

## BUILDING ENERGY AND ARCHITECTURAL FORM RELATIONSHIPS

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**Abstract.** Energy efficiency of buildings, of course, is now a major issue in the construction industry. It is being widely examined both among construction professionals and amateurs. There is no doubt that energy efficiency as a key factor in ensuring environmental sustainability will become the main driving force of the construction in the future. Buildings have to become more energy-efficient. This opinion is supported by the existing energy-use balance in Europe, indicating that the housing sector spends almost half of total energy consumption and building sector forms more than a third of total CO<sub>2</sub> emissions (Bradley 2010).

While discussing the subject of building energy efficiency, mostly different technical characteristics of buildings and engineering solutions are talked over. However, it has been relatively little examined how energy-efficient design affects the building's architecturally-aesthetic side, styles of expression and trends in the architect's profession. We learn that the essence for an energy-efficient building lies in smart modesty (Bokalders, Block 2010) and the rational utilization of materials (aim high – go low). And still – can energy efficient building be expressive, extravagant, and perhaps – even ambitious?

There are many ideas implemented in projects which show that energy efficiency is not an obstacle to large scale architectural ideas. However, in order to combine architectural and artistic ambitions with the principles of sustainability, architects should search for an entirely new approach to architectural expression based on a detailed assessment of solutions applied from environmental point of view. It requires a complex understanding of building shape, applied technologies, energetic benefits and cost parameters.

This article identifies the realised and experimental projects of the world and presents an analysis of classification of buildings according to typology. This publication gives general impression of the amplitude and topicality of the study issue, as well as the diversity applied to the architectural techniques. The article concludes that even creating a building's shape in a smart way makes it possible to use substantial part of the renewable energy offered by nature.

**Keywords:** sustainable architecture, energy efficiency, architectural shape, passive energy, eco-villages, adaptable skin, urban garden, eco tower.

### Introduction

Currently the energy efficiency ratio (energy performance) in building design projects have become a determining factor next to the functionality and aesthetic quality. The setting sustainability or, put simply, “the desire to be green”, is being increasingly used as a philosophical concept of design and therefore determines the building shape and appearance (Fig. 1). However, this idea is often turned into a trivial manifest of engineering equipment such as solar panels, collectors, etc. forgetting the large amount of energy required to produce this equipment. In this regard, the use of the double-skin facade systems, for example, that are regarded as an ecological alternative, is debatable, because it is related to large amounts of energy during production and high costs as well (pay-back more than in 35 years).

### Study Area

Gaining high energy efficiency requires an integrated approach to evaluation of the building's function-

nal and technical characteristics. Heating, ventilation, lighting are interrelated factors that form comfortable living and working conditions and all together affect the building indoor microclimate and total energy consumption. Design method, known as “integrated energy design”, provides a completely new approach that



Fig. 1. Masdar City project

evaluates all the factors influencing the performance of the building, including design and construction forms solution, applied materials, engineering equipment, etc. in the very early stage of the project in order to achieve optimum building energy consumption and cost balance. The goal is to assess effectiveness of applied technologies and focus on the efficient use of renewable energy. Building's construction forms and architectural features play the key role in energy performance of buildings. The importance of building's form is well illustrated by Professor B. Cody's (Graz Technical University) study "Form follows energy" (Cody 2010). It emphasizes the architectural importance and its role in the passive use of solar and wind energy (Fig. 2). Complementing the classic "form follows function", this approach introduces a new dimension to the architectural work – study of the architectural components and power connections, searching for new solutions of synthesis of building's form, functionality and design elements. So far, the following main study questions have been rised:

1. How important is the improvement of the energy efficiency performance that can be achieved by using passive energy sources by a method of building's shape optimization?
2. What solutions can be used in projects for Baltic states climatic conditions? Is a passive house the optimal solution for energy efficiency?
3. Can the relationship between energy and architecture lead to emergence of new forms and to completely new ways of architectural design process?
4. Can energy efficiency become the trend to determine the architectural style in the future?

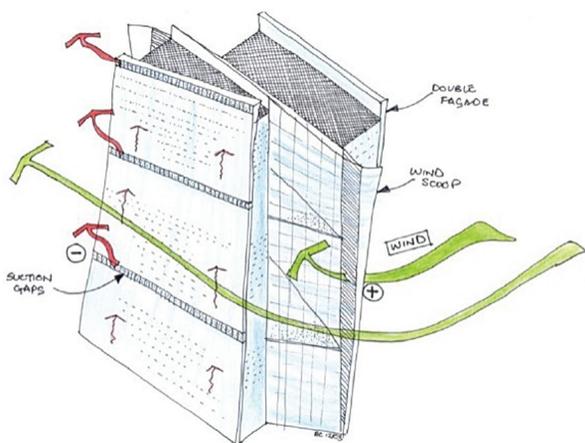


Fig. 2. Buildings' shape design sketch

## Data and Methods Used

The energy efficiency of buildings may be simply defined as the ratio between the internal climate and energy content required for maintenance of this climate. But the energy efficiency does not only mean a reduction in energy consumption, as it is often assumed. It is important to ensure that the energy consumption is provided from renewable sources! *Currently, general classification of the buildings is as follows: economic building (<80 kWh/m<sup>2</sup>), low-energy building (<40 kWh/m<sup>2</sup>), passive building (<15 kWh/m<sup>2</sup>)* (Blumberga 2010) as well as zero-energy building (producing the energy it consumes) and plus energy building (producing more energy than it consumes). Achievement of these criteria requires seeking for new directions in architecture and engineering equipment design.

Latvian construction standards currently define parameters mainly for the building's envelope, but the determining criterion will increase for a significant range. One will have to evaluate effectiveness of the entire building construction insulation envelope and air tightness, efficient heating and cooling supply with heat recovery (recuperation), effective ventilation solution (in public buildings – including air conditioning), location according to the cardinal points, passive solar energy and direct solar radiation monitoring, efficient lighting system and also a number of other factors. The main natural factors that affect the building's shape:

1. Sun (active and passive energy use and protection and the daylight provision);
2. Wind (protection from wind and wind energy use);
3. Precipitation (rain water use);
4. Earth energy (groundwater, surface water, subsoil energy).

Achieving improvements for energy efficiency can be done both by development of active energy use (mostly by technologies) and passive energy use (mostly by buildings' shape). At present, mainly only the parameters associated with the active use of energy (engineering equipment) are expressed in the design process, but the passive methods of energy use are of no less importance. Proper building's shape solution is one of the criteria through which the architect may have a significant impact on almost all of the criteria of buildings' energy efficiency. Environmental factors and complex approach of planning in the architect's work. The following steps of design process can be pointed out:

1. Evaluation of factors affecting energy efficiency.
2. Modelling of the building's volume (shape).
3. Evaluation of results / computer simulations.

## Solutions for Residential and Public Buildings

There are a series of successfully completed eco-villages in Europe, which, thanks to the expertly constructed building placement and configuration, not only consume energy but in fact create it. Such villages are created in accordance to the functional, energetical, solar and wind effects.

Eco-village in Freiburg (Germany) is renowned for buildings that produce significantly more energy than they consume. The “Solar City” complex in Linz (Austria) have become the 21st century urban planning model, thanks to the versatile use of solar energy (characterized by the name “Solar City”). Based on the experience gained from the project, city of Linz has set up a special sustainable urban design regulatory framework. The Swedish city of Malmö is famous for establishing ecological housing complex “Bo01” (Fig. 3), which is placed in the formerly degraded urban industrial zone. Today it is a completely new city district that has an interesting layout of buildings – for the wind retention purposes the orientation of buildings is done in a small angle to each other, thereby creating both an interesting perspective for viewing, and providing protection from the strong coastal winds.



Fig. 3. Malmö residential complex “Bo01” plan with the building layout angle

Significant is the building’s layout according to the cardinal points, because it provides maximum use of the solar energy. An important factor for the flow is the solution of windows facing southern side. Effective solution is creation of large glazing areas, such as winter gardens or verandas that surround the outdoor living areas and serve as specific thermal collectors. The southern facades are constructed as widely glazed winter gardens, where the accumulated solar heated air is led further to the residential premises through the built-in channel. Many buildings are solved this way, such as residential development in Kolding,

Denmark (Fig. 4), which consists of 59 terrace homes. In addition to the glazing, there have been built vertical solar panel elements that provide significant heat energy supply in addition to central heating equipment.



Fig. 4. Residential development in Kolding, Denmark

For heat storage purposes massive construction heat-accumulating planes are installed behind the glass planes.

Roof shape and slope is essential for active solar energy use by installing solar collectors, as it enables efficient solar panels to work. In this aspect, it is worth mentioning the current building in the southern Germany’s city of Freiburg, which encompasses an extensive residential and recreational complex of buildings on the area of 38 ha (architects “Rolf Disch Architekten”). Also passive house standards and the most advanced energy saving technologies, combined with solar power equipment groups, allow to produce more energy than the buildings can consume themselves.

Maximal potential use of solar energy is demonstrated by a number of unconventional projects, such as the pilot project “Rotating solar house Heliotrope” in Freiburg. This unusual building (Fig. 5) was built in 1994, and its design allows to produce up to six times more energy than the building consumes itself!

Energy-saving solutions are used also in architecture of public buildings. The requirements for the indoor climate, such as conditioning, illumination, power supply have to be taken into account while increasing the share of engineering equipment. Architects’ capability to look for ways reducing the amount of engineering equipment and building configuration here is of great importance. Evaluating the engineering costs, more and more designers return to simple, affordable and effective solutions, especially for ventilation and cooling. This means a transition to local and, consequently, less expensive systems that are also easier for all users. Large public buildings use so-called passive



**Fig. 5.** Rotating “solar” house “heliotrope” Freiburg

ventilation (advanced ventilation) methods by forming the roof and wall planes with a special shaft – the so-called “thermal chimneys”, which help to direct the air flow inside the building and increase air exchange capacity without any motor assistance. Also cooling can be done by use of passive cooling methods. This includes, for example, use of the subsoil temperature cooling. Also, green roofs, which make it possible to reduce significantly the amount of cooling in summer and serves as insulation in winter. Architects have to invent how to apply other methods of complex design and function of the object, such as separation of different temperature zones depending on the location as well as the use of premises to accommodate the different functional needs, depending on the time of the day. This has a lot to do with studies of human social behavior and habits.

### Pilot Projects of High-rises

A high-rise structure can hardly be energy-saving by its nature, as it is being increasingly subjected to wind loads and requires additional power for cooling, heating and other engineering equipment. Currently, the observed trend is to allow the building shape and large size “to work in favor of the building”. Various solutions are designed to allow all the energy to be produced within the building. So, for example, “Tower Power Linz” is the world’s first high-rise office built according to the passive house standards. It uses renewable energy to provide almost all the heating, cooling and fresh air supply. Solar radiation is the main useable energy source in the building. South facade of the building is fully equipped with solar panel system components, and they allow to reduce the consumption of CO<sub>2</sub> by about 300 tonnes annually.

Energy capture can be used by the whole volume of a building. For example, a pilot project called “Capture the Rain” (Fig. 6) is knowingly designed to collect as much rain water as possible throughout the building facade to provide the daily needs of the occupants (Capture the rain’... 2010).

Different types of projects become increasingly apparent, including those for which the basic idea is to create an environmentally friendly high-rises in a dense and intensely built-up urban environment. It is believed that this trend is evoked by the buildings’ occupants workplace alienation from nature and the working environment microclimatic negative impact on health. It is planned that the plant-rich hosting floors of the building will improve occupants’ comfort and working conditions, giving them an opportunity to enjoy the plant diversity in the densely urbanized metropolitan hearts.

Peculiar idea is to build high-rises as urban gardens. Thus storey area of the high-rise would be used to grow plants, and also trade in them. The ecological benefits of this idea is the cost reduction of agricultural products’ transportation for downtown residents getting the products from the suburban and rural areas. The buildings would be constructed so to grow the products locally within the city, in such special-purpose designed buildings. An example “The Living



**Fig. 6.** Ecological skyscraper “Catch the rain”

Tower” project (Fig. 7), in which the form of the building is designed so that the atmospheric precipitation naturally would water products grown in the building. If such building construction proves to be feasible, it is expected that this could lead to a significant turning point in the world’s great metropolitan development.

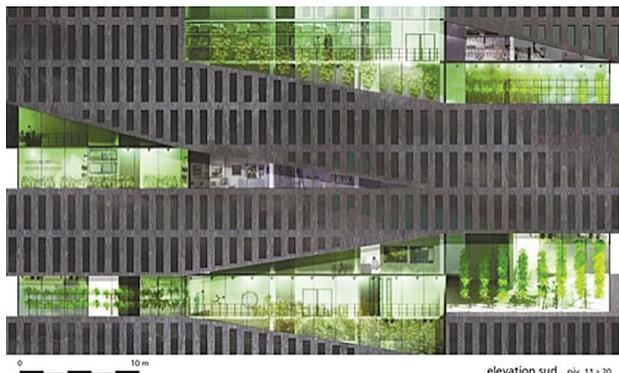


Fig. 7. Ecological skyscraper “The Living Tower”

## Conclusion and Findings

This article is intended to draw attention to one of the energy efficiency aspects of architectural design, which has not been studied sufficiently up to date. The impact of architectural shape on energy efficiency of buildings offers huge potential for energy savings, as seen in many realized and planned projects in Europe and the whole world. This approach requires a deep assessment of situation, specific environmental factors and complex approach of planning in the architect’s work.

Building construction forms and architectural features play a key role in buildings’ energy performance. Cleverly made buildings’ shape, with all its elements – roof, walls, windows, canopies, winter gardens, terraces, etc. – allows for productive use of passive solar energy for building thermal and lighting performance. Today, an architect in his work should be able to evaluate building’s energy assessment aspects and find solutions for its functional use. It is expected that in the near future design of the energy efficient building will lead us to a whole new generation of architectural design techniques and building shape design. The local and renewable resources in the Baltic States are also favorable to substantially improve energy efficiency in buildings, if such buildings are properly and smartly planned.

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## PASTATO ENERGIJOS IR ARCHITEKTŪRINĖS FORMOS RYŠIAI

R. Riekstiņš

Santrauka

Pastatų energinis efektyvumas šiandien yra labai aktuali tema statybų industrijoje ir nėra abejonės, kad tai bus pagrindinis veiksnys, ateityje užtikrinsiantis aplinkos tvarumą. Pastatai turi tapti energiją tausojančiais, nes, anot dabartinio Europos energijos sąnaudų balanso, beveik pusę visos energijos suvartoja pastatų sektorius, ir ši dalis sudaro daugiau nei trečdaliį visos CO<sub>2</sub> emisijos.

Vertinant pastatų energijos suvartojimą, daugiausia tyrinėjamos įvairios techninės pastatų charakteristikos. Visgi mažai dėmesio skiriama estetinei energetiškai efektyvaus pastato išraiškai, architektūrinės raiškos būdams ir architekto profesijos kryptčiai apskritai.

Straipsnyje analizuojami realizuoti ir eksperimentiniai projektai iš viso pasaulio, analizuojama energiją tausojančių pastatų tipologija. Daroma išvada, kad sumaniai kuriant pastato formas, galima naudoti atsinaujinančiąją energiją, kurią mums siūlo gamta.

**Reikšminiai žodžiai:** tvarioji architektūra, energinis efektyvumas, pasyvioji energija, ekologiški kaimai, prisitaikanti oda, miesto sodas, ekologiškas bokštas.