Environmental Innovations in the Construction of Social Infrastructure Facilities in Agricultural Holdings

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Abstract. The article considers the problem of building social infrastructure facilities in agricultural holdings and proves that the use of environmental innovations in the construction of such facilities not only leads to a reduction in resource and carbon intensity, but also provides a social and environmental effect due to informing and educating the population. Environmental innovations in the construction of social facilities can be used for the purposes of environmental education and training of not only children but also adults through open lessons, thematic lectures and demonstrations of sustainable construction techniques. As an example, we present the results of comparative evaluation of carbon footprint of the school building project with kindergarten and cultural and leisure center made of traditional monolithic reinforced concrete structures and 3D polystyrene foam panels, obtained with SimaPro 9.1.1.1 software. It is shown that the use of innovative construction technology leads to a reduction of the carbon footprint in the life cycle of a building by 1.5 times compared to traditional technology.

1. Introduction
Russia’s agricultural areas are the most significant natural resource of the country, the importance of which is increasing rapidly with the simultaneous acceleration of socio-economic development and severity of environmental problems. On the basis of agricultural enterprises in the early 2000s large agricultural holdings were created, which are now engaged in the development of the most profitable agricultural production, which allows the development of the territories while creating social infrastructure. Thanks to the state policy aimed at supporting the agro-industrial complex, agricultural holdings receive state subsidies and grants. However, using new machinery, technology and introducing advanced production methods, agricultural holdings do not actively develop the social sphere in rural areas and do not pay due attention to environmental education and upbringing. Paying greater attention to environmental issues in the design of social infrastructure facilities in agricultural holdings and combining technological innovation with social innovation are urgent tasks, which are necessary to build capacity for sustainable development and strengthen skills for coping with adaptation and prevention of climate change.

As foreign experience shows, a special role is played by environmental design of social infrastructure facilities, public and administrative buildings, schools, clinics, hospitals, cultural and leisure facilities. The application of ecological innovations in social sphere facilities will not only ensure energy and
resource saving but may become a valuable educational resource for the purposes of ecological education.

2. Problem statement
Agribusinesses with an integrated structure and full cycle – from production, storage to sales of finished products, creating jobs and providing decent housing and the necessary social infrastructure to the local population have a significant advantage in agriculture. Through the rational use of available financial resources and in the presence of state support it is necessary to develop social infrastructure in rural areas [1].

Unfortunately, the social infrastructure of rural settlements is at a low level. Construction activities in the countryside are still of rather low quality and are characterized by a disregard for the natural environment. Construction sites are often littered, construction waste is thrown outside the village. All this disfigures and destroys the natural environment of the countryside.

The ecological situation of modern villages needs to be improved by implementing measures that help bring the village closer to environmental friendliness. One of them is the development of ecological design of social infrastructure facilities using ecological innovations in rural construction [2].

3. Results and discussion
The global construction practice stimulates investments in environmentally friendly technologies (cleantech) aimed at using alternative energy and improving energy efficiency, reducing the use of energy and material resources throughout the life cycle of the facility, including construction, operation, dismantling and disposal of waste at the end of the life cycle. Modern building technologies should provide a comfortable environment inside the building, while being based on energy and environmentally efficient designs [3].

Active and passive ways of energy saving are used [4]. The first ones are characterized by the use of solar collectors, solar panels based on photovoltaic cells, recuperators, heat exchangers, underfloor heating, heat pumps for energy saving purposes. Passive methods include the development of the best overall architectural and planning concept of the building with the orientation of the building to the south, the use of light roofing, rational glazing, the use of heat-intensive building envelopes, energy metering units.

Let’s focus on some ways to save energy.

Use of modern building materials. The life cycle of a building is directly related to the life cycle of the materials used in construction. Construction is considered as one of the most material-intensive branches of the country's economy, the cost of materials used for the construction of buildings and structures forms more than half of the total cost of construction and assembly works and about one third of capital investment in the national economy of the Russian Federation.

At the design stage, building structures and materials can be selected taking into account not only their energy efficiency, but also the energy costs for their production and utilization at the end of their life cycle [5]. It is recommended to use modern composite and thermal insulation materials with higher strength and resistance to deformation. Compared with conventional ones, polymeric synthetic materials are lighter, easier to transport and install, resistant to chemical attack of aggressive environment, temperature fluctuations; they are safe for the environment. Industrial or construction waste can be used to produce such building materials, which will reduce the environmental load and energy intensity of the material's life cycle. Mineral wool, foam plastic, polyethylene foam, plywood, insulation made of natural materials can be used in construction.

Energy saving building structures and systems. Building structures and systems aimed at energy saving can include hinged ventilated facades, energy efficient underfloor heating and energy efficient windows, heat and water insulation of roofs and foundations of buildings.

Engineering methods to improve energy efficiency of structures. This method can include the use of recuperation in the ventilation of the building, heat pumps, the use of renewable energy sources, efficient
heat exchangers in air conditioning systems, energy metering devices, computer control of building energy systems [6, 7].

An example of the application of energy-saving building technologies in rural areas is an interesting project of an elementary school building in the village of Brandon, UK [8]. The single-storey school building for 390 students with a kindergarten, swimming pool and community space can be used both during and after school hours, which is ensured by the special design of the building. Technologies used in the design and construction of the building include heating the school with a biofuel boiler, natural ventilation and lighting. All of this has resulted in reduced energy consumption, lower lifecycle costs and a smaller carbon footprint.

We considered the project of construction of a school building with a kindergarten for 1375 pupils located in Pskov region. After working hours and at weekends, the building serves as a cultural and leisure center for the residents of the agricultural holding. For the purposes of energy and resource conservation, the project includes energy recovery in the air conditioning and life support system, the reuse of treated storm water, solar panels for energy generation, and heat-efficient “smart” glazing.

As building materials, the authors considered traditional monolithic reinforced concrete structures and innovative 3D panels using polystyrene foam, consisting of two single polystyrene foam blocks with wire connectors (figure 1). The modules are mounted in rows with each other using the seamless masonry method. The outer surfaces of the panels are usually plastered. 3D plates are flexible, allowing any flat or curved design to be realized [9, 10, 11]. Any facade construction is suitable for exterior walls, while gypsum plasterboard is suitable for interior finishing.

The advantage of this technology is that the structures are easily and quickly erected, and the installation does not require the use of specialized heavy equipment, such as cranes and lifting devices. In comparison with traditional monolithic construction the consumption of concrete is reduced by 35–40%, and reinforcement – by 25–30%. The low weight of the building allows for a lighter foundation. Concreting works are performed without heating and at sub-zero temperatures. The construction parts are manufactured with high precision, so the generation of construction waste is minimal, which is also a positive fact for the environment. The service life of buildings is 100 years and more.

![Figure 1. Styrofoam board for load bearing walls.](image-url)

Thus, improvements in energy efficiency, reductions in resource intensity and carbon footprint occur throughout the life cycle of a building made of innovative 3D panels as a consequence of a number of
factors: lower weight of the building, reduced waste generation, reduced energy and fuel costs for transportation of materials and waste, better thermal insulation properties reducing energy consumption at the stage of operation, and less time and resource-consuming disposal at the end of the life cycle [12].

The results of a comparative assessment of the carbon footprint in the life cycle of a building made of traditional monolithic reinforced concrete structures and with the use of 3D polystyrene foam panels are shown in figure 2.

Using ReCiPe (2016), IPCC (2017), EPD (2018) models based on SimaPro 9.1.1.1 software, the carbon footprint of a school building using 3D polystyrene foam panels was obtained and compared with the carbon footprint of a school building made of monolithic reinforced concrete structures [13]. As can be seen, the carbon footprint simulation results are almost identical in calculations based on different computational models. A school building made of traditional materials requires more energy and generates a carbon footprint of 14.5 Mt-eq CO2, exceeding the carbon footprint of an innovative 3D panel building by a factor of 1.5 (9.75 Mt-eq CO2).

Figure 2. Comparative assessment of the carbon footprint calculated on the basis of ReCiPe, IPCC and EPD models for a school building using 3D polystyrene foam panels and a school building made of monolithic reinforced concrete structures.

The use of foamed polystyrene boards in construction will reduce the load on the environment and improve the environmental and economic efficiency of construction. End-of-life recycling of new materials will reduce the amount of non-recyclable waste and close the life cycle, returning the waste to production as feedstock [14].

It is known that the issues of dismantling capital construction objects are considered at the design stage. Technologies for processing foamed polystyrene are only being developed so far, relying on foreign experience, as there this building material has been in use for more than 50 years. Styrofoam recycling technologies include sorting, dismantling of mechanical compounds with concrete and metal, shredding with shredders and crushers and washing. Styrofoam refers to thermoplastics and when heated under pressure below the melting point, it can be pre-compacted to produce compact polystyrene. After shredding, there are several possibilities for recycling: addition of pure waste to the primary product in the production of block and shaped parts, additive to building materials to produce light blocks, foam concrete, heat insulating plaster; soil additives; melting in the extruder into compact polystyrene with melt filtration, allowing new products to be produced by injection molding. Unfortunately, for shredded waste there is virtually no cleaning capability. Significant improvements in recycling quality can be achieved by using the dissolution method [15, 16]. However, we consider this
possibility of reducing the resource and carbon intensity of the life cycle of a building made of 3D panels for the future.

The application of environmental innovations in the construction of the school building and cultural and leisure center will be used for the purposes of environmental education and training not only children, but also adults through open lessons, thematic lectures and demonstrations of sustainable construction techniques. The carbon footprint calculations performed will serve the purpose of teaching students about ecology. In this way, the building will be available practical training resource for the environment, resource conservation and climate change mitigation.

4. Conclusion

Agro-holding companies should become the basis for technological and socio-ecological modernization of agricultural production based on the achievements of science and technology, but at the same time it is necessary to apply ecological design for the construction of social infrastructure.

Today, the network of general education schools in rural areas has increased by 105,800 student places, cultural and leisure institutions – by 24.6 thousands places, district and district hospitals – by 6.1 thousands places, outpatient and polyclinic institutions by 7.5 thousands. The number of visits per shift, medical and obstetric stations – by 751 units, sports facilities and playgrounds – by 304 units. There is a growing interest in healthy lifestyles among the rural population, especially young people, but there is a need to strengthen environmental sustainability skills.

Successful construction of social facilities requires the use of environmentally friendly building materials and innovative technologies, which can be used in the skillful organization of environmental education work to develop energy and resource saving potential and prevent climate change in the life cycle of buildings.

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