ENERGY IN ARCHITECTURE

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Problems of relations between energy issues and frequently discussed over the last decades. They are getting more and more attention in the contemporary design practice. As a result of consideration of energy aspects in buildings significant modifications in spatial and technical solutions as well as in legal and organizational design processes occur. This affects also methods of construction.

All these problems are nowadays widely debated and commented on in professional and scientific publications. The idea of energy in architecture has, however, many other connotations than the ones associated most frequently nowadays with the saving of energy as well as with the effective functioning that offers an adequate comfort to the users of buildings. Energy in buildings seen from broader theoretical perspective can also be considered and perceived in its symbolic aspect. Our imagination more often than not induces us to see in historic, and much more in many contemporary buildings, certain features that could be attributed to energy-related effects (Fig.1).

Among abstract ideas used by architecture, energy appears to be apparently the most interesting. It is not only due to its considerable potential in this regard but it also results from the importance of energy problems for space shaping processes. Therefore it seems appropriate to begin discussing this topic with the symbolic meaning of the term "energy" in architecture.

Symbolism

Comprehension of energy in its symbolic aspect, as a certain abstract idea immanently bound up with an architectural creation, can be related to many features of Psychological feelings appearing during the perception of some buildings happen to be consciously or unconsciously associated with their symbolic emanation of energy. This impression may indicate supposed topical "action" of energy or the effect of such an action in the past. In the latter case we may consider it a "post-energy-state" of the building. The above -mentioned convictions naturally depend on subjective assessment of architectural work. Symbolic intended or unintended energy features conceived by architects perceivable in designed buildings emerge in the form of buildings, selection of colours as well as in characteristic treatment of used materials.

Symbolism – the form

Energy is bound up with forms of buildings in a natural way. The physical existence of any form is not possible without "using" of energy in the process of its creation as a fragment of space. The use of the idea of energy as a formative factor in architecture leads to the creation of buildings or their fragments in a specific way. Its result is the domination of the effect of emanation of energy or the "petrification" of the post-energy-state of structure. The adoption of the first effect makes the building form to display symbolic cumulation of energy inside it and its potential emanation towards the outdoor space. In the most spectacular and technically advanced examples of buildings even a suggestion of resulting explosion can be perceived.

A good example of such formal solution is the BMW exhibition pavilion presented at the International Automobile Fair in Frankfort on the Main in 1999 (ABB Architekten). Another similar exemplary building is the Kunsthaus in Graz situated in the dense urban location (arch. P.Cook and C.Fournier) (Fig.2). In both cases their "bubble architecture" stylistics present pseudopneumatic forms marked with conspicuous energy potential which is associated with a tight and close-to-crack building envelope. If the second method is applied energy potential can be seen in buildings being in the state of unstable equilibrium. A representative example of this creative idea is the APL Tower in the port of Lisbon (arch. G.B. Architectos) (Fig.3).

Yet another method allowing to highlight symbolically effects of energy in buildings as an intentional concept for formal solution uses psychologically sensed dynamism of forms. This type of creative expression is undoubtedly most frequently recognizable even by laypersons in the art of architecture. Energy associations are then even more obvious than in the case of static buildings displaying perceptible potential energy. Dynamic structures apparently seem to be petrified in their final pseudokinetic stage following supposed sudden stopping of previously moving fragments or their expansion into surroundings. Among the most spectacular examples illustrating this method of symbolic manifestation of energy in architecture should be mentioned the Mercedes-Benz Museum in Stuttgart (arch. UN Studio) (Fig.4) and particularly the Hotel Marques de Riscal in Elciego, Spain, built in the years 2003-2006 (arch. F.O.Gehry).

The exhibition of physical effects of symbolic impact of energy on architectural matter is yet another result of creative experiments concerning the discussed problem. These efforts are concentrated substantially on stylistic issues. The post-energetical state of buildings is present in the architecture of Deconstructivism as a result of supposed interference of energy. Its stylistic feature are characteristic deformations and fragmentation of forms of buildings. These effects are attainable due to appropriate methods of designing forms, properties of used structures, technologies and materials. The deformations of buildings designed in the above-mentioned style involving energy features are often achieved perfectly by the application of components made of steel. Suffice it to say that perforated metal sheets, cladding or meshes have become quite popular easily formable building materials in the recent years. The perforated steel sheet has been used for the Copper Union building in New York (arch. Morphosis) as a façade finish and its second skin. It was a very realistic and convincing example of the idea of symbolic deconstructive formation of a building structure by "concealed" energy. Dominate in such cases light structures, however, heavy technologies also happen to appear.

The post-energetical state as a stylistic feature of architectural works can unexpectedly enough be referred to the compositional principle of asymmetry. It regards in particular the symmetrically composed forms or facades with asymmetrically located elements which distort symmetry – principle of composition having as a rule static character. Such deformation of symmetrical composition apparently suggests interference of power (energy) as a co-creative factor. Thus asymmetry as one of the compositional rules may be considered the effect of previous participation of energy in spatial creation. This reasoning could be underpinned by some scientific findings and theories that make it less subjective. In the light of the cosmologic big-bang theory the effect of then released energy caused the so called symmetry breaking. Asymmetry seems to be, therefore, in physics a rather natural energy- related state that induces transformation of symmetrical systems into the asymmetrical ones[1]. The problem of energy in architecture with its symbolic aspects could be then related per analogiam to natural physical phenomena in cosmic scale.

Symbolism – the colour

Symbolism of colours applied to buildings is a means of composition traditionally and readily used by architects. Intentional application of colours as a synonym of energy in art works has been even legitimized in industrial codification where definite colours symbolize anger, high temperature or motion that is conditions pertaining to energy. High degree of brightness and relevant colour are popularly enough, symbolically and psychologically associated with vigour, even with the high temperature of facades. Elements of architectural or plane artistic compositions painted with so called "warm colours" are gladly used by architects and then reveal symbolic connotations with energy (Fig.5).

Complicated colored compositions introduced by architects to buildings allow to obtain the effect of optic vibration on surfaces of facades thus suggesting the involvement of some kind of energy as an acting creative force. Consistent application of untypical colored panels of glass brought about a spectacular result of energy-induced quivering of the façade in the case of the Dutch Institute of Sound and Vision at Hilversum (arch. Neutelings-Riedijk, 2006). Colour as a means of artistic compositions reveals then in this discussion a significant potential.

Symbolism – the surface quality

Illusive effect of vibration is usually achieved not only due to appropriate colored compositions but also through proper treatment of surfaces of facades. One of the methods offering such poten-

[1] P. Davis, *Kosmiczna wygrana* (Cosmic jackpot), Warszawa 2008, s.177.

tial effects is the application of many small flat or three-dimensional elements and relevant fine division of elevations. This can be realized in many ways, for instance in the form of repeatable glass panels and plastic or metal elements arranged in different planes. Their diversified finishes enliven usually coherent and static forms of buildings. Resulting deformations and appearing additional reflexes give them characteristic dynamism and lightness. An example of the implementation of this kind of treatment is the Municipal Library at Nembro in Italy (arch. studio arche, 2007). Glass façade has been closed within another outer perforated envelope made of mobile, glazed ceramic tiles mounted to a steel grid. The outer skin is designed to play simultaneously the role of shading device. Due to the diversified mutual configuration of its tiles it gives the impression of vibrant envelope stimulated by energy. Energy as a creative factor may also assume the form of a special treatment of building surfaces transforming their symmetry into so called asymmetry in symmetry. This method has been used as the main compositional idea in the architectural concept design for the Faculty of Radio and Television, Silesian University at Katowice (arch. W. i M. Celadyn - 2011). Intentional completely different colour and surface treatment of both symmetrically arranged fragments of the main façade was intended to highlight the compound function of the building. Contrasting rythm, fenestration and set of selected colours but above all the diversified surface treatment of both symmetric parts of elevation were supposed to be the elements emphasizing their mutual opposition and to create a sort of energy-related tension between them (Fig.6).

Presently designed and erected buildings with pseudomobile facades located in public spaces play the role of Transparent or semi-transparent facades with applied stainless steel media-meshes or LED-panels turn them into giant screens that deliver visual information to passers-by. These elements integrated with the building structures give them characteristic look, for some being very controversial from the aesthetic point of view. They transform itself in the medium of communication carrying information and publicity. Technical solutions of such media facades do not hamper the functional values of buildings as they allow close-to-clear view of the outdoor space through the installation. Graphic designs or video projections presented on elevations create a new type of contemporary pseudomobile facades. Pioneering example of this kind has been the media-mesh elevation of the T-Mobile building in Bonn (Fig.7).

A very spectacular culture and television building complex CCTV in Beijing (arch. OMA/Rem Koolhas, 2008) is another even more complete architectural work that falls into this category. Complementarity of function and applied technical solutions used as the idea of its skin designed for the presentation of graphic animation is a characteristic feature of the building. Perceptible dynamism of its façade is not only technically animated by electrical energy systems but also seems to be inseparably associated with energy in the symbolic sense.

Technology

Technology in architecture and construction – it is a term with numerous connotations. As far as energy issues related to it are concerned and for this discussion we can make an assumption that it covers substantially the problems of functional and spatial solutions as well as technical building equipment. Functional and spatial effects are attainable with the use of technologies and materials. Technical aspects of relations between complex problems of energy and architecture pertain substantially to the issues of activities in three directions. These are energy gains, reduction of energy losses from buildings and of excessive energy in indoor spaces. Energy is, moreover, considered in relations to its many diverse forms. In the case of built environment it should be taken into consideration as thermal radiation, daylighting, air movement, acoustic waves and even electromagnetic radiation. Some of these factors have exerted their distinct impact on historic and vernacular architecture. Nowadays they frequently determine our architecture conspicuously. This regards layouts, forms and outer skins of buildings as well their interiors.

Technical aspects of energy in architecture are closely tight both to the process of appropriate formation of buildings at the design stage and to later additions of flat or spatial structures to existing buildings. Technology in energy-conscious designing process is also perceivable in inner and outer installations in buildings. It assures their economic and effective functioning. Devices and structures developed to gain energy from unconventional sources or to reduce the heat loss from buildings are more and more often used as standard architectural solutions. Mostly massive external walls with slightly glazed fragments being energy-passive have been subject to evolution towards the ones with greater proportion of glass. Finally they have turned to completely glazed outer skins becoming energy-active systems. The greater is the area of glazed parts of external walls the greater their susceptibility to the control of intensity of heat flow as well as daylight and air penetration into inner spaces. This progressing tendency in designing of energy-saving buildings is marked by the use of such technical structures as glasshouses and solar collectors or photovoltaic panels on facades and roofs. Application of transparent insulations on external walls or installation of diverse forms of wind turbines – these are also more and more often used methods of dealing with energy problems in contemporary architecture. Each of the above-mentioned energy-related solutions determines the forms and other components of buildings in a different way.

Technology – the gain of energy

The idea of integration of glasshouses with building structures as a method of gaining thermal energy with the solar passive heating system is being used in many ways. The most representative and complete example is the model house in Knoblachsland near Nuremberg (arch. Niederwoehrmeier & Kief). The maximum of solar radiation accessible in its inner spaces is assured by a glass envelope housing the primary structure of the building. This is the idea of the "house in a house". Passive methods of solar gain in such complete or partial form taking advantage of the well-known physical phenomena seem to be the most obvious and natural solution in architecture. They are, however, not deprived of problems.

Glasshouses integrated with the south-facing walls of buildings have become recommended elements in the low-energy strategy and an attractive idea for formal creation. Optimal shaping of building forms on account of energy gains in the case of glass walls substantially consists in their appropriate spatial configuration. For south-facing facades their most advantages inclination lies between 55 and 67 degrees. The best dispersed daylighting of inner spaces is attainable with the northern slope of glass roof within the range of 28 to 33 degrees.

Passive solar optic systems make possible the control of daylight in inner spaces through the enhancement of its intensity and its optimal even distribution. The installation of thes devices is recommended outside in front of glass walls and roofs or within their structure. The second component of the system that is the reflector mounted under ceilings of interiors allows to transfer the light beams inside up to 8 m deep from collectors or heliostats mounted on the exterior glazing[2] (Fig.8). In practice it gives the opportunity to daylight spaces located in the central area of lower stories of buildings including basements.

The horizontal and vertical surfaces of building glazed envelopes can be supplemented with single or groups of heliostats with supportive devices like focusing mirrors or light pipes. Concentrated light beams filtered and thermally modified due to this technological enhancement reach interior spaces and improve their daylighting conditions (Fig.9). An interesting example of this technology is the underground station in Berlin (fig.10). Solar collectors and photovoltaic panels allow to construct systems that are efficient in heat gains and generation of electricity from solar radiation. The technology used permits their installation on existing buildings. They can be components completely integrated with the building structure, if planned at the design stage, and appear as outstanding shaping elements (Fig.11).

Transparent insulation is sometimes applied on massive external walls. As a translucent leaf of their multilayered structure it transmit solar radiation to a massive part of walls and thus make the system energy-active. Fabricated as compound panels they allow to obtain solar thermal gain which is accumulated within the wall structure and further radiated inside to heat interiors. These systems gain popularity in some countries given their easy installation, especially in the case of existing buildings subject to thermal modernization.

Wind turbines as devices designed to gain energy from unconventional sources for buildings are still controversial for some non-energy-related reasons. This technology is so far sporadically used in architecture given their unsatisfactory performance, high cost and some reservations about aesthetics. Widely known are also some restrictions as to the insufficient wind velocity in many localities. They are important limiting factors. Some novelty in this dilemma are

[2] Siemens Aktiengesellschaft, *Daylight System*, p. 2.

scarce cases of their application on top of skyscrapers. One of them is a concept for Phare Tower in La Defense at Paris (arch. Morphosis - 2006). Modern wind turbines cleverly crowning this building have contributed to the unique formation of its silhouette giving it an individual interesting architectural character.

Perceivable progress in this technology and conception of turbines with vertical axles being particularly suitable for buildings and adherent spaces seem to have opened new interesting perspectives for this method of energy use in architecture (Fig.12).

Technology – the reduction of heat loss

Spatial concepts for buildings and their technical equipment designed to gain energy many times work also as elements of strategy of thermal protection and reduction of heat loss. As a rule, however, these functions are separated. Design methods considered rational for later building operation and heat loss reduction assume working out of optimal layout and form of the conceived building. Its most coherent form is a basic requirement of the shaping process. Other elements of the program of energy optimization are as follows: choice of adequate structure of external walls offering high thermal insulation and storage of energy, installation of thermal shields for glazed walls.

Evolution of structures of external walls that has occurred due to the research on the methods of reduction of heat loss from buildings through last decades presents the diagram in Fig.13. The development of the idea of modern external walls consist in their multilayered structure made of new building materials characterized by satisfactory physical properties and high thermal performance. Single glass walls sometimes occur to be transformed in complex structures for enhancement of thermal performance. The best results in this area can be achieved in the case of double facades where a second outer glass wall is added and thus a thermal buffer interspace is formed between both glass skins. The system can work as one insulating space for the whole façade or a set of individual spaces for every single story. Double facades have been recommended for twenty years especially for high-rise buildings.

Thermal stability as an advantageous physical property of building structures being of great importance for the comfort of interiors is usually achieved by the use of massive walls. In the case of glass walls, light by the nature, and characterized by the low thermal capacity, new technologies propose phase-change-materials integrated with them to improve their thermal stability.

Technology – protection against the excess of energy

Overheating of internal spaces enclosed by glass walls or roofs in summer is a crucial issue in contemporary glass architecture. Numerous new technologies widely being introduced in architecture are designed to alleviate and solve this problem. The protection of glazed walls and interiors from excessive solar radiation is usually assured by shading device mounted in the area of glazing. They can be fixed or movable. Their assortment is very diversified : overhangs, awnings, horizontal or vertical louvers, perforated sheets, eggcrates, blinds, rolling shades and the like. The above-mentioned passive solar optic systems can also be used as sun shading devices. Similar methods of solar energy controls are being used for glass roofs. In this case they are often even more complicated and form simultaneously external and internal cooperating protective systems.

Technology – the acoustic energy

Acoustic waves and the effect of their penetration through walls is another energy factor of great importance for architecture. It is usually underestimated in standard buildings. Acoustics in buildings is pondered particularly in the case of specific functions of buildings. Contemporary technology allows to solve acoustic problems regarding undesired propagation of sound or noises. Architects are usually interested in acoustics of interiors but these problems concern the close vicinity of buildings may be achieved by appropriate shaping of building forms depending on the direction of propagation of acoustic waves from noise sources. Convex or concave walls, their mutual spatial configuration, positive or negative inclination, optimal integrated with facades – all these are formal and technical means which are accessible for architects to control and solve acoustic problems. It is obvious that they can have a significant impact on architectural works also building`s surroundings. Amelioration of acoustic conditions in materials of elevations and their texture, acoustic screens and other devices.

Technology – the energy-related technical installations

Among numerous technical installations which mean a lot for energy concept for buildings so called solar chimneys should also be mentioned. They are part of ventilation systems operating basically in summer when they allow to evacuate the hot air from inside the building. These systems happen to be exposed outside the buildings and give then them a specific look. But heat pumps, ground heat exchanger, standard heating installations etc. are technical equipment and energy systems integrated with buildings, and as a rule located inside the buildings do not influence their architectural forms as well as their aesthetic quality. External walls have gradually transformed into complicated spatial structures composed of different systems cooperating in optimization and control of diverse forms of energy flow (Fig.14). Special acoustic dampers integrated with glass walls lower the intensity of noise penetrating into the building and ameliorate the acoustic comfort in interiors. We can assume, however, that the development of external wall systems may proceed in completely opposite direction than so far. Such signal has already been given when the idea of dynamic building skin emerged[3]. The effect of its implementation would be plane and not three-dimensional walls . They would make multifunctional systems boasting physical and technical parameters self-controlled and subject to users` expectations. Such scenario of the development of future

building technologies would allow to avoid presently existing energy-related problems that hamper the architectural creativity marked by minimalist stylistics.

Integrated design as a result of increasing role of energy problems in architecture

Energy problems in architecture should be considered not only in symbolic, spatial and technical aspects as we did above. They also have an increasing impact on the methods of professional work. The solution of multiple energy problems has become the dominating properly valued and analyzed in the design process modifies the character of architect`s work and gives the impulse to the search for sustainable architecture. Integrated design, which covers the life cycle of buildings, has evolved from the problems of energy in buildings and their impact on environment. It requires active participation of different specialists from many related professions in the process of creation. This method of work involves diverse aspects of projects like functional, constructional, environmental, economical, sociological, cultural as well as durability of structures. The resulting design solutions should respect the successive stages of building`s life to begin with the production of materials and building components through its construction than its use and maintenance including finally demolition, recycling and utilization of materials. Integrated design considers also different levels of optimization of applied materials, components or the whole structures of buildings. As a consequence of this reasoning there should come the development of the estimation methods of the most important stages of the construction process. Analysis of the above-mentioned factors that define the project`s quality entails the evolution of the design process. Aside from the former professional participants cooperating with architects many more new specialist are being involved in order to obtain a valuable design product. In the first place the climate engineers should be mentioned, next the experts in so called "green building" would advise on the tendency in architectural and constructional activities. Expected parameters of buildings for energy certification in energy- and ecological performance such as LEED, BREEAM or DGNB. From this discussion emerges the idea of energy in architecture in its new meaning that regards not only spatial, aesthetic and technical parameters of buildings but also significantly modified character of work and cooperation of all participants of the design process.

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[3] Mike Davis` idea from the year 1981. For further information see for example: A.Compagno, *Intelligente Glasfassaden*, Basel 1995, p. 8.