©2017 Published in 5th International Symposium on Innovative Technologies in Engineering and Science 29-30 September 2017 (ISITES2017 Baku - Azerbaijan)

New Methodology of Multi- Disciplinary Energy Auditing of Buildings in Azerbaijan

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Abstract

According to estimations by The State Statistical Committee of the Republic of Azerbaijan energy consumption by building sector adds up to nearly 47% of the country's final energy consumption, affirming it as the largest consumer in the final energy balance of the country. There is a great potential for increased energy efficiency as in new as existing buildings. The main goal of the energy audit is to get information about current status of the building, its systems and indoor climate, to develop energy efficient procedures (EEPs) applicable for this specific building, what investments will be needed to implement the procedures and how profitable they will be. To get reliable input information for the multi- disciplinary energy auditing should assess different systems of the building and propose tailored procedures. In the paper are given procedures, methodology, standards, schemes for energy auditing of buildings and expert recommendations. There are offered concrete recommendations and EEPs for buildings.

Keywords: building, energy audit, energy consumption, energy efficiency, energy efficient procedures

1. Introduction

In Azerbaijan Republic (AR) the buildings are the biggest consumer in the final energy balance of the country. Structure of the final energy consumption by sectors, in %, is: household- 41,4; commercial and public buildings- 5,6; transport- 28,6; industry- 16,1 [1]. Preliminary studies indicate that the specific energy consumption in buildings in Azerbaijan is comparable with Norwegian buildings where climate is severely colder [2]. Special heat consumption for heating of one square meter residential area is approximately 220 kWh in our Republic, but this indicator is less than 100 kWh in Norway. As seems, there is a huge potential for increased energy efficiency in the field of providing comfortable microclimate of buildings. Energy efficiency has therefore become increasingly important both for the economy and energy security of Azerbaijan. At the same time, before 2011 there were no any procedures, methodology, standards, schemes,

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tools and software for energy auditing of buildings and related regulations available.
Today there is a lack of systematic legislation in construction. Energy standards for energy efficiency of the building envelope are very low, standards are established currently for quality of HVAC systems in some types of buildings, such as schools, but not for their energy efficient equipment. One of the most significant issue is preparing and implementing legal, normative and technical acts/documents, introduce methods, tools and software for energy auditing and certification of buildings and increasing the capacities and skills on multi- disciplinary energy auditing. The Ministry of Energy (MIE) of Azerbaijan is responsible for establishing and implementation of the regulations related to energy efficiency and the control of the efficient use of the energy. State Committee of City Planning in conjunction with the Azerbaijan University of Architecture and Construction (AzUAC), International Eco-energy Academy and others Azerbaijan authorities and institutions prepared national regulations and standards related to energy efficiency in the building sector. More than 50 European and Russian technical standards and norms have been revised and developed for implementation them in national building codes, but final documents in terms of building energy codes have not yet approved.
The multi- disciplinary energy auditing issue is becoming more important in present time due to the fact that it can contribute to the actual saving of energy and natural resources and mitigation of environmental footprint of the building sector.
The paper has been divided in two parts. The first part of the paper is about factors influencing the energy consumption of buildings, energy performance indicators and requirements. In the second part of the paper it is given the detailed results of multi- disciplinary energy auditing of buildings in AR and expert recommendations.

2. Materials and method

In order to curtail the energy consumption in the existing and new buildings and improve the indoor environment it is necessary to apply energy auditing and carry out energy efficient technologies and procedures. Depending on the technical features and state of the building energy auditing can be simplified with accuracy of ± (10 – 15)% or detailed with guarantee and accuracy of ± (5 – 10)%. In general energy auditing of building consist of two main parts: first part is a study of the energy demands in the building structure and envelop and its all engineering systems such as air-conditioning, heating, ventilation, lighting, domestic hot water, high and low voltage electric installations, elevators (lifts), fire alarms and sprinklers, etc., the other part includes the recommendations for the efficient energy use, professional operation and maintenance routines, assuring planned and sustainable operation and maintenance of buildings. Each building is different that is why each project must be considered separately to find special energy savings possibilities. For detailed energy auditing all the features affecting the energy consumption of building and the indoor environment must be assessed: building enclosure (windows, outer walls, the lowest floor and roof), mechanical ventilation system, air conditioning, domestic hot water system, heating system, automatic control systems, various installations, lighting, etc. It is also necessary to take into account how the building and all engineering systems actually are being exploited and used, oftentimes not as they were designed. Through integration and interaction the passive and active energy- saving technologies with architecture design reasonably, the balance between creating a thermal comfort environment and building energy saving can be achieved [3].

2.1. Energy performance indicators

Energy performance indicators (EPI) provide a direct numerical expression of the energy efficiency of the building, for example: energy use per 1 m^2 conditioned area, kWh/m^2. The energy performance of a building is given by an overall EPI that is the weighted algebraic sum of delivered and exported energy per energy carrier. The overall EPI may represent: primary energy, CO_2 emissions, net delivered energy weighted by any other parameter defined by national energy policy (e.g. delivered energy or cost) [4]. This overall EPI can be complemented by other numerical indicators, for example: numerical indicator for energy use, energy need or delivered energy, thermal performance of the building enclosure (U-values, heat losses, etc.), losses through the heating system, efficiency of the domestic hot water system, automatic control or equipment, etc.

The requirements of the Directive 2010/31/EC (EPBD) [5] EN ISO 13790 for calculation of energy use for heating and cooling, EN 15603 «Energy Performance of Buildings – Overall energy use and definition of energy ratings», EN 15217 «Methods for expressing energy performance and for energy certification of buildings», SNIP 23-02-2003 [6] are issued to support calculations from the building energy needs to the primary energy as illustrated on Figure 1.

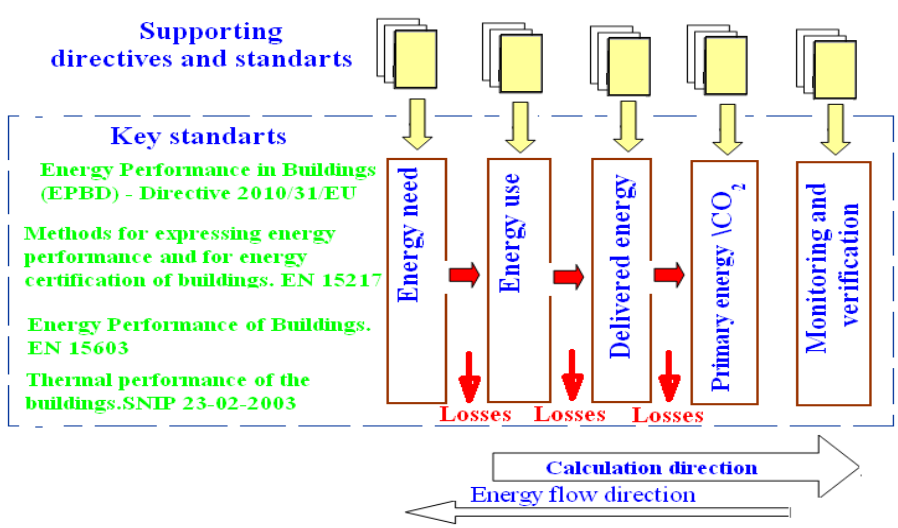

Figure 1. Scheme of calculation of building`s energy use from the building energy needs to the primary energy

2.2. Energy performance requirements

Energy performance requirements - energy performance target values for different building types could be provided for the overall EPI, total energy use, kWh/m^2a, or for each energy use for specific building services (heating, ventilation, domestic hot, cooling, lighting) for new and existing building (for different climatic zones, if applicable) [7]. Development of requirements on quality of building envelope and technical building systems are reported in Table 1.

Table 1. Energy performance requirements on quality of technical building systems and building envelope in Azerbaijan (extract)

Indicator	Energy performance requirements
U-value outer wall	$\leq 0{,}3\ W/(m^2\cdot K)$
U-value roof	$\leq 0{,}2\ W/(m^2\cdot K)$
U-value floor on ground	$\leq 0{,}2\ W/(m^2\cdot K)$
Max window area for residential buildings	18 %
Max window area for commercial and public buildings	25 %
Air tightness (at 50 Pa)	≤3,0 air changes per hour
Single family houses	$>3\ m^3$/hour per m^2
Heat recovery ventilation, /non residential	>70%
Compactness ratio SNIP23-02-2003	0,32 — 6-9- storey building

3. The energy audit

In order to get information about actual energy state of the building, its engineering installations and indoor environment to develop energy efficiency actions suitable for this concrete building is carried out the energy auditing. What investments will be needed to realize the energy efficiency actions and how profitable they will be the basic objective of the energy auditing. These actions also improve the indoor microclimate. Energy auditing is also needed to estimate the energy consumption of a building and present it in an energy certificate.

3.1. Procedures of energy auditing

In accordance with EN 16247:2014: Energy audit is systematic inspection and analysis of energy use and energy consumption of a building with the objective of identifying energy flows and the potential for energy efficiency improvements and reporting them [8]. Scheme of stages of energy auditing development process is shown in Figure 2.

Results of an inspection of the building, an evaluation and analysis of the existing situation are reflected in energy audit report. Recommended energy efficient actions with appropriate investments, savings and profit are presented in this one as well. Results and conclusion remarks of the energy auditing are also used to prepare the Certificate in accordance with to national and international codes. Energy audit is done by a specially trained and experienced energy auditors.

The summarize report of auditing consist on the next basic parts: detailed specification of running situation and energy consumption of building, identified energy efficient possibilities, description of the represented EEPs, environmental improvements, realization plan, financial plan, description of offered exploitation and maintenance and energy monitoring routines. EEPs is ranked according to their profitability.

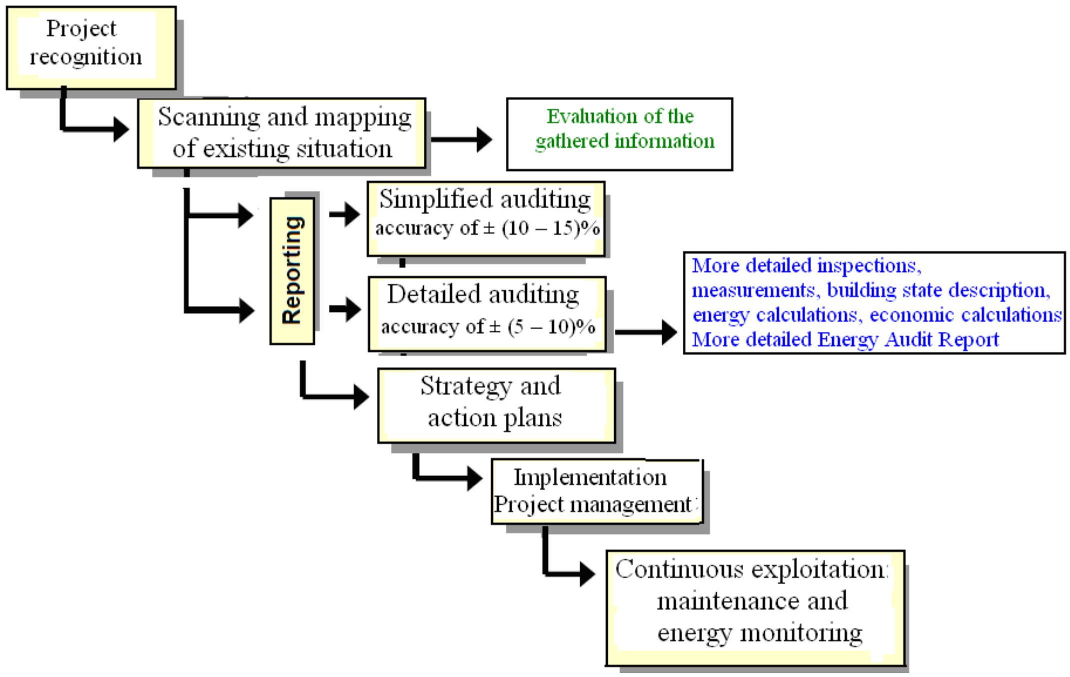

Figure 2. Scheme of stages of energy auditing development process

3.2. Methodology for energy performance calculations

On the base of software for energy auditing of buildings and calculation tools giving the possibility to perform energy and economical calculations, a number of different templates and manuals the authors were carried out multi- disciplinary auditing the follow buildings: in 5 secondary schools and in 1 vocational school in different climatic zones of AR, in 9- storey residential building in Baku, in kindergarten buildings, located in suburb of Baku and in study building of AzUAC. The energy audits has been carried out in accordance with the methodology indicated in the EN 16247:2014 Standard [5] and in SNIP [6]. In the energy audits conducted to study the energy efficiency of buildings the following aspects have been recommended to take into account: building typology, geometry, building enclosure (walls, roofs, windows, and floors); thermal properties, exploitation regime; occupants behavior; components, settings and characteristics of the technical building systems: mechanical ventilation, heating, air conditioning, domestic hot water, automatic control; heated volume definition and heating schedule; lighting; different facilities; energy consumption data in terms of m3 of natural gas; heating degree days. The data drawn from the outcomes have been incorporated in a special software and analyzed. Recommendations for improving energy efficiency in buildings have been developed with the support of the program. The recommendations comprise the investment required to improve the current situation and information on its maturity and economic service period. Based on the outcomes of the audit, reports on each building have been prepared separately. The reports reflect current situation in buildings, main factors for energy losses, as well as recommendations on elimination of the problems. There were carried out the economic calculations in means of software that included indicators of net saving (€/year), investments (€), profitability: payback time and net present value quotient. The energy auditing model has been designed by means of a special software. It is based on the quasi-steady-state calculation method [6,7].

Professional energy assessments include a blower door test, a thermographic scan, sometimes air infiltration measurement technique, etc. specific equipment such as, thermographic cameras, network analysers, gas combustion analysers, etc.

Software takes into account a number of parameters, starting from the thermal characteristics of the building envelope, climate conditions (including the influence of solar radiation) and ending with the influence of the automatic controls systems and generation efficiencies. Software takes into account the interconnection between the different systems and the energy saving procedures.

During energy auditing, beside energy calculations it is necessary to perform profitability calculation for the proposed energy saving procedures so the selected procedures are not only result in reduction of energy consumption, but also are cost-effective. Therefore special attention was given to profitability calculations and special software was provided. Energy auditing can be valuable tool to increase the profitability of the property.

3.3. Report of multi- disciplinary energy auditing

The case study is the study building of the secondary school No.4 located in the Ujar region of AR. Brief information about the school building: it was built and commissioned in 2011, it has 461 pupils, the total number of teachers and technical staff is 69.

Climate indicators in Ujar are: estimated temperature for summer 31.2^{0}C; average wind speed for summer 2m/sec; average relative humidity for summer 39%; estimated temperature for winter (-10)^{0}C; average wind speed for January 4 m/sec; average relative humidity for winter 69%. The heating period is 123 days. Heating degree days is 3690 (°C× day) **[6]**.

The building has a rectangular plan, it is a compact building, it is composed of two floors and attic. There is a boiler house next to the school building (Figure 3).

a)  b)  c) 

Figure 3. Energy auditing of school building: a- boiler house, b- attic with mechanical ventilation system, c- manifold of heating system in the boiler house

In table 2 are shown some main building data. The ratio of the transparent area to the opaque envelope is 20%. It consists of a reinforced concrete, the outside wall structure of the building is constructed with 0.4 m thick limestone and 0.08 m facing blockwork, U_{wall} =1.2W/m^{2}K, the roof U_{roof}=1.0 W/m^{2}K, double glazing windows with single air space with plastic frame with U_{wndows}=2.9 W/m^{2}K and with internal blinds.

Table 2. Building data, fragment of software

Conditioned area	2 475	m²	Walls	1 274	m²
Conditioned volume	9 390	m³	Windows	193	m²
Heat capacity	72	Wh/m²K	Roof	1 412	m²
Metabolic heat	8,0	W/m²	Floor	1 412	m²

The exterior doors are double layer wood U_{door}=3.4 W/m^{2}K. The floor of the the building's main entrance is marble (134m^2) other areas are covered by laminate and in each floor's classrooms as well. Minimum insulation procedures haven't been taken on external structures.

The heating system is double piped and distributed above. Heating devices are steel radiators. The heated water flows in non-insulated plastic pipes. The heating actual energy consumptions has been made by collecting of the gas bills of the last 3 years. The energy auditors did a premises- by-premises examination of the building to determine where the building is wasting energy, as well as a thorough examination of past utility bills.

The mechanical supply- exhaust ventilation systems for the school's sports and assembly halls, classrooms and cabinets have been designed and installed. In the construction process of the building, EEPs have not been taken in heating system and supply- exhaust ventilation systems. Recuperative heat exchanger, which is the main energy-saving equipment has not been designed. As the building is two-storey, heat losses through attic coating structures is huge. Heating system cannot keep the internal temperature in required level of (21-23^{0}C) [6]. The mean room temperature is 17^{0}C.

The following procedures are proposed to increase energy efficiency: thermal insulation of heating pipes with glass wool 0.05 m thickness between the boiler house and the school building, l=300m; thermal insulation of the attic roof of the building with mineral wool Rockwool with tickness 0.07m, in this case U_{roof} =0.4 W/m^{2}K; installation and commissioning of recuperative heat exchanger in the ventilation system; thermal insulation of the main pipe of ventilation system, introduction of an artificial lighing control. Thermal insulation of outer walls with mineral wool Rockwool 0.07m tickness in this case U_{wall} =0.45 W/m^{2}K. Energy budget by all budget items is shown in Table 3.

The final outcome of the report, carried out by a special software, is shown in Table 4

According to calculations the proposed energy efficient activities are not only improve the internal microclimate in the building, but also help reduce the building's costs for payment of energy accounts. Also, these procedures will reduce CO_2 emissions of 65 tons per year due to a reduction in gas consumption at the local boiler. Table 5 shows the final outcomes of the energy audit report, carried out by a special profitability software.

Table 3. Energy budget

Budget item	Standard	Actual		Baseline		After Measures	
	kWh/m²	kWh/m²	kWh/a	kWh/m²	kWh/a	kWh/m²	kWh/a
1. Heating	51,2	109,9	272 002	121,9	301 675	60,5	149 786
2. Ventilation (heating)	12,8	0,0	0	21,5	53 326	12,5	31 039
3. DHW	14,5	0,0	0	0,0	0	0,0	0
4. Fans and pumps	2,9	0,0	0	0,0	0	0,0	0
5. Lighting	16,6	6,6	16 406	6,6	16 406	6,6	16 406
6. Various	7,5	0,8	2 051	0,8	2 051	0,8	2 051
7. Cooling	0,0	0,0	0	0,0	0	0,0	0
Total	105,4	117,4	290 459	150,9	373 457	80,5	199 282

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Table 4. Energy efficient procedures

Parameter	kWh/m²	kWh/a	Real kWh/a
1. Heating: U - roof	52,24	129 299	129 299
1. Heating: Distribution efficiency	9,27	22 946	22 946
2. Ventilation (heating): Heat recovery	9,00	22 287	21 930

Table 5. The final outcomes

N	Energy efficient procedures	Initial invest ments, AZN	Energy saving kWh/a	Net profit, AZN/ year	Saved service time (Year)	Cost value payback time	Loan's Payable Time (Year)	Internal rate of return %	Net profi t	Net profit ratio
1	Insulation of heating pipes	2 000	22 946	459	15	4,4	4,6	21,7	3,8	1,89
2	Insulation of roof	15 000	129 300	2 586	20	5,8	6,3	16,4	26,2	1,74
3	Installation of recuperative heat exchanger	5 000	21 930	439	20	11,4	13,4	6,1	2	0,4

Technical recommendations on building:

1. carry out energy audits to improve indoor climate and study energy efficiency in buildings and implement procedures to eliminate energy losses;
2. install meters to ensure efficient use of water, gas, electricity, heat consumption;
3. take into account EEPs in designing and construction of new buildings;
4. pay special attention to the improvement of lighting and ventilation systems;
5. implement of special awareness-raising activities by administration for promotion of energy efficiency in buildings and work closely with civil society organizations in this trend;
6. issue energy passport for building;
7. develop awareness-raising materials about energy-efficiency and disseminate them.

4. Conclusion

Efficiency of energy and resource consumption in terms of providing of energy auditing of buildings defines one of the directions of a strategy of sustainable development of AR in the building sector. The energy auditing of buildings is a priority in AR, but the lack of properly technical norms makes its implementation slower than required. Our main goal in the building sector is approving of the new building standards, technical rules, and new technical comprehensive approaches for buildings concerning energy conservation and thermal performance of buildings. Besides lack of local regulatory framework and legislation norms there are many obstacles hamper energy auditing in buildings simultaneously: insufficient awareness of buildings owners about energy efficiency, lack of official promoting of energy efficiency projects by governmental structures, there is not enough specific equipment such as, thermographic cameras, network analysers, gas combustion analysers, etc. for an elaborate collection of data

The local auditors need to carry on further implementation of the developed methodology for calculating of the multi-disciplinary auditing in the buildings on the based national energy laws, to provide methodology on the local market. There are a lot of the training materials, the textbook for training of new specialists on Energy Auditing of buildings. Future auditors will be trained by AUAC`s experts.

This innovative methodology also can be a valuable instrument to spread the energy efficiency as an opportunity to increase the profitability of the buildings. Promoting to carrying out of regular energy auditing officials might encourage market converting, towards more efficient buildings, technologies and services, motivate behavioural changes in energy consumption by occupants and enterprises, as the result release resources for other targets. That is why we need to carry on development and implementation of the methodology of multi- disciplinary energy auditing. The first works in this direction are [9,10].

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