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The influence of ecology and economic factors on eco-architecture and the design of energy efficient buildings

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ABSTRACT: Vigorous human activity and population growth have a destructive effect on the environment. Ecological and economic factors influence modern architecture. In this regard, a number of measures need to be implemented for the preservation of natural resources. These include the development of alternative energy sources, the management of heat, and the treatment of water and air. In Kazakhstan, as well as around the world, the design and construction of energy-efficient buildings have increased and become more common. Energy efficiency is one of the key components of any ecological building. This factor guides the use of energy resources, so as to minimise negative impact on the environment. Heating, ventilation and air conditioning are the largest power expenses in a building. The use of alternative energy sources helps to lower them. Energy-efficient buildings are constructed with a minimum impact on the environment. The main emphasis is placed on the effective use of natural resources, and a decrease in the impact of waste and pollution on the environment. Energy-efficient buildings use materials necessary for construction, without affecting the natural world.

INTRODUCTION

Countries and people are substantially connected with the natural and geographical environment. Understanding environmental problems has led to the development of ecology and influenced economic development in the industrialised world. The centre of gravity of global problems was moved to the developing countries. The main thesis of the ecological culture can be stated: *nature as a permanent factor defines a way of life, traditions and spirituality of a people*. The ancient tradition of a nomadic way of life taught the Kazakh people to understand natural phenomena and to adapt to them through many centuries. People gained material benefits from nature, and began to understand and appreciate its importance. The dwellings of nomads were in harmony with the environment. Ecological pressure occurred with pre-industrial pollution, and then there was more pollution connected with multinational corporations and their production. Higher energy consumption by buildings became the basic criterion of architectural quality.

Since the 1990s, with the development of energy-efficient buildings, the priority has begun to move toward energy savings and improving the quality of a building's microclimate. There are examples of autonomous architectural zones, residential areas and buildings designed and built using different environmentally friendly energy-efficient technologies. Some of the best known concepts include: energy-efficient building; low-energy building; ultra-low or zero energy building; passive building; bioclimatic architecture; healthy building; smart building; intelligent building; high-tech building; sustainable buildings and advanced buildings. Sometimes, listed variety of technologies can be used together in proposing complex engineering solutions for individual buildings or for town-planning projects.

At the end of the second millennium, there was a significant change in the world in terms of energy conservation and environmental protection. In the 1980s, the *green* movement provided a new impulse to design buildings that spared the environment. Architectural means were deployed to reduce the burden on the environment. A modern trend in architecture is the design of energy-efficient buildings and structures [1].

Increasing the energy efficiency of buildings by using the energy of the natural environment consists of using natural sources for cooling, heating, ventilation and lighting. The source of light and heat is the sun, while cooling is affected by the organisation of natural ventilation. *Buildings that use the energy of the natural environment have a form and a shell that filters and distributes natural energy to the interior of the building in accordance with the needs of the inhabitants* [2]. Fencing structures and the shape of such structures must reflect unnecessary heat and harmful climatic influences. New technologies in architecture allow a versatile usage of solar energy. The use of passive and active means of solar architecture has significantly reduced the fossil energy requirements for the operation of buildings. Energy savings in construction reduces energy consumption and increases the competitiveness of the economy.

ECOLOGICAL PROBLEMS IN DEVELOPED AND DEVELOPING COUNTRIES

In the 1970s, an energy crisis resulted in an increase in fuel prices throughout the world. This was the main reason for the growing interest in saving energy and resources, and in renewable energy sources that could be used to supply heat to buildings and houses. Awareness of environmental problems led to the ecologisation of economic development in industrialised countries. This was reflected in the fact that the costs of environmental protection increased dramatically. The development of clean technology ensued. There was an *eco-industry* and *eco-business,* i.e. an international market for environmentally friendly equipment and environmentally friendly products. A system of laws and organisations for the protection of the environment was formed together with corresponding ministries and departments. Programmes for the environmental development of individual countries and regions have been developed. International co-ordination in the field of environmental protection has strengthened. New models of environmental development and novel technology have arisen from the developed world, which accounts for about 20 percent of the world's population [3].

Modern *industrial* pollution in developing countries is caused by the transfer of many polluting industries to their territory, primarily by the construction of metallurgical and chemical plants. The concentration of the population in the largest agglomerations is growing. *New* pollution in developing countries is also determined by the chemicalisation of agriculture. *Pre-industrial* degradation is the result of mass deforestation and desertification, which is the result of anthropogenic and natural factors, such as excessive grazing and cutting down of rare trees and shrubs, disturbance of the soil cover and fragile, easily destroyable ecosystems in arid regions.

CULTURE OF ENVIRONMENTAL BEHAVIOUR OF ETHNIC GROUPS

One of the most ancient theses says that the life of states and peoples is largely conditioned by the natural and geographical environment. Many thinkers linked the development of the culture of the people with geographical conditions and the specifics of the natural environment. This is confirmed by Gumilev who opined that *…the behaviour of ...each ethnic group is simply a way of adapting to its geographical environment* [4]. This statement by Gumilev builds on the idea of co-evolution, i.e. the joint development of nature and ethnicity. This defines the conceptual basis for environmental education. Hence, the main thesis of the conceptual foundations for the formation of ecological culture is to see nature as a constantly acting factor that determines the type of activity, lifestyle, customs and traditions, as well as spirituality of ethnic groups. Cultural ecology deals with the following: the habitat and technologies inherent in a particular culture for use of its food and other natural resources; behavioural models associated with certain technologies for the development of natural resources; and the influence of these behaviours on other aspects of culture [5].

Ecology, determined by the geographical, physical environment, the climate and flora, gives people the resources that are necessary for life, i.e. fertile land, animals for hunting, oil, metal, and others. These resources contribute to the development of certain types of activities, which in turn contribute to the creation of a special way of seeing the social environment, and form elements of a subjective culture in terms of norms, values and self-representation. The peculiarity of geographical conditions with vast steppes and open spaces, and a harsh continental climate promoted the development of a nomadic way of life and of cattle breeding as the main form of activity for the Kazakh people. In a nomadic culture harsh living conditions contribute to the development of co-operation. In such cultures, interaction, interdependence, responsibility and the desire for coherence are encouraged [6].

National traditions have formed over centuries, and they have their own peculiarities in the protection of nature. The tradition of the Kazakh people to lead a nomadic way of life contributed to a better understanding of nature. As with other ethnic groups, special natural phenomena, a reserve and a healing spring, natural monuments, giant trees, beasts and birds, were attached to the traditions of the Kazakh people. The traditions of creating protected areas, protecting birds and animals, and preserving forest, saw wealth begin to develop. The Tengrian faith gave the Turkic nomads the knowledge and ability to feel the spirit of nature, to become more aware of themselves as part of, and to live in harmony with, nature. They obey the rhythm of nature and enjoy its endless changeability; its multifaceted beauty. The national dwelling of nomads, the yurt, is an example of an eco-architecture in harmony with nature.

INFLUENCE OF ECONOMIC FACTORS ON ENERGY CONSERVATION IN CONSTRUCTION

Energy saving is a factor in construction encouraging the implementation of effective cost-saving energy measures. Economic stability requires the saving of energy resources in general, and in construction, in particular. The construction industry is a strong energy consumer. Today the role of effective energy saving and energy consumption is very important [7]. The economic factors affecting energy conservation in construction are affected by the following:

- inflation;
- investment attractiveness;
- tax privileges and conditions;
- credit availability;
- interest rate policy of energy-generating organisations;
- functioning of the energy market;

- physical wear and tear of equipment;
- legislation for energy saving;
- tools and methods of energy management;
- awareness of energy conservation in construction;
- depreciation of fixed assets;
- thrift, economy;
- construction policy;
- rational use of energy resources;
- high construction costs;
- state stimulation of energy conservation.

Today, the act regulating energy saving in Kazakhstan is the Law of the Republic of Kazakhstan of 13.01.2012 № 541-IV on Energy Conservation and Energy Efficiency [8]. Energy management allows construction companies to reduce energy costs, monitor energy consumption, and introduce effective long-term energy management processes. All this reduces the cost of production, increases the competitiveness of an enterprise and positively affects the environment. Energy consumption in Kazakhstan (per capita) is at a level comparable to developed countries. Kazakhstan has a significant potential to reduce energy consumption. The implementation of a variety of energy-saving measures requires huge investments. This requires the development of energy service contracts and carbon investments. To successfully achieve the set goals for reducing the dependence of GDP on energy, it is necessary to organise state control over compliance with energy consumption standards and the monitoring of the implementation of the programme, *Energy Saving 2020* [9][10]. The data for the specific heat consumption of buildings in a selection of countries are presented in Figure 1.

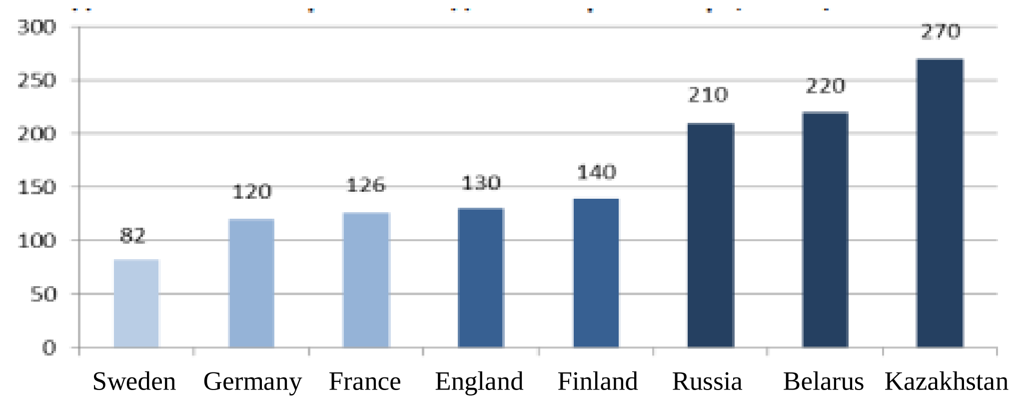

Figure 1: Specific heat consumption of buildings in the world.

Figure 1 shows that Kazakhstan consumes 3.2 times more heat per building than does Sweden. Thus, energy conservation in construction is a set of measures to increase energy efficiency, which results in lower costs for a useful effect.

CONCEPTS AND TRENDS IN CONSTRUCTION: CLIMATE AND HEAT SUPPLY

An energy-efficient building has effective energy consumption achieved through the use of various innovative solutions that are economically sound and are technically, socially and environmentally acceptable. An energy-efficient building has low or zero energy consumption. Here are some examples: energy-efficient building; low-energy building; ultra-low or zero energy building; passive building; bioclimatic architecture; healthy building; *smart* building; intelligent building; high-technology building; environmentally neutral building; sustainable building; advanced building [11].

A *passive building* is one in which non-traditional renewable energy sources are used, significantly reducing the amount of energy consumption over traditional energy sources. The idea of a passive building comes from the German scientist Wolfgang Feist, who developed and built the world’s first passive house in 1993 [12]. The main principles of the passive house are the superinsulation of protective structures; the use of energy from the earth (ground) and the sun; the utilisation of heat from sewage and exhaust air. Energy consumption of such a house is no more than 15 W/m^2.

Bioclimatic architecture is a relatively new trend in construction. The main principle is the harmony with nature of the building and the person living or working in it; and the distinctive feature is the abundant use of glazed spaces.

A sustainable building is where the ecological balance is maintained of man and the environment. Sustainable buildings are a reaction to human striving to conquer nature, by destroying and exhausting it. It involves a variety of opportunities for using environmentally friendly and renewable energy sources, optimising energy use, preserving the environment and resources, using recycled building materials, while improving the quality of the habitat.

In an *intelligent building*, the heat supply and air conditioning are controlled by computer technology. Light and heat in rooms and enclosing structures are optimised. This is mainly achieved through the correct orientation of the building in relation to the sun and by insulation.

The *high-technology building* is the most cutting-edge solution in terms of design and material. Energy saving, the quality of the microclimate and environmental safety are achieved through the use of technical solutions based on advanced knowledge.

The *healthy building* uses energy-saving technologies and alternative energy sources, environmentally friendly natural building materials (mixtures of earth and clay, wood, stone, sand) and environmentally friendly technologies to maintain a healthy microclimate. In addition, healthy house technologies take into account advances in air purification from harmful fumes. There are no emissions of harmful gases, radioactive substances (Radon gas), fine dust (causing allergic diseases), dirt, formaldehyde (emissions from smoking) and bacteria. There is suppression of pathogenic wave radiation from computers, cellular communications and Wi-Fi.

An ecological building is where there is no waste of building materials, with zero energy consumption and, as a rule, energy is generated for more than one building. All the technologies can be combined offering integrated engineering solutions, both in separately constructed buildings and in town-planning projects.

ENERGY- EFFICIENT ARCHITECTURE

An energy-efficient house does not depend on external energy and can itself serve as a source of energy. This is made possible through the rational use of heat and energy sources of the house itself and the surrounding area. Designing an energy-efficient home is a complex work that must take into account the multivariate approach, the rational choice of the thermal protection of the enclosing structures, the choice of engineering equipment and the efficiency of use of the renewable energy sources. One of the most important features when designing such a house is to ensure the ecological and efficient life cycle of the building. Such a building initially should be designed for a certain period of operation, be the most energy efficient during this period, and be safely demolished, without damaging the environment. The average life cycle for buildings of average height is 30 to 40 years [13].

The main feature of an energy-efficient house is the reduction of the external perimeter of the building relative to its internal volume. The construction of a house with *thermal buffers* reduces the perimeter of the thermal contour of the house, which borders directly on the environment [14]. In the climatic conditions of Northern Kazakhstan, a large number of energy-efficient materials is necessary for an energy-efficient home. The main elements of an energy-efficient house are: *warm* windows with wide window profiles and internal insulation, triple glazing with two low-emission coatings and filled with an inert gas. Heat loss through the warm windows is 2 to 3 times lower than through conventional double-glazed windows. To seal the outer shell requires a continuous vapour barrier. For internal thermal insulation, mineral wool heaters, organic heaters, expanded polystyrene and vacuum insulation are used. From the architectural point of view, the aim should be: compact volume of the building; the rational ratio of the area to the outer perimeter; optimised glazing; the use of thermal buffers (verandas, attics, and so on); and rational orientation to the outside.

The main feature of the passive house is extremely low power consumption. Such a house has the architectural concept to maximise heat collection from the external environment and its long-term preservation inside the building. This is expressed in the compactness of the premises, the zoning and tightness of the entire structure, and most importantly, in the application of quality insulation. The use of several layers of thermal insulation significantly reduces the heat transfer of the basement, walls, attic and roof. With the proper construction and design of the house, additional heat sources are not required, though a warm electric floor can be used in extreme cases. In planning, one takes into account that windows facing south provide the passive house with an influx of heat, which significantly exceeds the losses through them during the cold season.

The ventilation system in passive houses is usually arranged differently from the convection type. Its main component is the heat recovery unit. Air cleaners designed to maintain comfortable conditions in a room are also used in the passive house, because in a closed room air is very easily and quickly saturated with dust, carbon dioxide and carbon monoxide, as well as the products of dust mites. For passive houses that are built in areas with large differences in temperature or long periods of persistently high or low temperature, it is recommended to additionally use active heating systems and air conditioners. But, even the use of these usually does not require significant energy costs. A passive house built according to all the rules allows its owners to save up to 90% of the energy consumed by a similar house built in the traditional way, and this is a significant contribution to the conservation and careful use of the planet's resources [15].

Bioclimatic Architecture

Bioclimatic architecture is one of the current directions of architecture. The main principle of bioclimatic architecture is harmony with nature, the desire to bring the human dwelling closer to nature. The eco-designer Mack Dono writes *… I want to make sure that the bird, having flown into the office, does not even notice that it is no longer outside the* *building, but inside it* [16]. Buildings with a double translucent ventilated facade are built in France (architect Jean Nouvel), Finland and Germany. A double ventilated facade is an important element connecting the working premises to the environment. Such a facade meets the high aesthetic requirements of architects and builders, and makes a significant contribution to the creation of an energy-efficient and user-friendly building.

The architectural and engineering solutions of the *City Gate of Düsseldorf* building with regard to heat supply and air conditioning make it possible to declare this to be not only a building of bioclimatic architecture, but also a high-tech, intelligent and passive building. To a large extent, it is also a sustainable building. All these characteristics are implemented in this one building [17].

The bioclimatic building - *Ark* - equipped with an autonomous life support system, is designed as a response to possible climate change on the planet. The objective of the project was to create a healthy and comfortable environment for humans [18]. The building is designed as a unified energy system with uninterrupted power supply based on the use of alternative energy sources. Waste is used to generate thermal energy and is also converted into bio fertilisers.

The factors that determine the architectural, structural and engineering solutions of bioclimatic buildings can be divided into five groups:

- Group 1 - *landscaping and climatic factors* include the influence of the natural conditions of the building site (the nature of the relief, the orientation of the building), the effect of solar radiation (natural light, orientation to the sun, plantings), air flows (natural ventilation of the premises, aerodynamics of the building) and the influence of green spaces on the architecture of the building.

- Group 2 - *social and economic factors* involve the formation of a socially responsible consciousness among consumers. The introduction of natural components into the building significantly improves and revitalises the microclimate, improves psychological comfort, especially in multi-storey and high-rise buildings.

- Group 3 - *environmental factors* imply full control of the life cycle of the building, use of environmental materials, the restoration of closed natural cycles and the replacement of lost green spaces on the construction site.

- Group 4 - *power engineering factors* include the use of renewable energy sources, such as solar energy, wind, geothermal, water and biomass.

- Group 5 - *urban factors* include the passive protection of the building against the adverse effects of the urban environment, the level of greening of the urban environment, the degree of air pollution, and load on urban engineering networks.

These factors determine the principles and characteristics of the architecture of bioclimatic buildings, as well as the planning decisions of the territories and regions on which such types of building are designed.

PRINCIPLES OF ENERGY-EFFICIENT ARCHITECTURE AND ENVIRONMENTAL EDUCATION

At present, it is possible to confidently identify the set of basic principles for energy-efficient buildings:

- The first principle is *energy conservation*. The design and construction of buildings should minimise the need for the consumption of heat and electricity for their heating, cooling and air conditioning. The main principle of the passive house is the high efficiency of the building envelope, which reduces heat losses. The main methods for reducing heat losses are improved thermal insulation of the main enclosing structures, reduction of cold bridges in structures, increased sealing of the shell of the house, the use of special energy-saving windows for passive buildings and high-efficiency heat recovery from exhaust air.

  The project for building a waterfront in Putrajaya in Malaysia was developed by studio Nicoletti Associati (Italy). A double bioclimatic facade system with horizontally arranged light-reflecting elements is mounted to vertical columns. The distance between the elements is 60 cm. Such a *breathing* facade provides protection from sun exposure and bad weather. The project is aimed at applying various environmental technologies such as energy-saving lighting and water heating systems; water saving (secondary use of rainwater, installation of economical household appliances); selection of ecological building materials (natural wood, priority for locally produced materials); and waste management system (sorting, processing and recycling of waste) [19].

- The second principle is *interaction with the Sun*. The Earth’s atmosphere reflects up to 30 per cent of the radiant energy of the Sun. The Sun’s energy is the driving force for winds, currents, waves and the water cycle, and produces the climate. Ultimately, this energy also radiates into space [20]. The first stage in designing a solar house is the choice of the optimal shape of the building. Typically, a compact, square-shaped plan with a minimal perimeter of the outer walls is recommended. To reduce the surface of the outer walls, cylindrical, hemispherical and other non-traditional shapes can be used. In solar apartment houses, there is rarely any energy-saving system in its pure form. These houses also use several active collectors, as well as solar panels or a heat pump. In most solar homes, there is a duplicate source of energy supply. In the project, *Prishtina Solar Powered Mosque,* in the Kosovo city of Pristina, despite its inherent traditionalism, modern technologies were actively used. This is a solar-powered mosque in which the entire exterior surface of the building will be covered with solar panels [21].

- The third principle is *renovation and re-use* or reducing the volume of new construction. People used old buildings and structures or material from their disassembly, for erecting new buildings. Thus, the builders of the St. Alban Abbey in England used bricks from the ruins of the Roman city of Verulamium. In Russian and Scandinavian wooden architecture, healthy old beams and rafters were often crushed, removed from old buildings and reassembled in new homes. But, by the middle of the 20th Century, another approach seemed to have won favour - developers were urging the authorities and investors to pull everything down and build from scratch, which was seen as cheap and efficient. If such an approach had prevailed in construction, by the end of the 20th Century, the world would have lost almost all its old buildings. Fortunately, after some time, and under pressure from society, the city authorities of most countries came to understand the importance of preserving historic buildings.

- The fourth principle is *social orientation*. On the basis of this principle, buildings should be socially oriented and most appropriate for the needs of the tenants. The project, Coral Reef, a famous bold futuristic development of the Belgian architectural studio, Vincent Callebaut Architectures, offers an innovative urban concept designed to provide an alternative development for part of Haiti, which in 2010 suffered a magnitude 7 (on the Richter scale) earthquake. The architects presented a three-dimensional model of a self-sufficient village, built from prefabricated modules. This could become a haven for the resettlement of refugees affected by natural disasters. The structure has increased seismic stability and is equipped with powerful cleaning and bioclimatic systems, as well as renewable energy sources, i.e. hydro and wind turbines and photovoltaic panels [22].

- The fifth principle is *ecological orientation*. Nothing influences the architecture of the building, as much as the place where it was created. The European consciousness has long cultivated a different attitude to nature than that of Eastern philosophy. In Europe, nature was considered solely as a resource, and as an object of purposeful human activity. In the 21st Century, this attitude was revisited and rejected. Now, buildings are built on the principles of respect for the environment. Ideas of harmonisation of architecture and nature were embodied in the design and social structure of eco-cities and eco-settlements. Eco-settlement is the concept of an attractive place to live and work. Various eco-villages, designed or built, carry the idea of preserving the natural landscape, the use of renewable energy sources (solar, wind, hydro, geothermal), the manufacture of houses from natural materials and waste disposal through biological processing. As well, residents take cultural and social responsibility for the environment in the settlement. An example is the energy-free waste less eco-ethnical village of Yurt Village *Zhasyl Aul* designed in Astana in preparation for *EXPO-2017* [23].

CONCLUSIONS

First, the modern generation has entered a new era - the era of solar energy. The concept of the Earth as a single living organism will continue to develop, penetrating ever deeper into the minds of people and forming an ecological consciousness.

Second, the construction of an eco-house is seven to ten percent more expensive than a traditional building but, since the energy consumption is 90 percent lower than in a similar traditional building, the payback period to save money is on average seven to ten years. Eco-architecture is a special architectural concept that takes into account environmental factors in the design of the human habitat.

Third, at present construction and architectural companies compete among themselves for the title of manufacturer of the most environmentally and energy-efficient buildings. Due to well-planned hyper-structures and individual buildings, it is possible to significantly reduce the negative impact of people on the environment.

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