JUSTIFICATION OF EDUCATIONAL INSTITUTIONS ENVIRONMENTAL RECONSTRUCTION IN ACCORDANCE WITH THE UI GREEN METRIC RATING AND ENVIRONMENTAL STANDARDS

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Abstract. Educational institutions certified according to international and national environmental standards in construction were studied. The equipment of schools and universities with ecological architectural and engineering solutions is analyzed. The sections of environmental standards for certification of educational institutions BREEAM Education (UK), LEED for School New Construction and Major Renovations (USA), GB/T51356-2019 “assessment Standard for green campus” (China), GREEN ZOOM “Universities, campuses and innovative scientific and technological centers” (Russia) are considered. A comparative analysis of the data of environmental certification systems with the allocation of priority areas is carried out. Using the example of Yuri Gagarin State Technical University of Saratov (Saratov, Russia), a new concept for the ecological reconstruction of General education institutions is proposed.

Key words: general education institution, campus, environmental certification, sustainable construction, environmental standard.

1. Introduction

One of the priority goals of sustainable development today is the greening of all spheres of society, which is determined by a reduction in the resource potential of territories and an increase in the negative impact on the environment (Ridhosari and Rahman, 2020; Amaral *et al.*, 2020).

Global trends in certifying districts, territories, and buildings of various purposes according to international environmental standards are being actively applied to scientific and educational institutions.

Schools and University campuses consume much more electricity and other resources than other types of buildings, so their greening is especially important for sustainable development.

The concept of "Green University" has been strengthened in the world practice – it is an educational institution whose activities are aimed at protecting the environment: reducing CO2 emissions; reducing water and energy consumption; separate garbage collection; development of environmental infrastructure; environmental education and education; students participation in eco – projects. (Azar and Ansari, 2017; Jain *et al.*, 2017; Gu *et al.*, 2018).

A "green" school is, first of all, an object whose impact on the environment is minimal, and the level of consumption of energy and material resources throughout the entire life cycle is reduced (Pellegrino *et al.*, 2015; Yilmaz *et al.*, 2016; Ledesma *et al.*, 2020). Green schools help improve student health and academic performance (Akpinar, 2016; Olsson *et al.*, 2019; Zeng *et al.*, 2020).

American researchers of "green" schools surveyed teachers and administrators of 12 institutions about the impact of environmental decisions on students: 87% of respondents reported a positive impact on health; 71% of respondents noted a positive impact on student performance; 71% reported a positive impact on student behavior; 85% reported that their own health and productivity have become higher (Meron and Meir, 2017; Meiboudi *et al.*, 2018; Olivieri *et al.*, 2020).

School children and students should have direct contact with environmental solutions within the fundamental environmental concepts applied in General education institutions, allowing students to interact directly with the systems in the building (Goldman *et al.*, 2018; Guerrieri *et al.*, 2019).

Increased attention to the construction, design and operation of educational institutions contributes to the achievement of national sustainable development goals related to environmental protection (Tucker and Izadpanahi, 2017; Flax *et al.*, 2020).

Within the topic under study, the following goals and objectives of the survey were defined:

- To analyze eco-friendly educational institutions and General education institutions having eco certificates;
- To identify typical environmental solutions for schools and higher education institutions in the process of studying international experience;
- To study the requirements of environmental standards for certification of educational institutions-BREEAM Education (UK), LEED for School New Construction and Major Renovations (USA), GB/T51356-2019 "assessment Standard for green campus" (China), GREEN ZOOM "Universities, campuses and innovative research and technology centers" (Russia), make a comparative analysis of these documents;
- To identify problems and non-compliance of Russian higher education institutions, on the example of buildings of Yuri Gagarin State Technical University of Saratov (hereinafter referred to as SSTU) with modern requirements of eco-construction;
- To propose a new concept for the ecological reconstruction of several buildings of the SSTU campus.

2. Materials and methods

Based on the results of the collected material, the author uses a graph-analytical method of research: a systematic analysis of certified educational institutions is carried out; features of architectural and planning solutions of the studied objects are generalized into groups based on similar characteristics; the data obtained are systematized. A mathematical method is used to analyze the requirements of environmental standards in construction.

3. Theory

3.1. Analysis of green schools in foreign countries and Russia

The need to design and build green schools is becoming an important task today (Abdelaal 2019; Gulwadi *et al.*, 2019; Adenle *et al.*, 2020). Green schools, thanks to the visual study of aspects of environmental friendliness of architectural and technological solutions, educate children in the habits of "eco-friendly lifestyle", norms and rules of interaction with nature.

One of the first green schools were the school in Germany in the Rydberg district of Frankfurt am main (2004), built in accordance with the Passive House standard, and the Montessori elementary school in Aufkirchen, Germany (2003-2004), with special attention paid to energy conservation.

In the course of scientific research, the author analyzed the following examples of green schools in foreign countries: Bushbury hill School (England, 2013); primary school of science and biodiversity (Boulogne-Billancourt, France, 2014); Olivier de Serre primary school (Paris, France, 2015); Kathleen Grimm School (new York, USA, 2015); Copenhagen International School Nordhavn (Copenhagen, Denmark, 2017).

In Russia, in 2015, the Skolkovo international gymnasium was built in Skolkovo (Moscow region). The architectural and space-planning solution of the building is organized according to the basic principles of energy efficiency. The area of glazing is 40% of the wall area for the South, East and West orientation, and on the North wall the share of glass is 55% of the total area. The gymnasium is engaged in educational programs for students on separate collection of consumer waste.

The project of a secondary school in Kazan is an example of rethinking the principles of organizing learning spaces in accordance with the latest achievements of green architecture. The eco school uses alternative energy sources and pays special attention to three principles: avoiding toxic waste; careful use of natural energy; and creating a green space.

3.2. Analysis of higher education institutions in foreign countries and Russia

International experience in the construction of educational facilities with environmental certificates is analyzed: Brandon elementary school, sandy springs, Georgia, USA (BREEAM - Outstanding); the GlaxoSmithKline Carbon Neutral Laboratories for Sustainable Chemistry, Nottingham, UK (BREEAM - Outstanding); SWEE HOCK student center, London, UK (BREEAM - Outstanding); University of California, Davis, USA (BREEAM - Excellent); buildings of Kaohsiung American School Sustainable Campus, Kaohsiung, Taiwan (LEED - gold); buildings of Portland State University, Portland, USA (LEED - gold); buildings of the University of California, Santa Barbara, USA (LEED - gold); buildings of the University of South Florida, Florida USA (LEED - gold).

For green campuses, the technology of external window shading is considered particularly effective to reduce the use of air conditioning, the use of natural light due to the ratio of the area of Windows and walls at a certain orientation to reduce electricity consumption, the device of a green roof to improve the microclimate.

According to the 2015 education statistics published by the Ministry of education of China, the total area of primary and secondary school buildings across the country exceeds 2.59 billion square meters, they have about 290 million students with various levels of academic education and about 21,432,400 teachers, which has a significant impact on the ecological footprint of the planet.

In Russia, ANO NIIURS is currently certifying the ITMO Highpark Campus - the center for innovation, education and high technologies in St. Petersburg, in partnership with ONE of the international IT Universities according to the green ZOOM eco standard.

The following eco-solutions are expected on the Campus: safe conditions for cyclists and people with limited mobility; prohibition of the use of motor transport on the territory; charging stations for electric vehicles; security control of the surrounding area; green landscape and geo plastics of the surface; local construction materials; modern engineering equipment for creating favorable microclimatic conditions; devices for water conservation; carbon footprint tracking; energy-efficient lighting; non-traditional energy sources; "smart" automation; providing opportunities for healthy eating; public areas for eco events; separate waste collection and much more (Poddar *et al.*, 2017).

3.3. UI Green Metric World University Rankings and the all-Russian program Green universities of Russia

In 2010, the University of Indonesia (UI) initiated the creation of a world University ranking, which later became known as the UI Green Metric World University Rankings. UI Green Metric's list of the world's greenest universities includes 619 institutions from 76 countries, including 29 Russian universities. In 2019, 780 universities from all over the world participated in the ranking. This shows that UI Green Metric was recognized as the first and only world University ranking for sustainability (Marrone *et al.*, 2018).

The goal of the eco-sustainability rating of universities is to improve the environmental quality of universities around the world and introduce an energy-efficient management model for higher education institutions. The assessment is conducted in six categories: infrastructure; energy efficiency; environmental change; waste management; water conservation; transport policy; education.

In 2017, the peoples' friendship University of Russia (RUDN) rose to the 44th position in the UI Green Metric University sustainability rating, which was the best result since 2011. RUDN improved indicators on energy efficiency, environmental quality, waste management, water efficiency, transport infrastructure and education.

Since 2011, the all-Russian program "Green universities of Russia" has been operating in the Russian Federation-an Association of green universities of Russia (the Association includes teams of 100 Russian universities, including MGIMO, SPBU, RUDN, HSE, and others), aimed at involving students in various environmental programs, quests, and youth associations to implement environmental principles. In 2020, the management of the Yuri Gagarin State Technical University of Saratov (SSTU) plans to improve the environmental friendliness of the University for inclusion in the all-Russian rating of green universities.

4. Results and discussion

4.1. Analysis of foreign and Russian environmental standards for General education institutions

The English environmental standard BREEAM and the American standard LEED have special versions for eco-assessment of General education institutions (Worden *et al.*, 2020). Let's look at their sections in more detail (Table 1). In a comparative analysis, it was determined that LEED and BREEAM emphasize the reuse of elements in an existing building during major repairs. The difference between the systems is that BREEAM does not award credit for the reuse of interior elements, while LEED encourages the reuse of materials.

BREEAM solves the problem of daylight and glare control with separate credits, unlike LEED, which combines both of these criteria. LEED eliminates the heat island effect with two credits. The lack of BREEAM credits to address the heat island effect is a serious omission that affects both residents ' health and energy consumption, and should be corrected.

China has an environmental standard for educational institutions GB/T51356-2019 "Green campus assessment Standard" it is applicable to the assessment of new and reconstructed green campuses, primary and secondary schools and colleges (Shuqin *et al.*, 2019; Wang *et al.*, 2020).

The standard is divided into two sets of assessment systems: primary and secondary schools, vocational schools, and higher education institutions. The overall structure of GB/T51356-2019 includes six assessment categories (Table 2).

The standard provides a different rating scale for higher and secondary educational institutions, which allows you to evaluate them more objectively. Section 4, Primary and secondary schools, and section 5, Vocational schools and higher education institutions, include five types of assessment: planning and ecology, energy and resources, environment and health, operation and management, and education and promotion. For each category, an item can get a maximum of 100 points. Depending on the amount of points, you can get one, two or three stars.

In 2018, the Autonomous non-profit organization Research Institute for sustainable development in construction (ANO NIIURS, Saint Petersburg, Russia) developed the GREEN ZOOM environmental certification system "Practical recommendations for reducing energy intensity and improving the environmental friendliness of innovative scientific and technological centers".

The GREEN ZOOM standard became the first Russian standard for assessing the environmental friendliness of such objects. The percentage requirements of the system sections are shown in Table 3.

When analyzing the sections of the GREEN ZOOM environmental standard in percentage terms, it was found that the largest number of requirements are in the sections: "Good health" (21%), "Clean energy, energy efficiency" (16.1%), "Transport and infrastructure" (11.8%), "Clean water, water efficiency" (10.5%). There are fewer requirements in the sections: "Responsible consumption" (6.3%), "ecosystem Conservation" (5.6%), "Eco partnership" (4.2%).

Table 1. *Assessment categories BREEAM Education and LEED for School New Construction and Major Renovations.*

BREEAM Education Sections	Number of requirements, %		LEED Sections for School New Construction and Major Renovations
Management	17.08	6.44	Alternative Transport
Health &Wellbeing	15.86	22.54	Sustainable Sites
Energy	9.76	8.05	Water Efficiency
Transport	7.32	14.49	Energy & Atmosphere
Water	8.5	14.49	Materials & Resources
Materials	6.1	27.55	Indoor Environmental Quality
Waste	9.76	4.83	Innovation
Land Use & Ecology	9.76	1.61	Regional Priority
Pollution	1.22		
Innovation	17.08		

Table 2. *GB/T51356-2019 "Assessment standard for a green campus".*

Section name	Number of requirements, %
General rules	2.16
Conditions and terminology	4.32
Fundamentals	5.94
Primary and secondary schools	38.44
Vocational schools and higher education institutions	41.04
Features and innovations	8.10

Table 3. *GREEN ZOOM "Universities, campuses, and innovative science and technology centers".*

Section name	Number of requirements, %
Transport and infrastructure	11.9
Ecology of the building site	7.7
Ecosystem conservation	5.6
The fight against climate change	7.7
Clean energy, energy efficiency	16.1
Clean water, water efficiency	10.4
Good health	21.0
Opportunity for development	9.1
Responsible consumption	6.3
Environmental partnership	4.2

Table 4. *Comparative analysis of eco standards for General education institutions.*

Eco standard	Environmental assessment algorithm, %						
	A_n	B_n	C_n	D_n	E_n	F_n	G_n
BREEAM Education (England)	20,57	9,68	8,47	13,31	6,05	8,47	18,15
LEED for School New Construction and Major Renovations (USA)	3,22	16,10	11,27	14,49	9,66	6,44	29,16
GB/T51356-2019 "Green campus assessment standard" (China)	7,56	8,10	8,64	10,8	6,48	4,86	12,96
GREEN ZOOM "Universities, campuses and innovative scientific and technological centers" (Russia)	12,6	7,00	11,20	17,50	7,70	1,40	12,60
* Designations: An – ecology; Bn – territory; Cn – water efficiency; Dn – energy saving; En – materials; Fn – waste; Gn – microclimate.							
** Criteria that are not related to the above aspects are not presented in this Table.							

The author proposes an algorithm for analyzing environmental standards, i.e., allocating in each document the percentage of criteria for basic aspects that take into account the basics of environmental design: ecology (AP); territory (Bn); water efficiency (Cn); energy conservation (Dn); materials (En); waste (Fn); microclimate (Gn).

The following formula is used to determine the percentage of criteria for each section:

$$A_n = (100\% \div n) \cdot C^i_{nA}, \text{ where}$$

A_n – number of criteria in % related to a particular environmental aspect;
n – total number of standard requirements;
C^i_{nA} – capacity of the standard for a specific aspect.

Compare the analyzed environmental standards by the number of requirements for the above items (Table 4).

Comparative analysis has shown that in the standards under consideration, higher priority is given to: the organization of a favorable microclimate inside educational premises (29.16-12.60%); environmental friendliness of the construction site (20.57-3.22%); energy saving issues (17.50-10.80%); fewer evaluation categories for the use of safe eco-materials (9.66-6.05%) and rational management of household and construction waste (8.47-1.40%).

4.2. Compliance of SSTU buildings with UI Green Metric requirements and environmental standards

The history of the Saratov State Technical University began in 1930, at first it was the Saratov Highway Institute, which includes only two faculties. By 2020, there are more than 25 buildings and structures on campus. Some of the buildings belong to the 1950-1960 years of construction, some buildings were built in the 1980s, and the newest 25 building was built in 2014.

In the process of scientific research, three buildings of SSTU are considered – the six-storey 3 and 4 buildings (School of Urbanism, Architecture and Construction) in 1985 and the nine-storey 25 building (Innovation and Technology Center) built in 2014 (Fig. 1).

The following problems are highlighted and the compliance of 3, 4 and 25 buildings of SSTU with the requirements of environmental standards in construction and the UI Green Metric rating (Table 5).

After analyzing the above positions, we can conclude that the nine-story 25 building of the SSTU Innovation and technology center, built in 2014, includes significantly more environmental measures in contrast to the 3,4 buildings of the Institute of urbanism, architecture and construction, built in the Soviet period of the twentieth century.

4.3. Author's concept of environmental reconstruction of the SSTU campus

The importance of this study is to adapt the methodology of environmental reconstruction to higher education institutions to ensure their sustainability.

The proposed method of eco reconstruction of educational institutions includes 5 stages:

Stage 1: comprehensive assessment of environmental pollution of the site location using GIS technologies and full-scale survey on the following factors: air basin pollution; degree of soil pollution; dust load on the territory; degree of noise pollution; level of groundwater occurrence and their pollution; electromagnetic and radiation pollution.

Statistical data from the Federal state health administration and the Rospotrebnadzor administration can be used as a basis. The Department of Ecology of SSTU annually analyzes the compliance of buildings and structures on the SSTU campus with acceptable environmental indicators.

Table 5. Analysis of environmental activities on the SSTU campus

The main aspects of the environmental assessment / criteria	SSTU buildings 3,4, 1985	SSTU building 25, 2014
1. Environment and infrastructure of the territory		
Landscaping > 50%	-	+
Landscape arrangement of places for recreation	-	+
Sports ground	+	-
Energy saving lighting	-	+
2. Energy and climate change		
Compactness of the building and consideration of orientation to the cardinal directions	+	+
Effective insulation	-	+
Efficient lighting	-	+
Energy-efficient engineering equipment	-	+
Use of renewable energy sources	-	-
3. Materials		
Eco-friendly materials for surface finishing	-	+
4. The microclimate inside of premises		
Possibility of natural ventilation	+	+
Sun protection on Windows	+	+
Lack of brilliance and flickering	-	+
Noise protection and sound insulation measures	-	+
Ability to regulate the indoor climate	-	-
5. Waste		
Separate waste collection	-	-
Training programs on separate waste collection	+	+
6. Water		
Use of water-saving equipment	-	+
Rainwater harvesting	-	-
7. Transport		
Public transport Accessibility	+	+
Bicycle Parking lots	-	+
Ground Parking lots	+	-
8. Environmental education		
Training courses on eco design and nature care	+	+
Conferences and seminars on sustainable development	+	+

Stage 2: assessment of the current situation, collection of material, measurements and full-scale survey of buildings and structures. A detailed description of the studied objects is given: assessment of the location; transport accessibility; number of Parking spaces; relationship of the existing building with the adjacent buildings; orientation and possibility of natural lighting; style and color scheme of facades; materials for interior decoration; energy efficiency of the existing building shell; energy saving of artificial lighting; degree of light pollution; efficiency of engineering systems; waste management measures, etc.

Stage 3: building an architectural BIM model of the eco-reconstructed building using laser scanning technologies. Analysis of architectural and planning features of the building, for the possibility of further transformation and inclusion in the existing surfaces of facades and roofs of devices for generating alternative energy (Fig. 2).

To build a BIM model of the 3, 4 and 25 buildings of SSTU, the ScanIMAGER software package was used, which is intended for processing the results of three-dimensional laser scanning of architectural objects. The software package is built on a modular principle and comes in various modifications. The ScanIMAGER module is designed for processing a "point cloud" after three-dimensional laser scanning of space. It has been made the measurements, obtaining sections, volume calculations, construction plans and elevations of different surfaces.

Stage 4: Study of the main areas of work and departments of the campus, characteristics of labor processes. Proposal of technical and informational measures for eco-reconstruction of the campus in accordance with the work of departments of higher education institutions. The proposed measures can optimize the work of many departments of the Institute, helping to save resources, maintain a favorable microclimate, and create safe and comfortable conditions for campus users.

Stage 5: proposal for environmental reconstruction of a General education institution based on the analysis (Fig. 3).

In the process of eco-reconstruction, the following main eco-solutions are proposed.

Surrounding area: increased Parking spaces for bicyclists; favorable and safe conditions for Hiking and Cycling; regulation of rain flows on the territory; planting trees for shading, seeding the territory with perennial grasses that do not require watering; reducing the effect of urban heat island due to geogrids and the use of coatings with a high coefficient of solar reflection.

A view of the campus, SSTU

3,4 SSTU building

25 SSTU building

Interior of SSTU building 25

Fig. 1. Campus, SSTU, Saratov, Russia.

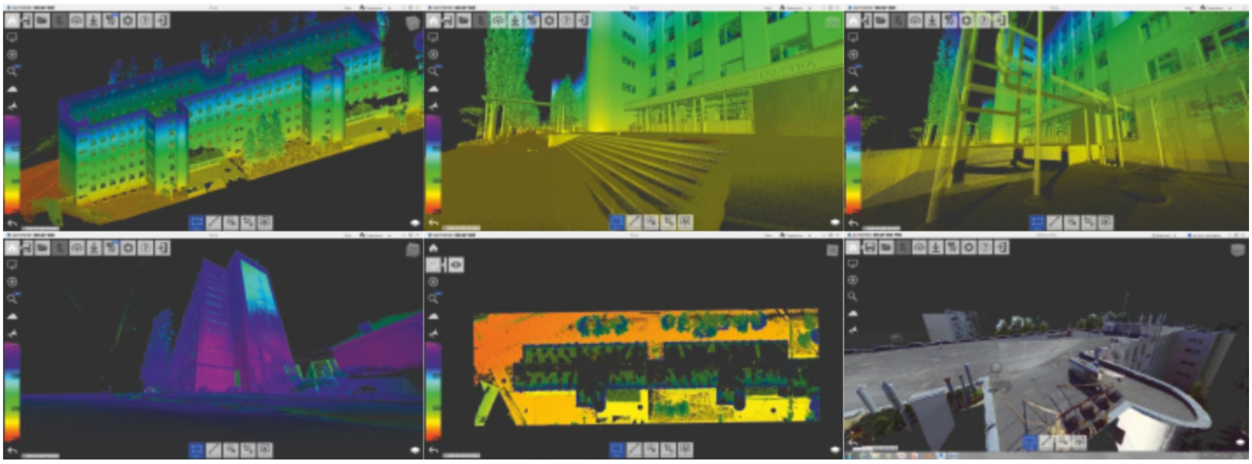

Fig. 2. Laser scanning of 3,4 and 25 cases using the ScanIMAGER software package.

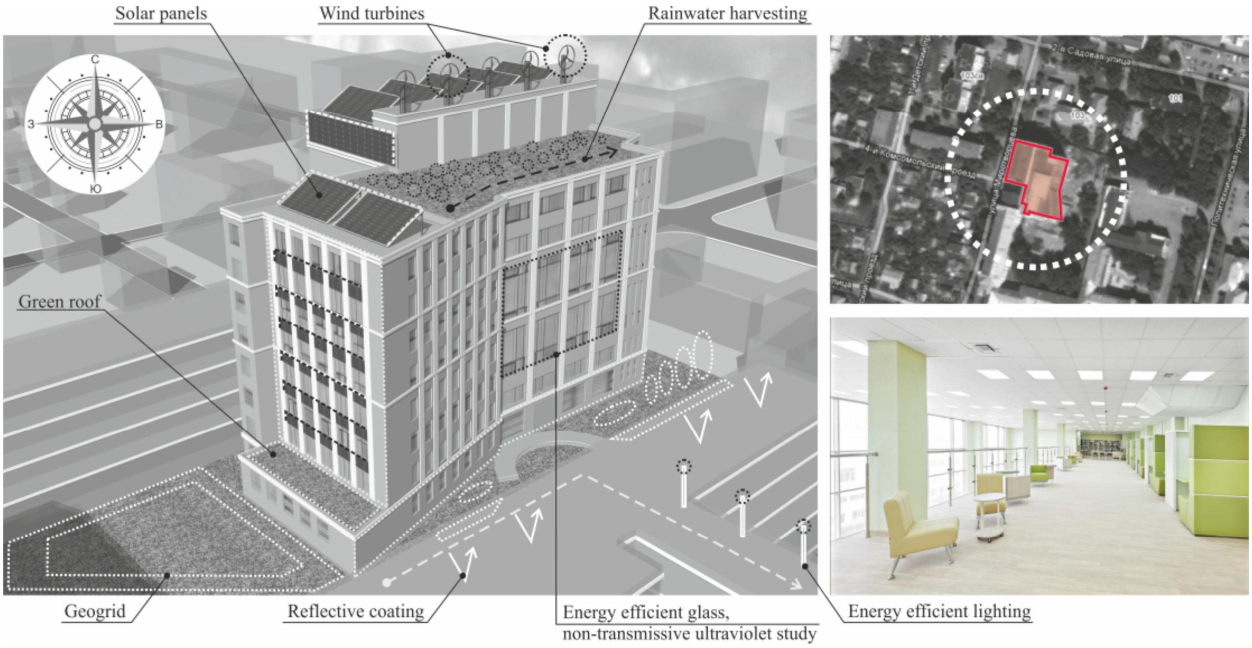

Fig. 3. Conceptual model with possible proposals for environmental reconstruction of the 25 building of the SSTU campus.

Water efficiency: irrigation of the surrounding area; monitoring of water leakage; reuse of water for household needs; collection of rainwater on the roof and territory (storage tank installed in the basement of the building); use of water-saving equipment; installation of water flow limiters.

Energy saving: reduction of CO2 emissions through the use of renewable energy sources (solar collectors and wind generators); energy-efficient glass that does not transmit ultraviolet radiation; reflective elements on the facade; use of led lighting; minimization of office lighting; reduction of night lighting (from 23 to 5 hours) by 50%, automation due to timers and sensors.

Materials: natural materials of local production; materials that do not contain VOCS; use of ultra-stable eco-paint for facades that generates energy; light color scheme of coatings; adding reflective particles (solar cells) to the exterior surface finishing; reuse of enclosing structures.

Waste: organization of centralized waste collection with separation (paper, cardboard, glass, metal and plastic (at least), organic waste (for compost), electronic waste (computer equipment); reuse of paper (waste paper collection).

Microclimate: green roof; ventilation air heating (cooling) systems; underground air cooling for natural air conditioning; arrangement of air gaps between walls; rational placement of workplaces and technical equipment; improved air exchange by opening window flaps; protection of the building from electromagnetic radiation and radiation; installation of sensors for tracking the level of CO2 in the premises; installation of mats in the vestibules for collecting dirt.

5. Conclusions

The analysis of eco-friendly architectural and engineering solutions of educational institutions showed priority areas that allow achieving high indicators for environmental protection, saving resources, creating favorable conditions for work and training, reducing waste and promoting environmental education.

Comparative analysis of sections and requirements (as a percentage) of environmental standards-BREEAM Education (UK), LEED for School New Construction and Major Renovations (USA), GB/T51356-2019 "green campus assessment Standard" (China), GREEN ZOOM "Universities, campuses and innovative research and technology centers" (Russia) identified priority areas of rating systems.

In the eco standards considered, the greatest attention is paid to the microclimate inside the building, improving the environmental friendliness of the construction site and energy efficiency of the campus. It is necessary to increase the proportion of requirements for the use of eco-friendly materials and recycling of household and construction waste.

The identified inconsistencies of the Saratov state technical University named after Yu. A. Gagarin with the requirements of UI Green Metric and environmental standards in construction allowed us to develop a new concept for the environmental reconstruction of campuses.

According to the identified problems, the SSTU campus has a wide range of tasks for further study and implementation, which are expected to be solved in further scientific research.

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