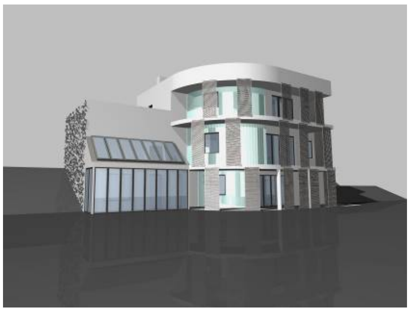

Figure 2 The designed building

The designed building is a three-storey house built on a slope. My original conceptual design of the building met the requirements of energy-conscious design, while the structural design had to be reconsidered. My aim was to improve the energy balance through passive solar design techniques, but eventually I used active solar design techniques, as well.

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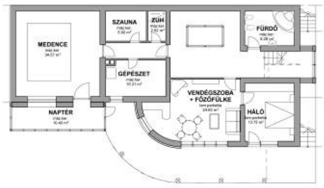

Figure 3Basement floor plan

The basement level is sunk below the ground level in order to fit the slope. On this level there is a self-contained suite, which is ideal for guests. There is also a sauna, a swimming pool and a games area with room for a billiard table. There is storage space and the building services room is also located in the basement.

When designing the floor plan of the building my aim was to give optimum orientation to the rooms. This is the reason why the self-contained suite is located along the south side of the building. The swimming pool area is on the north side of the house, because in summer it is the western side of buildings that is heated most by the afternoon sun with the air warmed up during the day. Thus the swimming pool area acts as a buffer zone, which prevents the guest suite from becoming excessively overheated.

Figure 4 Sunspace

In compliance with the principles of passive solar design a sunspace or conservatory is located adjacent to the swimming pool area. In winter the sunspace pre-heats incoming ventilation air. Furthermore, it is very pleasant to sit in the sunspace area and enjoy the occasional winter sunshine. In summer it is necessary to protect the area from being excessively heated up by solar radiation. This protection can be provided by an automated external shade system, but plants provide the best results. Carefully chosen plant species develop thick foliage with big leaves and provide shade during the specific period of the year when it is required. With annual plants the “shade system” can be changed as often as every year. To make the sunspace more attractive it is advised to grow plants recommended by an expert. Special plants need to be chosen, because there is no sunlight during the day in the hot summer season, so plants can only come to life in the evening.

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Figure 5 Downstairs floor plan

Space for the living area is located downstairs. A wind sheltered entrance to the building is on the north side of the building. The living room faces south, the study room has windows to the south and west. The utility room has east facing windows. The staircase, which provides access to different levels of the house as well as to the garden, is located on the east side of the building. The kitchen, which is evenly lit by natural light during the day from the north facing windows, is north to the open space living and dining area. The larder, which is adjacent to the kitchen, also faces north. The two-bay garage, which is over the swimming pool area, acts as a downstairs buffer zone. Being located on the west side of the house, it protects the living area from excessive heat.

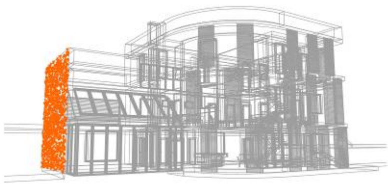

Figure 6 Green façade

To increase the efficiency of the buffer zones, on the west side of the house a green façade has been designed. The wall on the west side is screened from direct sunlight in summer by creeper plants climbing on a vertical trellis structure. Plants grown here can be evergreens, as in summer they cool the walls by the circulation of lower temperature air behind the leaves, while in winter their leaves or needles stick together, and thus protect the wall from cold when outside temperatures are lower.

Figure 7 Solar panels

The solar panels are located over the sunspace, on the outside wall of the garage, at an optimum 45 degree angle. The solar panels with their optimum angle and southern orientation provide the highest capacity to heat water for bathing, the swimming pool or for space heating purposes. Maintenance of the solar panels is from the ground floor patio.

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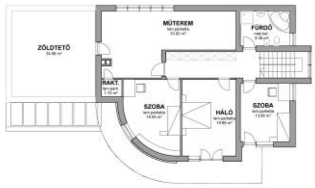

Figure 8 Upstairs floor plan

The bedrooms are located upstairs. There are two bedrooms for the children, and one for the parents. All of the bedrooms face south to take advantage of the nice view of the surrounding area. Privacy of the rooms is ensured by their location on a separate floor. For functional reasons the bathrooms and the utility room are designed to be located one over the other, in the same area of different floors. As an extra, the upstairs level features a studio, lit by natural light from the north.

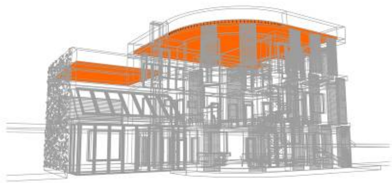

Figure 9 Green roof

From the studio there is access to the flat roof over the garage, with an intensive green rooftop, where even shrubs or trees can be planted. As it is an intensive green roof, it is suitable for leisure purposes. Selection of plants to be grown on the west façade and on the rooftop is done on specialist advice. There is an intensive green roof over the main part of the house, too. A suitable automatic irrigation system has to be installed on the green rooftops.

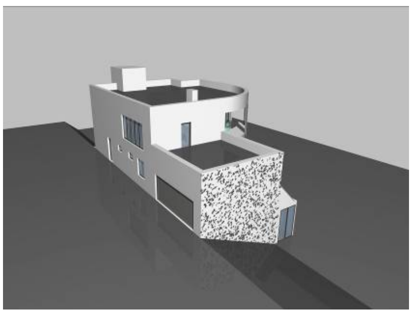

Figure 10 Bird’s eye view of building

The green façade and the green roofs contribute to creating a pleasant micro-climate around the building. The thick soil layer of the intensive green roofs protects the building from overheating. Carefully chosen plants clean the air and humidify it in summer, thus improving the living environment.

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Figure 11 Extensive glass surfaces on the south side

The orientation and layout of the building are planned according to the principles of passive solar design. Thus on the northern façade, with the exception of the studio walls, there are only small external openings. The house is open to the south however, to the greatest extent possible, in order to allow as much of the winter low-angle sun to enter the house as possible. The principal function of the veranda in traditional peasant houses was to provide shade and protect the building from heating up. With this considered, the patios and balconies attached to the floors as well as the roof panel were designed to provide shade for lower floors.

Figure 12 External mobile sun shade system

To enhance the protection from excessive summer heat a solar shade system with panels sliding on rails was designed. They can be adjusted to shade the building according to the direction of sunrays. Adjustment of the panels can be done either manually or automatically. When they are moved automatically, manual intervention is always possible – it may be necessary when the system is being cleaned. This manual adjustment is sensed by the system as a one-time adjustment, i.e. in the next cycle the panels are moved in the normal working order.

Figure 13 View of external mobile sun shade system

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When the layout of the floor plans was designed the rooms were arranged in a way that they get the most natural light possible in order to decrease electrical energy consumption. The use of differently sized external openings described above serves the same purpose. An ideal, or near-ideal orientation of rooms is beneficial, because it creates a pleasant sense of space and ensures energy savings at the same time.

Figure 14 Transparent thermal insulation system

A 10cm transparent thermal insulation system with heat resistant glass protects the southern and western walls of the building. In transparent (translucent) thermal insulation systems honeycomb structures are used, so that when the angle of sunrays is high, solar radiation is absorbed by them, while in winter with low-angle sunrays most of the solar radiation penetrates the structure and reaches the wall to heat it up.

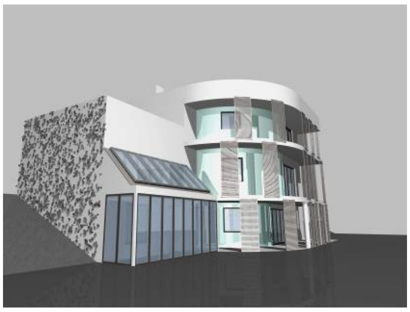

Figure 15 View of transparent thermal insulation system

The plants, trees and shrubs in the garden can modify the direction of the wind, thus decreasing its negative effects.

When the full concept of the building was completed, calculations were made to validate the adequacy of the concept. These calculations were conducted to evaluate the cost savings resulting from the application of active and passive solar design techniques. From the calculations it became clear, that certain structural changes had to be made to the design.

In the basement living area the original structure did not have the required thermal mass capacity (200 kg/m2). For this reason the size of the south facing external opening of the basement had to be decreased. With this, the transparent thermal insulation system covers an increased wall surface. Thus an optimal solution was found to the problem.

For the structure of the sunspace with its extended glass surfaces, adequate thermal mass is required. To achieve this, a 35cm stone wall was built in the sunspace. Even with this, the required thermal mass is not a guarantee against overheating, which means that mainly in spring, or perhaps as early as in February, excess heat is generated in the sunspace. This excess heat can be used for heat spacing in the building, which is facilitated by a ventilator with a built-in thermostat installed at the top of the room. When the temperature of the sunspace is higher than that of the rooms, the ventilator switches

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on and blows heated air into the rooms. Cold air from the rooms flows to the sunspace through under-floor pipes. The heating energy of the building can be reduced in this way.

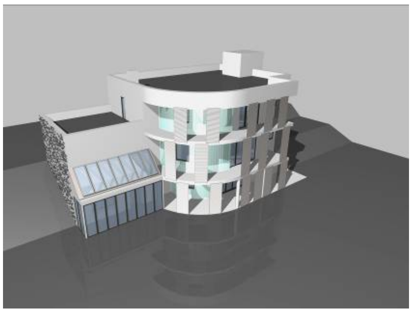

Figure 16 Bird's eye view of building

After the remedial modifications new calculations were made to give the energy balance of the building. The results of these calculations are summarised in the table below.

Table 1 Heating energy demand of the designed building

Annual heating energy demand of building	**54,07 MWh**	**100,0 %**
Transparent thermal insulation	8,49 MWh	15,7 %
Solar energy	23,27 MWh	43,0 %
Decrease through sunspace	0,63 MWh	1,1 %
Solar heat gain through sunspace	2,84 MWh	5,2 %
Internal heat gain	4,92 MWh	9,0 %
Real heating energy demand of building	**13,92 MWh**	**26,0 %**

The table above shows that as little as 26% of the heating energy demand needs to be covered by traditional space heating methods, if energy-conscious active and passive solar design techniques are used.

When developing the design of the building, it is essential that energy-conscious solutions are applied from the very beginning, as well as satisfying structural, durability, aesthetic, and functional criteria. A building is environment friendly, energy-consciously designed and comfortable if all these criteria are met.

I was awarded first prize in the Building Structures Section of the Scientific Student Circle Conference of the Engineering Faculty in 2003 for my work on energy-conscious building design. After further development of my work I was awarded sixth prize in the Building and Architectural Structures Section of the National Scientific Student Circle Conference in 2005.

The scientific work I have done greatly contributed to shaping my approach to building design. In my assignments I always pay special attention to applying the principles of energy-conscious design in the course of developing the concept and design of buildings.

REFERENCES

[1] Jurisits, József, ed.: Harmónia a természettel – az ezerarcú energia. (Harmony with nature – many coloured energy) Garay János Gimnázium, Szekszárd, 2000.

[2] Zöld, András.: Energiatudatos építészet Műszaki Könyvkiadó, Budapest, 1999.

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