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COMPARISON OF THE ENERGY EFFICIENCY OF RESIDENTIAL BUILDINGS IN AZERBAIJAN AND LITHUANIA

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Abstract. This study compares energy efficiency in residential buildings in Azerbaijan and Lithuania, regions with contrasting climates, to highlight how local conditions influence energy demands. Employing simulation data, we found significant differences: Azerbaijan's buildings require more energy for cooling, while Lithuania's need more for heating. The analysis indicates a 26.5% greater cooling demand in Azerbaijan and a 13.8% higher heating demand in Lithuania, underscoring the necessity of region-specific energy efficiency strategies. Additionally, the study explores the reduced energy consumption by fans and pumps, suggesting the potential for passive ventilation or the strategic deactivation of systems to conserve energy. These findings offer crucial insights for developing tailored, sustainable infrastructure in diverse climatic conditions.

Keywords: energy efficiency, residential buildings, Azerbaijan, Lithuania, thermal properties, cooling and heating, climatic differences**.**

1. Introduction

To combat climate change, it is crucial that the building industry is sustainable and has a portfolio of buildings that are more energy – and carbon-efficient. In 2020, buildings were responsible for 42% of the EU's total energy consumption and about 35% of energy-related greenhouse gas emissions (European Environment Agency, 2023). The aging infrastructure, with a substantial share of buildings over 50 years old and lacking in energy efficiency, presents a unique challenge across the continent, including in Lithuania and Azerbaijan. The EU has initiated ambitious policies aiming for a substantial reduction in energy consumption and greenhouse gas emissions from buildings. These policies provide a framework that countries like Lithuania and Azerbaijan can adapt to their specific conditions, addressing their unique challenges in improving residential building energy efficiency within their different climatic, historical, and socio-economic contexts. In addition, around 35% of the total stock of residential buildings is older than 50 years, and more than 75% are regarded as having poor energy efficiency (Economidou et al., 2011). The European Union (EU) has established two major declarations to guarantee significant energy savings and successive CO_2eq. emissions in buildings. These decrees are the Energy Efficiency Directive (EED) and the Energy Performance of Buildings Directive (EPBD) (Dulian, 2024). As part of its regulations, the EPBD mandates that all newly constructed public buildings must be practically zero-energy by the year 2025 and that all newly constructed structures must meet the same standard by the end of the year 2030. There is an abundance of widely accessible and, in many instances, economically feasible technology solutions that can reduce the energy demand of a building to Nearly Zero-Energy Buildings (Nzeb) requirements (Ostermeyer et al., 2017). Even though EU has ambitious goals to cut carbon emissions, only about a third of the residential building stock is replaced every year (0.4%–1.2%), and less than 5% are meeting the requirements for nZEB (Tadeu et al., 2022). This indicates that energy-efficient systems are not being utilized at the pace required to reach the EU's targets for decreasing emissions of greenhouse gases. This is the case even though these systems are readily accessible and may be employed inexpensively. The "energy efficiency gap" refers to the difference between what the industry is doing and what it is capable of doing in terms of saving energy. It indicates that there are market hurdles that are not technological and are preventing the deployment of these alternatives on a worldwide scale (Bertoldi, 2022).

2. Best practices

Annunziata et al. (2013) conducted a study on the national regulations in Europe as well as the national adoptions of the EPBD recast. The researchers discovered that European nations have used a variety of ways in their national regulatory framework in order to include the EPBD recast. An examination of the national building codes of eight European nations revealed the use of a variety of metrics in the establishment of the standards for the energy efficiency of buildings in those countries.

Comparably, Graziano observed that various indications were used in the process of establishing national requirements for low-energy buildings in each of the nine European nations that she looked at (Salvalai et al., 2015). In an analysis of nZEB definitions in 10 countries that are members of the EU, there was found to be a significant amount of diversity in primary energy usage numbers. Primary energy usage thresholds for nZEB vary significantly, ranging from less than 50 kWh/m^2 per year in countries with stringent energy efficiency standards, to up to 120 kWh/m^2 per year in others where climatic conditions or energy policies result in less restrictive requirements. Such discrepancies highlight the nuanced approach each country takes towards achieving high energy performance in buildings, reflecting differences in climate, available technologies, and policy frameworks.

2.1. Overview of energy use in buildings

Understanding the distinct roles energy plays across various building types and environmental contexts is crucial for devising strategies to reduce energy consumption effectively within Azerbaijan's diverse architectural landscape. (Azərbaycan Respublikasının Mənzil İnşaatı Dövlət Agentliyi, 2016). Furthermore, understanding the proportion of energy consumed by different types of buildings relative to total building energy usage is crucial. Recognizing how these proportions might evolve over time is also essential for effective energy management and planning.

2.2. Criteria for energy efficiency in the Lithuanian and Azerbaijani building codes

In the national building codes that were analysed, the energy performance standards for single-family homes are distinct from those for multi-family residences in the national building codes of Lithuania and Azerbaijan, criteria for energy usage along with other indicators are jointly applied to assess residential building. For instance, the 2019 Lithuanian building code, outlined in "Lietuvos Statybos Techninis Reglamentas STR 2.01.09:2019 on Energy Performance of Buildings stipulates criteria for specific primary energy use and 'other' indicators such as the building envelope's U-value and the electrical power requirements (The1) (Neverovič, 2014). Conversely, the Azerbaijani building code, detailed in "Azərbaycan Respublikasının Quraşdırma Qaydaları AQ-2019 on Building Thermal Performance", focuses on 'other' indicators, including the U-values of building components, without imposing specific energy usage (Azerbaijan Standardization Institute, 2024).

In Azerbaijan and Lithuania, the building envelope U values for various components are as follows (Enerji resurslarından səmərəli istifadə və enerji effektivliyi haqqında, 2022); (Valančius et al., 2022). Table 1 demonstrates the U values used for these purposes.

Table 1. U values used in calculations

Building Component	U-value in Azerbaijan (W/m²K)	U-value in Lithuania (A-class) (W/m²K)
Walls	0.28	≤ 0.15
Roof	0.22	~ 0.10
Floors	0.34	~ 0.15
Windows	1.8	≤ 0.8
Doors	2.0	≤ 1.0

3. Methodology

This study targets traditional residential buildings in Lankaran, a region in northern Azerbaijan known for its unique homes. Without using central heating systems, the goal is to make these buildings more energy-efficient. The prevalent residential structure in Lankaran, commonly identified as the traditional residential building, is slated for a transformation into a high-performance, energy-efficient entity consequent to this investigation. Specifically, this study will be conducted without factoring in the central heating system. The primary aim is to mitigate severe environmental impact in northern Azerbaijan by curbing fuel consumption. The implementation of a range of techniques, encompassing both passive and active measures, will be employed.

In this study, the Esbo Swegon Light database to obtain climatic data for Lankaran, Azerbaijan, and Vilnius, Lithuania will be used. This methodology ensures precise analysis of local climate effects on building energy efficiency (EQUA Simulation AB, 2019).

Both Lankaran, which is located in Azerbaijan, and Vilnius, which is located in Lithuania, have been chosen as the data source. The data collected from Vilnius will serve the same function for Lithuania as the information received from Lankaran will contribute to the construction of the reference model for the residential structure in Azerbaijan. A prominent city in Azerbaijan, Lankaran has qualities that are typical of the southern portion of the country. These characteristics include several cultural, historical, and architectural traits that are unique to the city. On the other hand, Vilnius, which is the capital of Lithuania, plays a significant part in the political, historical, and cultural landscape of the nation.

3.1. Building size

The average area of a studio-style apartment in Azerbaijan is reported as 90 square meters, while its Lithuanian counterpart exhibits a same size of 90 square meters.

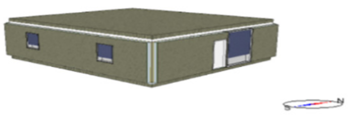

Figure 1. Representation of building

Figure 1 provides a graphical representation of a building with the dimensions mentioned.

3.2. Thermal properties

Residential structures in both Azerbaijan and Lithuania are subject to a mandatory minimum insulation requirement, in adherence to the respective national building codes established in each country (Valančius et al., 2022) (Azərbaycan Respublikasının Mənzil İnşaatı Dövlət Agentliyi, 2016).

The distinction in insulation requirements between Azerbaijan and Lithuania is influenced by climatic variations, with Lithuania's cooler temperatures necessitating more stringent insulation measures compared to the relatively milder climate in Azerbaijan (Hafez et al., 2023)

3.3. Glazing

In the context of mitigating thermal energy transfer, particularly minimizing heat loss in winter and heat gain in summer, the incorporation of high-quality glazing stands as a pivotal requisite (Encius & Baranauskas, 2018). In the context of enhancing energy efficiency within residential buildings, both Azerbaijan and Lithuania promote the use of advanced glazing technologies. Specifically, the adoption of low-emissivity (low-E) glass is encouraged to minimize heat transfer and improve insulation. However, it's important to note that achieving the highest energy efficiency standards in Lithuania, such as A++ classification, typically requires beyond double-pane windows. Triple-glazed windows with low-E coatings and filled with inert gas are often necessary to meet the stringent thermal performance criteria set for such top-tier energy-efficient buildings.

3.4. Weather data

The Esbo Swegon Light database will be referenced to acquire climatic data pertinent to the cities of Lankaran, Azerbaijan, and Vilnius, Lithuania. Figure 2 represents a typical climate data chart that includes various parameters measured over the course of a year, from January 1, 2024, to December 31, 2024, for Vilnius, Lithuania and Lankaran, Azerbaijan.

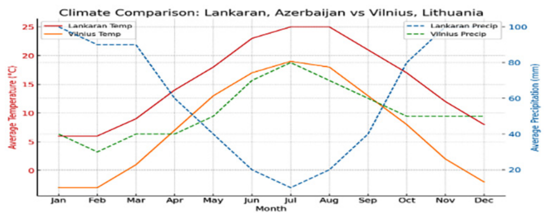

Figure 2. Comparison of weather data

3.5. Precipitation patterns

Lankaran, Azerbaijan: Experiences higher precipitation during the winter and lower precipitation in the summer. The wettest months are November through February, each with around 90–100 mm of rainfall (Maile et al., 2018).

Vilnius, Lithuania: shows a more evenly distributed precipitation throughout the year, with a slight increase in the summer months. The average monthly precipitation ranges between 30–80 mm (Sabunas & Kanapickas, 2017).

Overall, Lankaran has a warmer and wetter climate, especially in the winter, compared to Vilnius, which experiences colder winters with more evenly spread precipitation throughout the year.

4. Results

The data indicates that the facility is highly dependent on external electricity with significant consumption by equipment and lighting.

The simultaneous peak in equipment and lighting might suggest operational patterns, possibly during a shift change or a specific process that requires intense energy use.

Figure 3 and 4 includes a table that details the kWh consumption for each category, by month, and the total energy consumed for the year for building in Azerbaijan.

Month	Zone heating	Zone cooling	AHU heating	AHU cooling
1	1338.0	0.0	0.2	0.0
2	1239.0	0.0	0.2	0.0
3	845.7	0.0	0.0	4.1
4	335.2	0.2	0.0	55.8
5	76.7	43.5	0.0	387.2
6	0.0	272.4	0.0	705.4
7	-0.0	585.6	0.0	1228.0
8	-0.0	648.6	0.0	1330.0
9	-0.0	108.6	0.0	705.6
10	147.0	2.5	0.0	249.2
11	694.4	0.0	0.0	17.9
12	1100.0	0.0	0.0	0.1

Figure 3. Sensible and latent energy use in building in Azerbaijan in kWh

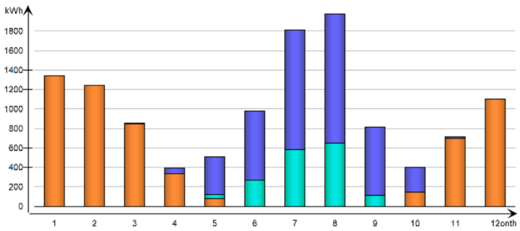

Figure 4. System energy for building in Azerbaijan

This detailed breakdown allows for an analysis of energy usage patterns and could be useful for identifying opportunities for energy efficiency improvements. The total energy consumption for Zone heating is given as 5775.9 kWh, Zone cooling as 1661.4 kWh, and AHU cooling as 4683.3 kWh over the year.

Month	Zone heating	Zone cooling	AHU heating	AHU cooling
1	1564.0	0.0	53.6	0.0
2	1254.0	0.0	34.6	0.0
3	880.8	0.0	7.2	0.0
4	307.0	1.2	0.1	11.3
5	25.3	96.3	0.0	110.2
6	-0.0	237.3	0.0	152.3
7	-0.0	385.5	0.0	362.7
8	0.0	338.0	0.0	260.1
9	39.8	32.1	0.0	37.6
10	349.5	0.1	0.0	0.0
11	937.3	0.0	4.7	0.0
12	1334.0	0.0	32.6	0.0

Figure 5. Sensible and latent energy use in building in Lithuania in kWh

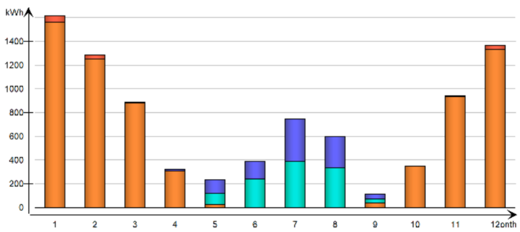

Figure 6. System energy for building in Lithuania

Figure 5 and 6 show the total annual energy consumed for each category, with Zone heating being the highest at 6691.7 kWh, followed by AHU cooling at 934.3 kWh, and Zone cooling at 1090.6 kWh. The total for AHU heating is relatively low at 132.8 kWh, reflecting its minor contribution to the overall energy profile.

Table 2 represents results of calculations for primary energy and CO_2 emission. Based on the kWh/m² figures provided for a 90 m² building:

Table 2. Results of assessment

Country	Heating Energy (kWh/m²)	Primary Energy for Heating (kWh/m²)	CO_2 Emissions for Heating ($kgCO_2/m^2$)
Azerbaijan	54.17	59.59	13.11
Lithuania	47.87	26.68	2.97

The process to calculate primary energy consumption and CO_2 emissions for heating in residential buildings in Azerbaijan and Lithuania takes the measured energy consumption in kWh/m² and adjusts it to include energy losses during production and distribution, as well as the environmental impact of these energy uses.

For Azerbaijan, with a natural gas conversion factor of 1.1 and a CO_2 emission factor of 0.22 $kgCO_2$/kWh, the primary energy use for heating is calculated to be 59.59 kWh/m², leading to CO_2 emissions of 13.11 $kgCO_2/m^2$.

In contrast, Lithuania, utilizing district heating with a conversion factor of 0.62 and a CO_2 emission factor of 0.10 $kgCO_2$/kWh, results in a primary energy use for heating of 29.68 kWh/m² and CO_2 emissions of 2.97 $kgCO_2/m^2$. This distinction highlights the reduced environmental impact of using district heating over electricity for heating needs in Lithuania.

4.1. Energy consumption (kWh and kWh/m²)

Azerbaijan: The cooling energy demand per square meter is higher at 29.43 kWh/m² without ventilation, suggesting a climate with greater cooling needs or less efficient cooling systems. With ventilation, the demand is 22.50 kWh/m², indicating a considerable need for cooling. The energy used for fans and pumps, at 14.37 kWh/m² when ventilation systems are on, points to efficient system usage or reduced operation time.

Lithuania: The cooling energy requirement per square meter is significant at 47.17 kWh/m² without ventilation and increases to 70.50 kWh/m² with ventilation, indicating a substantial need for cooling which may be due to warmer summer temperatures or less efficient cooling systems. The energy used for fans and pumps shows an operational consumption of 14.64 kWh/m², which suggests more frequent use or less efficient systems compared to Azerbaijan.

Azerbaijan requires more cooling energy per square meter than Lithuania, with an average demand of 26 kWh/m² compared to Lithuania's 58.83 kWh/m² with ventilation systems operational. For heating, Lithuania has a higher demand at 56 kWh/m² compared to Azerbaijan's 65.82 kWh/m² with ventilation off. The fan and pump energy for both countries reflect usage only when the ventilation systems are active, with Azerbaijan using 14.37 kWh/m² and Lithuania slightly higher at 14.64 kWh/m². The absence of fan and pump energy consumption when ventilation is off could indicate that these systems are not used or the buildings employ natural ventilation strategies. Energy comparison graph between Lithuania and Azerbaijan.

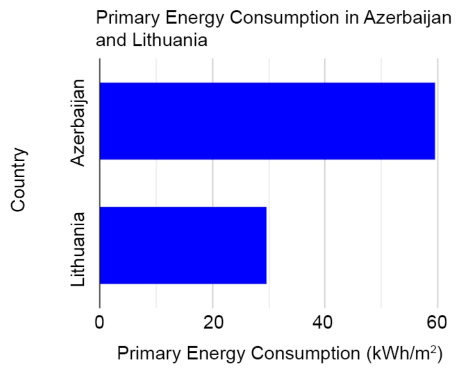

Figure 7. Primary energy comparison

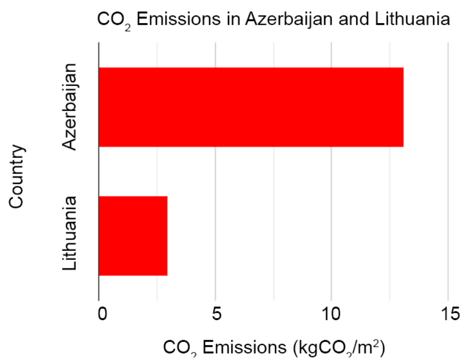

Figure 8. CO_2 emission comparison

Figure 7 and 8 illustrates a comparison of primary energy for Lithuania and Azerbaijan and CO_2 emission.

5. Conclusions

This study compared the energy efficiency of residential buildings in Azerbaijan and Lithuania. The analysis revealed significant differences in total energy consumption, highlighting areas for improvement and opportunities for sustainable practices:

1. Energy consumption: Azerbaijan's building consumed 7,524 kWh/year, with 4,875 kWh/year for heating and 2,649 kWh/year for cooling. In contrast, Lithuania's building consumed 5,057 kWh/year in total, with 3,210 kWh/year for heating and 1,847 kWh/year for cooling.
2. In Azerbaijan, converting the final heating energy consumption to primary energy using natural gas results in a primary energy consumption of 59.59 kWh/m². The corresponding CO_2 emissions are calculated to be 13.11 $kgCO_2/m^2$. Given the use of natural gas, this suggests a potential for energy savings and emission reduction opportunities, particularly if measures such as upgrading to more efficient heating systems or integrating renewable energy sources are undertaken.
3. Conversely, in Lithuania, utilizing district heating, the primary energy consumption for heating is significantly lower at 29.68 kWh/m² due to the more efficient nature of district heating systems. The CO_2 emissions are also lower at 2.97 $kgCO_2/m^2$, reflecting the lower carbon intensity of district heating, often supplemented by renewable energy sources. This showcases the environmental benefits of district heating compared to individual heating systems powered by electricity or natural gas.
4. Primary energy consumption: Lithuania's primary energy consumption for heating is actually lower than that of Azerbaijan when considering the more efficient district heating system. The initial higher value of 110.10 kWh/m² was due to the mistaken assumption that Lithuania's heating was electric-based.
5. CO_2 emissions: With the corrected calculation, Lithuania's CO_2 emissions for heating (2.97 $kgCO_2/m^2$) are notably lower than those of Azerbaijan (13.11 $kgCO_2/m^2$). This indicates that, contrary to previous calculations, Lithuania's heating system is not only more energy-efficient but also has a smaller environmental footprint in terms of CO_2 emissions.

These findings underscore the significance of selecting appropriate energy sources and the implementation of efficient heating systems to lower both the primary energy consumption and the CO_2 emissions. Although the current analysis concentrates on heating energy, the inclusion of cooling in future research stages will yield a more holistic view of the energy efficiency potential and the environmental impacts associated with residential buildings in Azerbaijan and Lithuania.

References

Annunziata, E., Frey, M., & Rizzi, F. (2013). *Towards nearly zero-energy buildings: The state-of-art of national regulations in Europe. Energy*, *57*, 125–133. https://doi.org/10.1016/j.energy.2012.11.049

Azerbaijan Standardization Institute. (2024). www.azstand.gov.az

Azərbaycan Respublikasının Mənzil İnşaatı Dövlət Agentliyi. (2016). *Azərbaycan Respublikasında uyğun qiymətə mənzil təminatının inkişafına dair Strateji Yol Xəritəsi*. https://mida.gov.az/static/media/menzil_t%C9%99minat%C4%B1n%C4%B1n_inki%C5%9Faf%C4%B1na_dair_strateji_yol_x%C9%99rit%C9%99si.ffa8bf71393872c8d6b1.pdf

Bertoldi, P. (2022). Policies for energy conservation and sufficiency: Review of existing policies and recommendations for new and effective policies in OECD countries. *Energy and Buildings*, *264*, Article 112075.

Dulian, M. (2024). *Revision of the energy performance of Buildings directive: Fit for 55 pack-age.* European Parliamentary Research Service. https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698901/EPRS_BRI(2022)698901_EN.pdf

Economidou, M., Atanasiu, B., Despret, C., Maio, J., Nolte, I., Rapf, O., Laustsen, J., Ruyssevelt, P., Strong, D., & Zinetti, S. (2011). *Europe's Buildings under the microscope. A country-by-country review of the energy performance of buildings.* M. Economidou (Ed.). Buildings Performance Institute Europe.

EQUA Simulation AB. (2019). *IDA Early Stage Building Optimization* . https://www.equaonline.com/esbouser/User_guide.pdf

Encius, R., & Baranauskas, T. (2018). *EPBD implementation in Lithuania*. *Status in december 2016*. https://epbd-ca.eu/wp-content/uploads/2019/04/CA-EPBD-IV-Lithuania-2018.pdf

Enerji resurslarından səmərəli istifadə və enerji effektivliyi haqqında. (2022). https://e-qanun.az/framework/48129

European Environment Agency. (2023). *Accelerating the energy efficiency renovation of residential buildings — a behavioural approach*. https://www.eea.europa.eu/publications/accelerating-the-energy-efficiency

Hafez, F. S., Sa'di, B., Safa-Gamal, M., Taufig-Yap, Y. H., Alrifaey, M., Seyedmahmoudian, M., Stojcevski, A., Horan, B., & Mekhilef, S. (2023). Energy efficiency in sustainable buildings: A systematic review with taxonomy, challenges, motivations, methodological aspects, recommendations, and pathways for future research. *Energy Strategy Reviews*, *45*, Article 101013.

Maile, T., Bazjanac, V., & Fischer, M. A. (2012). A method to compare simulated and measured data to assess building energy performance. *Building and environment*, *56*, 241–251. https://doi.org/10.1016/j.buildenv.2012.03.012

Neverovič, J. (2014). *Order regarding the approval of the energy efficiency action plan* (2014, may 30, No. 1-149). https://enmin.lrv.lt/uploads/enmin/documents/files/Energy%20Efficiency%20Action%20Plan%202014.docx

Ostermeyer, Y., Camasara, C., Naegeli, C., & Saraf, S. (2017). *Building market brief Switzerland* (1st ed.). CUES Foundation. https://eeg-plattform.ch/downloads/BMB_Switzerland_171123_BTA_DEF.pdf

Sabunas, A., & Kanapickas, A. (2017). Estimation of climate change impact on energy consumption in a residential building in Kaunas, Lithuania, using HEED Software. *Energy Procedia*, *128*, 92–99. https://doi.org/10.1016/j.egypro.2017.09.020

Salvalai, G., Masera, G., & Sesana, M. M. (2015). Italian local codes for energy efficiency of buildings: Theoretical definition and experimental application to a residential case study. *Renewable and Sustainable Energy Reviews*, *42*, 1245–1259. https://doi.org/10.1016/j.rser.2014.10.038

Tadeu, S., Rodrigues, C., Marques, P., & Freire, F. (2022). Eco-efficiency to support selection of energy conservation measures for buildings: A life-cycle approach. *Journal of Building Engineering*, *61*, Article 105142. https://doi.org/10.1016/j.jobe.2022.105142

The Lithuanian Standards Board. (2019). *Lietuvos statybos techninis reglamentas STR 2.01.09:2019 on Energy Performance of Buildings.*

Valančius, K., Grinevičiūtė, M., & Streckienė, G. (2022). Heating and cooling primary energy demand and CO_2 emissions: Lithuanian A+ buildings and/in different European locations. *Buildings*, *12*(5), Article 570. https://doi.org/10.3390/buildings12050570

AZERBAIDŽANO IR LIETUVOS GYVENAMŲJŲ PASTATŲ ENERGINIO EFEKTYVUMO PALYGINIMAS

Z. IBRAHIMOVA, K. VALANČIUS

Santrauka. Šiame tyrime lyginamas energijos vartojimo efektyvumas gyvenamuosiuose pastatuose Azerbaidžane ir Lietuvoje – skirtingo klimato regionuose – siekiant išsiaiškinti, kokią įtaką energijos poreikiams turi vietos sąlygos. Remdamiesi modeliavimo duomenimis, nustatėme reikšmingų skirtumų: Azerbaidžano pastatams reikia daugiau energijos vėsinimui, o Lietuvos – šildymui. Atlikus analizę paaiškėjo, kad Azerbaidžane reikia 26,5 % daugiau vėsinimo, o Lietuvoje – 13,8 % daugiau šildymo energijos, todėl būtina taikyti konkrečiam regionui pritaikytas energijos vartojimo efektyvumo strategijas. Be to, tyrime nagrinėjamas mažesnis ventiliatorių ir siurblių suvartojamos energijos kiekis, o tai rodo pasyvaus vėdinimo arba strateginio sistemų išjungimo galimybes siekiant taupyti energiją. Šios išvados suteikia svarbių įžvalgų kuriant įvairioms klimato sąlygoms pritaikytą, tvarią infrastruktūrą.

Reikšminiai žodžiai: energijos vartojimo efektyvumas, gyvenamieji pastatai, Azerbaidžanas, Lietuva, šiluminės savybės, vėsinimas ir šildymas, klimato skirtumai.