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A Case Study in Building Energy Passportization

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Abstract: The operating energy costs of buildings account for approximately 70–80% of the total costs throughout the entire life cycle of a building. From the moment putting the building into operation, it begins to consume energy, mechanical, electrical, and natural resources. In buildings, all construction and technical systems naturally degrade over time, both in terms of performance and in terms of efficiency, i.e., operating and maintenance building costs are rising, energy consumption is increasing, and microclimate quality is declining. As a solution to this issue, it is possible to consider building energy passport (BEP), as a tool to control the optimal building operation according to the indicators of the building passport and as an encouragement way of cities' sustainability. The building passport by its energy efficiency (BEP) and rational use of material resources is a special document – a certificate that contains information about the geometric and technical parameters of the building, its functional purpose, design solutions, thermal characteristics, and energy performance. This paper discusses the current state of the building passportization process in Azerbaijan and analyzes the existing shortcomings. Categories and component parts of BEP, types and levels of building information and data, scheme of inputs and extractions data during the building life cycle, key tasks of BEP, and strategic actions for the successful development of BEP are given. Building energy efficiency rating classes is calculated, and the main procedures to enhance the energy efficiency class are given. The requirements for experts who carry out the buildings' passportization are systematized.

Keywords: building energy passportization, energy efficiency, annual energy consumption, energy efficiency rating classes, material and energy resources

1. Introduction

On July 1, 2022, Azerbaijan adopted the law "On energy efficiency and efficient use of energy resources" [1], which is an addendum to the previous law "On the applying of energy sources in Azerbaijan" of 1996. According to the new law, the main areas of activity are:

- ubiquitous of buildings' passportization;
- applying active energy-saving procedures;
- installation of smart meters that determine the volume and cost of energy used for all types of buildings and facilities;

creation of the "Energy Efficiency Fund" (https://www.iea.org/reports/energy-efficiency-policy-in-azerbaijan-a-roadmap/setting-the-scene-energy-efficiency-in-azerbaijan).

The main tasks for the implementation of this law are:

- development of a regulatory framework in accordance with international experience in this area;
- stimulation and encouragement of the application of energy efficiency mechanisms;
- informing users about the environmental, social, and economic benefits of energy efficiency;
- training of personnel for the building passportization in the field of efficiency and rational use of natural resources;
- conducting regular building energy audits.

Although Azerbaijan owns significant fuel, energy, and material resources, the problem of their efficient accounting and optimal consumption is quite relevant today [2]. As in many countries of the world, most of the country's final energy consumption comes from buildings, construction structures, and facilities: generators, tanks, towers, utility lines, drainage pipes, etc. For Azerbaijan, this figure is approximately 45% (Figure 1). Therefore, increasing building energy efficiency requires significant efforts to implement efficient measures, which include building energy passportization [3].

The building energy passport (BEP) provides the key information and documentation on the building energy performance, which demonstrates code compliance. It can be applied to any building type [4]. It plays a valuable role in increasing the accessibility of information to a wide range of participants in the construction industry. Without accessible data, distinguishing an energy-efficient building from any other is impossible. Improving information flow is a necessary part of improving the quality assurance system of buildings and the

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Figure 1
The main energy consumers in Azerbaijan: 1 – buildings, 2 – industrial facilities, 3 – transport, 4 – others

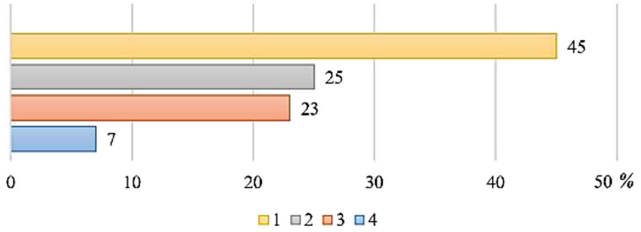
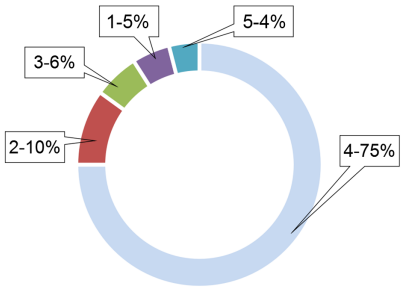


Figure 2
Building life cycle stages and their percentages of energy consumption



construction industry market as a whole. However, there are some obstacles to the implementation of BEP [5]. The article recommendations focus on reducing them.

This paper discusses the current state of the process of building passportization in Azerbaijan and analyzes the existing shortcomings. Categories and component parts of the building passport for energy efficiency, types and levels of building information and data, inputs and extractions data during the building life cycle, key tasks of BEP, and strategic actions for the successful development of BEP are given. Building energy efficiency rating classes is calculated, and a list of the main procedures to enhance the energy efficiency class is given. The requirements for experts who carry out the certification of buildings are systematized.

2. Literature Review and Research Methodology

To study the stated task, a literature review was conducted to study the experience of foreign countries in this area and an analysis of the situation in Azerbaijan was carried out. The review was based on materials from the Web of Science, Scopus, and other databases to familiarize with publications on the reference topic. Many years of experience of the author of the paper as a certified energy auditor of the international category (ENSI, Norway) also served as a source of information for this study.

Every building has its own life cycle, which includes the following stages [6]:

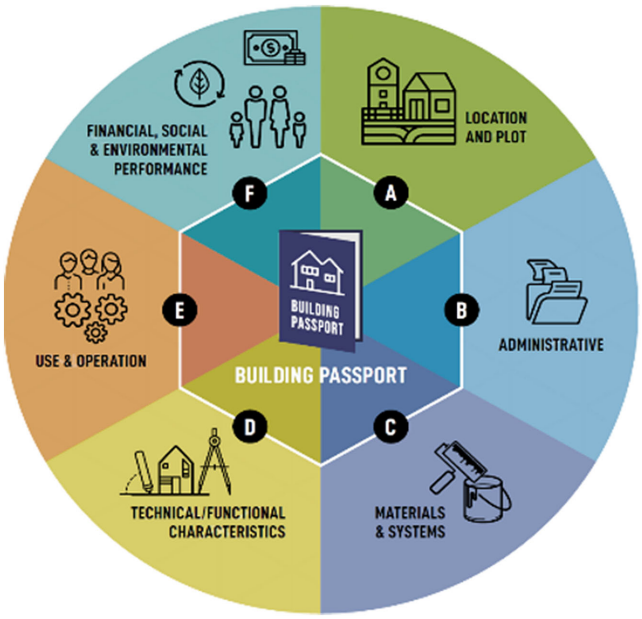
1) production and transport of building materials and equipment,
2) design,
3) construction,
4) operation, modernization, reconstruction, renovation,
5) demolition of a building that has exhausted its potential (Figure 2).

According to experts, the operating energy costs of buildings account for approximately 70–80% of the total costs throughout the entire life cycle of a building [7]. From the moment the building is put into operation, it begins to consume resources such as energy, mechanical, electrical, and automatic [8]. All building and technical systems naturally degrade over time, both in terms of performance and in terms of their efficiency, i.e. operating and maintenance costs are rising, energy consumption is increasing and the quality of the microclimate is declining [9]. As a solution to this problem, passport of buildings for its energy efficiency can be considered, which allows to control the building operation in accordance with passport indicators [10].

The building passport for energy efficiency (BEP) and rational use of material resources is a special document certificate that contains information about the geometric and technical parameters of the building, its functional purpose, design solutions, thermal characteristics, and energy performance (Figure 3 [11]). The composition and content of the energy passport of the building are given in the paper of Dmaidi et al. [12]. The BEP is compiled based on the results of an energy inspection to assess the efficiency of consumed energy and material resources and contains recommendations for the use of energy-saving procedures and information on the building efficiency class.

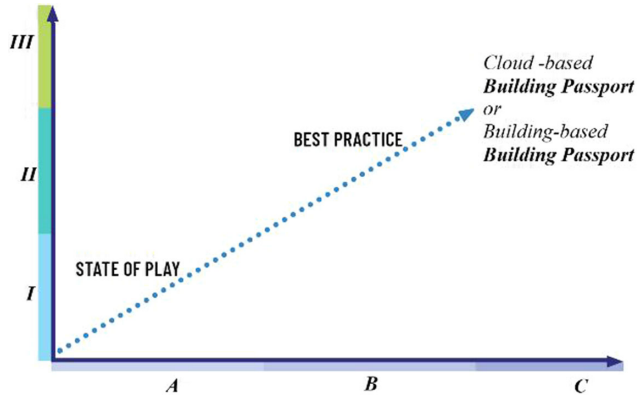
In many countries in Europe, BEP is mandatory for residential buildings and even individual apartments, such as in Germany. According to the Energy Efficiency Law of 2022, the next generation BEP is a comprehensive step-by-step roadmap for the long-term operation of a building for 15–20 years, if a building needs to be renovated while ensuring optimal indoor comfort parameters or the required microclimate indicators with individual solutions for each specific building. BEP shows the energy quality

Figure 3
Categories and component parts of BEP



of a building and includes types and levels of building information and data (Figure 4 [13]).

Figure 4
Types and levels of building information and data



It must be admitted that the process of passportization for residential buildings in Azerbaijan is not carried out. There are isolated cases of old buildings – two nine-storey buildings in a residential area of Baku and one architectural house in the suburbs of Baku in the village of Mardakan [14]. For industrial buildings and structures, certain activities are already planned in light of the 2022 Energy Efficiency Law. On the part of the specialists of the Azerbaijan Architecture and Construction University, a methodology for carrying out the passportization of buildings is being developed; it is proposed to conduct a series of training for local specialists on building energy auditing and following passportization, including the involvement of foreign specialists and companies.

3. Results and Discussion

Since 1996, Azerbaijan has applied the law "On the use of energy resources of the Republic of Azerbaijan" almost similar to the new one. It included the following issues:

- the mechanisms of control over the consumption of energy resources by state structures were considered;
- measures were taken to account for energy resources;
- the use of BEP was of a recommendatory nature;
- there were proposals to attract foreign specialists and investments;
- some attention was paid to the training of the national staff of energy auditors.

The existing passportization system before the adoption of the 2022 Energy Efficiency Law had mainly the following shortcomings:

- only individual buildings were subjected to an energy audit followed by certification;
- there was no regular monitoring of structures and engineering systems;
- due to the lack of technical data and indicators of the building in electronic format and their unsystematic storage, there was no organized exchange of documents, or information between specialists in different areas, and the search for the necessary information slowed down.

Therefore, the main trends in the widespread introduction of passportization after July 2022 are as follows:

- to adopt and implement the best world experience in this type of activity; to use a single form of certification, as a model, and to use the energy passport of buildings in Russia or Germany [15];
- to conduct the process of passportization in stages, starting with public buildings, initially buildings of industrial enterprises (SNiP 23-02-2003, Russian acronym, Construction Norms and Regulations, "Thermal performance of the buildings, In Russian, vol. 91, p. 67, 2003). The use of a digital building passport will help to eliminate the shortcomings and problems listed above. An electronic building passport (EBP) is an information-automated interactive building model that stores all catalogs with design, technical, operational, graphic, and calculation documentation (GOST 26253-2014, Russian acronym, Construction codes, "Buildings and constructions. Method for determining the thermal stability of enclosing structures", in Russian, 211, p.77, 2015). With the help of BEP, it is possible to quickly assess the current state of the building in terms of the state of structures and their thermal parameters: outside wall insulation, facing materials used, foundation and roof insulation, type of glazing, frame for windows, etc., and propose appropriate energy-efficient measures [16].

The EBP contains a section on the thermal characteristics of the applied building materials and engineering equipment. The new law recommends using certified building materials, equipment, and appliances, i.e., having a technical passport, which contains the technical certificates of all building elements, including heating, ventilation, air conditioning, refrigeration, electrical installation, plumbing, and instructions for their servicing, operation, maintenance, and repair. Just as a building data sheet provides information on its energy performance, an equivalent building material data sheet provides detailed information on the thermal and other important characteristics of the materials, and especially on the recyclability and reusability, which facilitates the recycling of materials at the end of a building's life cycle, i.e., the trend of non-waste demolition and reconstruction of buildings are maintained, which is significant from the view of their environmental friendliness. Cycles of data input and retrieval throughout the life cycle of a building are given in Figure 5.

The EBP also contains a section on building energy efficiency class, which reflects the result of the application of cumulative energy-saving measures taken at the design and construction stages, carried out during operation. The most modern way to determine the energy efficiency class is the calculation-experimental, i.e., accounting of all energy-using equipment, a detailed calculation of the energy consumption of engineering systems, and a detailed analysis of the efficiency of the building as a whole are carried out [17]. All necessary calculations are carried out by means of special programs and the energy consumption curve is modeled; as a result, the class of the building is established.

Building passport has extensive possibilities and benefits for stakeholders. It helps with optimization building management and decision-making. Key tasks are shown in Figure 6 [18].

In addition to the calculation and experimental methods, there are also the following ones for checking the energy efficiency rating class of buildings:

1) short-term measurements;
2) through a series of continuous measurements;

Figure 5
Inputs and extractions data during the building life cycle

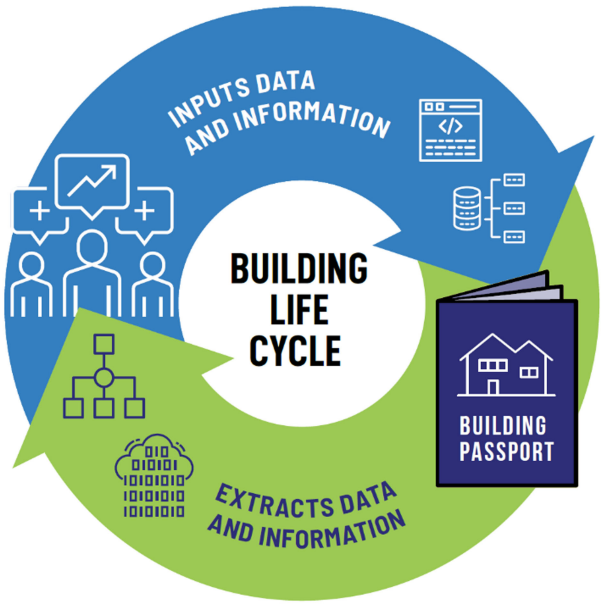


Figure 6
Key tasks of BEP

3) based on the analysis of the readings of energy consumption meters.

For the computational-experimental method of efficiency, estimating control and measuring equipment and instruments are used:

- thermal imager;
- flow meter;
- gas analyzer;
- range finder;
- pyrometer;
- lux meter, etc.

According to the calculation-experimental assessment method, the building energy efficiency rating class of a building is a generalized indicator of its quality [19], and it could be also referred that the implementation of measures for the increase of building energy efficiency, generally, has indirect consequence, in terms of beneficial influence, on the quality of the building, due to the materials used and adopted construction details, particularly in the building envelope, and to the systems applied. The building energy efficiency rating class is assessed by the deviation gap (Δ) of the actual specific building energy consumption (q) by q-normative. The class of the building is indicated by Latin letters A-G and is posted on the facade. The deviation interval is calculated by Equation (1):

$$\Delta = \frac{q - q_{\,normative}}{q_{\,normative}} 100\% \quad (1)$$

q is the specific annual energy consumption, containing t ventilation and heating, hot water supply, electricity costs, (kW h)/m^2; $q_{\,normative}$ is the standardized base level of the actual specific annual energy consumption, (kWh)/m^2.

Indicators of the total standard level of the specific annual consumption of energy resources and the corresponding interval of deviations of the actual specific energy consumption from the standard according to the energy efficiency classes are given in Table 1, according to the degree-day value for Baku's heating period, which equals early 2000°C day.

Table 1
The number of total specific annual energy rate of buildings by efficiency rating classes

Energy efficiency class of buildings	Specific annual rate of building energy resources, (kWh)/m^2 at baseline		Deviation value %
	For a 5-storey building	For a 9-storey building	
A++	47.83	44.98	−60
A+	55.82	53.59	−50
A	65.78	63.11	−40
B	76.74	75.67	−30
C	93.28	89.23	−15
D	109.56	104.72	0
E	137.06	131.27	+25
F	184.47	167.99	≤50
G	184.47	167.99	≥50

The presence of class B, A, A+, or A++ means that such a building saves 30–60% of energy resources due to the use of modern engineering equipment and optimal thermal insulation of external building envelopes [20]. A building with an energy efficiency index D allows you to save up to 15% of resources. The smallest energy efficiency class is G, i.e., half of the energy costs are lost. According to the new law, renovation works will be carried out in such buildings to upgrade the building envelope, energy meters will be installed, and motion tracking sensors and energy-efficient lighting lamps will be used. For new buildings, the energy efficiency class should be higher than class C (Table 1).

Buildings of levels D, E, F, and G are referred to as the low class. The author's practice shows that buildings built before 2011 in Baku, generally, do not meet the requirements of energy saving and energy efficiency.

The main procedures to enhance of energy efficiency rating classes of buildings include:

- facade regulation of heat and cold supply, i.e., different thermal conditions for the premises of the northern and southern facades;
- heat-reflecting glazing, which saves up to 25% of energy costs;
- mechanical ventilation with recuperation system;

- innovative systems for monitoring and recording energy consumption, tracking energy flows in automatic mode, recognition of leaks, unauthorized connections, quick response to emergency situations;
- Smart home system – remote control of equipment operation using a smartphone thermal insulation of the facade, which, although it is a laborious and expensive process, but allows to reduce heat loss up to 12%.

Figure 7 illustrates major procedures for realization BEP. BEP encourages the implementation of sustainable cities and communities (Figure 8).

Figure 7
Strategic actions for the successful development of BEP

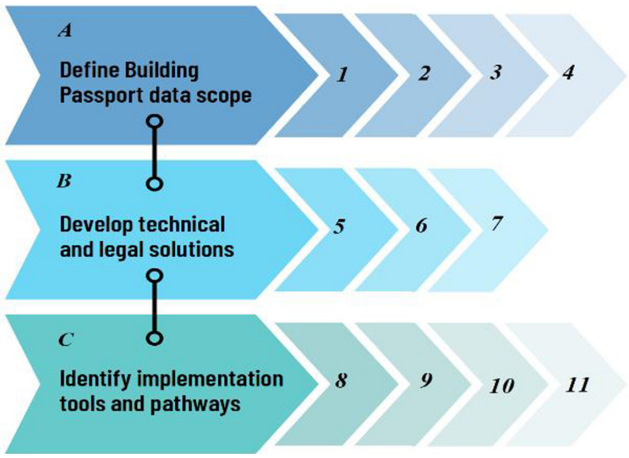
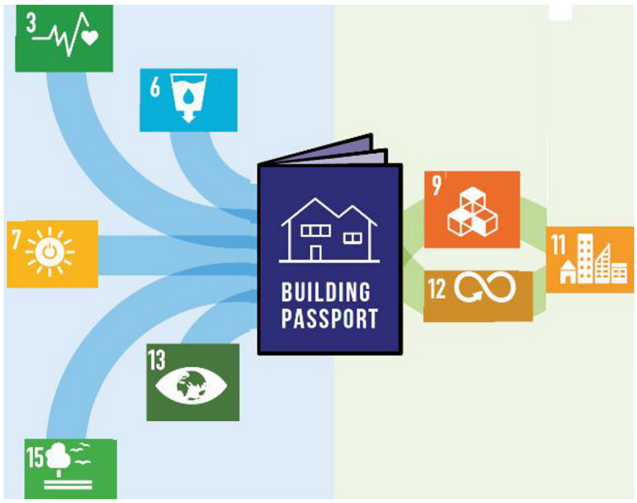


Figure 8
Encouragement of cities' sustainability



The need to ensure the proper quality of the building passportization process has made specialists endowed with very specific competencies in demand. Energy passportization experts are recognized as experts of the new generation. They must have different competencies. Specifications for specialists should have [21]:

- proper qualification;
- higher technical education;
- at least 3 years of experience in the specialty (design, supervision, control, construction management of buildings or their engineering systems or power systems), this requirement does not apply to university teachers in specialized specialties;
- certificate of completion of the course on energy audit of buildings, issued by an accredited institution, a recognized organization or an authorized body;
- professional skills, the specialist must:
- have the knowledge to calculate energy characteristics and energy efficiency indicators;
- have knowledge and qualifications in the technology associated with the surveyed object;
- know metering devices and measuring equipment;

have the skills to summarize the results and data.

4. Conclusion

Buildings and structures, as the largest energy consumers, have the greatest potential for energy saving, and therefore energy-saving measures in them are a priority. The main goal of Law on Energy Efficiency and Efficient Use of Energy Resources, which came into force on July 1, 2022 in Azerbaijan, is to reduce the consumption of energy and fuel resources by 30% by 2030. Active energy-saving measures include the building passportization for their energy efficiency, the installation of smart meters that determine the volume and cost of energy used, and the creation of an "Energy Efficiency Fund."

A building passportization which may allow to control the building operation, in accordance with passport indicators, could help to reduce the energy consumption mainly related to the degradation of building and technical systems over time; protect the environment in a negative context of declining quality of the microclimate; and promote cities' sustainability goals (Figure 8).

The above law established the registration principle of certification of buildings for their energy efficiency and also determined the procedure, promising deadlines, budgeting, and stages of certification of buildings of all types, starting with budgetary and industrial enterprises. The types of passports for buildings of various purposes are determined on the basis of a single form, European standards, and directives when maintaining the settlement part of passportization.

The competence of specialists in certification of buildings is ensured by the establishment of relevant qualifications:

- work experience,
- pre-qualification,
- mandatory completion of training programs,
- passing exams,
- continuous improvement.

The following recommendations are intended to facilitate the development of a national BEP system:

1) Appoint and establish an expert group to steer BEP, to agree on the guidelines for an integrated documentary process which includes [22]:
   - The verification process, which contains documentary and inspection protocols for building audit;
   - Process of document management, which has capture and storage of inspection verification materials within BEP;
   - Document retrieval which contains inspection at the new construction and data analysis for sale.
2) Develop a specialized training course for local professionals depending on their skill level [23] and establish an appropriate training center in collaboration with international experts;

3) Develop the legislative system related to BEP in general and introduce the legislative and economic incentives from the state through subsidizing, introducing a simplified taxation system, and paying part of the costs of BEP.

This study analyzes the situation in Azerbaijan, calculates the specific annual energy consumption by energy efficiency class, and systematizes the requirements for specialists in the certification of buildings. The results of this study will contribute to the acceleration and systematic process of certification of buildings and improve their energy efficiency.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by the author.

Conflicts of Interest

The author declares that she has no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

Author Contribution Statement

Samira Akbarova: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Project administration.

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