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Innovative Learning Environments

The Role of Energy—Efficient Investments in Russian Preschool Education Facilities (A Case Study of the Khanty-Mansyisk Region)

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Abstract

This paper discusses an example of an early childhood development facility intervention in the Khanty-Mansyisk region of the Russian Federation and its potential to produce efficiency gains in the region and the country overall. The government of the region is introducing changes to the built environment of its early childhood development centers. The proposed new design is based on the concept of the learning environment as a third teacher. The smaller footprint of the new buildings will increase the amount of active space per child, and the new design will include energy efficiency measures. The economic impact of these measures will reduce operating costs throughout the lifecycle of the building and provide strong evidence to education policy makers in the rest of the region and the country as a whole in favor of child-centered, healthy, and energy efficient early childhood development infrastructure.

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Introduction

The demand for high-quality early childhood development (ECD) support is growing in Eastern Europe and Central Asia. Indeed, many post-transition countries have similar issues in regard to preschool service delivery and the provision of educational facilities. In the Russian Federation, ECD remains a high priority for federal and regional policy makers. According to national statistics, 66.2 percent of children aged 0 to 7 are enrolled in the Russian early childhood education system (UniSIS, 2015). The Russian government recently introduced a set of reforms to improve the quality of the early childhood education system and its operational management at the regional level (Bennett et al, 2012). The new federal state standard of preschool education, adopted in 2013 (Government of the Russian Federation, 2013), required regional ECD systems to become more child-centered, diverse, and flexible in terms of their content and learning environments. Furthermore, aiming to increase enrollment in kindergartens, the Russian federal government has introduced policy interventions to support the new construction and the maintenance of existing educational facilities in the regions, as well as to equip the kindergartens with relevant modern technology. At the same time that these federal initiatives are happening, many policy makers at the regional level strive to reduce the construction and operating costs related to preschool facilities.

This paper is the first attempt to reflect on the practical application of the new ECD standard norms to the design of preschools in Russia. Starting in 2013, the World Bank and the Department of Education and Youth Policy of the Khanty Mansyisk Autonomous Region of Russia (hereinafter referred to as Khanty-Mansyisk) began a pilot project aimed at increasing the efficiency and improving the quality of the region's ECD system by introducing an innovative design in its preschool education facilities to foster modern pedagogy and learning. The project also aimed to use cost- and energy-efficient approaches in the construction process and, thus, to reduce expenditures on electricity and heating as well as the kindergartens' operational and maintenance costs.

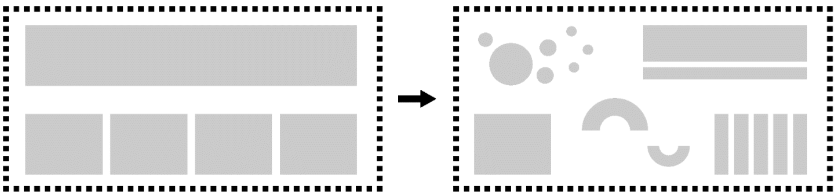
In this paper, we examine the proposed design of the new type of learning environment in detail as it would be implemented in a kindergarten with a capacity of 220 places in Beloyarski City. Based on this example, we argue that converting the spatial arrangement of preschool facilities into a more open learning environment may improve the quality of the every-day learning process. A more open learning environment can stimulate better communication among children, facilitate stronger cooperation between children and the pedagogical staff, and improve current teaching practices. By comparing the use of energy and heating in the pilot kindergarten with the consumption of those still laid out in the traditional way, we found that the new approach to the design of ECD facilities is less costly and more energy-efficient, which is a strong argument in favor of child-centered ECD infrastructure design.

Creating New Learning Environments

To understand the importance of the learning environment, we first look closely at the process of child development and learning. A child goes through various biological and psychological changes, acquiring certain physical characteristics, language, cognitive and socio-emotional skills. Every child develops and learns differently. Many well-known pedagogical experts, such as Rudolph Steiner, Maria Montessori, and Jean Piaget, have highlighted the importance of developmental stages defined by age and the fact that education should respect the natural development of children, reflecting their needs and supporting their independent exploration (Scott, 2010). A child should take an active and self-directing role in the learning process. According to Lev Vygotsky, another fundamental aspect of children's cognitive development is their social interaction with their teachers or parents (Vygotsky, 1978). Also, recent research in learning science has shown that collaboration within the child's group of peers can accelerate his or her learning (Sawyer, 2006). However, the most important activity to foster a child's cognitive development, creativity, social cooperation, flexibility, and learning is play. Therefore, the roles of the curriculum and the teacher are to support and facilitate this learning process, and the environment is the spatial framework for this process. Based on the approach of the Italian pedagogue Loris Malaguzzi, this learning environment can become a third element in the teaching process, representing not only a tool for educators but also a source for the child's own discoveries and experiences (Cagliari et al, 2016). Architect and researcher Christopher Day (Day et al, 2007) has pointed out that our environment influences the way that we think, feel, and act. The environment shapes our habits, beliefs, and values and can encourage our physical, mental, and social development. Overall, the built learning environment has a spillover effect on the agency and executive function of children, increasing their ability to learn (Prescott et al, 1967; White and Stoeklin, 2003, and Maxwell, 2007). Thus, indoor areas such as playrooms and group spaces and outdoor areas such as playgrounds in kindergartens designed in accordance with the pedagogical concept of this preschool facility and children's developmental needs are essential to any high-quality preschool system.

Although there is still only limited evidence on the connection between types of learning environments and the learning outcomes of children, we have a good idea of what constitutes a good quality learning environment and about how it has a positive impact on a child's development. Nowadays, many preschools in OECD countries are designed to allow children to communicate with each other and to share common activities in open environments with multifunctional equipment that is always accessible to make maximum use of the kindergarten space. One of the notable differences from traditional kindergarten design is the avoidance of a complex system of closed corridors, which are replaced by central multi-use spaces in an open configuration. As shown in Figure 1, this open spatial configuration can play the same role in a kindergarten as a main square plays in a city (Ceppi and Zini, 2001). Given that children learn in different ways, this new open kindergarten design caters to all kinds of learning modes, from active to calm spaces and from dynamic group spaces to more individual areas (such as resting and reading corners).

Figure 1: Changes in the Educational Environment from the Institutional Typology (left) to the Educational Landscape Typology (right)



Source: Jure Kotnik

Studies in the United States have shown that the spatial configurations of education facilities as well as their noise, temperature, light, and air quality all affect children's learning and children's and educators' abilities to perform (Schneider, 2002). For instance, one study found that an improvement in school conditions from extremely bad to good led to an increase of approximately 10 percent of a standard deviation in children's learning achievements (Michaelowa and Wechtler, 2006). Further research has shown a positive correlation between a high-quality preschool physical environment and improved academic achievement among children from low-income families (Mashburn et al, 2008). The spatial arrangement of kindergarten rooms can affect how children play and behave, and if there is a high density of children in a kindergarten, this can lead to aggressive or destructive behavior (Rohe and Paterson, 1974 and Kantrowitzand Evans, 2004). The "biophilia effect," which represents human exposure to images of nature and green vegetation in their surroundings, can improve learning and working conditions inside the building, as well as withstanding the influence of harsh weather conditions outside (Lidwell et al, 2010).

According to studies of the relationship between sports activities and brain functions, physical activity also fosters children's mental development so designing spaces for children to be physically active is very important for increasing their cognitive abilities and improving their learning performance (Meyer and Gullotta, 2012). A study of the impact of outdoor environments in 11 preschools in Stockholm has shown that a spacious area with vegetation, shrubbery, and broken ground can increase physical activity among children and improve their health (Boldeman et al, 2006). Another study, conducted in 36 primary schools in Spain, showed that exposure to the green environment within and around the educational institution can also improve children's working memory and reduce inattentiveness (Dadvand et al, 2015). The "Clever Classrooms" study conducted in UK suggests that the physical characteristics of classrooms may explain up to 16 percent of the differences in the learning outcomes of children (Barrett et al, 2015). In short, the evidence is overwhelming that the physical environment can significantly affect child development from an early age.

While most of the recent global focus on changes in kindergarten architecture has been on increasing play, there has also been an emphasis on sustainable construction, the thoughtful selection of building materials, and the energy efficiency of facilities from the construction phase through to their day-to-day operations. How much energy buildings use is affected by their different design and operational characteristics. Studies have shown that the largest amount of energy consumption occurs while the building is being used rather than in the construction phase (Sartori and Hestnes, 2006). Buildings can become more energy efficient through the careful design and implementation of best practices in the following parameters: (i) the building's form and orientation; (ii) insulation; (iii) natural ventilation; (iv) construction materials; (v) daylight illumination; and (vi) the installation of high-quality doors and windows. An effective building envelope enables the use of highly efficient equipment and energy sources such as low temperature waste heat, heat pumps, and renewable energy (IEA, 2017). In recent years, many countries have developed new energy standards for buildings aimed at stimulating the efficient use of energy and promoting the use of renewable energy sources (Hegger et al, 2016).

As Table 1 shows, a sample of energy efficient kindergartens and schools from several countries suggests that there is potential for a 50 to 70 percent reduction in thermal energy consumption for space heating, while the energy consumed by equipment and lighting can be reduced by an average of 30 percent.

Table 1: Energy Consumption in Energy-efficient Schools and Kindergartens in Various Countries

	Energy consumption (kWh/m2/year)	Heating (kWh/m2/year)	Electricity (kWh/m2/year)	Reduction in consumption for	
				Heating (kWh/m2/year)	Electricity (kWh/m2
Bulgaria					
Dobrich: Pilot reconstruction project	99.5	n/a	n/a	by 53%	
Norway					
Nardo School, Trondheim: Reconstruction of primary school	99	29	43	by 70%	n/a
Austria					
Kramsach, Tyrol: Construction of energy-efficient kindergarten	n/a	14	n/a	n/a	n/a
China					
Beijing: Green micro energy consumption kindergarten	68	12	40	n/a	n/a
Denmark					
Vejtoften, Høje-Taastrup, Denmark: Reconstruction of kindergarten	n/a	69	n/a	by 54%	n/a
Ballerup: Reconstruction of Egebjerg School (1997)	109.3	87.3	22	by 50%	by 30%

Sources: Mørck (2003); Norwegian - Bulgarian Cooperation Project (2011), and Rose and Thomsen (2012)

Given the fact that, in Russia, the government funds ECD institutions, federal and regional policy makers often welcome the opportunity to save public money by using these new technologies so that they may be able to reallocate the saved expenditures to enhance other areas of child development and early learning.

Current Design of and Energy Use in Russian Kindergartens

The traditional approach to kindergarten design in Russia was to create a single room for each activity, which usually transformed a preschool facility into a labyrinth of corridors and separate rooms. This particular spatial arrangement has been reinforced by current sanitary and fire regulations, which are designed to protect children from diseases, to ensure their safety, and to prevent any possible risks. These regulations are based on the "group isolation" principle, which discourages the mixing of different groups within the school (generally, a group consists of 15 to 30 children and one or two teachers).

A usual day in a Russian kindergarten is very structured, as are the learning activities and games, which are mainly directed by the teacher. The current teaching practices are strongly correlated with the traditional spatial organization of a kindergarten and define the interaction between the adult teacher and the children, which is often very formal and involves the teacher-oriented form of education. Moreover, Russia is the only country in Europe which requires: (i) the presence of medical staff in kindergartens; (ii) a daily check of the health of the children as they arrive at the kindergarten; and (iii) the principle of "group isolation." Given the emphasis that the Russian education system puts on ensuring children's health and well-being in ECE facilities, the principle of "group isolation" has several limitations. The first two limitations relate to a lack of physical development: (i) the children have little space to run and move, and (ii) the limited size of the room increases the risk of a disease spreading. However, the major issue is inefficiency in the use of space. For example, Danish kindergartens are usually 40 percent smaller in terms of overall space than Russian kindergartens (around 10 square meters per child versus around 20 square meters per child). However, there is up to four times more so-called "active space" — the space available for boys and girls at any time —in Danish preschools than in Russia's (2.5 square meters per child compared with 7 to 8 square meters per child) (Shmis et al, 2014). Thus, adopting these proportions in Russia preschools would generate tremendous savings in terms of both space and costs.

Another way to save public funds would be to increase the energy efficiency of educational facilities, which have the greatest technical potential for energy conservation in comparison to other types of buildings. Overall, the building sector in Russia is the largest consumer of energy, mostly due to inefficient design and long heating seasons

(Bashmakov, 2017and Lychuk et al, 2012). The largest share of consumption comes from district heating.[1] According to the Government of Russia, the country possesses very old heating infrastructure, which is in critical condition and needs replacement. "Ninety percent of power stations, 70 percent of water boilers, 70 percent of electric grid technologies, and 66 percent of district heating networks were constructed before 1990" (Lychuk et al, 2012). International assessments have shown that losses from district heating systems can be as high as 60 percent, but those in OECD countries account for only 20 percent because they have led the way in adopting modern, energy-efficient systems and appliances (IEA, 2014). While the number of energy-efficient buildings in the Russian public sector (including schools, social and medical facilities) is low, this indicates that there is great potential for energy savings. For example, only 16.9 percent of all public sector facilities in Russia obtain at least the D-level (standard) class of energy efficiency, while 84 percent fall into the E (least efficient), F (low), and G (very low) energy efficient classes (Russian Ministry of Energy, 2017b).

A review of 3,069 preschools in eight federal administrative districts of Russia showed a trend of increasing energy consumption, with the largest consumption again accounted for by heating (Russian Ministry of Education and Science, 2013). More recent data by the Russian Ministry of Energy confirms that annual levels of consumption of thermal energy and electricity by public education facilities are steadily growing in almost all Russian regions (Russian Ministry of Energy, 2017b).

Educational institutions consume maximum four types of energy: (i) electricity; (ii) thermal energy (delivered through the transmission networks usually in the form of hot

[1] Heat generated in a centralized location through a system of insulated pipes for residential and commercial heating requirements such as space heating and water heating.

water); (iii) hot water; and (iv) natural gas (although the number of institutions using gas is negligible). Most of the energy used in education facilities is for space and water heating.

There are very few energy audit research studies of preschool educational facilities, but even these sparse findings indicate that there is an existing potential for energy savings. For example, an energy audit and energy consumption analysis of 10 operating kindergartens connected to the district heating transmission networks in Saint-Petersburg showed that the actual heat losses of the kindergarten buildings exceeded the normative standard by 30 to 40 percent. Many buildings are over-heated due to the degraded condition of buildings, a lack of thermal insulation, poor energy management, and the absence of any controls or meters to regulate the temperature (Vatin and Nemova, 2012). According to Moscow City data, the technical potential for thermal energy savings in education facilities in Moscow constitutes 25 to 80 percent, especially in heating (35 to 70 percent) and electricity (15 to 25 percent) (Guzhov, 2012). According to the estimates of the International Finance Corporation and the World Bank, the overall technical potential for energy savings in educational institutions in Russia might be as much as 80 percent (IFC/World Bank, 2008).

Some Russian preschool buildings have had some energy-efficient retrofitting done, but the most popular measures have been the reinforcement and thermal insulation of doors and windows rather than an upgrade of the overall envelope of a kindergarten building (Russian Ministry of Education and Science, 2013). Any rehabilitation of heating systems has tended to involve the installation of metering equipment rather than of new heating transmission systems (only 25 percent of buildings are equipped). Also, upgrades of electrical energy systems have mostly involved simply upgrading lighting equipment.

In fact, there is much potential for making energy savings in the lighting of educational facilities. The Global Environment Facility, a worldwide partnership for addressing environmental problems, has estimated that public buildings (including educational facilities) could potentially save 41.6 percent of their annual consumption of energy for lighting (Lychuk et al, 2012). However, research on energy-efficient policies in Russian preschool facilities has shown that very few have invested in LED-bulbs/lumps and occupancy sensors (18 percent and 8 percent respectively) both in urban and rural areas (Russian Ministry of Education and Science, 2013).

Novelty of the New Kindergarten Design in the Khanty-Mansyisk Autonomous Region and Its Potential Educational Impact

Located in Western Siberia, Khanty-Mansyisk is one of the few Russian regions, where population growth has been steady, even during the economic shocks of the 1990s. The percentage of children aged 1 to 7 years old covered by ECD services remained stable for several years at around 58 percent (58.6 percent in 2005 to 58.8 percent in 2013). However, in 2014-2015, coverage increased to 67.6 percent (UniSIS, 2015). Due to high birth rates, there is a growing need for additional spaces in preschool facilities. There are 422 official preschool institutions in the region, and their operations costs are rising (Department of Education and Youth Policy of Khanty-Mansyisk, 2017 and Koveshnikova, 2013).

According to Russia's national ECD standard (Government of the Russian Federation, 2013), the learning environment in kindergartens should meet the following main requirements:

- It should maximize the educational potential of the building and land plot.
- It should stimulate and promote communication between children, as well as between children and adults of different ages.
- It should be rich, flexible, accessible, inclusive, multifunctional, and safe and should support the variety of children's needs, provide a range of educational programs, and take into account the social and climatic characteristics of the area where the kindergarten is located.

To address these requirements, the team City-Arch[2] designing the new energy-efficient kindergarten in Beloyarski City of the Khanty-Mansyisk Region incorporated several important elements including a multifunctional open space, playrooms combined with sleeping areas, and design elements to increase the building's transparency (for example, the glass doors or glass elements in the walls of the corridors). In addition, they grouped all functional zones in a specific order to make them accessible for children and to allow optimal use of space for learning and play activities.

In the new design, a multifunctional open space is located in the center of the building replaces traditional corridors to serve as a connecting point where all users of the building can meet during the day and use it for various meetings, theater, and music activities. As

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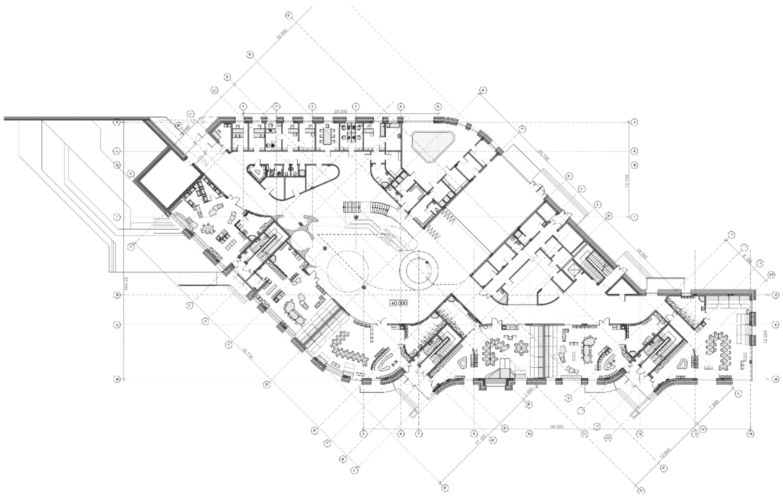
[2] City-Arch – a Russian design engineering firm involved in preschool facilities design in the Khanty-Mansyisk Region - http://city-arch.ru/.

shown in Figure 2, all of the different groups' rooms (marked in green) have separate entrances that lead to the multifunctional open space (marked in gray). This open area will have different zones for individual and group activities and will thus be able to accommodate different aspects of the learning process.

Figure 2: The Floor Plan of the Proposed New Kindergarten in Beloyarski City



Source: City Arch (2015)

As seen in Figure 3, the upper floor will be connected to the multifunctional open space on the lower floor by a chute that can be used as a slide by children during the day to encourage physical activity. In contrast with the "isolated" group rooms, this multifunctional open space will increase interaction among children and between children and the teachers, strengthen the kindergarten community, and provide more space for play and joint educational activities.

The walls of the group rooms will incorporate transparent glass to provide visual connections between the group spaces and the multifunctional open space. This arrangement will enable children to observe other activities being carried out by their peers and will allow for more frequent communication between children of different ages.

Figure 3: Multifunctional Space in the New Kindergarten Design

Source: City Arch (2015)

Combining the playroom and the sleeping room will reduce the kindergarten's total area but will increase the space available inside the playroom from an average of 2.5 square meters to 4 square meters per child (assuming each group contains 20 children). The zones for eating and changing clothes are incorporated into the playroom common area. Increasing the size of the playroom will not only give children more space to play but will also make it possible to arrange the space in different ways. Including the multifunctional open hall, the overall active space per child will amount to 10.5 square meters.

The arrangement of the outdoor landscape in the proposed design is based on making the outside space a complementary learning and developmental environment for children. To make the playground area as large as possible, the designers have positioned the new kindergarten building close to the border of the land plot instead of in the center of the land plot, which is the traditional placement. Although, under the group isolation principle, a separate playground would be provided for each group of children with all of these little playgrounds looking identical, the designers of the new kindergartens suggested making each group's playground in a different style and based on a specific activity. Moving the groups of children around these different playgrounds according to the daily curriculum schedule will expand the children's learning experiences and involve them in various play activities.

When the kindergarten in Beloyarski City featuring this new learning environment is constructed, it will be necessary to provide additional training to the teaching staff to enhance their professional skills and to ensure the learning environment is used to its full capacity.

It will also be necessary to carry out the post-occupancy evaluation including all active users of the facility: children, pedagogues, administrative staff, and parents. During these assessments, the above-mentioned hypothesizes may be tested providing additional qualitative and qualitative information for further research.

Potential Energy Savings from the Hypothetical Application of the New Design to a Kindergarten in Beloyarski City

To analyze the energy savings that might be achievable when new kindergarten is constructed in the Khanty-Mansyisk region in accordance with this new design, we looked at the existing Semitsvetik kindergarten in Beloyarski City, which has a total capacity of 220 children and whose facilities include a swimming pool. We chose this particular kindergarten, because it represents a typical modular preschool facility in the same municipality and has the same capacity (number of children) as the new one.

We analyzed the layout, dimensions, and energy use of the existing Semitsvetik kindergarten building as of 2013, and these characteristics are presented in Table 2. The data came from Beloyarski City administration, as well as City Arch, the engineering design company that designed Semitsvetik kindergarten and developed the proposed new design for ECD facility in Beloyarski City**.**

Table 2: Characteristics of the Semitsvetik Kindergarten, 2013

Gross heated floor area	4,713.1 square meters
Capacity	220 people
Actual heating system	Single-tube horizontal adjustable heating system connected to the district heat transmission network through an individual heating station built in the basement of the kindergarten. The cast-iron radiators and individual heating station are equipped with automatic temperature controllers. Heat-transfer fluid – water with the temperature ranging between 95 and 70 C.
Actual floor heating system	The heated floors are installed in the playrooms on the 1st floor, in the swimming pool, as well as in the resting and changing rooms near the swimming pool area. Water temperature is controlled at the individual heating station. Heat-transfer fluid – water with the temperature ranging between 30 and 40 C.
Actual ventilation system	Plenum-and-exhaust ventilation system with mechanical forced and natural convection, as well as a local exhaust ventilation near the areas of harmful emissions. Heat-transfer fluid – water with the temperature ranging between 70 and 95 C.
Actual lighting system	Kindergarten building is equipped with normal and emergency lighting delivered by general and combined lighting systems. For repair purposes, portable lighting is provided. The main sources of light are fluorescent lamps, compact fluorescent lamps, and incandescent lamps. The lighting equipment is controlled by tumbler switches. The power consumption for lighting is set at 80.3 kW.
Gross consumption of electricity	218,843.00 kW-h
Gross consumption of thermal energy	860,641.77 kWh
Expenditures on electricity	RUR 806,634 (US$25,350)
Expenditures on thermal energy	RUR 916,554 (US$28,804)
Consumption of thermal energy per m²	182.6 kWh/m²
Consumption of electricity per m²	46.4 kWh/ m²

Source: Data provided by Beloyarski City administration and City Arch company (2013).
Note: Exchange rate for 2013 = US$1 to 31.81 Russian rubles

City Arch also informed us about the planned engineering systems for the proposed new kindergarten in Beloyarski City and with their projections of the consumption of thermal energy and electricity. Their estimates were peer reviewed and approved by the Regional Construction Supervision Agency of the Khanty-Mansyisk Autonomous Region. These data are presented in Table 3 (DSSPDP, 2017).

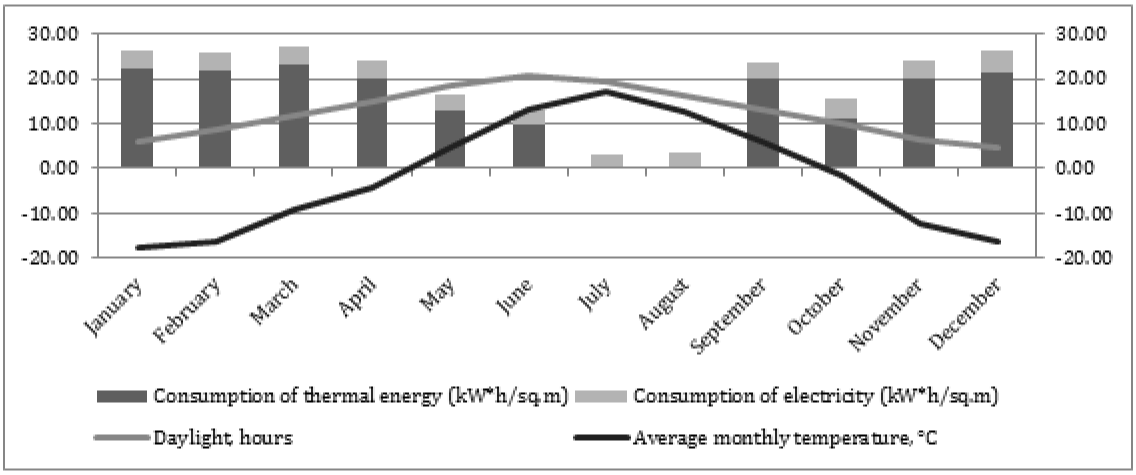
Table 3: Characteristics of the Proposed New Kindergarten in Beloyarski City [check] (as approved by the Construction Supervision Agency)

Gross heated floor area	3, 238 square meters
Capacity	220 people
Planned heating system	Double-tube horizontal adjustable heating system connected to the district heat transmission network through an automatic individual heating station using an independent scheme. This will make it possible to maintain hydraulic and thermal conditions for the internal heat supply system as well as to self-regulate heating and ventilation depending on the outside-air temperature. The building will be equipped with steel radiators with thermostatic valves. Heat-transfer fluid – water with the temperature ranging between 60 and 80 C. Different elements for calculating, controlling, and managing heat consumption will be installed in the individual heating station.
Planned floor heating system	Playrooms, sanitary rooms, changing rooms, the open playing space, the sports hall, and the swimming pool will have heated floors. The temperature in each room will be adjusted by the temperature controllers. Heat-transfer fluid – water with the temperature ranging between 80 and 60 C and the floor will reach 30/35 C through the water mixing units.
Planned ventilation system	Plenum-and-exhaust ventilation system with mechanical forced convection and exhaust air heat recovery. To save thermal and electrical energy, expelling ventilation will be used, a supply of fresh air will be provided to the playrooms, exhaust - through the changing rooms and sanitary areas. Automatic control of air consumption done by CO_2 sensors will be installed in the playrooms, changing rooms, the open space play area, and the sports hall. For the hot summer periods, an additional cooling system for the ventilation units will be in place. The ventilation and cooling system will be fully automatic with an option of remote control/temperature management.
Planned lighting system	Electrical equipment with energy consumption of class A and A + will be provided. On the premises of the kindergarten, lamps with energy-efficient bulbs and controls that are automatically responsive to the level of daylight will be installed.
Projected consumption of electricity	83,585 кWh
Projected consumption of thermal energy	179,215 кWh
Consumption of thermal energy per m²	55.3 kWh/m²
Consumption of electricity per m²	25.8 kWh/m²

Source: Data provided by the design engineering firm City Arch, 2017 (DSSPDP, 2017)

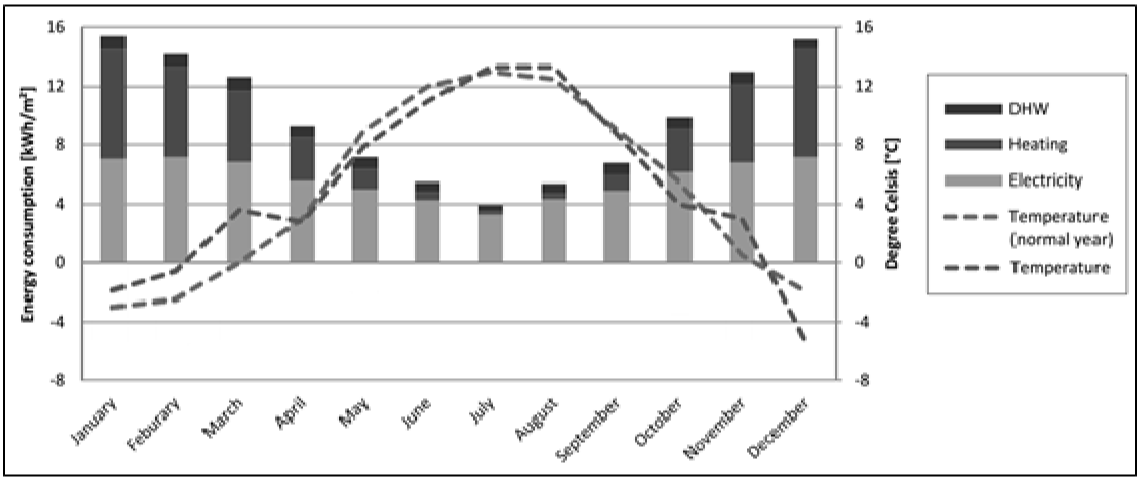
The breakdown of electricity and thermal energy consumption is provided in Figure 4 below. Energy consumption is inversely related to the length of daylight and outdoor temperature. The coefficient correlations of these indicators range from -0.69 to -0.85. The 2013 estimates for the Semitsvetik kindergarten show that the monthly distribution of energy consumption is uneven and may depend not just on weather conditions but on other factors as well such as various inefficiencies due to the building's condition and design, the improper operation and maintenance of the building, and/or its users' behavior. International best practices derived from energy efficiency projects for kindergartens and schools show that energy efficiency can be achieved by introducing automated control systems and energy accounting. A best practice example in an educational institution in Norway is shown in Figure 5 below.

Figure 4: Energy Consumption by the Semitsvetik Kindergarten and the Distribution of Temperature and Daylight Hours in Beloyarsky City, Khanty-Mansyisk, 2013



Source: Department of Education of Khanty-Mansyisk

Figure 5: Energy Consumption of an Energy-efficient Elementary School and the Distribution of Temperature in Trondheim, Norway, [what year?]



Source: Norway ECO-City project: Nardo School, Trondheim, 2012// http://www.ecocityproject.eu/PDF/ProjectResults_Trondheim_NardoSchool.pdf

Electricity and thermal energy consumption at the Semitsvetik kindergarten seem excessive. Based on the 2013 data, average annual consumption of thermal energy and electricity per square meter in the kindergarten was approximately 182.6 kWh and 46.4 kWh respectively. The most energy-efficient kindergartens consume no more than 68 kWh per square meter per year. The most successful energy efficiency projects (a kindergarten in Austria and a primary school in Denmark) managed to reduce thermal energy consumption to 14 kWh/m² and electricity to 22 kWh/m² respectively. The existing kindergarten in Beloyarski City consumes 13 times more thermal energy and three times more electricity than the most energy-efficient kindergarten and school buildings.

Achieving energy efficiency depends considerably on the conditions in educational institutions, including the availability of materials and technologies, logistics, and the specific character and climate of the area. Therefore, with this information, we conducted a cost-benefit analysis specifically of building a new energy-efficient kindergarten facility in Beloyarski City.

The operating costs of the Semitsvetik kindergarten in 2013 were RUR 2.2 million (US$69,000). This included expenditures on electricity and thermal energy, which totaled RUR 806,634.49 (US$25,357) and RUR 916,554.21 (US$28,813) respectively. Consequently, increasing the energy efficiency of the kindergarten by 1 percent would save up to roughly RUR 17,000 (US$534) annually. The proposed new design will also reduce the heated floor areas by one-third (from 4,713 to 3,238 square meters), resulting in additional savings.

We devised three scenarios to quantify the benefits as high, moderate, or low. Depending on which scenario is applied during the construction of the new energy-efficient building, thermal energy consumption will be reduced by approximately 70 percent, 50 percent, or 30 percent respectively, and electricity consumption will be reduced by approximately 44 percent, 22 percent, and 11 percent respectively. We arrived at these estimates based on (i) the characteristics of the new kindergarten from the technical design documentation and (ii) international best practice examples of energy-efficient schools. According to the technical design documentation, thermal energy consumption in the new kindergarten is expected to be 55.3 kWh/m², and electricity consumption is projected to be 25.8 kWh/m² (70 percent and 44 percent less than in the existing Semitsvetik kindergarten respectively) (DSSPDP, 2017). The two best practice examples were the reconstruction of a primary school in Nardo School, Trondheim, Norway, which reduced energy consumption of thermal energy by 70 percent, and the reconstruction of Egebjerg School in Ballerup, Denmark, which reduced thermal energy consumption by 50 percent and electricity consumption by 30 percent.

We then calculated the total benefits (net present benefits) of building the proposed kindergartens using the following formula:

$$MAINTENANCE_{BENEFITS} = \sum_{t=1}^{N} \frac{H_t + E_t}{(1+i)^t}$$

Savings from the reductions in thermal energy and electricity use are represented by (H_t) and (E_t) respectively, with the kindergarten year as (*t*), where (*i*) represents the 6 percent discount rate for human development projects, and (N) is the operation period of the kindergarten (in the project in question, it is up to 50 years).

We used the following formula to calculate H_t and E_t:

$$H_t = \tau_{H_t} * (S_a - S_b) * (\varepsilon_a - \varepsilon_b),$$

$$E_t = \tau_{E_t} * (S_a - S_b) * (\mu_a - \mu_b)$$

Established tariffs for thermal energy and electricity are represented by (τ_{H_t} and τ_{E_t}) respectively, the year is represented by (*t*) (RUR/10^9 calories), and (S_a – S_b) is the difference in the heated floor areas between the Semitsvetik kindergarten (4,713.1 square meters) and the proposed energy-efficient kindergarten (3,238 square meters). (ε_a – ε_b) and (μ_a – μ_b) represent the differences in thermal energy and electricity consumption respectively (per square meter) between the Semitsvetik kindergarten and the proposed kindergarten. The results of these calculations are presented in Table 4.

Table 4: Total Benefits from Investing in the Construction of an Energy-efficient Kindergarten in Khanty-Mansyisk under Three Scenarios

Scenario	Operations costs		Savings (over 50 years), million RUR, US$		**Savings (RUR per place), %**
	thermal energy	Electricity			
(1)	(2)	(3)	(4)	(5)	(6)
High (as designed)	70%	44%	70.2	2.2	**28.3%**
Moderate	50%	22%	46.1	1.4	**18.1%**
Low	30%	11%	41.1	1.3	**10.3%**

Source: Authors' calculations

We found that proper design and project planning can save up to RUR 70.2 million

(US$2.2 million) in energy consumption costs during the lifecycle of a kindergarten. With the kindergarten’s construction cost being RUR 1,1 million (US$34,580) per child, the potential savings as the result of the proposed new design are equivalent to 63 more places for children.

Conclusions

The kindergarten design project in the Khanty-Mansyisk Autonomous Region aims to introduce conceptually new child-centered learning environments to Russian architectural design practice. Such environments are consistent with the requirements of federal state educational standards for early childhood development in terms of accessibility, flexibility, and multifunctionality, and create opportunities for children to participate actively in their personal development. These changes in the design of ECD facilities will provide more learning opportunities, encourage better communication among children and between the children and the teachers, and enable the optimal use of the built space for each child. In traditional kindergartens, indoor space was used ineffectively, but the new design will make it possible to create flexible and larger spaces for children to play – increasing from an average of 2.5 square meters to 10.5 square meters of active space per child. At the same time, the footprint and the overall space of the building will be decreased from 4,713 square meters to 3,238 square meters in the new kindergartens.

The cost-benefit analysis of the design interventions and the application of energy-efficiency technologies give us a preliminary understanding of the potential economic outcomes of the pilot project. The new energy-efficiency concept will reduce the costs of using and operating the buildings. In addition, optimizing the space might also reduce the construction costs of the building. Our research findings suggest that the decreased consumption of electricity and thermal energy in the proposed new kindergarten could generate up to RUR 70.2 million (US$2.2 million) in savings over 50 years, including lower operating costs. This finding sends an important message to other public building developers about the need to focus on getting "more from less" from public spending.

It is important to note that the approach that we have described may be profitably applied not only in other regions of Russia but also in many countries of Eastern Europe and Central Asia. These countries still use the traditional approach to the spatial organization of ECD facilities and do not analyze potential expenditures based on the concept of the buildings' lifecycle.

When the new kindergarten is built, this is likely to add additional variables to the cost-benefit analysis model and to affect our final calculations and results. It will be useful to undertake a post-occupancy evaluation of the newly constructed kindergarten that includes all active users of the facility: children, teachers, administrative staff, and parents to test our hypotheses and to provide additional quantitative and qualitative information for further research.

The creation of the new kindergarten may also be a good time to start experimenting with and changing current teaching practices. Teachers will have to learn how to use the new spaces in their daily teaching activities and ensure that they are being used effectively and are meeting the needs of the children. The municipality of Beloyarski City may wish to analyze, select, and promote best practices within the region and later across the country.

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