The Basic Principles of Ecovillage Design

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Abstract. The article discusses the basic prerequisites for the emergence and development of ecological settlements, analyses the concepts of eco-settlement and sustainable development. As a result of the analysis of literature sources, the basic principles of eco-settlement's design were identified: the principle of ecological functioning, the principle of using traditional building materials, the technogenic principle and the principle of sustainable transport development.

1. Introduction

The emergence of increased interest in energy-efficient architecture is related to a number of factors. The dominant ones were the rapid technological progress of the 20th century, the expansion of technical capabilities and the introduction of new technologies, which ultimately led to the intensive natural resources depletion. All this entailed a violation of the natural balance in the natural environment. Thus, the question of a reasonable restriction of environmental management and environmentally prudent pressure on nature has come to the fore. One of the most effective methods for solving eco-problems was the emergence of energy-efficient buildings. Starting from the 60s, energy-efficient areas and eco-settlements have started appearing along with few energy-efficient buildings, especially in Europe, North America and Australia. It should be noted that most European countries are actively involved in the process of greening the cities, among these countries Sweden stands out (since 1980 about 20 eco-settlement projects have been implemented here), as well as the Netherlands, Denmark, Belgium and Norway. At the moment, in Ukraine and the CIS countries, environmental design is only limited to the creation of separate eco-housing objects, despite the fact that there is a fairly large number of unrealized projects of ecological settlements created by design centers specializing mainly in the field of environmental architecture.

2. The concept of eco-settlement

In order to understand the very essence of ecological settlements, it is necessary to turn to the interpretation of this term.

In the analysis of scientific works some variants of the term *"eco-settlement" (ecovillage)* definition were identified, the first of which was coined by R. Gilman in 1991 in the report of the Institute of Context for the Earth Trust, where he described it as "Human-scale, full-featured settlements in which human activities are harmlessly integrated into the natural world in a way that is supportive of healthy

human development, and which can be successfully continued into the indefinite future [1]." According to Gilman, an eco-settlement, unlike traditional settlements, is a phenomenon of post-industrial society.

However, a more realistic explanation of this concept was suggested by Holick and Connelly: "a community of up to several hundred people that meet the material, economic, social, emotional, cultural, and spiritual needs of its inhabitants whilst being in harmony with its natural environment." This definition placed great emphasis on the human's spiritual needs among other facts but, in general, most of the ecovillagers do not share the same religious beliefs and quite often have different ones than other community members. Therefore, spirituality should not be considered as one of the core principles of this concept [2].

Another author, Albert Bates, gave an upgraded but at the same time a bit too detailed description of the ecovillage that could be used as a definition: "Ecovillages today are typically small communities with a tightly-knit social structure united by common ecological, social, or spiritual views. These communities may be urban or rural, high or low technologically, depending on circumstance and conviction. What they share is a deep respect for nature, with humans as an integral part of natural cycles. Ecovillages address social, environmental, and economic dimensions of sustainability in an integrated way, with human communities as part of, not apart from, balanced ecologies [3]"

Later, this definition was interpreted by eco-settlers themselves, whose interests were represented by the Global Ecovillage Network. In their view an ecovillage is an: "intentional, traditional; rural or urban community that is consciously designed through locally owned, participatory processes in all four dimensions of sustainability (social, cultural, ecological and economic) to regenerate their social and natural environments"[4].

Sustainable development is understood as a model for the use of resources, a model for interaction between people and nature, and a model for civilization development based on innovation, in which the vital needs of the current generation are achieved while preserving the environment, improving health, and without depriving future generations of such an opportunity.

At the same time, the problem of sustainability of natural-anthropogenic systems is solved in two ways.

The problems of creating a favorable social microclimate:

- Providing a variety of job opportunities that meet the aspirations and preferences of people.
- Meeting the increasing demand for housing, focusing on the construction of the particular ethnic requirements of people of different nationalities.
- Guaranteeing variety of high-quality services, including medical care and education.
- Expanding the range of leisure and recreation facilities.
- Interaction of settlements with the environment.

The problems associated with urban ecology microclimate:

- The use of energy-saving technologies and alternative / renewable energy sources, reducing the negative impact of energy production and usage on human health and the environment;
- Creation of favourable conditions for organizing and developing the private housing sector where appropriate, as well as identifying and enhancing its role for sustainable development of human settlements;
- Creation of convenient transport connections and the use of eco-transport;
- Development of energy-safe and inexpensive methods of construction, production and distribution of appropriate building materials, production of local building materials, based on the maximum use of local resources;
- Use of recycled materials and adoption of standards and regulations in construction, with the goal of enhancing the use of low-cost local building materials;
- Recycling wastes;
- Comfortable and healthy heating (cooling) systems using radiating surfaces that transfer heat directly to a person through waves, without preheating the air;

- Supply and exhaust ventilation, providing a constant flow of clean air without the effect of draft [5].

3. Basic principles of ecological functioning of eco-settlements

As a result of the analysis of the world's experience and theoretical studies of ecological settlements, the basic principles of ecological functioning and development of their living environment were formulated according to the concept of sustainable development:

- *The eco-equilibrium principle* – the principle of maintaining a state of the environment, which provides for its self-regulation, the reproduction of natural air, water, soil, plants and animals by taking measures aimed at stabilizing the anthropogenic load, compensating for adverse effects on the environment and observing conditions for the equal ecological balance of all elements of the system.
- *The energy saving principle* – orientation of design decisions on the use of engineering and technical systems that work on the basis of renewable energy sources: sunlight, geothermal sources, wind energy, tides, their rational location on the territory; the use of passive methods of energy saving and bioclimatic architecture techniques based on the maximum use of microclimate regulation methods, the use of effective heat-insulating materials, etc.[6]
- *The eco-functional principle* – the principle of planning the territory taking into account the natural and climatic features of the area, the choice of a favorable location for the site, a rational approach to the planning of the territory considering orientation to the cardinal directions, the establishment of landscaped areas in the "fabric" of settlements, minimizing the area of development.
- *The psychophysiological principle* – creation of a space favorable from the psychological point of view, guided by the methods of video ecology, taking into account the peculiarities of the human visual perception of the architectural environment and the basic principles of ergonomics.
- *The traditionalism principle* – construction from ecologically sound, traditional materials, intrinsic to the locality of construction, taking into consideration spiritual, cultural, national traditions and peculiarities of the development region on the design stage.
- *The social comfort principle* – conducting activities aimed at educating the population to the ecological principles and the concept of sustainable development, encouraging the population to have a healthy lifestyle, the developing ecotourism and permaculture.

4. The principle of using traditional and advanced building technologies in eco-settlements design

Traditional Ukrainian national architecture, which has been formed over the centuries and aimed at the rational use of local building materials and the construction of structures that would match the properties of these materials, has been reflected in nowadays construction. The technology of constructing clay buildings has been known for over six thousand years. However, despite the simplicity and cost-effectiveness of traditional forms of housing, along with environmental and progressive trends, there remains a lot of primitive, technically imperfect and conservative structures.

Several basic construction technologies were used for residential buildings: erection of a straw bale block house, straw bale cast (clay) house and mazanka. Mazanka is the warmest kind of house among the other ones built of clay. It is also the fastest in construction, but no less laborious. In Europe, mazanka was known even before the Middle Ages. Technologies of this type have been successfully used in construction so far, mainly in the Middle and Far East, in Africa, India and China, Germany and France (half-timbered houses), and even in Italy and Spain farm buildings are made in a similar way [7]. However, in order to understand the possibility of using such traditional technologies on the territory of Ukraine in modern realities, it is necessary to analyse the positive and negative features of this method of construction. The results are presented in Table 1.

Table 1. Analysis of positive and negative features of traditional Ukrainian houses.

№	Negative features	Positive features
1.	Insufficient thickness of enclosing structures, which leads to disruption of the thermal and sanitary-hygienic regime of the dwelling.	Use of local building materials: clay, wood, straw, reeds, etc.
2.	Construction of a clay building is a very labour-intensive task and takes a long time to dry and shrink the wall.	Maximum simplicity of building structures.
3.	Lack of thermal insulation of the floor due to lack of foundation in the usual sense.	Saving of wood achieved through the use of frame-type buildings and the active use of straw and reeds.
4.	The occurrence of cracks due to the use of raw wood.	Environmental friendliness of building materials and construction technologies.
5.	Increased fire risk of thatched and reed roofs.	Cost-effectiveness of traditional technologies.
6.	The need for constant maintenance of thatched or reed roof.	Streamlined straw roofing helps wind protection.
7.	Negative effect of rainfall on enclosing structures in case of insufficient roof overhang (less than 600-800 mm).	Decorative and picturesque home decoration emphasizes traditional Ukrainian vibrant color.

Thus, taking into account all these shortcomings and paying attention to mistakes made in the construction of traditional dwellings, it is possible to use the experience of the previous generations' experience to build ecologically sound and comfortable housing in the design of ecological settlements. However, special attention should be paid to the advanced technologies that are actively evolving and fully consistent with the concept of sustainable development in the field of architecture and urban planning. Such technologies include the construction of straw blocks, geo-blocks, super-adobes, construction with the use of a wooden frame, construction from bamboo.

4.1. Straw blocks

These are structures where the elements of the walls are straw bales stacked on top of one another or that filling a wooden frame. Such buildings have good thermotechnical characteristics due to the large thickness of the outer walls and the structure of tightly pressed straw. Their main advantages are low cost of construction, short construction time, environmental friendliness, operating economy, high fire safety (after finishing with plaster).

4.2. Geo-blocks

The main feature is the use of local "geo" resources (earth blocks or natural stone) in the construction. For example, the presence of stone materials, especially in hot and arid climatic zones, allows to achieve optimal temperature comfort. In this case, the light openings in the building have minimal size to avoid overheating in the daytime or overcooling at night.

4.3. Super-adobe technology

A distinctive feature of this technology is that the walls of the building are erected from simple sacks filled with soil. Unlike simple adobe structures, super-adobe homes can be used in flood-prone areas. Sacks with soil are traditionally used for flood control and dam construction, as well as for the construction of defense structures. Another specific feature of this technology is that it is much more difficult to erect straight walls rather than curved or domed. This is their advantage, as dome houses are very strong. Their shape balances the external load in all directions.

4.4. Wooden frame

To date, the erection of wooden buildings involves both traditional methods of construction from wood and advanced technologies. For example, round sections of tree trunks can be used to save wood as the main wall material. This is considered a waste-free way of constructing walls.

Unlike straw and clay blocks, the use of wood as a constructive and enclosing material allows the creation of large-scale structures of different types. At the same time, the necessary level of comfort is achieved both due to the high thermotechnical characteristics of the wood itself, its aesthetic properties, and due to the spatial solution of the building.

4.5. Bamboo buildings

Bamboo houses have been erected in regions with high seismic activity (mainly Southeast Asia) from time immemorial. The plant has tremendous flexibility, and in the case of an earthquake, tsunami or other natural disaster, the houses of this material are often simply bent, but not deformed like other structures. And even if the bamboo house falls when rocking, it will not cause death to people inside and near it because the material has a very light weight. In terms of environmental friendliness, bamboo is the leader among all kinds of wood known to the mankind. This plant grows so quickly that there is no need to use any chemical additives and pesticides when cultivating it. In addition, the bamboo stems contain unique components that have antiseptic and antibacterial properties [8, 9].

5. Technogenic principles of ecovillage design

To date, renewable energy sources are being actively used in the design of energy efficient districts and settlements. One of the major advantages of alternative energy is its environmental friendliness: the process of obtaining energy from renewable sources is not accompanied by the formation of environmental pollutants; does not lead to the destruction of natural landscapes; virtually eliminates hazards to biological substances; does not threaten ecological balance of ecosystems [10].

The following buildings can be distinguished by their orientation towards usage of different natural energy sources:

- solar-energy buildings (effectively using the energy of the sun);
- wind energy buildings;
- geo-, hydro- and aerothermal energy buildings;
- buildings with combined use of different natural energy sources [11].

Passive and active energy-saving technologies are also used when designing homes within eco-settlements.

Passive energy saving means the complex application of measures that help to keep heat, provide natural ventilation, cooling and insolation due to the natural properties of materials, structures and physical processes. Its essence is that the residential or non-residential premises have zero consumption of heat and electricity, i.e. there is an opportunity to control the heat loss and the excess heat indoors.

Passive or smart homes are self-sufficient in terms of heat and electricity generation through modern technologies that allow for absolute thermal insulation, by receiving electricity from solar or wind energy. The passive house also implements devices that allow efficient use of natural sunlight and produce fresh air inside the building, while maintaining the temperature balance in the premises. Passive home heating is due to the heat generated by the people living there, household appliances and alternative energy sources.

Active energy saving is defined as the product of sustainable change through the measurement, monitoring and management of energy use. In order to ensure active energy savings, it is necessary not only to install economical devices but also to control them only using the required amount of energy.

It is the control factor that is critical to maximizing efficiency. Currently, in the computer and telecommunications business there is a concept of "intelligent building". An intelligent building is a building with a single cable architecture that enables the circulation of the whole information flow:

telephony, LAN, video and other data down to the large life support and building management systems [12].

In Ukraine, it is more common to use passive energy saving systems through the use of energy-saving natural materials. Active energy saving systems (solar and wind energy, etc.) are more common in Europe and the Americas (Table 2).

Table 2. Energy saving systems in world ecovillages and ecovillages of Ukraine.

№	Name and location	Year of foundation	Energy efficient technology
1.	Auroville, India.	1968	Utilization of solar and wind energy, technology of construction from the compressed soil.
2.	The Farm. Summertown, USA.	1971	Photoelectric elements, wind turbines, use of secondary resources, micro-hydroelectric power plant.
3.	Soldiers Grove. Clayton, Wisconsin, USA.	1973	Use of solar energy, biogas.
4.	Findhorn. Moray, Scotland, United Kingdom.	1980	Utilization of wind and solar energy, zero-emission construction.
5.	Okologisk, Landbisamfund. Denmark.	1983	Geothermal heat pump, restricting entry of cars into the territory.
6.	Crystal Waters, Australia.	1985	Passive solar heating, natural materials, solar panels.
7.	Ecolonia. Aalphen aan den Rijn, The Netherlands.	1991	Use of passive and active solar energy.
8.	Solar Village in Fefki. Lykovrissi, Greece.	1991	Active and passive solar systems, renewable heating systems.
9.	Anningerblick. Guntramsdorf, Austria.	1992	Passive solar energy, resource-saving building materials.
10.	Source Valley (Долина Джерел). Kyiv region, Ukraine.	2003	Construction from ecological materials.
11.	Rainbow (Радуга). Ukraine	2010	Use of solar energy, construction of ecological materials.
12.	Chmyrivka. Cherkasy region, Ukraine.	2010	Construction from natural materials.
13.	New Mayapur. Dnipropetrovsk region, Ukraine.	2006	Construction from natural materials.
14.	Green cliffs. Kyiv region, Ukraine.	2012	Straw construction.

The *technogenic principle* also considers the eco-design of buildings as an integral part of eco-habitation in terms of use of various technologies in buildings, such as alternative energy sources (solar panels, wind generators, etc.), and their direct impact on the form and composition of structure.

In modern architecture, the introduction of wind turbines directly into the facade of the building is actively used. This was made possible after engineers created attractive, silent and compact windmills with sophisticated bending of the blades [13].

Also, a significant contribution to the formation of the three-dimensional and compositional structure of architectural structures was made by the placement of solar batteries and collectors on the facade and their introduction directly into it.

However, there is a need to differentiate the purpose of these technologies in the context of different architectural objects. There are two main principles:

- aesthetic purpose;
- practical purpose.

In this context, *aesthetic purpose* involves the use of alternative energy sources as decorative elements in most cases, even though these renewable energy sources do not cover the building's energy needs.

The *practical purpose*, as opposed to the aesthetic one, is to supply the building with necessary amounts of energy and, in some cases, even produce excess energy that could later be used to supply the neighbouring buildings [14,9].

6. The principle of sustainable transport developing

There is a number of transport types that can be referred to as the environmentally friendly means of transportation.

All eco-transport can be roughly divided into several types:

- electric;
- hydrogen;
- biofuel, independent of fossil fuels;
- bicycle transport, etc.

The term eco-transportation should be understood in the sense that it tends to minimize the impact of humans on the environment through vehicles' usage.

The main idea of eco-transport is to abandon internal combustion engines and to introduce electric vehicles. The main difference between electric cars and internal combustion engines is the ability to use different sources of energy: from burning fossil fuels at thermal power plants, using nuclear energy and renewable energy to various batteries. However, the main drawback of electric vehicles is the undeveloped gas station infrastructure. Electric cars can also use hybrid power supplies, where electricity is produced by combustion of diesel and gasoline [15].

However, electric vehicles are not limited to passenger cars. These are also *include* trains, airplanes, planes, seagoing vessels, motorcycles, scooters, etc.

Main characteristics of sustainable transport are listed below:

in the field of natural environment:

- limitation of emissions and wastes (polluting air, soil and water) to ensure the environment's ability to absorb / recycle / clean the reduced pollution;
- ensuring the functioning of vehicles at the expense of renewable or inexhaustible energy sources;
- utilization of natural resources used in vehicles and infrastructure (such as steel, plastic, etc.).

in society:

- ensuring the necessary level of accessibility for people and their property of this generation and all future generations;
- promotion of human health;
- assistance in maintaining a high standard of living;
- setting the noise penetration limit below the level accepted by society;
- security for people and their property.

in the field of economy:

- financial affordability for each generation;
- maximization of economic efficiency and minimization of economic costs in design and operation;
- support of a strong and diverse economy.

7. Conclusions

As a result of the analysis of the experience of designing eco-settlements abroad and in Ukraine, the basic principles of designing eco-settlements and their structural elements have been identified, taking into account the use of natural materials, energy efficient technologies and sustainable transport in their construction. It was found that it is possible to get a fairly economical and simple construction technique based on the existing one, considering all the shortcomings and using the positive features of traditional

Ukrainian architecture. With this goal in mind, it is possible to correct the basic errors by following steps: arrangement of high-quality tape foundation, protection of the adobe from the capillary suction of the plinth, the arrangement of a steep scaffold, the construction of walls with a thickness of not less than 500 mm, the attic insulation strengthening, the organization of a roof overhang of not less than 600-800 mm, and the employment of highest quality home maintenance techniques. The design of eco-habitats should also take into account the specific features of the local climate, the availability of certain local building materials, and subsequently choose technology that is appropriate in each particular case. At the same time, it is necessary to pay close attention to the advanced technologies which are actively developing and modernizing without losing their environmental friendliness.

The study also found that most Ukrainian eco-settlements significantly differ from the US and European eco-settlements, particularly by their inferior level of technological support, and are also characterized by a fairly low level of transportation support. These findings impose certain priorities for architects and urban planners of eco-settlements – namely, to take all the shortcomings into account and to correct deficiencies in order to bring eco-settlements in Ukraine to a higher level and ensure a decent standard of living for people.

References

[1] Ardzijauskaite V 2009 *Ecovillages: is it a way to reach environmental sustainability? Case studies in Denmark* (Denmark: Aalborg University) p 95
[2] Hollick M and Connelly M 1999 Learning from ecovillages worldwide *Communities* **104** 62-65
[3] Bates A 2003 Ecovillage Roots (and Branches) *Communities Magazine* **117** 10
[4] Grigor'ev V and Ogorodnikov I 2001 *Greening cities in the world, Russia, Siberia* (Novosibirsk: GPNTB SO RAN) p 152
[5] Maslov N 2003 *Urban planning ecology* (Moscow: FGUP Graduate School) p 285
[6] Mahlabani Y, Shahsavari F and Motevali Z 2016 Eco-village, amodel of sustainable architecture. *J Fundam Appl Sci* **8(3S)** 1835-1847
[7] Daniljuk A 1991 *Ukrainian hut* (Kiev: Scientific Thought) p 110
[8] Pecherceva O 2015 The traditional principles of structural elements disigning in the ecovillages, *Improving the organization of traffic and the transport of passengers and goods* (Minsk: BNTU) pp 46-53
[9] Blagovestova O and Pechercev O 2019 Using traditional and modern construction technologies in design of ecological settlements *Scientific Bulletin of Civil Engineering* **4** 5-10
[10] Selivanov N, Melua A and Zokoley S 1988 *Energy-active buildings* (Moscow: Stroyizdat) p 376
[11] Lapin J 2005 *Autonomous ecological houses* (Moscow: Algorithm) p 416
[12] Tetior A 2008 *Architectural and construction ecology* (Moscow: Academy) p 368
[13] Tabunshchikov Y, Brodach M and Shilkin N 2003 *Energy-efficient buildings* (Moscow: ABOK-PRESS) p 200
[14] Guk V and Pechertseva E 2014 Trends in the formation of energy-efficient eco-settlements, *Improving the organization of traffic and the transport of passengers and goods: a collection of scientific papers: based on the results of the annual International Scientific and Practical Conf.*, Minsk: BNTU) pp 41-47
[15] Kondrat'ev A 2012 The role of green transport in supporting sustainable urban development *Theory and practice of social development* **4** 342–44