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Research Article

Certification of Buildings and Measures of Energy Efficiency Class Improvement

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Abstract

Nowadays, the problems of energy efficiency and energy saving are found in different spheres of construction. Various energy-efficient technologies are used to reduce energy consumption. The certification process is carried out at different stages: design, construction and reconstruction, which is leading to improvement of energy efficiency of the building, etc. The article covered the European standards that determine the coefficient of seasonal use of thermal energy (E), as well as the current energy efficiency classes of the Republic of Armenia. Both the EU and the Republic of Armenia have tightened requirements for enclosing structures. In Armenia, the thermal characteristics of enclosing structures can be improved by 15% to 41% depending on the degree-day value of the heating period. The value of the specific characteristic of thermal energy depends on climatic conditions, space-planning solutions, orientation of the building, etc. The standardized value of this characteristic for heating and ventilation varies from 0.414 to 0.336 W/m^3 ℃ depending on the area of the heated building and its number of storeys. And for a residential building with an area of 1000 m^2 and more, the non-standardized value does not depend on the number of storeys of the building. Classes of energy efficiency of buildings are determined by the value of the deviation of the calculated value of the specific characteristic of the consumption of thermal energy for heating and ventilation of the building from the standardized one. For determining the class of energy efficiency, the article considers a one-story residential building without thermal insulation and with thermal insulation of enclosing structures. To increase the energy efficiency class of a building from D to C, it is necessary to improve the thermal characteristics of the enclosing structures, i.e. reduce heat loss of buildings by 30% or more.

Keywords

Energy Efficiency, Energy Saving, Certification of Buildings, Degree-day of the Heating Period, Thermal Characteristics, Enclosing Structures

1. Introduction

Increasing energy efficiency and energy saving are gradually becoming the norm in our life. Both political and economic barriers arise to the implementation of energy conservation and energy efficiency. The development of civilization

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has led to environmental problems, lack of energy resources, and so on. The world community is faced with the need to take serious measures to reduce energy consumption both in industry and in the housing sector [1-3]. Nowadays, two areas of energy efficiency improvement are the most promising.

1) saving energy resources by minimizing energy consumption and energy losses in buildings and structures,
2) application of new technologies that use renewable energy sources.

The energy efficiency of a residential building is ensured by the implementation of the following measures:

1) optimal thermal insulation: the use of enclosing structures with high thermal characteristics,
2) energy-saving windows: double-glazed windows, windows with inert gas, as well as heat-reflecting glass coatings,
3) energy-saving systems: use of ventilation emissions by heat recovery,
4) renewable energy sources: use for heating and domestic hot water supply [4, 5].

Most of the apartment buildings in Armenia were built 30-60 years ago, and now work is underway to strengthen them, extend their service life, reduce heat loss and heat gain by modernizing them according to energy efficiency standards. In Armenia, an average of $100 to $120 was spent on heating per month. For new buildings, as well as modernized buildings, the average monthly heating fee is $60. Energy efficiency programs are being implemented in different regions of Armenia: in Alaverdi, Tashir, Dilijan, Spitak, Berd, Gyumri, Kajaran, Ashtarak and other cities (Figure 1), and in Yerevan, there are not only energy-efficient residential buildings, but also kindergartens, sports schools and cultural centers. [1, 6].

Figure 1. *Modernized building in the city of Spitak [1].*

The main laws "About Energy", "About Energy Saving and Renewable Energy", etc. has adopted and is implementing in RA. In 2007, the National Program on Energy Saving and Renewable Energy was approved. In 2010, the National Action Plan on Energy Efficiency was approved, which provides for the development of new standards for energy efficiency in buildings. In 2011 the Five-Year Strategic Program for the Management, Maintenance and Operation of the Multi-Apartment Housing Stock of the Republic of Armenia was approved. In 2004, Armenia joined the IBC "Thermal Protection of Buildings" interstate building codes, which considered the requirements of the relevant EU documents, and the relevant document was prepared in 2008 within the framework of the UNDP/GEF heat supply project

In 2009, within the framework of the same project, proposals were developed for energy audit and certification of apartment buildings. In 2013, a draft of legal and institutional measures aimed at the development of energy efficiency in the field of urban development was developed. [7, 8]. In 2016, legal and institutional measures aimed at improving the energy efficiency of buildings [1] were developed, which are included in the requirements of building codes and legislation in the field of energy efficiency. But, unfortunately, these legislative documents specify only the requirements for enclosing structures of buildings and structures, and do not provide measures or measures to improve the energy efficiency class. This problem is important, since in Armenia old buildings need to be modernized and the energy efficiency class needs to be increased from a lower level to a higher one. The article discusses and provides an example of upgrading the class from a lower D class to a normal level. Since energy efficiency is an important area of development both in Europe and in Armenia, it is desirable to draw parallels between European and Armenian standards and types of certificates.

2. Materials and Methods

The following sources of information were used: European standards for energy efficiency of buildings, economic standards, and scientific publications on the topic. The standards were compared according to the following criteria: thermal insulation requirements, energy consumption calculation methods, energy efficiency classification.

In foreign countries with a mild climatic condition (Spain, France, Germany, the Netherlands, etc.), the requirements for the thermal resistance of enclosing structures are more stringent [9, 10]. For example, the heat transfer coefficient for windows ranges from 1.3 to 2.5 W/(m^2 ℃), and for walls and floors 0.17 W/(m^2 ℃), for roofing 0.09 W/(m^2 ℃), which led to a decrease in heat flow and an increase in the energy efficiency of buildings. In Armenia, to increase the energy efficiency of buildings, they also tightened the requirements for the thermal characteristics of the enclosing structures, and depending on the duration of the heating season, the required thermal resistance ranges from 1.8 to 4.6 (m^2 ℃)/W or the required heat transfer coefficient is 0.22 to 0.55 W/(m^2 ℃) [5].

The energy efficiency of buildings is determined by the coefficient of seasonal use of thermal energy (E): passive - E ≤ 15 kWh/(m^{2}year), energy-efficient - E≤ 70 kWh/(m^2 year), ordinary house - E ≤ 110 kWh/(m^2 year) [9, 10]. To assess the energy efficiency and class of buildings in European countries, it is customary to use the EP (Energy Performance) coefficient (Table 1), which determines the amount of electricity spent on heating, hot water, lighting, ventilation, and the operation of household appliances [10, 11].

Table 1. *Building class and energy efficiency coefficient (EP).*

Class name	Class of the building	Energy Efficiency Coefficient or Energy Performance (EP)
Passive	A	EP ≤ 0.25
Economical	B	0.26 < EP ≤ 0.50
Energy saving	C	0.51 < EP ≤ 0.75
Standard	D	0.75 < EP ≤ 1
Less energy-consuming	E	1.01< EP ≤ 1.25
Energy-consuming	F	1,26 < EP ≤ 1,50
The most energy-consuming	G	EP > 1.51

The energy efficiency of residential and public buildings in Armenia is assessed according to the current regulatory data of MSN "Thermal Protection of Buildings", which provides the classification of buildings: very high class (A++, A+, A), high (B++, B), normal (C+, C, C-), lower (D), low (E). Classes A, B, C are established for newly constructed and reconstructed buildings at the stage of project development and subsequently they are specified based on the results of operation.

The requirements for enclosing structures in Armenia are as strict as in European countries, these measures lead to improvement of thermal performance, as well as an increase in the energy efficiency class of buildings and structures. European standards have advantages, since they consider energy efficiency in a complex, taking into account the systems that provide a microclimate in the premises, and Armenian standards take into account only the loads on heating and ventilation. For clarity, Table 2 presents possible correspondences of energy efficiency classes.

Table 2. *Comparison of energy efficiency classes European Armenian.*

European		Armenian	
Class name	Class of the building	Class name	Class of the building
Passive	A	very high	A++, A+, A
Economical	B	high	B++, B
Energy saving	C	normal	C+, C,
Standard	D	normal	C-
Less energy-consuming / Energy-consuming	E, F	lower	D
The most energy-consuming	G	low	E

Within the framework of the project, studies were carried out to determine the class of the building depending on the value of the specific consumption of thermal energy for heating and ventilation of the building from the volume of the structure.

3. Results

The required heat transfer value is determined considering the simultaneous implementation of three requirements:

1) element-by-element: heat transfer resistance should not be less than the standardized value,

2) complex: the specific thermal protection of the building should not exceed the standard value,
3) sanitary and hygienic: the temperature on the internal surfaces of the enclosing structures should not be lower than the minimum permissible value.

In different regions of Armenia, the requirements for enclosing structures vary depending on the duration and average temperature of the outside air during the heating period, or rather, on the "degree days of the heating period". We carried out calculations to establish how this factor affects the thermal characteristics and how much it is necessary to increase the thermal insulation to ensure the required conditions. Figure 2 shows the normalized value of the specific thermal protection of the building from the heated volume of the building and the degree-days of the heating period.

It is evident from the graph that the standardized value of specific thermal protection decreases with an increase in the volume of the building and the degree-day value of the heating period, which leads to a tightening of the requirements for the thermal characteristics of structures from 15% to 41%.

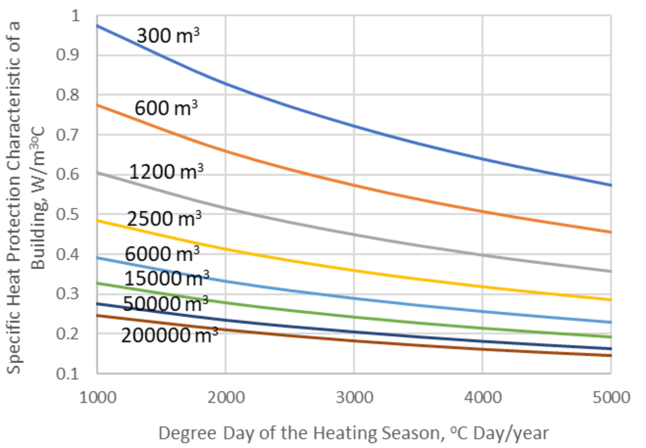

Figure 2. *Standardized values of the specific thermal protection characteristics of a building depending on the heated volume of the building and degree-days of the heating period.*

For example: assuming the internal air temperature of 20 ℃, the degree-day of the heating period was, for Yerevan D_{day} = 2660 ℃ day, Jermuk D_{day} = 4558 ℃ day and Gyumri D_{day} = 4177 ℃ day. [12]. Therefore, for a heated building with a volume of 300 m^3, the specific thermal insulation characteristic of the building for Yerevan is -0.76 W/m^3 ℃, Jermuk -0.6 W/m^3 ℃, and Gyumri -0.62 W/m^3 ℃.

The specific heat protection characteristic of building structures influences the determination of the thickness of the heat-insulating layer, and to assess energy efficiency it is needed to determine the values of the specific characteristics of thermal energy consumption for heating and ventilation of a building.

The calculated value of the specific characteristic of thermal energy consumption for heating and ventilation of the building depends on climatic conditions, space-planning solutions, orientation of the building, and thermal insulation properties of enclosing structures. Figure 3 shows the values of the standardized specific characteristics of thermal energy consumption for heating and ventilation of low-rise residential buildings from the area of the heated building.

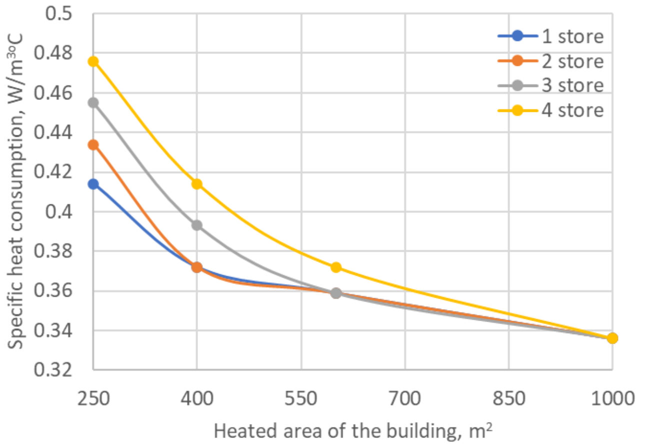

Figure 3. *Standardized specific characteristic of thermal energy consumption for heating and ventilation of low-rise residential buildings from the area of the heated building.*

As can be seen from the graph for a low-rise residential building with an area of 1000 m^2 and more, the standardized specific characteristic of thermal energy for heating and ventilation is 0.336 W/m^3 ℃, and does not depend on the number of storeys of the building.

4. Discussion

Considering the above data, calculations were carried out to determine the energy consumption of the building for heating and ventilation of low-rise residential buildings (Figure 4.) taking into account the climatic indicators of Yerevan.

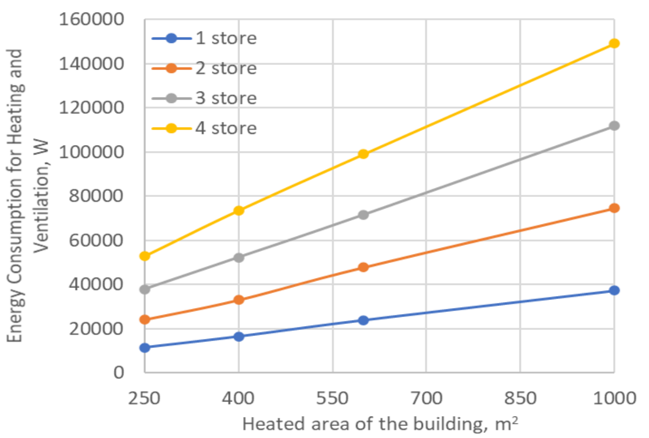

Figure 4. *Values of the building's energy consumption for heating and ventilation of low-rise residential buildings from the area of the heated building.*

From Figure 4 it is clear that for a residential low-rise building with an area of 250 m^2, for 1, 2, 3 and 4-storey buildings, energy consumption for heating and ventilation is respectively - 11488.5 W, 24087 W, 37878.6 W, 52836 W.

To assess the energy efficiency of a building and the energy saving class, it is necessary to determine the deviation of the calculated value of the specific characteristic of thermal energy consumption for heating and ventilation of the building from the standard. Figure 5 shows the calculated (base) value of energy consumption (11488.5 W) for a one-story building with an area of 250 m^2 and the corresponding energy efficiency classes.

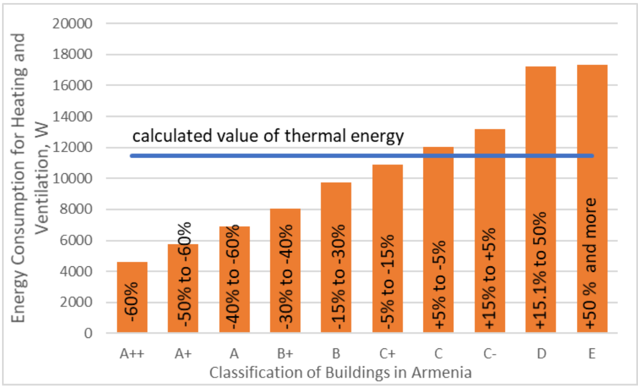

Figure 5. *The estimated (baseline) value of energy consumption (11488.5 W) for a one-story building with an area of 250m^2 and the corresponding energy efficiency classes.*

For example, let's consider a non-thermally insulated one-storey residential building with the following parameters: a=12 m, b=20.8 m, h=3 m, with an area of 250 m^2, the heat load for Yerevan is 17250 W, which corresponds to a lower D class of energy efficiency. By applying thermal insulation measures, it is possible to increase the energy efficiency class, according to the calculated data, when adding a thermal insulation (polyurethane) layer with a thickness of 60 mm, the thermal load of the building decreased to 11250 W, which corresponds to the energy efficiency normal C class [13].

In Armenia, as in European countries, a standard for energy efficiency certificates for buildings and structures has been developed, which is shown in Figure 6.

This document contains information on efficiency, i.e. energy consumption, which is necessary for heating and ventilation of the building. This certificate will allow us to compare the energy efficiency of different buildings.

In general, the necessary regulatory framework is being created in Armenia and specific measures are being implemented to improve the energy efficiency of buildings, which will reduce energy consumption, reduce greenhouse gas emissions and improve the quality of life of people.

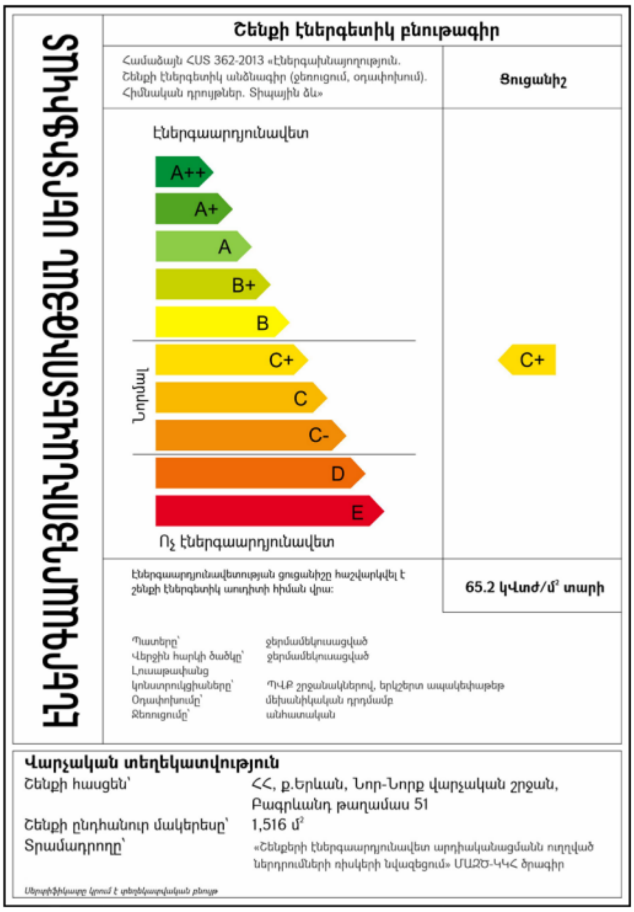

Figure 6. *Energy Efficiency Certificate Accepted in Armenia.*

5. Conclusions

1. Depending on the value of the degree days of the heating period, the thermal characteristics of the enclosing structures should be improved from 15% to 41%.
2. The standardized specific characteristic of thermal energy for heating and ventilation for a residential building with an area of 1000 m^2 and more does not depend on the number of storeys of the building.
3. To increase the energy efficiency class of a building from a lower D class to a normal C class and above, it is necessary to reduce the heat loss of buildings by 30% or more.

Abbreviations

NUACA	National University of Architecture and Construction of Ar-menia
IGN	Institute of Geological Sciences
NAS	National Academy of Sciences
RA	Republic of Armenia
E	Energy
EU	European Union
IBC	Interstate Building Codes
UNDP	United Nations Development Programme

GEF	Global Environment Facility
EP	Energy Performance
HGSV	Heat and Gas Supply and Ventilation

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Author Contributions

Naira Egnatosyan: Conceptualization, Data curation, Formal Analysis, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft

Siranush Egnatosyan: Formal Analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft

Lusine Martirosyan: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Resources, Validation, Visualization, Writing – original draft

Aleksey Rudomyotkin: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Software, Validation, Writing – original draft

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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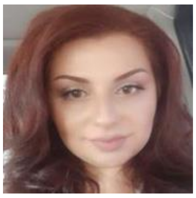
Biography

Naira Egnatosyan – Associate Professor of HGSV Chair, Junior Researcher of the IGS of the NAS of RA. The main scientific fields are energy efficiency, thermal protection, heating, ventilation and air conditioning of buildings and constructions. Took part in the scientific ISTC A787 project "Strategy for Development of Environmentally Safe, Cost Effective and Sustainable Energy Sector of Armenia in the Situation of Shutting Down of the Nuclear Power Plant". In 2022 took second place in the innovation technology competition and received the "Look into the Future" medal. Currently, the head of the internal grant competition is organized by the NUACA.

Siranush Egnatosyan – Associate Professor of HGSV Chair. In 2011 participated in and completed advanced training courses "Energy Audit and Audit Equipment", "ESCO Establishment and Basic Business", organized by USAID. In 2022 took second place in the innovation technology competition and received the "Look into the Future" medal. Currently is a researcher in the program "Maintenance and development of the Construction and Urban Economics Research Laboratory". The main research fields are energy efficiency of building using heat pumps systems and renewable energy sources.



Lusine Martirosyan is a teacher in HGSV Chair. In 2009 completed a bachelor's degree in the field of Thermal Power Plants from the Faculty of Energy of the National Polytechnic University of Armenia. In 2024 completed a master's degree in engineering from the Faculty of Construction of NUACA. The main subjects are automatic systems of domestic gas equipment, engineering systems, heating and cooling of buildings. Currently, research for the internal grant competition is being organized by the NUACA with the topic "Energy Certification of Buildings and analysis of Increasing energy efficiency".

Aleksey Rudomyotkin is a second-year student of the Master of Heat and Gas Supply and Ventilation of the Armenian National University of Architecture and Construction. In 2023, he received a Bachelor of Engineering degree in Water Supply and Wastewater Disposal from the same university. He is a participant in various research programs of the university and a practicing heating and cooling engineer. Currently, research for the internal grant competition is being organized by the NUACA with the topic "Energy Certification of Buildings and analysis of Increasing energy efficiency".

Research Field

Naira Egnatosyan: heating, ventilation, air conditioning, energy efficiency, building construction.
Siranush Egnatosyan: heating, ventilation, energy efficiency, energy saving, heat pump.
Lusine Martirosyan: heating, ventilation, renewable energy, building construction, thermal protection of buildings.
Aleksey Rudomyotkin: water supply, water disposal, heating, ventilation, energy protection of buildings.