Expert Recommendations for Energy Improvements in Educational Facilities: Case Study- School Buildings in Azerbaijan

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Abstract. Energy efficiency and resource saving are the key parts of the state policy in Azerbaijan. They cover all areas of the economy, including the building industry and the educational institutions. Therefore utilizing of innovative architectural design and construction strategies, energy-efficient engineering equipment and renewable energy sources should be raised to the level of the current requirements. In pursuit of this aim, examining and evaluation energy consumption in the educational buildings at their operational stage are ones of the contemporary issues and offering recommendations by the implementation the energy improvements is crucial. This article makes research to find energy efficient opportunities and then suggest proper measures and recommendations for educational buildings, what solutions can be used in schools to reduce their energy consumption. There were examined some school buildings in different climate regions of Azerbaijan. There had been performed energy auditing of them and the results were processed by software. Technical data and results for 2 school buildings in Ujar and Lankaran are given here. The recommendations for energy improvements in educational buildings were proposed by the local experts- architects and auditors. Findings can be used for fulfilling a multi-disciplinary energy audit of any educational buildings.

1. Introduction
Energy efficiency and resource saving are the key parts of the state policy in Azerbaijan. They cover all areas of the economy, including the building industry and the educational institutions [1]. The durable progress of modern cities and settlements and their consistent development strategy has a close connection with energy efficiency and usage degree of renewable energies [2]. Nowadays, the main energy consumers are buildings, industrial enterprises and vehicles. According to the information of the state statistical committee up to 47% of initial energy consumed in Azerbaijan is used for the communal needs of buildings and a great part of this energy is mainly utilized for heating of the residential buildings and lighting of the public buildings including educational institutions [3-5]. As seems, there is a tremendous energy saving possibilities in buildings, also in educational institutions. Heat and electricity are the most wasteful items for buildings [6-7]. Utilizing of innovative architectural design and construction strategies, energy-efficient engineering equipment and renewable...
energy sources should be raised to the level of the current requirements. In pursuit of this aim, examining and evaluation of energy consumption in educational buildings at their operational stage are ones of the contemporary issues and offering recommendations by the implementation the energy improvements is crucial [8].

This article makes research to find energy efficient opportunities and then suggest proper measures and recommendations for educational buildings, what solutions can be used in schools to reduce their energy consumption. There were examined some school buildings in various climate regions of Azerbaijan (figure 1,2). There had been performed energy auditing of them and the results were processed by software. Technical data and results for 2 school buildings in Ujar and Lankaran are given here. The recommendations for energy improvements in educational buildings were proposed by local experts- architects and auditors. Findings can be used for fulfilling a multi-disciplinary energy audit of any educational buildings.

Figure 1. Case study- school buildings in Ujar and Lankaran.

Figure 2. Boiler houses of the school buildings in Ujar and Lankaran.

2. Methods
Low energy requirement or energy-efficient building means such building that keeps indoor climate indicators conforming to the construction norms, standards and codes but they use less amount of energy for heating, ventilation, cooling, lighting and other services in comparison with the operated buildings. For example, according to average construction indicators in America, when new or renovated buildings utilize up to 15% less energy in comparison with the operated buildings they are considered like energy-efficient buildings [5]. The energy-saving potential of school buildings by using proper architectural-planning-design solutions and modern technologies, such as energy-efficient heating and mechanical ventilation systems, proper natural passive ventilation strategies, optimal building enclosure construction materials and components can be used successfully.
A lot of factors have an influence on energy consumption used for heating, ventilation and cooling of school buildings. Major factors are: climate indicators of the construction region, height and form, compactness of the building, orientation of the building sides to the cardinal points, utilizing of the renewable energy sources, correct design and operation of ventilation system, the existence of internal heat sources and recovery energy from them, application of the proper insulation materials for building envelope, using of more efficient window and door types, area of glassing surface and level of natural illuminance, selection of facade color and so forth [8].

The energy gains and losses of any building are completely connected with the local climate conditions and features, that is why it is needful to take into attention both the building location and climate characteristics for all architectural-planning-engineering solutions. Main indicators of design climate conditions for given Ujar and Lankaran regions are presented in table 1.

**Table 1. Design climate conditions.**

| Indicator, unit                              | Ujar | Lankaran |
|---------------------------------------------|------|----------|
| Average design external temperature, °C, for winter | -10  | -4       |
| Design internal temperature, °C             | 22   | 22       |
| Average wind speed for winter, m/s          | 4    | 4.7      |
| Prevailing direction of winds in wintertime | North-East | South-West |
| Average design external temperature, °C, for summer | 31.2 | 37.8     |
| Average wind speed for summer, m/s          | 2    | 2        |
| Average relative humidity for winter, %     | 69   | 75       |
| Average relative humidity for summer, %     | 39   | 53       |

According to the valid construction codes, average indoor air temperature in the educational buildings should be +(20-23) °C, air relative humidity should be within range 40-60%, speed of the air flow- 0.1-0.2 m/s. The quantity of the required fresh air in classrooms and maximum density of carbon dioxide gas emissions depend on age of the pupils and there are depicted on figure 3 [9].

**Figure 3.** Amount of required fresh air in classrooms and maximum density of carbon dioxide gas emissions depend on age of the pupils

For a number of school buildings in different climate regions of Azerbaijan there were carried out multi-disciplinary detailed energy auditing by local internationally certified experts from Azerbaijan University of Architecture and Construction on the based of new methodology developed by them. Measurements of the indoor climate indicators had been carried out by the multi-function measuring
instrument Testo 435. Thermographic camera was used getting heat losses from the junctions on the building envelope.

3. Results
Several measures were taken and proposed in relation to the architectural-planning-design solutions, the building envelope structures, the engineering-communication systems, operation and maintenance of school buildings on the base of investigations conducted to enhance indoor air quality and cut down energy consumption. The recommendations concerning of energy-efficient actions of educational buildings and facilities are given here.

3.1. Architectural-planning-design solutions
As part of the general concept of energy-efficient educational buildings the architectural solutions are defined by next measures that increase the thermal efficiency of the buildings [10] choosing the location of the building, taking into account:
- the landscape, that reflects the influence of the relief, the presence of reservoirs, the nature of greening;
- the existing development in the area of the proposed construction, that takes into consideration the influence of development on the microclimate, especially in urban conditions: amount of solar radiation, air temperature, wind speed and direction.

Based on the results of the studied buildings, the authors gave recommendations on taking into account the above principles. General concept of architecture formation of educational buildings for Ujar and Lankaran regions combines the principles of thermal zoning and the use of "buffer zones" accounting for amount of solar radiation and wind direction and speed [11]. It is shown on figure 4.

Action plan proposed for enhancing of energy efficiency for new and existing educational facilities consists of the next parts.

**Figure 4.** General concept of architecture formation principles of educational building for climate conditions of Ujar and Lankaran.

- auxiliary rooms and utility premises, main classrooms, -buffer zone- neutral area, glazed space, - heat core, greening, entrance,
- prevailing direction of winds in wintertime
3.2. Building envelope

3.2.1. Outside wall structures. Repair of joints, cracks, local deformations, sealing of thermal bridges, filling of holes, restoration of cladding surfaces and architectural elements of the facade, considering the possibility of placing an additional insulation layer on the north facade, subsequent painting of the facade, repair of the rainwater pipes, cleaning of natural ventilation shafts and flue channels [12-13].

3.2.2. Ceiling structures. Filling of cracks and holes in reinforced concrete structures, examination of steel dams, wooden constructions against fire and saturating fireproof mortar on wooden structures, repairing roofing, adding an insulating layer on the roof- local gravel or mineral materials.

3.2.3. Floor construction. Repair of floor, insulation of floor in toilets, considering the opportunity to add insulation layer from lower surface (as suspended ceiling) in buildings having occupied but unheated premises.

3.2.4. Window, exterior doors, entrance. Creation of tambours for entrance, providing of the tightness of doors and windows, utilizing of sun protective equipment on windows, replacement of single-glazed windows with double-glazed ones, filling of the volume between panes with argon or krypton gases.

3.3. Engineering- communication systems

3.3.1. Heating system. Putting any reflective insulation layer behind the heating devices under the windows, replacement of the steel pipes with non-corrosive more durable metal-plastic pipes, covering the pipes in basements with a thermal insulation layer, application of measuring and regulating devices.

3.3.2. Ventilation system. Use natural ventilation channels in the classrooms and toilets, mechanical ventilation system in kitchen, showers, laboratories, local ventilation in dining-rooms and kitchens, recuperative heat exchanger. It is recommended to use zoned ventilation and hybrid ventilation strategies, which imply mixed regime ventilation by suitable combining mechanical and natural ventilation. As energy saving solution in school buildings can be used demand control ventilation systems based on CO₂ emissions and excessive humidity in premises. For the gyms, meeting rooms and conference halls if they are located on the upper floor it is suitable to install a deflector which substantially enhances amount of the removed air without energy consumption.

3.3.3. Lightening. Provide left-sided natural lighting in the classrooms, double-sided natural lighting in the workrooms and gyms, use the environmentally friendly fluorescent lamps for artificial lighting of the educational rooms.

3.3.4. Water supply system. Drinkable water, hot water, sewerage and rainwater systems must be in working condition conforming to the construction norms. Washing stands, toilets, medical premises must be provided with cold and hot water constantly. Alternative energy sources are expected to be used for getting of hot water. Prevention of all leakages, examination of working condition of siphons and pumps, installation of meters and water-saving taps. Give information to pupils about financial and ecological effect of efficient water use.

In order to decrease energy costs spent for building envelope and engineering communication systems, their daily, monthly, seasonal exploitation and energy monitoring should be conducted correctly. Following the operation and maintenance instructions can reduce the consumption of energy resources (electricity, heat) and the negative impact on the environment and increase building life cycle, provides stable educational conditions.
4. Discussion
The author team suggests the integrated measures towards energy efficiency and the expansion of environmental education in the schools. These measures should be reflected in the educational programs, extracurricular activities and in the school textbooks. International experience shows that reflection of the environmental education on different stages of learning process has more effective impact on the achievement of expected outcomes. [14]. Taking this into consideration, it's recommendable to apply the concept of the environmental education [15-16].

Technical recommendations on educational facilities:
- develop of scientifically grounded architectural-planning-design solutions and identification of a methodology for the consistent architectural design of them;
- implementation of the research results in the design in order to confirm the effectiveness of the established principles of architectural solutions for energy-efficient buildings;
- carry out energy audit to realize actions to reduce heat losses to get better indoor environment;
- use pilot projects for the modernization of educational institutions;
- implement special educational activities by institution administration for sustainable use of natural and energy resources;
- share the information about the achievements with the neighborhood institutions;
- provide energy certification for educational facilities;
- develop special awareness-raising information materials and spread them to institutions.

5. Conclusion
The design, construction, maintenance and operation of educational buildings and facilities on the based of the principles of environmental friendliness, energy efficiency and optimum economy for the buildings is one of the top trend in modern social life in Azerbaijan. It performs the sophisticated interaction of a lot of the proficient specialists-exerts-architects, engineers and builders. Educational buildings account for one of the large part of the building industry that is why they consume a substantial proportion of the total energy use. At the time, the optimal architectural-planning-design solutions and proper operation of educational buildings are essential for getting indoor air quality. Presiders for enhancing energy efficiency of educational buildings suggested by local experts create a condition to increase building life cycle, to decrease the consumption of energy resources (electricity, water, heat) and their negative influence on the environment, to provide a high level of indoor air quality for the stable educational conditions, to decrease of exploitation costs of buildings.

Our experience has shown, to obtain proper features of buildings often can be affordable for private institutions due to the fact that the building owners are interested in to get a building energy certification. In some regions of Azerbaijan private educational institutions are becoming gradually an alternative to state educational ones. Local experts need to carry on to act in this direction of achievement of energy efficiency for educational facilities.

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