URBAN SUSTAINABLE DEVELOPMENT BASED ON ECO-HUMANISTIC PRINCIPLES



# TECHNOLOGICAL ASPECTS OF CITY ECOLOGY (BIOCLIMATICS, “GREEN ROOFS”)

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Due to global climate change and disruption of natural balance structure, the cause of which to large extent is an active invasive human activity and waste of natural energy resources, there is urgent need for rational use of energy sources and reducing of greenhouse gas emissions. Innovative technologies and new architectural and engineering approaches to the construction of buildings are in demand. Technological maintenance of high standards of living conditions and dwelling comfort is a necessity factor of health and life quality of people. Dwelling ecology is a key element of the relationship of the human environment with the surrounding natural environment. Currently, necessary stringent demands as to resources savings, energy conservation, energy efficiency, along with increased demands to the quality of life support are reasonably put forward buildings. Appropriate measures aimed at education, clarification, popularization of knowledge and consolidation of the joint efforts of all thinking and active part of the population are needed for active dissemination and implementation of new approaches and technologies. Optimization problems of ecological dwelling standards and introduction of "green" technologies require interdisciplinary professional studies involving architects, engineers and town planners, professionals in the field of urban planning, urban economics and law.

## *Contents*

## Introduction

Technological aspects of the urban environment ecology are basically those that are commonly presented in the international practice and concern trends and the best ways to meet the challenges of sustainable development in the context of today’s ecological architecture, energy efficiency, comfort, higher quality of life, harmonious unity with the natural environment.

The urgency of the environmental problems of our time and their obviously not-turn-down solutions require significant measures involving education, explanation, popularization of knowledge and consolidation of joint efforts of scientists, inventors, experts, designers, architects, contractors and manufacturers. The ability to see and be aware of environmental issues, to understand the causes of their origin gives a man the keys to the solution of many actual problems of modern environmental issues. This course is developed to fill a significant lack of information in this field in the domestic researches and give clues to the understanding of ecological features of the architecture and solving problems related with them.

The course structure is built on a common scheme. Contents, Introduction and Objectives of the course give a general orientation in the subject. Hyper-links, a list of figures and tables, a glossary help students to easily manage studying topics, and serve as meaningful markers for the assimilation of the material. Questions, assignments and keys are a reliable means of the course revising, self-control, and preparing for the exam. References and the list of works recommended for further research enable expanding the professional competence.

The main part of the course consists of three chapters. The first chapter deals with the development of technology for solving urban environmental problems. Basic concepts and trends are given, the main factors of structures’ interaction with the environment and ways to address the environmental aspects of the buildings in the historical perspective are considered, modern engineering solutions and materials are examined. Topical issues of comfort, energy supplies, energy saving and energy efficiency of buildings are highlighted.

The second chapter concerns such actual field of ecological architecture as architectural bioclimatics. The principles and basic trends of bioclimatics, their application to solving the ecological architecture problems are focused. The relationship between bioclimatic indices and seasonal climatic factors of the environment, as well as geographical data, in particular with respect to Ukraine, are given.

The third chapter is devoted to "green roofs" which are effective solutions for problems of involving wildlife in the urban fabric, moisture and heat regulation and improvement of the urban climate. Results of extensive experience and long-term solutions in this field were summarized.

## Objectives of the course

The textbook is assigned for profound study of the educational material of the lecture course "Sustainable city development on the basis of eco-humanistic principles” by master-students of specialties: 8.06010201 "Architecture of buildings and structures," 8.06010202 “Urban development” 8.06010203 "Design of architectural environment."

The aim of the course is to provide future professionals with the knowledge and skills in the field of the design of energy efficient buildings and the rational use of environmental factors in securing energy supply, heat supply, optimal lighting and ventilation, along with a considerable saving consumption.

The objective of the textbook is to benefit the formation of future specialists the professional approach to innovative technologies of ecological architecture. The complex of actual approaches and solutions of ecological architecture due to rationalization and economy along with the increased living standards is studied in this textbook, as well as the ways of harmonious interaction of buildings with the environment, including urban agglomerations conditions are examined there.

This course consists of logically interrelated chapters where the most urgent problems of ecological architecture of buildings in the context of the urban environment are covered. The basic concepts and problems of building sustainability are given. We consider the ecological problems of energy-efficient buildings, their architectural and engineering solutions, which architectural bioclimatics provides. We offer certain measures to improve the indoor microclimate, the climate of the urban environment and we also consider the innovative technologies of green roofs and green facades design as the methods of efficient thermal insulation, as well as preservation and development of the urban flora and fauna, improvement the psychological perception of urban development.

In the frame of this course it is supposed to form and develop the following students competencies:

– at the level of general competences - the formation of knowledge according to the main directions of ecological architecture, the ability to develop critical and analytical thinking;

– at the level of research competences - the ability to be engaged in innovation activity in the field of ecological architecture and urban development, professionally analyze functional processes of buildings maintenance and city life, identify problems and propose science-based solutions;

– at the level of professional competences - understanding of the scale and intensity of anthropogenic and technical impact on the environment, forecasting of potential risks and consequences of this impact, and the corresponding updating of the system of the environmental measures while designing the architectural objects and planning the urban structures.

## Glossary

**Albedo** (of facades, roofs and coverings of buildings and structures of urban development) is surface reflectance depending on the texture, color and structure of materials. The ability to reflect or absorb any light is a factor that determines the temperature of the structure surfaces which are the facade, roof, etc.

**Architectural bioclimatics** is architectural designing of buildings with the most efficient application of environmental factors to create comfortable conditions for the building performance (minimum cost-maximum effect). The basis of this trend is the concept of "home as a living functioning organism", which takes into account the features of climate and environmental conditions helping to achieve the heat and light comfort inside, with comfortable level of air and moisture exchange. It can be implemented by architectural and design solutions for external forms of the building and the interaction of its interior spaces, with architectural elements which enable independence on the mechanical and electrical systems and devices (e.g., most efficient use of the natural light, natural ventilation, natural convection heating in winter and cooling in summer). Architectural bioclimatics is based on natural factors and it can be called the most natural trend in architecture. Bioclimatic design integrates the physical factors of the environment and the internal spaces and adapts them to the inhabitants’ ways of lives, their specific features and characters. Positioning of structure location on the landscape conditions and its orientation to the cardinals, taking into account specific seasonal changes in the climate and light conditions are performed in agreement with the internal structure of the building in order to maximize the effect of natural factors (light, heat, cool, etc.) in terms of seasonal changes. The special features of bioclimatic design are considering of numerous geographical and physical factors, parameter analysis and searching for new technical solutions.

**Ventilated facades** are a technology of elevation construction which enables an air circulation between the wall and the wall cladding of the building. It is a system consisting of coating materials mounted on a metal frame attached to the building walls.

**Vertical gardens** are a phytowall or a system of phytowalls, i.e. a vertical or inclined structure, based on a special design frames for placing living plants. Vertical gardens are used for decorating either exterior (facades of buildings, roofs, industrial structures), or interior spaces. Plants for vertical gardens are selected depending on the climate, the specific maintenance conditions and certain artwork styling decisions. The use of vertical gardens contributes to aesthetic and environmental solutions of modern urban environment problems. The purpose of vertical gardens is not limited to decorative and aesthetic functions. For bioclimatics and the urban environment microclimate a more essential factor is to protect roofs and facades of buildings from summer heat and winter cooling.

**Green roofs** or living roofs are roofs partially or completely covered with vegetation. There are two types of landscaping roofs - extensive and intensive.

The extensive type is a green carpet of turf or succulent plants on the topsoil with drainage. The intensive type is more complex and involves planting shrubs and small trees in containers.

**Microclimate** is the climate of a local area that differs from the one of the surrounding area. The term applies both to the small spaces of a few square meters (home, a winter garden) and to the spaces with the size of tens of square kilometers (a forest, a pond, a village, a town).

**Low-energy house** is a house with low energy consumption as compared with a standard house. Such a house is usually characterized by increased insulation, minimizing heat losses, energy efficient windows, low penetration of outside air (infiltration), forced ventilation with heat exchange, as well as by more stringent requirements to heating and cooling. Such houses contribute to the implementation of the "sustainable development" concept as they significantly reduce carbon dioxide emissions into the atmosphere and consume less power.

**Passive house** is a house that consumes little energy and enables living without traditional methods of heating. The necessary amount of primary energy for cooling or heating does not exceed 15 kWh / m2 per year. Overall consumption (including heating, cooling, ventilation, accessory needs, water heating, lighting, household equipment work, etc.) should not exceed 120 kWh / m2 per year.

**Thermal radiation** is transfer of energy from one body to another in the form of electromagnetic waves due to their thermal energy. Thermal radiation mainly occurs in the infrared portion of the spectrum, i.e. in the area of the electromagnetic spectrum between 0.74 microns to 1000 microns.

**Sustainable landscape gardening** is designing and implementing of landscaping for urban areas, residential and industrial facilities associated with the concept of "sustainable development", aimed at harmonizing the human habitat. Green spaces are a kind of cities’ respiratory organs; they clean the air of harmful substances and saturate it with oxygen. Organic gardening and plant cultivation as well as using of indigenous (local) species are as a whole characteristic of this trend. Local plants attract local insects, which attract native birds, reptiles, etc. That is the basic prerequisite for the biotic community (sustainable biological balance).

## Recommended reading

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**Internet resources**

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## List of figures

# CHAPTER 1. MODERN TECHNOLOGIES IN SOLVING URBAN ENVIRONMENTAL PROBLEMS

*Environmental problems of the city environment originate from the environmental problems of dwelling houses, public and industrial buildings. Buildings and structures, as the basic elements-cells constituting the city body, form the functioning fabric of the city, run through by the networks of roads and energy strands. Healthy cells determine the health of the body, but defective, unstable or "insatiable" cells provoke diseases. Healthy rational buildings form the bases of the city health on the whole.*

During the last half century, the significant change in the ideology of design and construction took place in the developed countries and new directions of ecological architecture and new environmental technologies. Even since the 1960s, the searches of both professionals and amateurs became the considerable breakthrough in "green" architecture. The dynamics of the ecological architecture and energy-efficient technologies was accelerated after the global energy crisis of 1973 - 1975 (the effects of the "oil embargo"). The problem of the search for alternative sources of energy became urgent. In the1960-1970s, the development of nuclear power engineering, which was significantly cheaper and relatively cleaner when compared with the technologies based on the combustion of coal and oil products, became the prospective trend of power engineering in developed countries. However, a number of accidents at nuclear power plants, and most of all the Chernobyl disaster in 1986 showed the real threats of the "peaceful atom" and urged active introduction of power technologies of converting wind energy, sunlight and tidal energy in Western Europe. Just after 1986, wind generators and silicon solar batteries were widely spread along with the development of government programs and laws related to green power engineering in some Western European countries. The concept of energy efficiency and corresponding trends of energy efficient technologies and architecture of energy efficient buildings appeared in the world practice. The scientific bases of design were intensively developed, need for which with the growth of knowledge is continually increasing, and new aspects, new goals and tasks are emerging. The arsenal of the wide range of achievements of modern trends in science and technology, from biomimetism and bionics to space technology, appeared in the creative work of a modern architect.

In addition to finding solutions for energy-saving technologies, alternative power engineering, energy efficiency of buildings, special attention is paid to the environmental safety and comfort of dwelling, environmental protection, replenishment of natural resources. The concept of harmonization of the city, building, dwelling with natural environment, that is an essential factor of psychological and climatic comfort and at the same time a source of renewable energy resources, has become the dominant idea of the present day green architecture. The actual aspect of modern green architecture is the adaptation of technological and morphological characteristics of the buildings structure, that ensure indoor comfort and microclimate in accordance with the external factors of climatic and geographical features.

The requirements and "green standards" that make demands for "green buildings" are rather high and specific, and they demand high professional training and spacious mind, and therefore they cannot be satisfied with the outdated principles of standardized design. Thus, the actual theoretical knowledge gives designers and builders modern vision of problems and possibilities to master the main methods of solving various problems of ecological architecture.

## 1.1 Building as a functioning organism

Metabolism of a building

Dwelling is treated as a habitat, shelter from elements, but more than that, it acts as the outer macro-shell of a person, as if it is the external projection, prolongation of a human being with his life and spiritual needs. Today, a person's home, whether it's a country cottage or a city apartment, is not just a "family home", but it is rather complex technically equipped object, filled with energy arteries -- electrical wiring and gas pipeline; life-support and metabolism systems - water supply and sewerage systems; ventilation equipment, air conditioners, refrigerators, lamps; and a kind of "nervous system" - audio and video equipment, telephone, receivers, video surveillance systems, burglar alarm systems, computers and the Internet. Like any artificial organism, the dwelling functions, receives light and heat, consumes water and energy, breathes, emits products of metabolism, produces wastes.

Getting out oxygen from air, a functioning building emits carbon dioxide into the environment. An average cottage-house produces annually some tons of greenhouse gases. Multiplying these figures by the total number of apartments and cottage-houses, we receive the global figures of the problem. The problem of air exchange and air pollution is even more actual against the background of annual growth of the number of cars and landfills and waste products.

An ecological approach to designing energy-efficient (and particularly energy-active) buildings considers a building as an organism closely interrelated with external environment. At the same time, the tasks concerning the organization of effective natural exchange processes within the space of the building with the external environment (including the purposes of energy use of the natural environment) acquire priority significance.

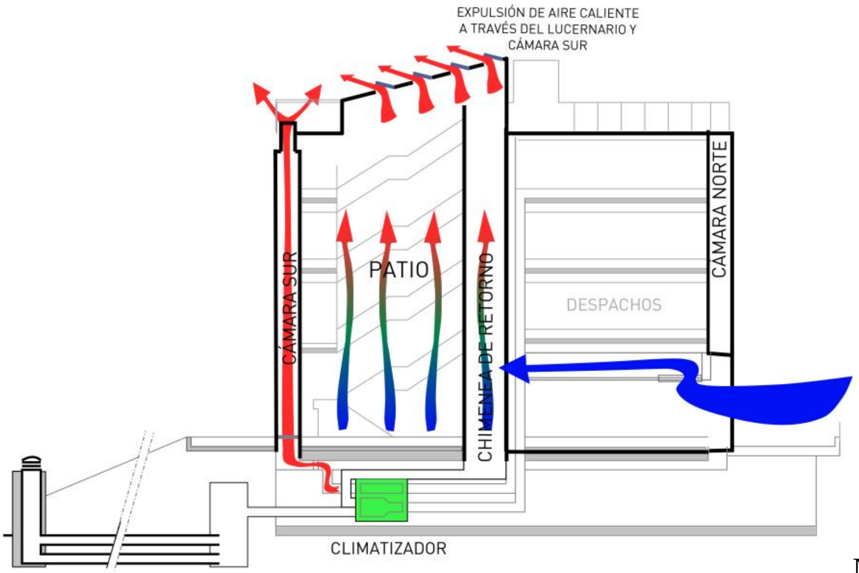
The main problem of buildings maintenance is the volume of power consumption. The technologies of passive house construction allow significantly reduce power consumption. Power consumption in the housing sector is reduced with the use of new energy-saving technologies and thanks to the use of new materials and the use of energy-active technologies and "green" tariffs makes apartment houses additional energy producers.

In order to follow the optimal operational parameters it is necessary to take into account natural and climatic conditions, corresponding orientation of a building to the cardinals, estimation of sanitation and engineering systems in accordance with the purpose and function of a building, normative illumination of the premises, recuperation and the appropriate temperature-humidity conditions.

These problems are solved by the arsenal of means and methods of ecological architecture of passive house building: landscape, space-planning, constructive, engineering and technological means, where technical systems perform simple auxiliary and corrective functions.

## 1.2 Energy-passive houses

Passive houses are designed, in order to passively, without using engineering equipment and energy resources, that is, thanks to the architectural and planning solutions, absorb, accumulate and keep the maximum amount of heat in winter and off season (in summer - coolness) from the environment. The heating of passive house must be performed by the heat generated by solar and geothermal energy, alternative energy sources, household appliances, the people living in the house.




South North

Fig. 1.1 The principle of work of natural balanced convective system of ventilation with heat exchange as illustrated in Edificio de emisiones cero (CIEM), en Zaragoza. Architect Octavio Cabello, Zaragoza, Spain.

Hot water supply is performed by renewable energy equipment, heat pumps and solar collectors. Ideally, the passive house is to be an independent power system that does not require expenses for maintaining comfort temperature.

Such features are achieved through proper architecture, designed for passive capture and accumulation of heat inside the house of the appropriate layout and geometry of the building, special engineering solutions that provide ingress of maximum amount of winter sun inside the building, protection from overheating by intense zenithal summer insolation, as well as accumulation and maximum preservation of the received heat (or coolness) using quality insulation, hermeticity, ventilation systems with recuperation and heat exchange, and the corresponding space-planning decisions based on the principle of zoning.

Solar heating

Using solar energy for a passive house is designed on the basis of complex climatological and geographical characteristics of the region, where the geographical latitude of the area and the corresponding angles of sun rays inclination during the summer solstice and winter solstice (during the solstice on June 22 and December 22 respectively), solar radiation intensity, annual average number of dull days, temperature and air humidity, wind speed, precipitation, etc are taken into account. Solar heating system must be capable to absorb solar radiation and convert it into heat, accumulate heat and distribute it in the heating zones without forced intervention.

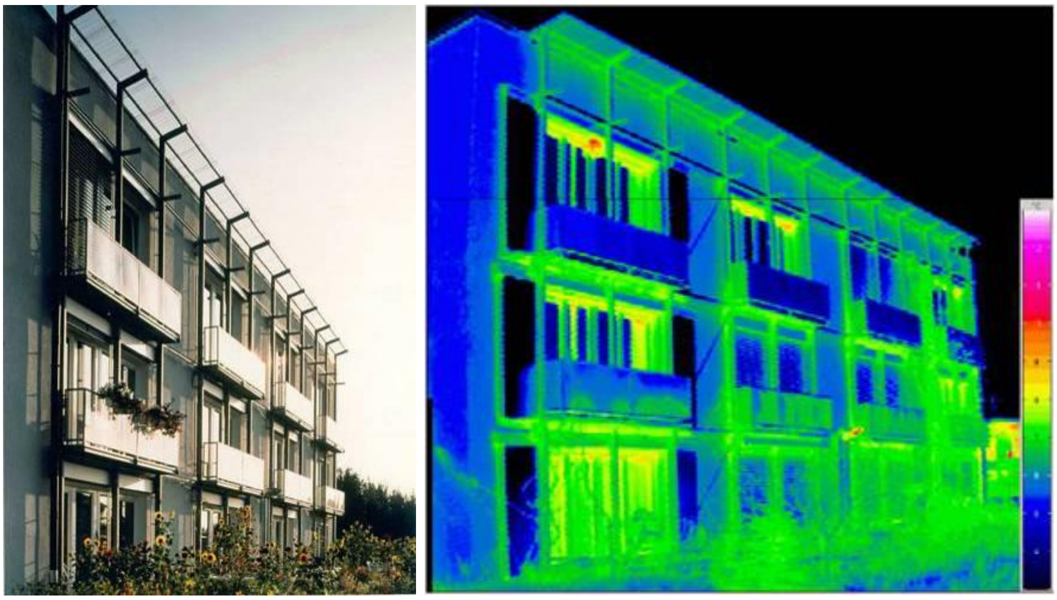


Fig. 1.2 Passive House in Darmstadt, Kranichstein district. Architects: prof. Bott-Ridder, Vestermayer, 1991 South facade (photo H.G. Esh) and thermal imaging of the same photo of the facade (photo V. Fayst)

Passive systems form a key foundation of the building, which should be designed so as to provide the most efficient use of solar energy for heating. Along with the windows and glazed surfaces of the south facade for sunlight interception, glazed openings in the roof and additional windows in the upper part of the building are also used, that increase the level of comfort and illumination of rooms. One of the most important conditions of the effectiveness of the passive heliosystem is the correct choice of the location and orientation of the building based on the criterion of maximum inflow and capture of solar radiation without losses during winter months.

At present, the following passive solar heating systems became widespread:

– the system of direct irradiation, when the solar radiation passes through the window glass, that intercept infrared rays (greenhouse effect);

– the system of "massive wall", representing a thick wall with one dark absorbing surface, which is covered by window glass with a gap of 100-120 mm, where heated air circulates;

– the system of "water-filled walls" which are filled with the heat accumulating liquid (today, salt solutions and paraffin, etc. are also used as infillings) and sun heated panels, containers or pipes;

– the system of "water-filled roof", where containers painted black, which serve as a sort of heat accumulators are installed on the top of the floor;

– the thermosiphon systems in which the system of air heating (the thermal collector) is located below the thermal accumulator that allows it to be heated effectively.

In a passive house, the effective heat insulation of all enclosing surfaces (walls, floors, roofs, windows, basement and foundation) forms several layers of internal and external heat insulation, that does not allow to let in cold air and let out heat from the house. Besides, cold bridges are eliminated in the enclosing surfaces.

The basic techniques of passive house organization

The following methods are important for architectural and engineering solutions of a passive building:

– correct spatial and functional orientation of the building and its rooms to the cardinals;

– relative compactness of the building and the optimal area of the facades;

– openness of the south side for insolation, the orientation of the maximum amount of translucent structures to the south, placement of bay windows, conservatories, winter gardens, loggias on the south side, the use of Trombe walls and solar greenhouses;

– presence of massive pieces (for the accumulation of heat) in places where direct sun rays from the low winter sun fall;

– volume-planning solution of shallow premises in which the rays of the low winter sun would fall on the back massive (preferably dark with low albedo) wall, warming it up and the space of premises;

– use of buffer space on the north side of the building (welfare facilities, bathroom units, stairs, ventilation chambers, electric board rooms, ventilation shafts, etc.);

– heightened humid, wind and thermal protection of the building on the north side, construction of earthfills, dead floors, green screens, tree-planting, adjacency with another building, etc., hermeticity of the building;

– proper glazing of the building, minimizing of the translucent openings on the northern facade, through which the heat would leave the building;

– qualitative thermal insulation of walls and fencing structures, utilization of the ventilated facades, passive protection from the summer overheating;

– use of underground channels for passive preheating (or pre-cooling) of air or water, combined extract-and-input system of ventilation with recuperation.

Energy characteristics of a passive house

Up to 90% of energy is saved by the passive method due to the above mentioned approaches. Additional energy can be saved due to the use of appropriate active engineering equipment.

Modern EU standards of the building energy consumption

The main feature of the energy passive house is low power consumption - consumption of heating does not exceed 15 kWh / m2 per year, about 10% of the specific energy per unit of volume, consumed by the majority of modern buildings.

European standard of passive house anticipates that energy consumption for house heating is not more than 15 kWh/m² per year (compared to what ordinary brick house constructed in Germany before the 1970s, consumes up to 300 kWh/m² per year).

In the UK, a passive house is to consume energy 77% less than a standard house. Since 2007, every house sold in England and Wales should get the rating of energy efficiency. "The certificate of energy efficiency" will be a compulsory part of the "The home information package". The independent inspector will examine each house for sale, and he will determine the efficiency rating of the house in terms of energy consumption and CO2 emissions.

In Ireland, a passive house is to consume energy 85% less than a standard house and to emit CO2 94% less than a standard house.

Since March 2007, new buildings in Spain must be equipped with solar water heaters to provide independently from 30% to 70% of hot water needs, depending on the location of the house and expected water consumption. Non-residential buildings (shopping malls, hospitals, etc.) should have a photovoltaic equipment.

According to the European classification of energy consumption level buildings are divided into:

– The old buildings (constructed before 1970s), requiring about 300 kWh/m² per year for their heating.

– The new buildings (constructed from 1970s to 2000s) - 150 kWh /m² per year.

– The buildings of low energy consumption (since 2002, a lower standard construction is not allowed in Europe!) - 60 kWh /m² per year.

– Passive houses (the Law has already been adopted, according to which since 2019 it is banned to construct houses at a standard lower than the passive houses in Europe!) - 15 kWh /m² per year.

– Zero energy houses (the building with the same architectural standard as a passive house, but they are equipped with the facilities that permit energy consumption only of its own production) - 0 kWh / m² per year.

– Energy plus houses (buildings that are mounted with engineering equipment: solar panels, collectors, heat pumps, recuperators etc) generate more energy than they consume.

However, zero-energy or energy plus buildings differ from passive standard neither by its own architectural and planning methods nor by the main principles of planning and construction, in which the amount and capacity of engineering equipment are only increasing.

Energy Performance Of Building Directive

Energy Performance of Building Directive, adopted by the EU in December 2009, says that after December 31 2019 in Europe it will be allowed to build the houses only according to the standard not lower than the passive one.

In some European countries (Denmark, Sweden, Finland, Germany etc) special state programmes aimed at bringing the building regular objects to the conditionally passive level have been developed (ultra low energy houses – up to 30 kWh/m² per year).

Fig.1.3 Villa Ronde is located on the ocean coast near Tokyo and is developed by the French/Japanese architectural bureau Ciel Rouge. The round shape of the house allows the sunlight to penetrate into the building all day long providing natural lighting.

Currently, the cost of construction of the passive house per square meter is 8-10 % more than the averages for a typical building. Additional costs of the building are recovered within 7 to 10 years. At the same time there's no need to lay pipes for heating inside the building, to build boiler houses, fuel storages etc. The price increase in building of passive houses is offset by a considerable reduction of operating costs. While a typical building consumes from 200 to 400 kWh/m² per year, a passive house consumes only 15 kWh/m² per year.

The energy efficiency of passive systems is relatively low so far – today they recover near 50% of buildings’ energy demand. However, their comparatively low cost price, convenience and comfort, good operational characteristics, ease of using and emphasized sustainability have determined the expediency of passive systems' application when designing a wide range of architectural objects – from cottages, townhouses and multi-storied dwellings to offices and public buildings and facilities. Operational characteristics identify high economic efficiency of passive systems, crucial for the optimal ratio of the price of one-time project and construction engineering costs to the value of savings in the long term.

The soundproofing is a very important aspect of a modern dwelling. The soundproofing norm of building ranges within 30-40 decibels. As for multi-apartment buildings (primarily in the former Soviet space), the soundproofing of apartments in prefabricated buildings leaves a lot to be desired.

Today the technology of passive houses doesn't always allow to refuse completely from gas or electric heating or cooling, especially in regions with high temperature contrasts, in zones with extreme temperatures. In such cases the use of solar and wind electrical generators and biogas facilities come to the rescue.

### 1.3 Active energy buildings

Features of active energy buildings

Active energy buildings are oriented to the effective use of energy potential of natural climatic factors of external environment for partial or complete autonomous power supply by means of range of measures based on application of volumetric and planning, landscape and town-planning, engineering and technical, constructive means which include the focus of spaces, architectural forms and technical systems on energy sources of external environment (sun, wind, geothermal energy etc) , enabling to substitute conventional finite resources (oil, coal, gas etc) for renewable.

During architectural and building design when defining volumetric and planning solutions for an apartment or a house (height, width, area), a special attention is given to: minimization of costs of material and natural resources while constructing, eco-friendliness in exploitation, provision of comfort and cleanliness. Constructive systems and functional schemes of designed or reconstructed buildings and facilities must conform to eco-friendly standards. Volumetric and planning and constructive solutions include the choice of building's optimal shape and the orientation towards cardinal points taking into account seasonal factors and wind rose; the room orientation and size optimization of areas and volumes; the maximum use of underground room for technical purposes; the planning of green utility networks (ventilation, heating, sewage, garbage disposal etc); the greening of building's roof and walls and the nearby territory' s improvement, the choice of green coating etc.

The design concepts of high-comfort apartments suppose the functional division of day time and night time zones, the availability of at least two sanitation facilities, the availability of additional maintenance (boiler, storeroom, household chemistry storages etc) and recreation (playroom, gym) rooms, the through and horizontal/vertical airing scheme. The solutions for living spaces in two levels are preferred.

Fig.1.4 The effective use of solar energy PV and by thermal solar collectors. Fotohof Haus, Salzburg, Austria.

Of course, not every building equipped with solar collectors, solar panels, wind generators and batteries (even if it's a power station) is classified as an active energy one. The difference between produced and consumed energy indicators, correlated to the cost of necessary activities and means, determines, as a result, the level of advisability and energy efficiency. In order to prevent energy generation from turning into the useless process, to prevent generated energy from being spent on forced conditioning or on excessive heating of surrounding space, on energy-intensive household appliances, numerous electric actuators, motors, pumps, complicated electronic control system, engineering devices etc (in that case this generated energy is going to just drain out), an active energy building, first of all, must be designed, at least, as a passive house, but with additional functions of energy conversion and production. In such a case, active energy buildings let not only save energy during the process of their exploitation, but self-support its own necessities and even sell surplus production directly in customer's network (providing the relevant legislation and the use of green tariffs).

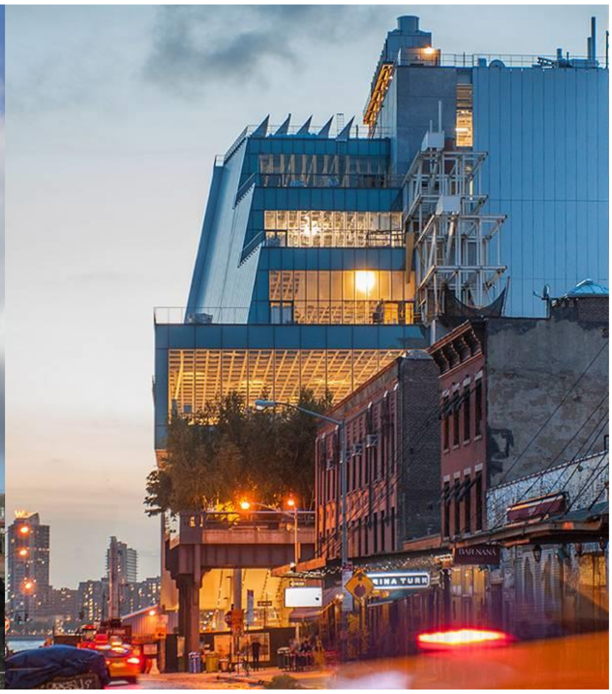


Fig.1.5 Active energy multi-apartment building Green Building (arch. Terry Farrel & Partners). View of the south-western side of the building. (left)

Fig.1.6 The New Whitney Museum, the view along Gansevoort Street. Arch. Renzo Piano (photo Karin Jobst). Both cases clearly show the efficient morphology of the buildings, specified by corresponding technological solutions. (right)

Classification of active energy buildings

Depending on kinds and ways of preferred energy consumption, conversion and generation according to the accepted focus on the use of one or another (or several at the same time) natural energy source, active energy buildings are subdivided into:

– solar active energy buildings (effectively using solar energy);

– wind active energy buildings;

– thermal buildings, using geo-, hydro- and aerothermal energy;

– bio active energy buildings, using the biofuel energy – biogas, biomass, solid biofuel;

– buildings with the combined use of different natural energy sources.

The practice of exploitation suggests that under present conditions, the full replacement of traditional energy resources for renewable isn't always economically reasonable, because of the low efficiency of currently existing technological means of electricity generation and transformation from renewable energy of natural environment against the background of their significantly high cost. That's why various combined schemes of energy supply, combining the use of traditional and one (or several) types of alternative means are deemed the most appropriate.

Such materials are well known and, unfortunately, are still used in mass construction:

According to the degree of energy-active object there are such types of buildings:

– With low energy activity (replacement of up to 10% of energy revenues);

– Average energy activity (replacement of 10 - 60%);

– High energy activity (replacement of more than 60%);

– Energetically autonomous (replacement of 100%);

– With excess energy activity (when the production of energy from natural sources exceeds the needs of the building and allows to transfer the excesses of energy to the grid to other consumers).

The experience of recent decades shows that the most cost-effective (on payback) and the most popular for the foreseeable future are buildings with an average energy activity in which the energy is provided by renewable natural resources from 40% to 60% of total demand.

In the area of buildings and structures reconstruction built on the same technologies and standards of energy consumption, a vital trend of full-replacement of traditional energy sources requires qualified alternative solutions. These solutions can provide the ability of the energy structure gradual modernization of buildings from the condition of energy efficiency to the use of alternative energy by methods and standards of passive technology in the first place and then by active technology.

Today energy-active buildings are the most perspective direction of modern architectural objects. Energy efficiency and sustainability are necessary and mandatory requirements for the evaluation and adoption of design solutions in modern construction of developed countries.

### 1.4 Energy supply in the modern house

One of the major advantages of alternative energy is its sustainability: the process of obtaining energy from renewable sources is not accompanied by the formation of polluting waste, does not lead to the destruction of natural landscapes, virtually eliminating hazardous substances for biological emergencies, i.e. it does not threaten the ecological balance of ecosystems.

Renewable energy sources, many of which are available practically everywhere and at different scales, are used in modern construction. They include:

– solar energy (thermal and light components of solar radiation);

– thermal, namely geothermal (heat warmed the upper layers of the earth's crust, the constant temperature of soil and rock masses, deep layers heat, etc.), hydrothermal (groundwater heat, surface water bodies, hot underground sources) and aerothermal energy (open air heat);

– kinetic (motional energy), namely energy of the air flows (wind energy) and the kinetic energy of the water flows (energy of streams, rivers, waterfalls and tides);

– biomass energy (vegetation, organic wastes of industrial and agricultural production, as well as the life-sustaining activities of people and animals).

Use of biomass energy is realized obtaining energy through traditional combustion of biofuels and biogas-concentrate (containing up to 70% of methane). Methane fermentation, resulting in the formation of biogas, is the most radical and effective method of sewage disposal, which is very important for the solution of the major problems of environmental protection and water recycling. This process is accompanied by the formation of valuable organics. Finally, biogas is a real alternative to petroleum and natural gas when used as a fuel for engines and boilers that produce heat and electricity because this fuel can be produced independently - directly from the potential customer and practically anywhere where organic waste materials are.

Despite the diversity of climatic and geological conditions, natural energy resources are distributed non-uniformly and in different capabilities. Therefore, in each case, reasonable preference for the use of one or another a natural source of energy is determined by specific local conditions: geographical latitude, local climatic conditions, and the number of sunny days per year, frequency and intensity of the winds, the nature of hydrological factors. For example, the use of geothermal energy of underground water proved to be the most effective on the subpolar northern latitude with the dark winters in Iceland. Due to this fact the country was able to completely abandon the import of coal and oil. Energetics of water resource and biofuels are widely used in Sweden and Finland. Wind energy is traditionally used in the Netherlands and Denmark. The use of solar energy is the most preferable in Mediterranean countries, on the southern latitudes of the temperate and subtropical belt where a lot of sunlight and heat. This energy is used for direct conversion into electrical and thermal energy for heating the coolant and hot water supplies of buildings, for heating massive elements of buildings, etc.

It is necessary to ensure the proper rational form and orientation while designing and constructing energy-active buildings with solar collectors. Solar batteries and thermal solar collectors are placed on the side facing the southern slopes of the roofs, on the screens of loggias, on the walls etc. Heliostats can be flat or focused (for higher temperatures or electric power installations with boiling liquid), static (fixed mounted on the midday zone) and mobile (tracing the course of the sun).

The owners of wind and solar energy generator units are individuals and companies in countries with a developed system of green energetics. They sell excesses of energy output to the state on special tariffs. The cost of "green" electricity purchased by the state is much more expensive than traditional one. This allows covering considerable material costs of expensive equipment and makes the development of alternative energy sources more reasonable and attractive (there is also a special system of credit and economic support for the development of green energy). As a rule, energy-active buildings are connected to a general electrical grid but in the case of a lack of self-generated electric energy they consume energy from this grid and in the case of overproduction they pass excesses back to this grid (special electric power meters are installed for this purpose, providing reverse motion of electric energy).

## 1.5 Ventilated facades

So-called ventilated facades systems are becoming increasingly popular in modern construction. Mounted ventilated facades system is one of the most technologically advanced ways of finishing walls of buildings. Ventilated facades systems can simultaneously solve a number of important tasks, which include: the creation of an aesthetically attractive look of a building and protection of structures from mechanical and weather influences. Also they help to achieve a significant increase in the level of sound and thermal insulation and increase the useful life of a building as a whole. Ventilated facades increase vapour barrier of building, improve aeration of the material and thus prevent the development of fungi, increase fire-resistance of the walls and the overall level of fire safety.

During the reconstruction of facades of old housing it is often required to perform additional weatherization of walls according to the new established standards of Thermal Engineering and Building Climatology. In this case, a significant technical solution is the additional weatherization of walls from outside. The most optimal technology of ventilated facades is where the heater is placed inside the frame, has the necessary aeration and moisture protection, and is closed with decorative facing screen on the top.

Structure facades systems, similar to modern ventilated facades, have been used previously in the Nordic countries and Western Europe in the 1950s and quickly gained popularity and became in demand all over the world. Mounted ventilated facades systems have received widespread use in Germany, where, based on research, structural parts and assembling technologies of ventilated facades were developed in their today’s form. Today the Association of materials and components for ventilated facades (FVHF) operates in Germany. Under its aegis the competition for the German Facade Prize is held every two years.

## 1.6 Modern Sustainable Materials and Technologies in Construction

In green buildings everything should be in compliance with environmental standards, including the use of technologies and materials that do not harm the environment, it is a necessity dictated by the life itself. Giving preference to environmentally friendly construction technologies and materials, we are also concerned about our health and the health of our children. At the European Union enterprises engaged in production of construction materials, there are strict requirements to comply with the standards of environmental safety.

Today, the developer is offered a wide range of building materials. The difference is not only in prices but also in the quality and safety of their use, of their ecological compatibility, since some materials are harmless, while others, on the contrary in a varying degree contaminate the environment or may even nearly without being noticed be dangerous for the health of the people in the building. The average person spends one way or another most of the time indoors (at home, at work, in shops or public places, etc.). It makes up about 3/4 of all the time. It is therefore of great importance, which materials the buildings are built from and the rooms are finished with. We create a healthy environment constructing a building from ecological materials and using them in interior decoration.

Eco-friendly construction materials are those which can be manufactured and used without any danger for people and the environment. They are divided into two types: completely eco-friendly and relatively eco-friendly materials.

Completely ecological building materials

The nature itself generously gives us completely ecological building materials. These include wood, stone, natural adhesives, rubber, cork, silk, felt, cotton, natural leather, drying oil, straw, bamboo and others. All these materials have been used by man for building of houses for centuries. Their disadvantage is that they do not always comply with the technical requirements (they may be not fatigue-proof and fire-proof enough, difficult to be transported, etc.).

Relatively eco-friendly materials

Relatively eco-friendly materials are those that possess better technical features and are made of ecological stuff (raw materials) that has to be technically refined further, requiring high power inputs. Brick, tile, roofing tiles, foam concrete blocks, materials made of aluminum and silicon are referred to as relatively eco-friendly materials. Recently passive houses are often built from recycling inorganic waste such as concrete, glass and metal.

The most common and affordable material we have is right under our feet. It is ground. Various types of soil - clay, loam, sand have long been used in the construction and in various combinations they make rammed-earth structure. One of the popular materials in green construction nowadays is soil-concrete in the form of soil-concrete blocks. The composition of soil-concrete blocks in addition to ground may include peat, ash, pine needles, sawdust. Cement stabilizes the others components of the mixture making it moisture-resistant. It is also possible to use non-stabilized soil-concrete blocks, the so-called mudbrick, for residential buildings construction. These mudbricks are made of soil. Construction from mudbricks has many advantages (low cost, high strength, fire resistance, low thermal conductivity).

The use of local natural stone is traditional. In each region, it is accepted to use its own resources. For centuries, limestone, dolomite, sandstone have been used in building construction (from castles and cathedrals to stone houses in towns and villages).

Artificial sandstone

As far back as the 19th century in England artificial sandstone was invented, which is not worse than natural sandstone by its technical properties. To manufacture it, the backing is not needed. The sand is mixed with calcium chloride and water in certain proportions and gets stabilized with liquid glass. The reaction gives sintered grains to form a monolithic solid block. A byproduct of the chemical reaction is sodium chloride (table salt), which after solidification of blocks is removed by holding them in water. Artificial sandstone can be molded, cut, surface-tooled and shaped. This material is heat-resistant and has low thermal conductivity. The density of the material can be changed by varying the proportions of the components. Color pigments can be added to the material, giving it a wide range of colors and tints.

Today, a unique material geokar is available in the market. The basis of it is the peat processed into a paste with addition of shavings, chopped straw and sawdust. Peat blocks are obtained by thorough drying of raw materials. Peat is a natural antiseptic and kills harmful micro-organisms. Geokar is the best option for the construction of environmentally friendly buildings. It can be used both for the construction of multi-storey buildings, and farm buildings, load-bearing walls, partitions, as well as insulation of buildings. Geokar is affordable. Its advantages are durability, bactericidal effect, heat capacity, radiation-proofing. Furthermore geokar absorbs noise and odors, is resistant to rot and rodents. Peat blocks are easy to use in construction and manufacturing. Geokar houses "breathe", the air in it is clean and fresh. In winter such a house is very warm, in summer it is cool.

Very ancient and durable material is adobe brick, which is composed of clay, sand, straw and water. The material is very heatproof and durable, proven for centuries. Clay also maintains moisture balance indoors. In excess of moisture inside, it absorbs moisture, and when it is dry the clay gives the moisture back into the air.

Lay kilned brick

Bricks are made of the clay without the use of chemical additives and dyes. The walls made of this material are solid, durable, resistant to the harmful effects of the environment. The least power-consuming brick is considered the one that is made of clay with the addition of arming straw. After drying in the sun such bricks are ready for use. The houses, built from this type of brick, home more than a quarter of the population of the entire planet. In areas with a dry climate, they are especially durable. The most “friendly" brick to a human among the great number of brick types is the clay kilned brick. The walls made of it do not rot, are waterproof, fire-resistant and durable and possess high heat capacity and thermal conductivity.

Tuff and coquina

Traditionally low-rise buildings are usually built from tuff and coquina. These materials can be shaped with an ax and a saw. Tuff is used for producing rectangular blocks for masonry. It is frost resistant and very durable, but cannot be used for the construction of multi-storey buildings.

Straw and cane

Vegetative materials, such as strawboard and reed-fiber board, are also widely used in the construction of low-rise buildings. They are based on straw and cane which are pressed into slabs of the rectangular shape and stitched with wire. To make the block more resistant to rodents, a little of lime or borax is added.

Kerpen

New building material Kerpen has a porous structure. It is made of natural raw materials with the addition of industrial wastes. In terms of environmental properties, Kerpen may be compared with the ordinary glass. The Kerpen foam can be used in building construction as thermal insulation and cladding. Kerpen is frost resistant and durable, resistant to atmospheric changes and moisture.

Half-timbered house

It is impossible not to pay attention to environmentally friendly building material wood. An interesting variant of buildings presents the half-timbered houses. This is a unique kind of design, the framework of which consists of vertical posts and horizontal beams with diagonal struts and braces. The framework made of beams is open from the outside of the building, painted in a color, which is contrasting to the wall and creates a distinctive expressive geometric pattern on the front. The space between the beams is filled with bricks or wattle and daub material, or carved wooden panels. This technology is very reliable – the half-timbered houses exist in cities and rural areas of Western Europe for several centuries, from time to time being renovated and refurbished.

Finnish

Wooden house

The traditional "Finnish" (in Europe known as the "Swedish") wooden house is such a kind of half-timbered house where the framework is made of timber, covered inside and outside with the smooth lining boards. The inner space of the house walls is filled with insulation (with vapor sealing). Such houses can withstand long northern winters, severe frosts and during the summer they protect securely the house from overheating.

Zidarit is used in the frame-monolithic construction. These plates are fireproof, waterproof, resistant to microorganisms and insects. Zidarit consists to 89% of ground wood, 10% of cement and 1% of water and liquid glass. In construction, zidarit plates are used as formwork.

Fibrolite

Similar to zidarit material, but with a wider range of applications, is the fibrolite. It consists of the filling, locking and binding components. The "wood wool", specially treated softwood chips are used as the filling component. The bischofite – crystal sea salt – is used as the locker. The magnesium oxide is used as binding component. Fibrolite is used as formwork in the monolithic frame construction as well as the material to make floors, internal finishes and partitions. This eco-friendly building material is highly robust. Its main advantages are the sound insulation, thermal insulation, fire resistance and ease of use.

For interior finishing of the walls, such materials as wood or mats of straw, jute, bamboo are best suited or – at least – plaster and wallpaper. It is highly recommended to check if there is the marking "CE", which indicates compliance with the European environmental standards, in case when parquet or laminate are used for flooring.

Materials for roofing

Eco-friendly materials for roofing are kiln clay tile and natural laminated slate (not to be confused with asbestos cement sheets), glass tiles. However, because of the large weight they require respectively higher slope and stronger construction of the roof.

Environmentally unfriendly construction materials

Extremely attractive, aesthetic and stylish today are the reed, thatch and straw roofs. These roofs are breathable, well protected against summer heat and winter frosts, are moisture-proof and regulate very well the internal moisture conditions.

Thanks to a special fire-retardant and antifungal treatment, they get even more reliable and durable. The use of straw and reed as a roofing material is especially popular in Great Britain, Northern Germany, Denmark, Netherlands, Belgium and France.

Harmful or environmentally unfriendly construction materials are materials, for the production of which the synthetic materials, ruinously affecting both the environment and health are used. Many materials on a chemical base often not only have toxic properties but, furthermore, are carcinogens and mutagens. The natural self-destruction or recycling of such construction materials is out of the question. After their use, they are brought into landfills, where they continue to pollute the air and the soil. Moreover, their production requires greater energy consumption.

– Styrofoam at heating allocates toxic substance styrene, which may induce severe poisoning and provokes thrombosis of blood vessels.

– Expanded polystyrene and extruded polystyrene. It also contains styrene. But besides hexabromocyclododecane (HBCD) is added into the insulants by the technology based on them for reducing the combustibility. The European Chemicals Agency has announced HBCD as one from 14th most dangerous toxic substances.

– Polyurethane foam and insulating boards based on polyurethane contain toxic substances isocyanates.

– Polyvinyl chloride decomposes under sunlight, releasing hydrochloride, which provokes the liver diseases and blood vessels. On heating (in sunny areas or the system "warm floor") polyvinyl chloride starts to produce toluene and xylene. PVC linoleum, vinyl wallpaper and decorative PVC film is also responsible for the release of heavy metals into the air. These substances are carcinogens, they can cause the development of cancer eventually accumulating in the human body.

– Paints, varnishes, mastics of low quality are considered the most dangerous for health because they have got lead, zinc, and toluene, xylene, cresol, which are carcinogenic and mutagenic. Polyvinyl chloride is included into the composition of many paints and varnishes.

– Particle board (chipboard), hardboard (fiberboard and MDF), plywood, veneer send off formaldehyde into the air actively being a part of binding urealformaldehyde mastic. Formaldehyde vapors may be sent off these materials over the years with the same intensity. The inhalation of formaldehyde can cause headaches, dizziness, mucous membrane irritation, allergic reactions, asthma. Formaldehyde is a carcinogen.

– Mineral cotton is excluded from using it inside the building because of phenol formaldehyde in its content and emission into the air needle glass microparticles. Safer mineral cotton is also produced with using a binder based on acrylic mastic.

– Asbestos and asbestos cement plates (forbidden in the construction of the

European Union) can cause serious lung diseases (up to cancer) due to the inhalation of micro particles of asbestos fibers.

– Concrete is known by density and durability. Unfortunately, the concrete prevents free penetration of air and contributes to the concentration of electromagnetic waves. It also has poor sound insulation. Crushed granite which contains radioactive uranium (on an average 10-25 gr. per ton of granite - i.e. only 0.3 m3) is added into the concrete composition for the production of panels, slabs and monolithic structures. The content of uranium, thorium and other radioactive elements in the crushed stone may be in larger or less concentration. It can be more or less radioactive. The practice shows that the exceeding a level by radiation in separate panels above accepted limit in 25 mR / hr is not uncommon.

– Reinforced concrete has the same drawbacks as concrete does, but in addition it also concentrates the electromagnetic emissions from electrical grids and electrical appliances in the building. At the same time, the expanded lath r/c frame shades the positive natural electromagnetic external factors of the Earth. As a result, people living in the houses or working in the offices constructed from such materials often suffer from rapid fatigability and the weakening of immune system.

*– Asphaltic concrete is used everywhere to cover the roadway, sidewalks, etc. It consists of stone screening dust and bitumen. The screening dust is radioactive in the same way as a chip in the concrete(see above) and bituminous binder heated in the sun sends off the carcinogenic fumes. The manufacture of asphaltic concrete usually is concentrated in towns (at the place of the direct use) and is extremely unhealthy not only for working on its production, but also for people in the nearby districts. The streets and squares are covered by carcinogenic fumes day with cars emissions in hot summer create a unique cluster for the urban atmosphere. It's time to start thinking and proceeding to positive changes for the health of the living population and healthy future generation.*

**Questions and tasks**

1. What are the special features of "green" architecture?

2. What are the characteristics of an energy-passive building?

3. What are the current standards of power consumption for passive buildings?

4. What is the classification of current European buildings on the level of power consumption?

5. Can every building, equipped with solar batteries, wind-powered generator, etc. be considered as energy active buildings?

6. What is European buildings’ classification by the degree of energy activity?

7. How are ventilated facades organized and what are their characteristics?

8. What is the difference between sustainable and unsustainable materials?

# CHAPTER 2. BIOCLIMATICS

In the context of ecological technologies’ development in the western architectural preparation the architectural bioclimatics has been formed as the applied discipline considering the influence of the natural environment external factors (insolation, radiation, the geothermal and atmospheric phenomena, etc.) on form making and technological solutions of buildings for the purpose of vital comfort level maximization and building impact minimization on environment. The architectural bioclimatics is directly connected with ecological architecture, ecodesign, "green" technologies. The field of bioclimatics consideration consists of the passive house technologies, heat transfer, recuperation, passive solar systems design, protection against excessive insolation and an overheat, effective use of natural lighting, etc. The understanding of the ecological architecture principles and designing of passive and power effective buildings is impossible without knowledge of bioclimatics.

Today bioclimatics is studied practically at all architectural faculties of leading universities in Europe and the USA. The knowledge of bioclimatics fundamentals and competency in outlining schemes of insolation and heating exchange is compulsive for the practicing architects today.

## 2.1 Bioclimatics as a tool of problems solution in eco-architecture

The influence of external climatic factors on the living conditions in the building

In general bioclimatics is the science studying the factors of relations between climate and a living matter, the influence of climatic factors on organisms. Accordingly, the architectural bioclimatics is the applied discipline considering the influence of external climatic factors on the building as a direct macrocover of a human organism. Man is directly covered by skin, which maintains the thermal balance of the organism; it sweats and breathes Clothes are the next covering shell after skin. A dwelling or a house is the third cover and the shelter for several people, for a family. If for comfortable and practical clothes are specified basic requirements to be proportionate, functional, heat insulating and thermobalancing - warm when it’s cold and cool when it’s hot, dry and water resistant on the outside and, on the contrary, permeable for vapor from the inside, "breathing", a well-aerated, - the same can be said about the building. Accordingly, the building should be (besides durability and beauty) functional, proportional, convenient, warm in winter frosts and cool in summer heat, light balanced, aerated, breathing.

Bioclimatics directly considers factors facilitative for health, the conditions of thermal and humidity comfort, control of CO2 level in indoor premises, using the natural light and comfortable lightning of inside spaces.

Bioclimatics building adapts to a certain climate conditions practically in the same degree as any local resident is traditionally adapted for local climate by his behavior, his way of life and traditional clothes. In each climatic zone, every culture has fixed historically traditional types of dwellings being formed over many generations.

The examples of structures' features in north climate

The houses of northern people are built so that they effectively accumulate heat and save limited natural resources. Traditionally, the center of the northern house was an oven with thick walls, a chimney equipped with sophisticated labyrinths and conserving heat well for a long time, distributing it evenly throughout the inward extension. The premises of northern homes, as a rule are low to warm them up quickly without wasting wood, peat or coal. The colder the climate is, the more compact houses become, the more laconic shape is the less protections and niches they have to achieve a minimum external surface, for the house not be cool in conditions of long frosty winter. The preferred material for the northern dwellings has traditionally been timber – warm and dry allowing to raise the structure quickly.

The examples of structures' features in south climate

In the southern climates the proportions of premises are traditionally different. They are larger, with high ceilings for the rising up of heated air to the ceiling convectionaly in the summer heat with having time to cool down and drop down already cooled significantly. Therefore, in the ancient Italian and Spanish palazzo there is no need for an electric forced air-conditioning of the premises, even when summer heat reaches the mark of 35 ° C. The traditional for Mediterranean climate atrium adds comfort being an open or covered patio that improves described above the distinctive features of self-cooling convectional air flow and contributes to the comfort of the internal microclimate of the structure. Embedded in the atriums group of plants, mini gardens, fountains, small ponds, aquariums strengthen the air movement and its heat and moisture exchange. The Mediterranean tradition of atrium buildings spreads to the countries of North Africa, the Middle East, Central Asia, Latin America and the Caribbean Region because using of atrium appeared to be such convenient and effective in hot climates. Building facades in the southern climate are traditionally light, sometimes even white for better light and heat reflection. As a rule, the southern building facades have long loggias, balconies and other protruding structures, casting deep shadows, and thus contributing to the building sides protection from sun rays' overheating.

From modern experience of bioclimatic architecture it is possible to allocate the application of optimal building morphology depending on climatic conditions, use of sun-protection structures on the lit building sides (vertical on east and western ones, and horizontal on southern ones), minimization of glazing on northern building facades, use of roofing coverings in light tones (that reduces its heating in a warm period of the year).

Natural ventilation systems that use natural convection of air due to heating by the solar heat, or due to ventilation towers of the building are applied beside in addition to a complex volumetric-planning solution, which takes into account the particular location and climate. Recuperation systems, solar collectors and geothermal units are included to the general scheme of the building's heat exchange. The inclination angle of the solar collectors' installation is varied depending on geographical latitude.

## 2.2 Factors of interaction of a building with the environment

The features of "green" architecture

Designing "green buildings" encourages architects and engineers to find such technical solutions that minimize the negative aspects and optimize positive impact of the energy, environmental and technological factors that determine building as a human living environment. In the process of designing “green buildings” it is difficult to divide the work of an architect and an engineer; they cooperate in the course of the entire design process and only such a union can be successful in reaching the purpose.

The main problems when designing "green buildings"-

The sources on "green buildings" methodology list the following key objectives that are directly related to the architect`s competence: the orientation of the building to the parts of the world, building`s layout in the neighborhood, the choice of the form for the building envelope, glazing and the materials for fence, consideration of a building as a single energy system based on the impact of the outdoor climate. Buildings with natural ventilation should have an orientation and placement of the inflow and outflow channels to provide equal air circulation in the premises under any directions of the wind. Convection factor allows providing updrafts even when calm. High albedo factor of the wall and roof reflecting surfaces protects against overheating, both the building itself and the surrounding air envelope. Flat roofs of buildings are often recommended to plant with the climate-relevant plants to reduce overheating of the roof in summer and heat loss in winter and to provide a positive moisture conditions around the building.

An important objective when designing buildings that use ecological forms of energy is to find ways and means to transform, accumulate and distribute the air, heat and light streams in order to maintain optimum microclimate parameters of the premises under conditions of cyclic (daily, seasonal) and periodic (cloudiness, precipitation) changes of the environment parameters. In this process there are the following key objectives:

– to collect energy, to get the required amount of energy taking into account its dissipation in the environment, i.e. to compensate the insufficient power of the natural energy flows;

– to save, accumulate the collected energy (to compensate time difference in periods and seasonal and day irregularity of supply and consumption of energy);

– to distribute the energy, to provide controlled distribution of energy in the building for providing the required at the moment functional, technological and microclimatic parameters of the parts and elements of the building.

## 2.3 Effect of climatic and geographical conditions on the shape of architectural features of buildings

Located in a natural environment the building is influenced by solar light and the heat (infrared) component, various climatic factors - wind and precipitation, the influence of the Earth's energy, peculiar geological and hydrological factors. At the different latitudes the angle of the luminous flux of the Sun and its intensity, day length and seasonal temperature fluctuations, are naturally different and determine the conditions for the well-known differentiation of climatic zones.

The outdoor factors of building maintenance

In the northern hemisphere in the morning still not hot rays of the sun light the eastern facade, at noon the most active solar phase lights and heats the building in the south, and in the afternoon sunshine and the afternoon heat are transferred to the western facade. Northern facades are the darkest, coldest and wettest. Sunlight reaches there either reflected or only during the summer solstice in the northern latitudes (during so-called "white nights"). Insolation conditions essentially vary at different latitudes and it defines a great difference in traditional forms of buildings and their features in different climatic zones from tropical to subarctic regions.

Fig. 2.1 Modern energy efficient buildings taking environmental factors follow the outlines of the natural objects. Residential building in Marseilles. (left)

Fig. 2.2 In the London City Hall designed by Norman Foster the south facade in summer shadows itself due to a negative slope, and the summer afternoon rays of the high sun light even the sloping north side; the top of the building is protected from overheating by on-blown cover. (right)

In addition to the sun exposure, a building is influenced by direction and intensity of prevailing winds; the air masses from the north are able to chill the northern parts of the buildings substantially, especially in winter. Air masses from the south heat the building and it can cause significant discomfort in summer.

Therefore, the north and south facades of energy-efficient buildings can substantially differ on geometrical configuration, the nature of glazing and cladding, the use of various thermal insulation or heat-absorbing materials and technology in accordance with the difference of climatic problems. If the south facade should be protected from overheating, the north one needs to be insulated and sheltered from the cold northern winds. If the sun protection of the southern facade has horizontal lamellae the solar shading of the east and west facades have vertical ones (in the temperate latitudes of the northern hemisphere). Therefore, differently oriented and exposed to the elements facades of the same building are fully justified to use different engineering and architectural solutions (of course, having the general compositional and stylistic unity).

The shape of a whole building and the form, slope and structure of the roof are directly determined by the frequency and intensity of precipitation. The most important function of the roof is to protect from rain, cold in winter and overheating in summer. Therefore, the traditionally preferred forms, ramp gradients and materials vary/ depending on the climatic zones.

Fig. 2.3 Ecological terraced houses designed by IdeinLab Architects use extensive green roofs, solar panels and natural supply and convective ventilation with thermal exchange.

The influence of environment on morphology of buildings

Actively interacting with the environment, energy-efficient buildings adapt to the physical characteristics of their location, making a maximum use of bioclimatic morphology, often causing the increasing similarity between architecture of modern energy-efficient buildings and biomimetics. The similarity of these buildings with wildlife is not accidental because the objects of nature by their existence are obliged to evolution and variability of living in a changing environment. The development of modern construction technologies and materials gives the modern architect great opportunities to achieve the desired solutions and shapes.

Using environmental factors significantly changes the architectural conservative dominance of verticals and horizontals in the direction of natural bionic structures with their more complex shapes determined by many physical parameters. An energy-efficient building begins to perform a number of functions related to the maximum use of natural light along with protection from overheating with the infrared part of the spectrum, the most efficient use of the angle of inclination of the solar batteries and thermal panels to correspond with the position of the sun at different times of the day throughout the different seasons of the solar year. In modern practice, architects achieve a uniform distribution of light flows by modeling the corresponding geometry of facades, taking into account the geographic latitude of the location and compliance of angles of incidence of sunlight at different times of the year.

Often used in ecological architecture exploited green roofs, pergolas, gadgets for gathering and accumulation of rainwater, ventilated roofs, ventilation and recuparation devices also profoundly affect the silhouette morphology of this type of buildings.

### 2.4 Physical features of buildings' functioning and indoor climate

With all the relative diversity of geographical and climatic factors human tends to show almost the same decided preference in the home microclimate, which is achieved by different people in different climatic zones in different ways.

Requirements of maximum practicality, rationality, economy, high comfort and safety for human health are determining for buildings designed and constructed according to the principles of "green architecture". High standards of life support and comfortable atmosphere are achieved in these homes because of systems that control insolation intensity, the use of passive heat exchange (heating or cooling), a constant influx of fresh air, and the effective passive heating systems.

#### 2.4.1 Heat transfer, aeration, air-conditioning and humidity conditions of an ecological building

With a wide range of external temperatures and humidity conditions microclimate of home should be within the "room temperature" from +18 to + 27 ° C and an with optimum level of relative humidity of 40-60%.

Room temperature standards

Preferred "room temperature" depends on the individual, and many other diverse factors such as time of year, time of day, lighting, humidity, ventilation, clothing, physical exercise, illness, sleeping or waking, hot or spicy food and so on.While one person prefers the environment temperature +16 ºC, another may prefer +28 ºC. Many times you have seen it in public buildings, in transport - the places where different people with different preferences are collected together. At the same time it can be too hot and stuffy for one, and it can be too chilly and drafty for another. Sometimes, according to the sanitary code, the indoor temperature is legally defined as minimum or maximum allowed temperature for residential, public and industrial buildings. Basically, the range of acceptable indoor temperature varies from +17 °C to +22 °C in winter and to +27 °C in summer.

Temperature standards of buildings

Today almost everywhere there are unified temperature standards of the maintenance of buildings, which include natural light conditions for living accommodation. Heat insulation of buildings and their heating systems have to provide a constant indoor temperature from +18 °C to +22 °C, and in corner rooms - from +22°C to +24°C.

Waterproofing, vapor barrier of roof coverings and intermediate floors, tightness of connections, and heat-insulating features should not seal tightly the building to deprive it of natural movement of air and the ability of moisture exchange. Therefore, the processes of recovery, air exchange, thermal convection, and maintaining a positive moisture conditions are the most important technological needs. In conventional houses the ventilation is realized by natural movement of air which usually penetrates into the room through special gutters in the windows and retreats through passive ventilation systems in the kitchens and in the bathrooms. Passive houses use 2- or 3-chamber glazing windows filled with argon or krypton inert gases with a low thermal conductivity. Glasses for such glazing windows are manufactured and treated by special technologies, and are coated with heat-reflecting membranes. Sometimes the windows are equipped with shutters and blinds to have additional heat insulation. It is reasonable to direct the biggest translucent structures and large windows to the South (in the Northern hemisphere). Then they bring you more heat than you have lost.

Recovery and heat exchange of passive house

Heat transfer of passive house operates by applying controlled ventilation system with highly efficient process of heat recovery. In energy-efficient buildings the ventilation of premises is carried out in a balanced supply and exhaust installation with highly efficient countercurrent heat exchanger (air-air). More significant energy efficiency can be achieved if the supply air enters through a special underground air duct provided with a heat exchanger, and goes out of the building due to convection through the exhaust channels. In heat exchanger the heated air gives up heat to the cold air. In winter the air for the building is taken from the southern facade through the ducts warmed by sunlight and then it goes to the recuperator where before removing the waste home air gives its heat to incoming fresh air through a heat exchanger.

Thus, even in a cool season the fresh air coming into the building can be heated to +17°C without using gas or electric heating devices. In summer, the hot air, entering the underground duct from the Northern façade without any electric air conditioning is cooled there due to a constant cool basement area to comfort level of temperature from +18°C to +22°C. In a passive house comfortable conditions are constantly supported only by regulation of dampers and valves in air-duct channels, and there is a need for restricted use of low power heaters or air conditioners for minimizing temperature control only occasionally.

Fig.2.4 Thermal control, energy recovery, thermal transmission and air conditioning systems in CIEM building. Arch. Octavio Cabello. Zaragoza, Spain

Thermal balance features

Heating, air conditioning and ventilation system is an important factor of passive house, which expends resources more efficiently than conventional house. It is important to distinguish the indoors air temperature from the temperature of radiating surfaces, because in these buildings floor surfaces and walls radiate the heat. Their temperature may reach +28°C in winter, +25°C in off-season period and only +22°C in summer. Thus, passive houses achieve comfort conditions and healthy atmosphere.

In summer, when the indoors air temperature can reach the maximum in +28° C due to cool walls thermal transmission, the person has a mild cool. In winter, when the indoors air temperature is +18°C and walls are warmer, we have a return heat exchange.

Interior finishing materials and humidity

The basic indicator for the comfort temperature of the environment is feeling of heat balance of air temperature and surfaces in the room at a constant optimal humidity. Thus, the internal microclimate of eco-house is radically different from microclimate of municipal multi-storied blocks of flats dried by central heating and waterlogged and stuffy greenhouses. When we have specific technological approaches in passive house, first of all harmless natural "breathable" materials are used in the interior finishing. It provides the constant maintenance of the healthy humidity, condensate and emissions, which essentially prevents the development of pathogenic microflora and aerobic fungi of Aspergillus, and effects on sanitary conditions and comfort of living positively. The most important is that a healthy climate in eco-house is provided primarily through the maintaining of stable and optimal for human health air humidity (40% - 60%), when seasonal changes of air temperature are from +18°C in winter to +30°C in summer.

Ventilation and humidity standards

According to the standard requirements of aeration in modern buildings it is 3 $m^3$/h in residential rooms, it is 60-90 $m^3$/h in the kitchens, and it is from 25 $m^3$/h to 50 $m^3$/h in bath rooms. The air humidity should be at least 20% and not more than 65 %, where the optimal value is 60 %. In addition to air- and moisture exchange, in modern houses air ionizers, ozonators and air purifiers are increasingly used.

The level of relative air humidity

The optimal level of relative air humidity for people is 40-60%. Lower humidity increases the drowsiness and fatigue, deterioration of health, reduces working capacity, dries skin and mucous membranes, accelerates skin aging, increases risk of respiratory infections. Besides that dry air contains the excessive amounts of positive ions. The dust particles do not settle for hours, and it creates unfavorable conditions not only for allergic individuals and persons suffering from various pulmonary diseases, but also for healthy children and adults. Especially dry air is dangerous for newborns. So hydration is necessary. Higher humidity reduces the amount of suspended dust and improves the protective functions of skin and mucous membranes. But this process should be controlled. Excessive hydration can lead to the growth of molds and the population of dust mites. The optimal level of humidity for dust mites is 75-80%, and for molds it is 65% and more. Besides that, the excessive humidity is the reason of clothing damping and deterioration of wallpapers. Hydration should be adjustable. The optimum level of relative humidity for household allergies people is 40-50%.

The optimal level of relative humidity for people with domestic allergy is 40-50%.

The same level of humidity that is optimal for human is required for things surrounding him: furniture, musical instruments, works of art. Indoor plants, especially tropical ones, require higher humidity. At the same time during the heating season in houses with central heating, as well as in premises with air-conditioning relative humidity is often lower than in Sahara Desert (20-30%).

### 2.4.2 Sun protection, light reflectance and protection from overheating

For energy-efficient buildings it is important to have the sunlight getting balance together with the regulation of sunlight heat penetrating. It is necessary to light the room with natural daylight, keep the possibility to ventilate premises through windows and openings preserving the ability to observe external space, but premises must not be overheated. The task of the sun protecting devices is in providing the required level of lighting and making distribution of natural light as evenly as possible to limit indoor air overheating and to provide energy saving.

Fig. 2.5 Architectural solutions, both combining active facade shade making geometry, awnings, pergolas, lamellas and bright reflective surfaces with a high albedo provide the most optimal sun protection.

Sun protecting devices include:

– shade making façade elements - belts, balconies, canopies, niches, etc.;

– canopies, pergolas, tents, awnings;

– external louvres, outdoor venetian blinds, front lamellas, reticulated lattice aerated shells, heat protective glazing made of special glass (which filters the infrared part of the spectrum).

Architectural volume-planning tasks

Architectural volume-planning tasks for sun protection (for protection from overheating in hot weather and sunlight blinding) of buildings include:

– rational facades and parts of buildings orientation, rational zoning of primises, their window openings and rooflights concerning with the sun positions to the time of the day light and midday rays' declination at solstice points of the solar year (the highest - on June 22 and the lowest - December 22) concerning with the region geographic latitude;

– the intense relief creation of facades exposed to sun exposure, improvement of shade making structures - active vertical planes on the east and the west sides and horizontal - on the south, galleries and deep loggias forming;

– the use of heat-reflective, heat-absorbing and light diffusing glass and plastics (polyacrylic or polycarbonate) as materials to fill the buildings light openings;

– the use of thermal insulation materials and air spaces in the external walls construction , installation of ventilated facades;

– "green roofs" arrangement, facades greening;

– facades covering arrangement (southern ones first of all) and roofing elements by materials with high albedo (light with high reflectivity) and inner surfaces’ finishing focused on the south side in the cooler shades;

– greening of surrounding areas with the most intense and prolonged sun exposure;

– roads and pavements covering with materials without heat capacity.

Fig. 2.6 Openwork horizontal lamellas oriented perpendicular to the midday rays direction give an effective sun protection of southern facades in the form of pergolas and movable shutters with louvers.

Technical sun protection includes ventilation, cooling, air conditioning.

Constructive sun protecting devices are divided into fixed and adjustable. The selection of the most appropriate types of sun protecting systems is based on appropriate measurements and calculations.

Interior sun protecting devices (blinds, curtains, louvers, roller blinds) that are installed directly in the room are ineffective because they are heated by absorbing solar radiation which had already penetrated into a room i.e. they become a secondary source of heating this room.

External solar protection systems make up the most effective means of the light and thermal balance providing. Their rational use of diffuse sunlight distributing creates light comfort and reduces the load on indoor air cooling, often making air conditioning unnecessary.

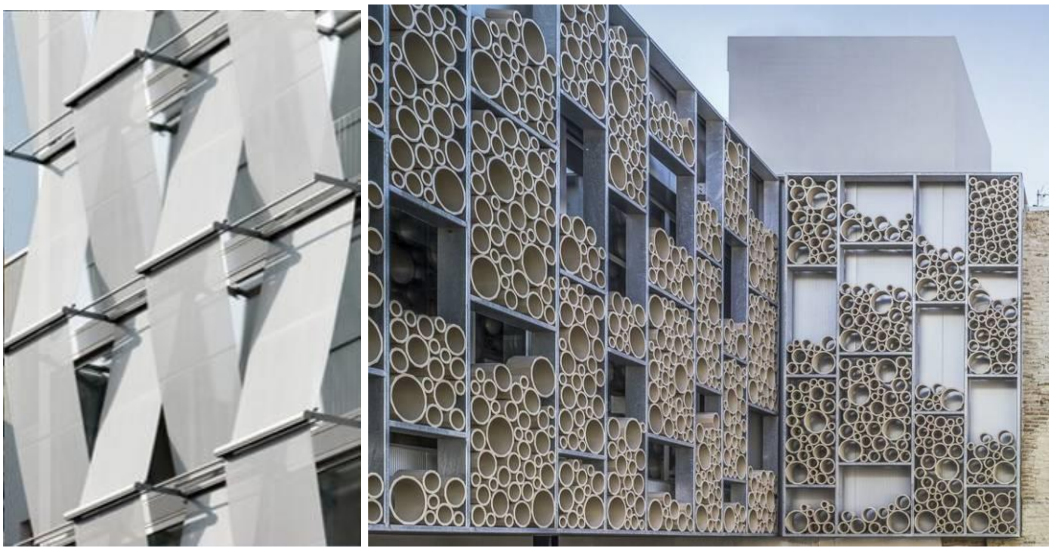


Fig. 2.7 Wide variety of technical and design solutions, materials, exterior sun protecting systems textures gives architect impressive feasibility of artistic expression, style and originality.

Passing through the glazing, solar energy is divided into three components: reflected radiation, absorption of radiation, transmitted radiation. In order to get rid of solar heat excess in the room, i.e. to reduce the transmitted radiation special brands of glasses that allow achieving the desired effect are used for glazing in modern construction. But because of impossibility to control the amount of transmitted light flux in summer and winter in this case, the use of these materials is limited. Therefore, in addition, different kinds of sun protection systems that will manage the process of solar energy passing stream, without breaking the standards for working space lighting. The best sun protecting effect is achieved by limiting sun exposure space through light openings integrating the use of insulated glass in the outer-bound of window and exterior adjustable louvres.

Among all sun protection systems facade louvers are the most effective. They regulate the level of natural light in the room and protect against heat, what is contributed significantly by air natural movement in the space between the louvres and window glass.

It is conveniently and easy to control outdoor blinds with the help of manual knobs or electric drives, which besides may be managed by the climate sensors (wind, temperature, sun, precipitation, etc.) and react automatically to changing weather conditions. Special sensors, that monitor the climate state, can control the lowering of the lamellaes in bright light and uplifting during strong wind gusts, ensuring safety and long service of the items. Such sun-protection systems may also be programmed to mobility during daylight hours – to lower lamellaes in the morning and lift in the evening.

Fig. 2.8 Lamellaes of external sun-protection blinds - vertical or horizontal, larger or smaller size - easy to install and convenient to further exploitation, give facades stylishness of high technology.

Fig. 2.9 Impressive dynamic sun-protection systems make an autoparking facade in the USA a contemporary works of art.

External sun blinds do not require special care, they are easy to clean and wash. Wide variability of the design of external sun-protection blinds gives the building the expressiveness and originality. Aluminum is mostly often used for the production of external blinds, for it has the qualities of lightness, strength, durability and environmental friendliness. Lamellaes may also be transparent and translucent made of heatproof glass. Recently, the lamellaes with silicon photovoltaic (PV) cells (surface photovoltage elements) are being developed and at the same time in addition to sun-protection functions supply with electricity.

Even after many years of exploitation lamellaes look and function like new, thanks to the protective polymer coating, anodized parts bearing structure and textile elements on the base of Kevlar-thread. The funds spent on their installation, pay off many times over the life and work reliably for many years.

### 2.4.3 Systems of solar lighting

The PV lighting systems includes skylights, special windows in mansard rooms, translucent glazed openings in the ceiling, and also light detectors and light guides, so-called light wells or light pipes. The structure of PV lighting systems is designed in such a way that they prevent the penetration of heat into the premises in summer and cold in winter, filter out ultraviolet and infrared rays. Positive qualities of the PV lighting systems are their environmental friendliness and energy saving properties (power saving on lighting, conditioning, heating), comfort for eyes and positive impact on the general condition of physical and emotional health.

Fig. 2.10 Design of the most common type of light pipes - a system of light-receiving cupola, concentrating and directing the flow of light into the light guide-pipe, which delivers the light into the room through a diffusing dome.

Operational principle of light tube

Light pipes (or light tubes) constitute a system of light-receiving device, that is transparent, collecting and concentrating dome light, and equipped with a Fresnel lens or heliostat reflector, or light-reflecting LightTracker plate, which focus the collected light and direct rays right into the light pipe - the light guide device, which is a pipe with reflective internal surface, so transmitting solar light with minimal losses. The upper part of “the Sun well“ is located on the roof of the building, or the sunny side of the facade. The lower part is disposed into the room. Passing through the light pipe and being focused the light enters the room through the dome, installed in the ceiling, and illuminates it with evenly scattered natural light. The basis of the internal reflective surface of a light pipe is aluminum, covered with a coating consisting of multiple layers of special light-reflecting film and the antireflection layer, where each layer reflects its own spectrum of light.

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Fig. 2.11 Seamless metallic element - flashing is used for attachment of the PV lighting system with a roof. It is produced in different versions depending on the roof covering.

Fig. 2.12 Bright illustrations of light pipes’ application in the remote areas of external walls of a house. We may illuminate such distant areas like halls, corridors, stairwells, bathrooms and toilets with the help of light guide systems utmost effectively.

Light is transmitted almost without losses (except for infrared and ultraviolet parts of the spectrum). Light is transmitted through the pipe with greater efficiency when the pipe is straight and short. If the light pipe has angles, twists, or large length the portion of light is lost on refraction and dispersion. Transparent materials with higher reflectivity are used to minimize losses (e.g., fiber optics). Solar light scattering devices at the bottom of the light pipe can be of different configurations as round, rectangular or polygonal domes, in the form of extended light-stripes to suit every taste.

A 300 mm-diameter light pipe is able to light 8 $m^2$ area , making it unnecessary to use electric illumination in the daytime in corridors, halls, stairways, bathrooms, technical rooms, basements, and so on. Under European conditions, one such system allows to prevent annual emissions into the atmosphere up to 7.4 tons of $CO_2$.

Fig.2.13, Fig.2.14 The PV lighting systems with light pipes are now widely used in industrial, commercial and public buildings. Unlike skylights, the light pipes do not heat the air in the premises, they are not contaminated with dust and precipitation, do not leak and, most importantly, spread evenly diffused light flow. In a night-time the system can continue to illuminate the interior space due to the integrated economical LED lamps.

The diameters of light guide tubes range from the least – 250 mm, medium – 350 mm, and to the largest – 530 mm. A variety of additional components, such as a dimmer (light level control), ventilation kit, light kit with economical LED backlight (integrated into the light guide tube and activated in the dark), various focusing and scattering lenses are produced for the light pipe systems.

Relative disadvantages include the need of interference into the roof structure and limiting of fiber length. This equipment does not fit for block of flats.

The field of application for light tube systems

In Europe and America sunlight systems have already occupied a separate niche for a long time and are widely distributed in the cottage housing construction, equipment of supermarkets, schools, libraries, office buildings, and others. Solar energy systems in the form of light pipes are used for lighting of residential, public, educational, sport, commercial and industrial buildings, at warehouses, workshops, underground premises, subway stations etc., that lets reduce energy consumption significantly and bring positive nature of sunlight into premises in winter time.

### 2.5 Means of modeling processes

The main objective of bioclimatic architecture design is in creating rational, economical and comfortable environment provided by architectural and engineering solutions. It is necessary to account large number of real factors that contribute to it or prevent calculating the measures of providing required comfort. In fact at the process of design the building certain physical model is created and it reflects its work in real conditions. Bioclimatic modeling is the most important subbase of architecture ecological design. Modeling of a designed building gives opportunities to take important architectural and engineering solutions in actual operating conditions taking into account the real dynamics and physics of the processes. Insolation modeling, natural lighting and impact on neighboring buildings, the optimum orientation and efficiency of recovery and heat pumps are not always represented in the form of sketches and hand calculations. So to simulate a variety of bioclimatic factors they use as full-scale models (in smaller scale in the form of models - as three-dimensional as planar in transverse cross-sections) and computer models.

#### 2.5.1 Computer modeling possibilities

Computer modeling has the advantage when you can choose between many options and their assembling without the need of time consuming manual calculations and prototyping. Modeling is a complex set of points that are performed in specialized programs with algorithms based on the processes physics. The calculation involves many factors and parameters, and correct results depend on their competent input into the model. As a rule, models compared with real objects are simplified things and various programs will produce different results of the calculations.

Rating systems: LEED, BREEAM, DGBN, Green Star and others became the implementation of sustainable development principles in steel bioclimatic. They do not just evaluate a building according to the principles of the concept of "sustainable development", but also provide guidance on what exactly should be done while project and operation to make building certified.

Building Energy Modeling

Building energy model is an essential part of rating system - Building Energy Modeling (BEM) – a complex of engineering calculations which shows building operation throughout the year at the level of parameters that describe energy consumption processes, which takes into account all the connections between building elements and energy consumers in actual operation. Each rating system sets certain limits and modeling must be carried out within them. Initial data for the BEM-calculations is always refined while design, and these calculations results, in turn, is used to detail the architecture and determine the impact on building lifecycle. Revit Conceptual Energy Analysis gives architects the opportunities for quick converting conceptual 3D-models into analytical ones for integrated studies of future building energy efficiency. With the help of advanced software, such as Autodesk Vasari, today it is possible to make a model of building energy consumption at the stage of pre-project solutions. The main attention is paid to building mounting, orientation and interaction with the environment and the climate.

Components of modelling

Main components of a model can be grouped into the following categories:

– Geometry of the building and environment is an obvious and important component in the total energy consumption model. At present, many architectural programs allow to export geometry of the buildings in the special-purpose formats: gbXML (Autodesk Revit and ArchiCAD) and IFC (Autodesk Revit). To create the geometry, software SketchUp is increasingly being used, for which a lot of modules for creation an energy consumption model is written, for example OpenStudio. Wherein, calculations are performed in one of the most powerful modeling software – Energy Plus. These files are then imported into the BEM program and permit to avoid the introduction of routine updates. The geometrical model includes only the elements involved in the process of transfer of mass of heat: external and internal walling, elements of the internal thermal inertia, shading elements of the building and environment. All of them, except for shading, are described by the physical parameters of the materials they are made of. Compulsory basic parameters are: density, layer thickness, thermal conductivity, heat capacity, and the reflection coefficients of visible and infrared radiation. These parameters can be entered in universal formats, both in architectural and calculation programs, for example, when it is required to control changes in power consumption depending on changes of walling, building orientation, etc.

– Weather data are arrays of environmental parameters: temperature, humidity, pressure, wind speed, solar radiation values. These data are used both in manual and computer calculations, and part of them are included into the regulatory documents. In practice, the arrays of values per hour for each parameter are used, which are, in turn, the input data for energy-modeling programs. As well, detailed model of the environment is required for a detailed simulation of the building. Detailed dynamics of the external environment are taken into account in the course of calculation that makes the calculation results much closer to the reality.

– Schedules are the model parameters values per hour replacing the fixed value, for example, the estimated temperature in the room. This is the most powerful tool for flexible configuration of a model, the possibility to enter and control the real dynamics of power consumption and the parameters change. No building is functioning in isolation itself. Number of people is changing, lighting is switched on and off depending on the illuminating conditions and the presence of people, air conditioners are switched on and off depending on the excess heat from lighting, people and the sun, etc. Calculated values and internal loadings of the building are simulated not by separate values, but as external conditions, in the form of hourly profiles. There are 2 types of schedules: specifying the internal loadings (quantity of people, power consumption by systems of lighting and equipment, water consumption) and specifying the internal parameters (indoor climate, parameters of engineering systems, etc.). There are whole libraries of schedules of the first type for the majority of public and office buildings, and also for housing. These libraries are collected by the ASHRAE and CIBSE standards on the basis of long-term observation and allow simulating internal loadings of standard premises approximating energy consumption model to the real conditions.

Calculations for the building certification are particularly complicated due to the fact that they must be carried out strictly in accordance with the requirements of each rating system. Moreover, in fact, the simulation should be carried out twice, to determine the "basic" level on the base of the standard building and for the current project. Only then, we can make the correct conclusions about how we managed to reduce consumption of resources.

**Questions, tasks and keys**

1. What is bioclimatic and what falls within the scope of its consideration?

2. What are the objectives of architectural bioclimatic?

3. Is it possible to design the objects of ecological architecture professionally without knowledge of bioclimatic?

4. How physical, geographical, climatic, landscape factors of the environment can influence morphology of passive buildings?

5. What temperature and moist conditions parameters are defining for comfortable microclimate of premises?

6. How are recuperation and heat exchange of passive house performed?

7. What are the architectural planning objectives of building solar control?

8. What are "light pipes" and what is their principle of their operation?

9. What are bioclimatic modeling methods?

# CHAPTER 3. “GREEN ROOFS” AS THE TECHNOLOGIES FOR IMPROVEMENT OF URBAN CLIMATE AND ENERGY EFFICIENCY OF BUILDINGS

In hot sunny summer months, when the asphalt melts and exudes carcinogens and roofs covered with asbestos-cement, roofing felt and galvanized steel are overheated on the solar fire pan, streets and neighborhoods are transformed into stone ovens. In winter, during the strong frosts the same asbestos-cement and metal roofs are the best conductors on both sides – the outside cold into the building and vice versa, internal building heat out into the cold.

The saturation of urban air by dust and aerosols, exhaust of cars, products of combustion and greenhouse gases not only creates a special gas-dust dome over the city, but also inevitably and irreversibly poisons the health of residents.

Urban development with its sidewalks, highways, squares and other structures blocks and seals up the natural environment, making the flora, and the city fauna limited and scarce as well. Cities, towns and urban settlements thus take away the habitat of herbs, flowers, shrubs and trees, poorly reducing all the natural diversity to the dominance of only the most hardy plants – wheat grass, knotweed, dandelions, etc.

Insects live among the herbs and flowers, and the less species of plants the lower species of insects visit the rare city parks and lawns as a result. Birds are fed by those insects invisible to us. So today in the cities we often see only the regulars of urban garbage dumps – sparrows, pigeons and crows.

All these significant negative factors of urbanized area, connected with the reduction of the natural environment can and should be corrected by the introduction of natural biotops into the city, by returning some urban areas to the nature, by rational reconstruction of nature corners wherever it is possible – on the sidewalks and squares, in the pedestrian areas, squares and parks, as well as on green roofs and green facades of the buildings.

In many European countries, there are programs and associations actively promoting the idea of greening buildings. In a number of European cities work on roofs and facades greening are paid by the municipalities, and in a number of the most developed countries the federal laws on "green roofs," prescribing a mandatory or encouraging “greening” of flat roofs of new buildings have been introduced.

## 3.1 Motivation for Green Roofs Using

Green roofs in energy effective buildings

Both in passive and energy active buildings the green roofs are one of the necessary conditions. They are the most important energy saving component for significant reducing energy expenditure for heating and air conditioning. Green roofs provide protecting buildings from overheating when it is hot and substantially reduce the need for technical systems of climatic control. Also, in cold weather the greened roofs are the way to reduce the heat loss and the cost of buildings’ heating, moving such buildings towards the standards of the passive house.

Green roofs and urban climate

Green roofs are a whole system of plant layer, soil substrate, drainage layers, waterproofing and heat insulator. Such multi-layer blanket prevents buildings from climatic extremes of the environment much more effectively than any traditional insulation does. Plants breathe, absorb carbon dioxide and make oxygen evolution, as well as they evaporate phytoncides and moisture. Due to the natural evaporation of volatile ethers and moisture from the plants the circulation of ascending flows and their cooling (principle of the refrigeration and air conditioning is just based on the effect of the evaporation process) activates. In addition to natural comfort increase, natural cooling of green roofs in summer heat significantly reduces the cost of an artificial air-conditioning directly within each individual building, but also significantly reduces the heating of urban development surfaces in general. In the hot season, a large concentration of green roofs can significantly reduce the average temperature of the whole city. Roof greening gives the greatest effect in built-up areas where paved and asphalted places prevail, that is, exactly in the "stone labyrinths", in urban centers.

Plants are natural filters of water and air

Greened roofs absorb, filter, and purify rainwater, thus allowing reducing the precipitation flows on the streets and offloading the sewer systems. Plants are natural air filters. Roof greening contributes to a significant reduction of urban air pollution and enriching it with oxygen, which in turn improves living conditions and creates the preconditions for a healthier environment.

Green roofs are a necessary psychological comfort, returning the natural environment for a human. They serve as a decoration of buildings, streets and cities. But most important, they have become a habitat for flora and fauna, bringing the life in its diversity and balance to the urban depressive environment. Green roofs can serve as a place of rest, and may also be used as very effective agricultural mini-farms for growing flowers, fruits and vegetables, etc.

Green roofs are barriers for the city noise; the loose soil substrate absorbs low-frequency sounds, and the plants themselves damp medium and high frequencies.

Roof greening extend the life of roofs and ceilings themselves, protecting them against aggressive weather attacks. In energy-efficient buildings the solar PV panels and thermal collectors coexist on green roofs without losses and concerns.

### 3.2 Key Technologies of Green Roofs Layout

The tradition of using green roofs have a long history and vast geography: from "the hanging gardens of Babylon" on the south to the north turf-covered roofs of the ancient houses in Ireland, the Faroe and Orkney Islands, in Norway, Iceland, etc. It is an interesting fact that due to their ability to absorb excess moisture and to accumulate moisture when there is its lack, living roofs have been the most widely used even both in hot, dry climate and wet, cool one. All it depends on the choice of vegetation and draining features.

Essential arrangement of green roofs

Modern methods of greening roofs have appeared relatively recently, since the 1960s, and from that time they have constantly been improved. The common and most important requirement for green roofs is the availability of a strong ceiling and adequate structures that can support the weight of several sub-base layers plus the weight of wet soil and the weight of plant mass. The types and dimensions of load-bearing structures may vary depending on the intensity of planting, but their non-compliance can cause the collapse of floors. As a rule, a green roof sub-base consists of a thick layer of heat insulator (foam concrete), on the top of which the required slope is mounted to drain excess moisture to water intakes. There is a durable waterproofing of 2 or 3 layers of polymeric membranes on the cement mortar that not only retain the water from leaking, but do not give the roots grow into the floors. A drainage layer of coarse fractions of light granular materials is arranged on top of the waterproofing. These materials do not absorb water but allow it to leak through them freely (granite crushed stone is not desirable to use due to its heavy weight). Also, drainage borders should be on the perimeter of green areas, along the walls and fencing structures. Drainage may consist of a number of layers of different fractions (large fractions are at the bottom, fine ones are at the top), between which a plastic net is placed to prevent sedimentation and mechanical re-mixing of fractions. Two or three layers of plastic net are placed over the drain under the soil substrate to prevent the ingress of soil into the drain voids and their blockage. The thickness of the soil substrate can be different depending on the type of greening.

Extensive greening

There are two types of greening roofs: extensive and intensive. Extensive greening involves achieving aim by minimal means. Roofs are covered with a thin layer of the substrate where not tall and undemanding plants are planted. Extensive green roofs in practice require a minimum cost to operate and require little maintenance. Plants for such roofs are chosen mostly local and have native-resistant characteristics of the regional climate. For extensive greening stonecrops (sedum), saxifrages, meadow grasses and clovers are perfectly proven. Stonecrops for example, do not even need an earth mixture – just a slight layer of porous substrate fixed on a waterproof roof.

Intensive greening

Intensive greening resembles a garden on the roof. Tall plants (junipers, shrubs) and even not tall trees may demand up to one meter of soil high, filled hills and containers. Labor and time consuming permanent care, irrigation and drainage are needed for them, so this type of roof greening is called intensive. The layout of intensive greening involves its application on specially designed reinforced ceilings, capable to bear heavy weight.

Fig. 3.1 "Crystal Garden for Wandering" on the green roof of the Ministry of Foreign Affairs of the Federal Republic of Germany in Bonn, 1983. Architect Mary Bauermeister

Finally, there is the practice of using wet biotops on the roofs. These are shallow reservoirs having a closed cycle of biological exchange, with aquatic plants, amphibians and even ornamental fish. Such ponds on the roof are called “blue roofs”.

### 3.3 Green Facades are Vertical Gardens and Green City Health Keepers

So-called "vertical gardens" or green or living walls, phyto-walls, are compositionally designed installations of living plants that are placed vertically in special structures.

Vertical greening of facades

Vertical gardens on the exterior walls of buildings are used not only for aesthetic purposes, but primarily due to the achievement of environmental goals. Similarly to green roofs, vertical gardens have the same motivation and practically the same qualities as green roofs and they are attractive for their ability to clean the air, saturate it with oxygen, phytoncides and necessary moisture.

Under general principles of the vertical position and the general availability of irrigation and drainage systems, designs of vertical gardens differ in materials, design fixture and technological features. Plants for vertical gardens are selected depending on the conditions of insolation and the specific art solutions in texture and color, but it is usual to try using low-growing or dwarf types that do not require large containers for the substrate and can withstand outdoor weather conditions.

## Questions, tasks and keys

1. What is the relationship between green roofs and energy efficiency in buildings?

2. What are the main positive features of green roofs?

3. In what way are the green roofs generally arranged?

4. What is the difference between extensive and intensive roof greening?

5. What is the cost-efficiency of greening roofs?

6. What are the features of vertical gardening?

## Questions and tasks

### 1.1 Building as a functioning organism

What is a metabolism of the building?

### 1.2 Passive houses

Name the passive solar heating systems.

Name the main methods of passive house organization.

What are the EU current standards of house energy consumption?

What is the European Classification of houses in terms of energy consumption?

### 1.3 Energy-active houses

What are the features of energy-active houses?

What is the classification of energy-active houses?

### 1.4 Energy supply in modern houses

Name the main renewable energy sources?

How does the "green tariff" work?

### 1.5 Ventilated facades

What are the features of ventilated facades?

What are the main structural solutions of ventilated facades?

### 1.6 Modern eco-friendly materials and technologies in construction

What is the difference between eco-friendly materials and non eco-friendly?
What is the difference between absolute eco-friendly materials and relative eco-friendly materials?

### 2.1 Bioclimatics as a tool of eco-architecture

What is the influence of external climatic factors on living conditions in the house?

Give examples of differences between the features of houses in the northern and southern climate

### 2.2 Interaction factors of house and environment

What are the features of “green” architecture?

What are the main objectives in the design of "green houses"?

### 2.3 Effects of climatic and geographical conditions on shaping features of house architecture

How do external factors of the environment influence the maintenance of houses?

How can physical environmental factors affect the morphology of houses?

### 2.4.1 Heat transfer, aeration, air-conditioning and humidity conditions of ecological house

What is "room temperature"? What are its standards?

What are temperature norms of homes?

How does recovery and heat transfer of a passive house occur?

What are the thermal balance features of a passive house?

What are the norms of air exchange and humidity of premises?

What is the importance of maintaining optimal indices of relative premises humidity?

### 2.4.2 Sun protection, light reflection and overheat protection

What are the architectural planning tasks of houses sun protection?

### 2.4. 3 Solar lighting systems

What is a "light pipe" and what is the principle of light pipe operation?

Give examples of light pipe systems applications

### 2.5.1 Possibilities of computer modeling

Where and why are energy patterns of houses used?

Name the main categories of computer modeling components of energy-efficient houses

### 3.1 Motivation of green roofs use

What are the major negative factors of urban environment?

What is the connection between green roofs and technologies of energy-efficient houses?

How can green roof affect the climate of the city?

How can plants affect the quality of urban air?

### 3.2 Basic ways of organizing green roofs

What are the basic ways of organizing green roofs?

What is the difference between extensive and intensive roofs greening?

### 3.3 Green facades - vertical gardens, green city medics

What is vertical greening of facades and what is the function of vertical greening?