ARCHITECTURE CIVIL ENGINEERING ENVIRONMENT
The Silesian University of Technology
No. 1/2015

THE GRAPHIC PRESENTATION OF BUILDING'S PASSIVE HEATING AND COOLING STRATEGY

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Received: 17.09.2014; Revised: 29.10.2014; Accepted: 20.12.2014

Abstract

The proposed energy diagrams reveal a clear link between development of the spatial design and energy management in buildings. This relationship has an impact on the energy efficiency and microclimate of a given building. The mentioned relationship highlights an importance of incorporating the energy diagrams at the first step of the building design process since they have a very practical value. Showing a graphic representation of the heating and cooling processes can be an advantageous tool in energy efficiency analysis and finally the basis for adopting the optimum spatial as well as the construction and material solutions.

Streszczenie

Między kształtowaniem przestrzennym a gospodarowaniem energią w budynku istnieje wyraźny związek, który przekłada się na sprawność energetyczną i mikroklimat wnętrza budynku. Zależność ta uzasadnia potrzebę stosowania schematów energetycznych już na wstępnym etapie projektowania obiektu. Mają one wartość praktyczną. Przedstawiając w graficzny sposób procesy zachodzące w ramach strategii ogrzewania i chłodzenia, mogą być one pomocnym narzędziem analiz efektywności energetycznej i, w końcowym rozrachunku, podstawą przyjęcia optymalnych rozwiązań przestrzennych i konstrukcyjno-materiałowych.

Keywords: **Energy diagrams; Passive heating strategy; Cooling processes; Energy efficiency analysis.**

1. INTRODUCTION

Energy analyses in the form of diagrams which illustrate dependences between a building structure and energy management in the passive systems of energy acquisition become a necessary design element at the very beginning of the building design process. They are of particular importance in case of the sun-oriented buildings taking advantage of solar energy used for heating purposes. Based on passive systems they employ their basic structural components in the processes of heat acquisition, storage, distribution and conservation. Application of energy diagrams in the design process is no longer a possibility but a condition or reasonableness in taking decisions already at the stage of a concept. Still some time ago the architects' design work was mainly based on the artistic search for the means of expression, beauty, forms and proportions. An imperative of energy efficiency in building engineering requires something more. It is connected with the incorporation of the energy issues into the design process at the stage of creating the form and structure. EU directives, which force the member states to impose severe restrictions on energy consumption and reduction of the CO_2 emission, resulted in tightening the legal regulations concerning the parameters of energy saving and thermal insulation (Regulation of the Minister of Infrastructure on technical conditions to be met by buildings and their location, Chapter X, Law Journal 75, item 690), introducing requirements connected with energy saving and establishing coefficients till 2021.

2. BUILDING'S PASSIVE HEATING AND COOLING STRATEGIES

Having an impact on every building solar radiation provides measurable benefits in the form of heat. In view of the fact that heating requirements do not coincide in time with the intensity of radiation and the amount of possible heat gain there is need to draw heat from that source in a controlled way. At the stage of the development of the spatial design it requires an integrated attitude towards the heating and cooling strategy. The first one favours the solar gain during the heating season defining the methods for a building to acquire heat, to store it and distribute it within its interior. It also takes into account activities intending to maintain and recover heat, which decrease the demand for it during the utilization of a building. They consist in increasing thermal insulation and providing tightness of external partitions and also recovering heat from the ventilation systems. The aim of the cooling strategy is to limit the gain and to favour the loss of energy under conditions of high heat loads outside the heating period. It requires to get rid of the access of heat from a building as a result of proper distribution of the ventilated air. In practice, there is one more strategy, the strategy of natural lighting. It should help to make the choice between natural and artificial lighting for particular rooms. Each of the presented strategies serve different purposes as a result of which the functional conflict may occur, that can be prevented by selecting appropriate solutions [1, 2].

3. IMPACT OF ENERGY-RELATED ISSUES ON THE FUNCTIONAL AND SPATIAL DEVELOPMENT OF BUILDINGS

The concept of utilizing the solar radiation energy to improve the annual heat balance is reflected in the passive architectural solutions. The selection of them is conditioned by the location, character of the local climate, physiographic features of the area, method of a given building's utilization and by economic reasons.

The impact of the energy related issues on the spatial and functional development of buildings becomes apparent in all its aspects:

a. location of a building – There is the need to optimally orient a building relative to the sun, according to its functional and energy needs, because of the use of heat and sunlight. Rational solutions are also required from its location relative to the ground and prevailing wind in order to protect it against the loss of heat during the heating season. Embedding a building in the ground or covering its sides with earth also provides significant benefits during heavy heat load in summer becoming, at the same time, a part of the cooling strategy;

b. layout of the shape of a building – Two objectives are taken into consideration in order to obtain an energy-efficient shape. The first one is based on creating a compact shape, which allows to reduce the heat exchange surface between the usable environment and the surrounding, obtaining a favourable ratio of the external partitions surface area to the cubic capacity (A/V). The second objective requires a bigger opening of a building to the sun through developing the southerly exposed facade in order to improve the efficiency of the solar heat acquisition;

c. shape of the external structure – From the energy perspective, the external partition should act as a thermal protection of a building and should be liable for the solar heat gain. In the first instance, the condition is met by a tight structure of the partition, in the second one – by application of transparent materials characterized by a high level of infrared radiation transmittance. The rate of the facade glazing is conditioned by the partition location. Maximum glazing should be provided at the southern side and owing to the heat loss – the minimum one at the northern side;

d. arrangement of functions – The layout of rooms can be guided by the principle of the thermal zoning, which aims at the optimal utilization of the solar and the internal heat in a building. It allows to reduce the heating requirements in sunlit places and in places where the waste, operational heat is generated (e.g. kitchen). This entails the grouping of rooms of similar heating standard and also hierarchization of the elements of the operational function of a building according to the heating needs. Functional and spatial structure can also be prone to the seasonal variation of thermal divisions. It enables to reduce the usable area of high heating standard in winter and to enlarge it in summer;

e. shape of the inner structure of a building – Traces of subordination to the energetic requirements can be visible in the general characteristics of the interior structure as well as in its basic elements. An example of the complex approach is to obtain the spatiality of the interiors at the insolated side which facilitates the acquisition and distribution of heat in a building. However, the densification of the inner structure by applying the cellular layout of rooms at the cold, northern side, reduces the convective heat transfer and creates a thermal buffer between the microclimate of the interior and the outer environment bringing about the reduction of the loss of accumulated heat in winter. Characteristic spatial components of energetic importance are the glazed atriums used in order to improve the thermal and lighting conditions. As a result of locating glasshouses on the edges of a building, irrespective of the cardinal points, the thermobuffer spaces, thermal curtains are created, which reduce the insulation requirements of the internal facades. Moreover, an additional energetic role can be ascribed to the basic elements of the interior structure depending on their material characteristics. For example, walls and floors, which constitute the structure of a building and the tool of the interior division, can perform the function of the heat store;

f. selection of building materials – The building substance is expected to have more beneficial technical parameters within the functions performed by it. Particular energy features are: thermal accumulation, which allows to accumulate heat in a building and also heat conductivity, which conditions the efficiency of heat absorption and heat release through the material;

g. selection of technical systems – It concerns the application of systems collaborating with the basic elements of the building in order to achieve the desired energy effects (e.g. technical sun-shading systems).

4. EXAMPLES OF THE GRAPHICAL METHOD FOR DETERMINING THE ENERGY ISSUES IN A BUILDING

An impact of the energy issues is best expressed by the energy concepts graphically worked out in the form of schematic diagrams, visualizations or spatial development models. They present passive methods of the solar heat acquisition, its distribution in a building as well as the possibilities of coping with its excess. They determine the activities aimed at increasing the energy efficiency and improving the microclimate of the interior, the effectiveness of which is proved in the heat balance. The scope of those activities and an extent to which they affect the shape of a building is worth analysing on the basis of a few examples. They are the result of many years of experiments carried out by the authors of this publication during their didactic work on projects of energy-efficient buildings.

The first of the presented examples is an ecological nursery school with a corrugated green roof (Fig. 1). The key part in the energy concept is played by expanded skylights, which due to their scale, strongly emphasize their presence in the space, defining the character of the building development. They are covered with a double glazing with an integrated sunshading system. The casings of the skylights are provided with white reflective surfaces in order to increase the insolation area within the interior. The whole contributes to the system of direct gains with a simplified distribution of heat within the interior (each room and space uses the heat accumulated under the floor).

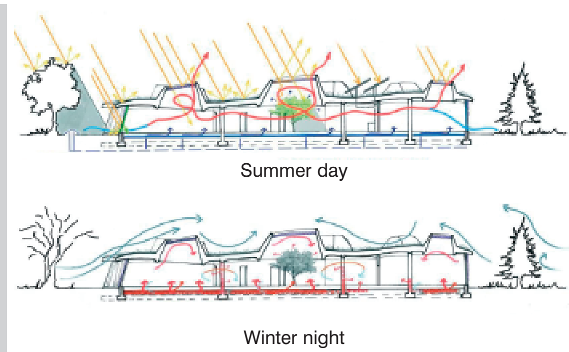

Figure 1.
Energy diagrams presenting the operation of the building during the most extensive thermal loads, during a winter night and a summer day. The work of a student, Dariusz Doung Vu Hong, made within the subject: "Design of energy efficient architecture"; in the third semester (academic year 2011/2012)

In the next example the building takes the shape of a flattened mushroom (Fig. 2). In its stem (ground floor) there are lecture rooms and in its cap – recreational rooms. A streamlined shape reduces the winter wind pressure exerted on the building diminishing, at the same time, the extent of cooling the surface area of the outer partitions. In great part, the mushroom cap opens its interior to the light and the solar heat, as it serves the recreation. Its extensive protrusion beyond the outline of the ground floor walls constitutes a natural protection (resulting from the shape of the building) for the lecture rooms against the solar radiation in summer without the need to install the shields on the facade. However, that kind of shape does not reduce the solar gain during the heating season.

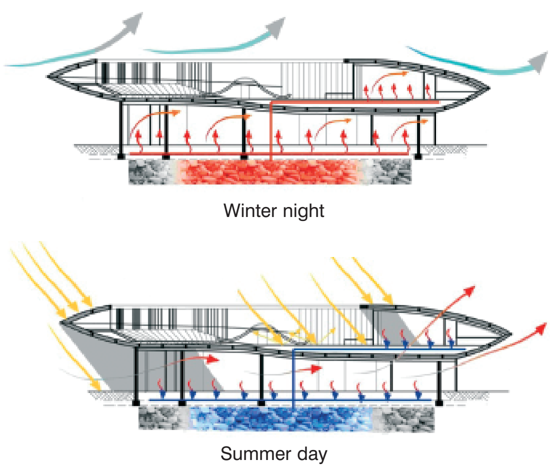

Figure 2.
Energy diagrams presenting the operation of the building during a winter night and a summer day. The work of a student, Anna Gliszczyńska, made within the subject: "Design of the energy efficient architecture"; in the third semester (academic year 2012/2013)

The next energetic concept (Fig. 3) copies the principle of operation of a solar tower. The basis of the design assumption is a glazed communication area embedded in the ground, from which particular blocks of the building structure spring upwards. The mentioned blocks house the principle functions of the building (the building is intended to be a municipal community centre). The heat acquired in the glasshouse during the day and accumulated in a store, which is situated under the floor and filled with stones, is released over time and gravitationally goes up. Searching for an outlet it flows inside the double casing of the blocks springing from the glass, where it

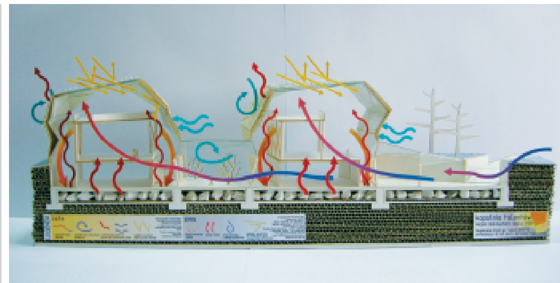

Figure 3.
Model presentation of the energy principles on an annual basis. The work of a student, Magdalena Orzeł, made within the subject: "Design of the energy efficient architecture"; in the third semester (academic year 2011/2012). Photo: J. Figaszewski

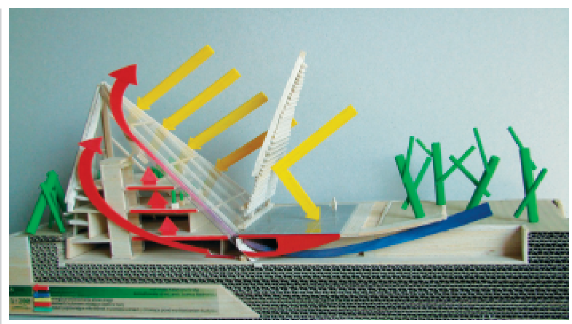

Figure 4.
Model presentation of the energy principles on an annual basis. The work of a student, Katarzyna Sroka, made within the subject: "Design of the energy efficient architecture"; in the third semester (academic year 2010/2011). Photo: J. Figaszewski

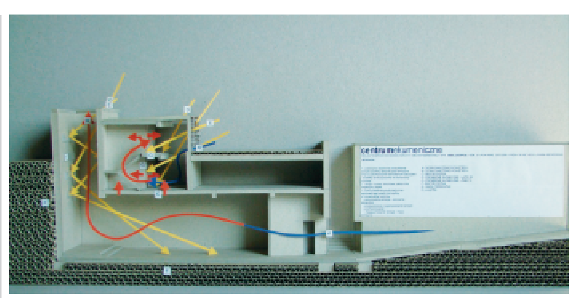

Figure 5.
Model presentation of the energy principles on an annual basis. The work of a student, Kamila Cierpioła, made within the subject: "Design of the energy efficient architecture"; in the fourth semester (academic year 2007/2008). Photo: J. Figaszewski

is distributed among the usable areas. The blocks of the building are provided with the collector and reflector systems to distribute the light.

The fourth example of a building in the shape of a sloping quadrangular pyramid is equipped with a ventilated glazed facade on its southern side, which effects the process of the excess heat removal in summer (Fig. 4). In case of traditional solutions the sun shading systems are installed inside the double-skin facade. In this case the rule was renounced and the outer structure of shields was introduced, which is moveable at its base. The inclination of that openwork partition depends on the season of the year and on the sunbeams angle of inclination. In summer it rests on the ventilated facade reducing the insolation of the interior. In winter it takes a different position opening the facade to the sun. An additional benefit of such location is that a part of the solar radiation is reflected onto a horizontal air collector installed on the ground, from where the acquired heat is conventionally transferred to the usable spaces. The moveable partition made of shields strongly accentuates the energy contents of the designed building.

The last of the discussed energy concepts (Fig. 5) illustrates the principle of creation and operation of the solar chimney. The ecumenical centre sunk in the ground has an underground sacred space accessible from a ramp. Solar heat and sunlight reach its interior thanks to the reflective surfaces of a chimney covered with a skylight. During the summer the solar chimney supports the natural ventilation and the process of cooling. Air circulation is carried out through the intake ventilation holes situated in the lower parts of glazing in the entrance zone of the chapel and the exhaust ventilation holes situated in the upper parts of the chimney, determining the uplift pressure ventilation. In order to reduce the heat gain from solar radiation the skylight can be made of angular and selective glass.

The presented examples of schematic diagrams or energy models emphasize a strong relation between the development of the spatial design of a building and the method of the passive heating and cooling. They show that the energy assumptions can determine the adoption of structural and material solutions without the necessity of applying the active systems based on installations and devices. It happens this way because the required energy effects can be achieved thanks to the application of physical phenomena taking place in a building and its vicinity accompanied by the accepted architectural solutions. Falling on a building the solar radiation undergoes reflection, absorption, dissipation or transmission. These phenomena are relevant to acquire and store heat. In turn, the distribution of it within the building takes place on the basis of the effects of heat exchange: convection, radiation, conduction and evaporation. Primary components of the building structure participate in this process having spatial as well as construction and material dimension, as well as the added components, including parts of the equipment and elements, fastened to the building structure by means of the construction exclusively attributed to them. In the energy diagrams, the functions in the strategy of passive heating and cooling are ascribed to them, which become significant depending on the season of the year. The whole range of solutions applied within this scope is outlined in Table 1. Energy components specified in it, which make up the systems of glazing, storage, distribution and regulation of heat as well as the thermal and sun protection, become apparent in various parts of the building and create one organism, which is responsible for the proper course of heliothermic processes.

Energy dependence of the development of the spatial design in buildings was best conveyed by words “form follows energy”, which in the light of functional changes that a building undergoes during its operation become more current than the classic expression of Louis Sullivan “form follows function”.

Table 1.
Components of the spatial structure of the building participating in strategies of passive heating and cooling. Worked out by: J. Figaszewski

Heating / Cooling Strategy		Spatial components	Structural and material components of a building	
			Solid structural elements	Added elements
Heating strategy	Preference of energy gain – Solar heat gain	internal atriums, passages, overall spatial shields, winter gardens, non-utilized glasshouses, convective-loop system, solar chimney, sun scoops	windows, translucent shields, glazed perforations of partitions, single glazed facades, skylights, glass structures of roofs, solar walls, walls with transparent insulation	blind windows, specular or diffusing reflectors
	Storage of heat	underground heat stores, roof-pond system	external solar walls, massive internal partitions from accumulative materials, floors of high thermal capacity materials, light partitions or layers of partitions containing phase-change materials	water tanks in glasshouses, containers made of net and filled with stones
	Distribution of heat	double-skin facades, atriums, system of channels in partitions	accumulation partitions as heat radiators, partitions made of high thermal conductivity materials	air flow regulating flaps
	Limitation of energy losses – conservation of heat	Rooms with lower heat standards as buffer spaces from the north, glasshouses as thermal curtains	green roofs and walls, partitions of high thermo-insulation and of limited perforation, low- e glazing, glass sets with transparent insulation	earth shields, solid or adjustable thermal shields: exterior-mounted panels, interior draperies, shutters, pop-in panels, microperforated foils, sun-powered louvers
Cooling strategy	Reduction of energy gain	arcades, galleries, loggias, double-skin facades	Green roofs and walls, overhangs, spectrally selective glazing	Earth shields, roofs, static or moveable sun-shading systems: shutters, exterior awnings, roller blinds, brise-soleil, (rotating fins) eggcrate, horizontal screens, external shading system Refleksol, metal or fiberglass screens
	Preference of energy loss	solar chimney, internal atriums, shower towers, roof ponds	Balanced ventilation holes in transparent partitions, walls with phase change materials as a cooling system	green plants, water tanks in greenhouses

5. IMPORTANCE OF THE ENERGY DIAGRAMS

Preparing a project an architect must comply with the guidelines of the technical conditions, which need to be met by buildings and their location. Not always, however, the mere acceptance of permissible coefficients can guarantee a high energy efficiency of a building, which is the result of the reduction of the heat loss in its outer structure. At that moment, the spatial and technical solutions presented in graphical convention emphasize also the possibilities of using available and economically justified renewable sources of energy to design an energy efficient building of high internal comfort.

Graphic diagrams make the basis for a discussion in an interdisciplinary forum. They can serve both in the course of the IDP – Integrated Design Process and in the course of the IED – Integrated Energy Design [5]. Thanks to the creation of a design team composed of such specialists as: an architect, a construction physicist, a power engineer, an expert in ventilation and air conditioning, the introduction of the principles takes place as a result of the initially accepted energy simulations and modelling. The analysis of the diagrams can be the basis of technical evaluation in the whole design cycle.

Architecture is the key discipline, which assumes responsibility for final decisions concerning the design of a building with low demand for energy as a result of adopting solutions favourable to minimize the heat loss and energy gain from renewable energy sources including the ones from the sun and wind (presented in the diagrams).

Energy diagrams become helpful in evaluation of costs and benefits coming from the investments both in the field of activities concerning the passive acquisition of energy as well as the active support of this system by means of a series of technological devices designed by the trade experts who have a complete picture of an efficiently functioning organism.

During the didactic process of students on the Faculty of Architecture in the Silesian University of Technology energy diagrams in the form of drawings and scale models were introduced within the subject of "Design of energy efficient architecture" as a task and justification of the accepted architectural concepts. In case of young people who are at the threshold of the future profession of an architect this methodology of teaching provides the basis of the primary knowledge, shapes the awareness of the necessity to take into consideration the views and relationships falling within the scope of energy issues in the designed buildings.

Social consciousness has been growing. For the investors' part, the cost of investment is crucial apart from meeting the formal requirements, for the buyers' part the measurable operating costs are essential. Efficiently assumed energy diagrams or changes, which are necessary to be introduced to them during the design process, can contribute to optimize the investment and operation costs for the time of the reimbursement of expenditures.

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