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# ASSESSMENT OF THE EFFECTIVENESS OF ENERGY-SAVING CONSTRUCTIVE SOLUTIONS IN LOW-RISE RESIDENTIAL BUILDINGS: EVIDENCE FROM FERGANA REGION, UZBEKISTAN

**Khalimov Khabibullo Bakhtiyarjon ogli**
Doctoral student of Samarkand State University of Architecture and Construction.
E-mail: xabibulloxalimov887@gmail.com

**Abstract**
This article evaluates the effectiveness of energy-saving constructive solutions for low-rise residential buildings under the climatic and construction-market conditions of Fergana Region, Uzbekistan. The study combines statistical climate data, national construction statistics and a heat-loss calculation model for a representative 120 m² single-family low-rise house. Fergana is characterized by a dry steppe climate, an average annual temperature of approximately 15.3°C and annual precipitation of about 308 mm. Monthly climate data were used to calculate heating degree-days (HDD18 = 2,109 °C·day) and cooling degree-days (CDD24 = 342 °C·day). The evaluated constructive package includes external-wall insulation, roof/ceiling insulation, ground-floor thermal improvement, low-emissivity double glazing and reduction of uncontrolled air leakage. Results show that the integrated package can reduce delivered heating energy from 32,316 kWh/year to 12,826 kWh/year, corresponding to a 60.3% reduction. The analysis confirms that building-envelope measures are particularly relevant for Fergana, where low-rise housing is commonly developed by households and non-state actors. The paper concludes that energy-saving constructive solutions should be considered not only as engineering improvements but also as a practical regional strategy for reducing fuel demand, improving indoor thermal comfort and supporting Uzbekistan's transition toward more energy-efficient building standards.
**Keywords:** Low-rise residential buildings; energy efficiency; constructive solutions; thermal insulation; heat loss; Fergana Region; Uzbekistan.

## 1. Introduction

Energy efficiency in residential buildings is one of the most practical directions for reducing fuel consumption and improving indoor comfort in Uzbekistan. Low-rise dwellings are especially important because they usually have larger envelope areas per square meter of floor space than apartments, and their construction quality strongly depends on individual developers, local workmanship and material availability.

The relevance of this topic is strengthened by the fact that the World Bank estimated the average specific heat consumption of residential buildings in Uzbekistan at about 290 kWh/m², a level considerably higher than in countries with similar reliance on natural gas and more mature building-energy standards [3]. The same study links the high technical potential for energy reduction in buildings to inefficient boilers and insufficient thermal insulation of existing envelopes [3].

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Fergana Region has a specific combination of continental dry climate, hot summers, cold winter nights, active private construction and strong demand for individual housing. Official construction statistics for 2024 show substantial new construction volumes in Fergana Region and a very high role of non-state construction actors [2]. This makes the assessment of constructive energy-saving solutions highly relevant for new low-rise housing and renovation of existing houses.

2. Materials and Methods

The research uses a combined statistical and engineering-calculation approach. First, climate indicators for Fergana were systematized using monthly average temperature, precipitation, humidity and sunshine data. Second, construction-sector statistics were used to justify the practical relevance of low-rise and individual housing. Third, a representative 120 m² low-rise house was modelled to compare baseline and improved thermal performance.

The basic heat-loss coefficient of the building was calculated as the sum of transmission losses through the external envelope and ventilation/infiltration losses. The annual heating energy demand was then estimated by the degree-day method. The calculation is not a substitute for dynamic simulation, but it is transparent, reproducible and suitable for preliminary comparison of constructive alternatives.

**Calculation approach:** $H = \Sigma(U_i \times A_i) + 0.33 \times n \times V$; $Q_h = H \times HDD18 \times 24 / (1000 \times \eta)$, where H is the total heat-loss coefficient (W/K), U is thermal transmittance (W/m²K), A is area (m²), n is air-change rate ($h^{-1}$), V is heated volume (m³), HDD18 is heating degree-days and η is heating-system efficiency.

**Table 1. Climate indicators used for the energy-efficiency assessment in Fergana**

| Month | Avg. temp., °C | Precip., mm | Humidity, % | Sun, h/day | HDD18 | CDD24 |
|---|---|---|---|---|---|---|
| Jan | 1.7 | 22 | 67 | 7.1 | 505 | 0 |
| Feb | 4.0 | 30 | 66 | 7.9 | 392 | 0 |
| Mar | 9.8 | 43 | 62 | 9.5 | 254 | 0 |
| Apr | 15.2 | 45 | 56 | 11.2 | 84 | 0 |
| May | 21.2 | 34 | 46 | 12.7 | 0 | 0 |
| Jun | 26.5 | 23 | 32 | 13.4 | 0 | 75 |
| Jul | 29.0 | 10 | 30 | 13.2 | 0 | 155 |
| Aug | 27.6 | 7 | 33 | 12.4 | 0 | 112 |
| Sep | 22.5 | 9 | 40 | 11.2 | 0 | 0 |
| Oct | 15.0 | 24 | 50 | 9.7 | 93 | 0 |
| Nov | 7.9 | 30 | 64 | 8.1 | 303 | 0 |
| Dec | 2.6 | 31 | 67 | 7.0 | 477 | 0 |

***Source: compiled from Climate-Data.org monthly climate table for Fergana; HDD18 and CDD24 calculated by the author using monthly mean temperatures.***

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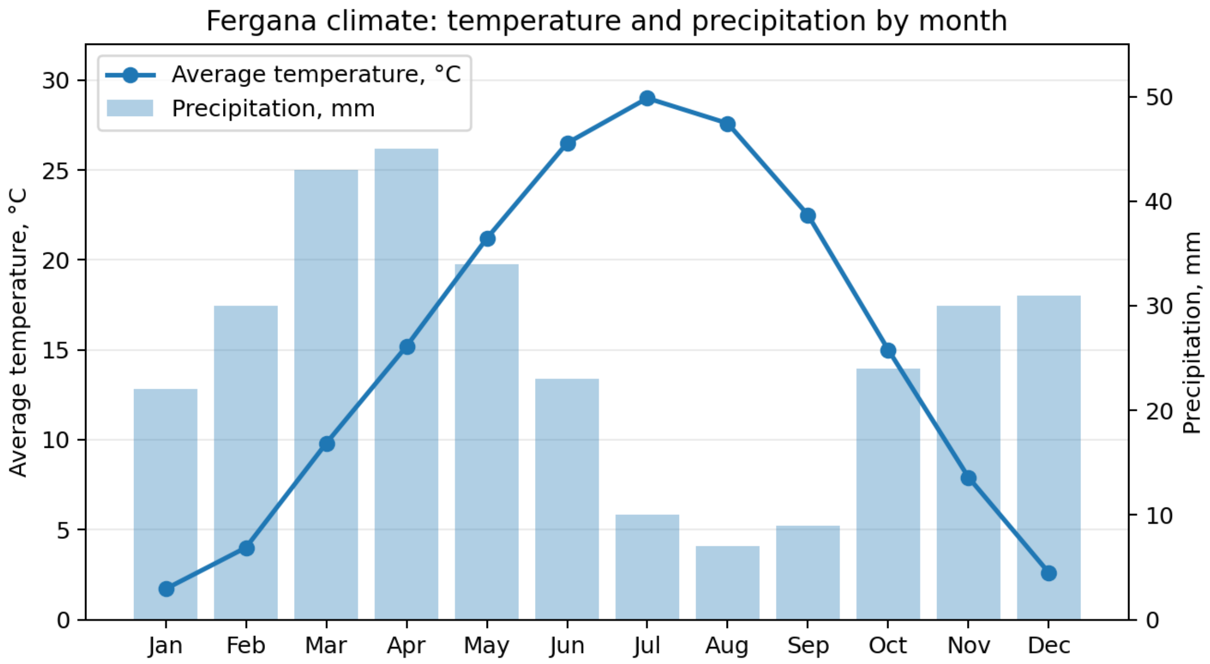


*Figure 1. Monthly average temperature and precipitation in Fergana*

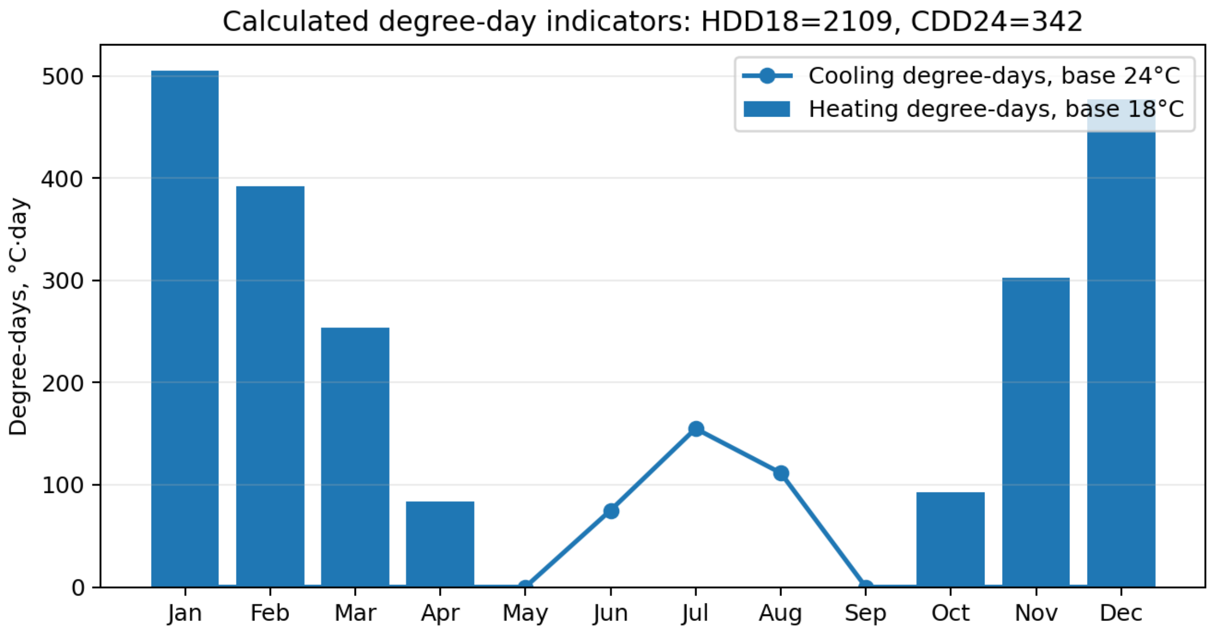


*Figure 2. Calculated heating and cooling degree-day distribution*

**Table 2. Statistical construction context relevant to residential energy efficiency**

| Indicator | Value | Interpretation for low-rise housing |
|---|---|---|
| New construction in Uzbekistan, total | 176,841.3 billion UZS | 75.6% of total construction works |
| Fergana region new construction | 12,254.5 billion UZS | One of the higher regional volumes |

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| Indicator | Value | Interpretation for low-rise housing |
|---|---|---|
| Informal-sector construction, Uzbekistan | 70,768.8 billion UZS | 30.3% of total construction works |
| Individual housing construction in informal sector | 52,616.0 billion UZS | 106.4% compared with 2023 |
| Non-state ownership share in Fergana construction | 97.7% | Indicates strong role of private housing and small developers |

***Source: Statistics Agency under the President of the Republic of Uzbekistan, Construction Works in the Republic of Uzbekistan, January–December 2024.***

**Table 3. Representative low-rise residential building prototype**

| Parameter | Assumed value | Explanation |
|---|---|---|
| Heated floor area | 120 m² | Typical single-family low-rise house |
| Heated volume | 336 m³ | Floor area × 2.8 m room height |
| External walls | 150 m² | Opaque wall envelope excluding openings |
| Roof/ceiling | 120 m² | Ceiling under attic or roof slab |
| Ground floor | 120 m² | Floor in contact with ground/crawl space |
| Windows and external doors | 25 m² | Approx. 21% of floor area |
| Indoor heating set-point | 20°C | Comfort-oriented design value |
| Heating-system efficiency | 85% | Representative gas boiler efficiency for comparative analysis |

**Table 4. Baseline and improved thermal characteristics of envelope components**

| Component | Area, m² | Baseline value | Improved value | Baseline H, W/K | Improved H, W/K | Reduction |
|---|---|---|---|---|---|---|
| External walls | 150 | 1.20 W/m²K | 0.35 W/m²K | 180.0 | 52.5 | 70.8% |
| Roof/ceiling | 120 | 0.90 W/m²K | 0.25 W/m²K | 108.0 | 30.0 | 72.2% |
| Ground floor | 120 | 0.80 W/m²K | 0.40 W/m²K | 96.0 | 48.0 | 50.0% |
| Windows and external doors | 25 | 2.80 W/m²K | 1.40 W/m²K | 70.0 | 35.0 | 50.0% |

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| Component | Area, m² | Baseline value | Improved value | Baseline H, W/K | Improved H, W/K | Reduction |
|---|---|---|---|---|---|---|
| Air leakage / ventilation | — | 0.80 ACH | 0.45 ACH | 88.7 | 49.9 | 43.7% |

***Note: U-values are used as representative engineering assumptions for comparative evaluation. Final project design must be checked against the current SHNQ 2.01.04-2018 requirements and local design documentation.***

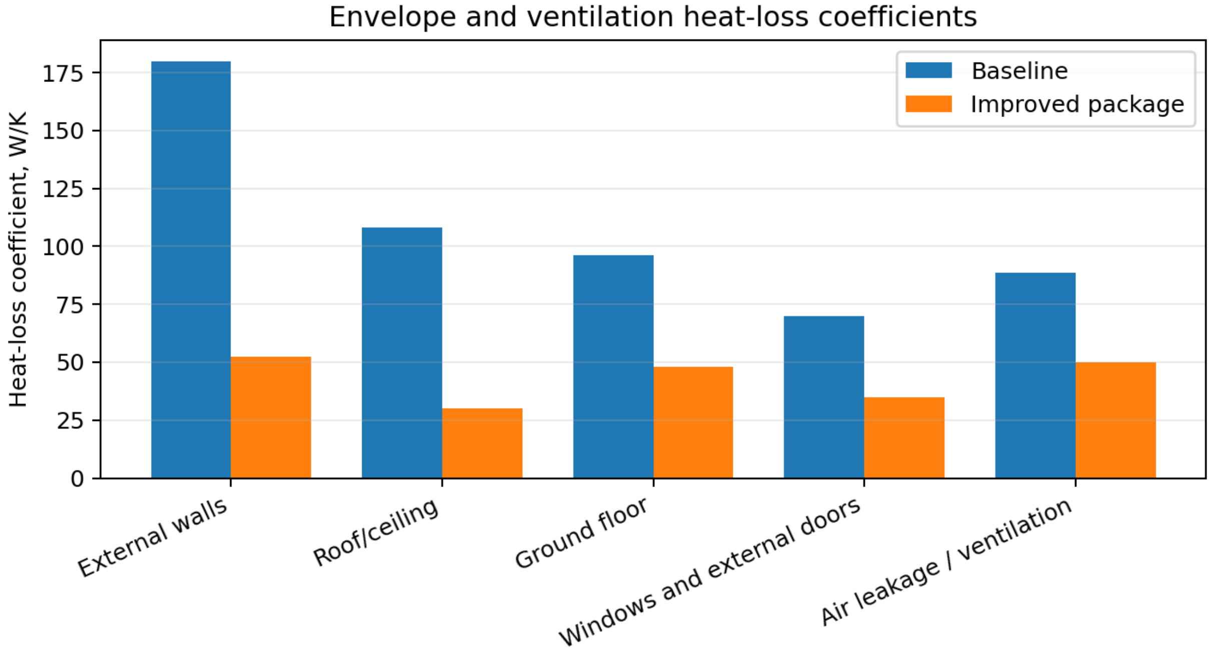


*Figure 3. Reduction of heat-loss coefficients after constructive improvements*

3. Results and Discussion

The baseline house has a total heat-loss coefficient of 542.7 W/K, consisting mainly of external walls, roof/ceiling, ground floor, windows and uncontrolled air leakage. After applying the integrated constructive package, the total coefficient decreases to 215.4 W/K. This means that each one-degree temperature difference between indoor and outdoor air requires substantially less heating power.

Using the calculated HDD18 value of 2109 °C·day and a heating-system efficiency of 85%, the delivered annual heating energy of the baseline house is estimated at 32,316 kWh/year, or 269 kWh/m²·year. The improved package reduces this value to 12,826 kWh/year, or 107 kWh/m²·year. The resulting annual saving is 19,490 kWh/year, equal to 60.3% of baseline heating energy.

The result is technically plausible for a full-envelope package. UNDP experience in Uzbekistan reported that new and renovated energy-efficient public buildings consumed 25–50% less energy for heating than earlier buildings [4]. The present model produces a higher reduction because all main envelope measures are applied simultaneously to a small low-rise building, where the envelope-to-floor-area ratio is high.

**Table 5. Heating-energy performance of individual and integrated constructive measures**

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| Scenario | H, W/K | Energy, kWh/year | Specific, kWh/m²·year | Saved, kWh/year | Saving |
|---|---|---|---|---|---|
| Baseline existing house | 542.7 | 32,316 | 269 | 0 | 0.0% |
| External-wall insulation only | 415.2 | 24,723 | 206 | 7,592 | 23.5% |
| Roof/ceiling insulation only | 464.7 | 27,671 | 231 | 4,645 | 14.4% |
| Ground-floor insulation only | 494.7 | 29,457 | 245 | 2,858 | 8.8% |
| Low-E double glazing only | 507.7 | 30,231 | 252 | 2,084 | 6.4% |
| Airtightness improvement only | 503.9 | 30,005 | 250 | 2,311 | 7.2% |
| Integrated package | 215.4 | 12,826 | 107 | 19,490 | 60.3% |

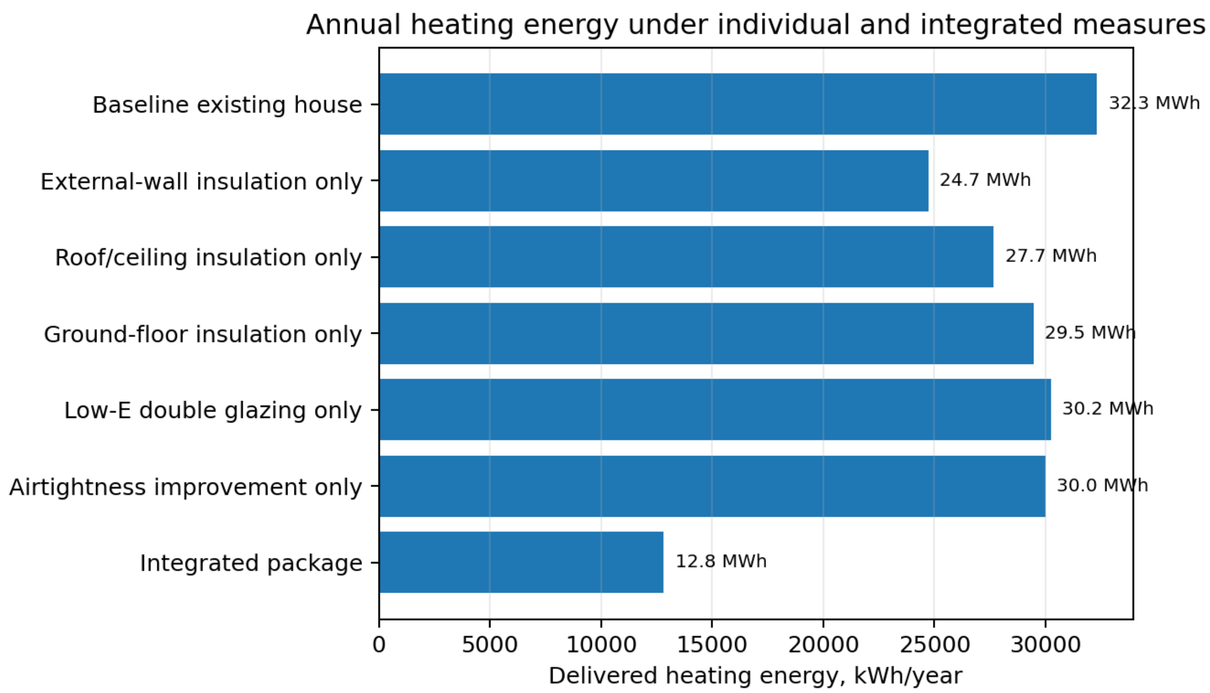


*Figure 4. Annual heating-energy demand by scenario*

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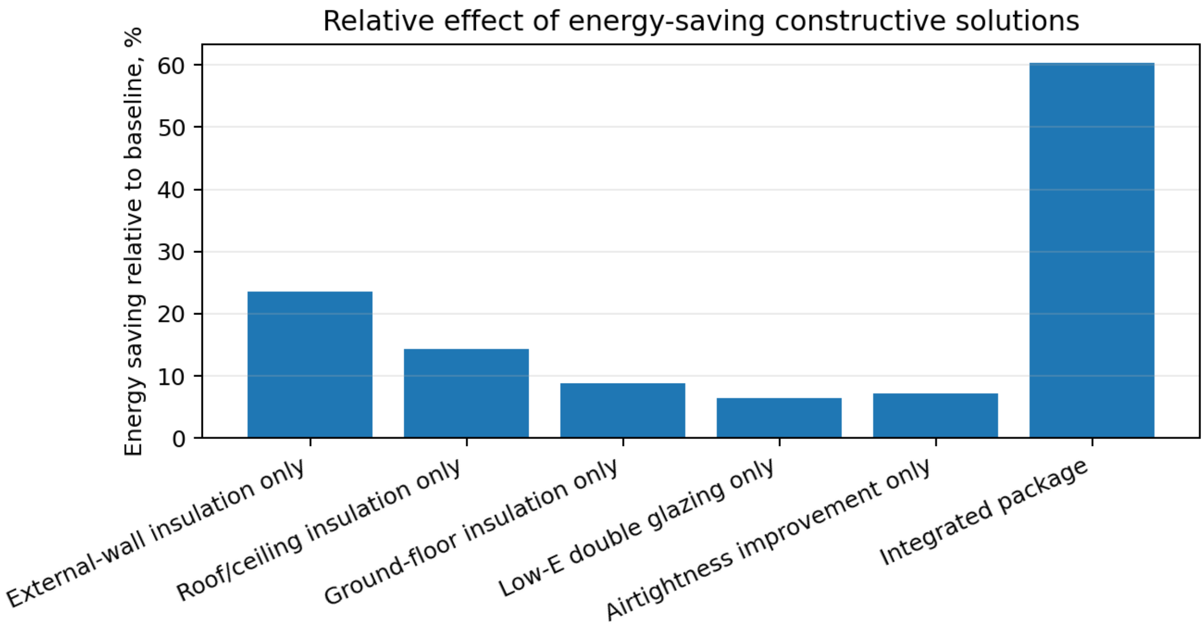


*Figure 5. Relative saving of constructive solutions compared with the baseline*

**Table 6. Economic and environmental sensitivity of the integrated package**

| **Gas tariff assumption, UZS/m³** | **Gas saved, m³/year** | **Bill saving, million UZS/year** | **$CO_2$ reduction, t/year** |
|---|---|---|---|
| 1,100 | 2,052 | 2.26 | 3.90 |
| 1,550 | 2,052 | 3.18 | 3.90 |
| 2,000 | 2,052 | 4.10 | 3.90 |

***Note: Natural-gas equivalent is estimated using 9.5 kWh/m³ and 1.9 kg $CO_2$/m³. Tariff values are used as sensitivity assumptions reflecting recent differentiated household gas-price discussions in Uzbekistan; real bills depend on meter status, consumption block, season and local service conditions.***

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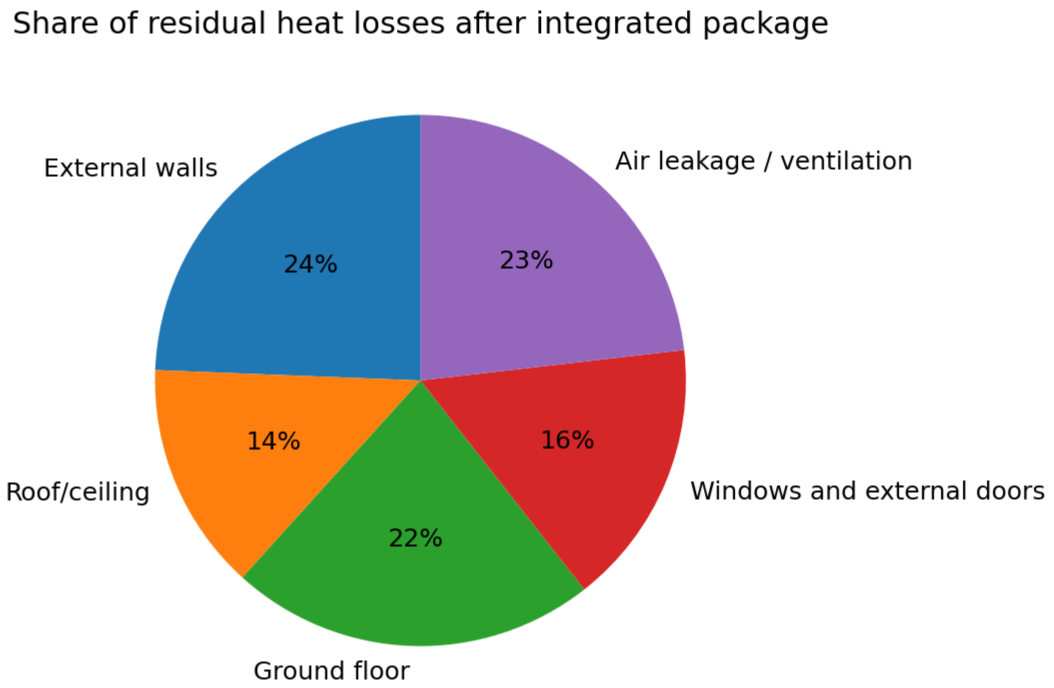


*Figure 6. Residual heat-loss shares after applying the integrated package*

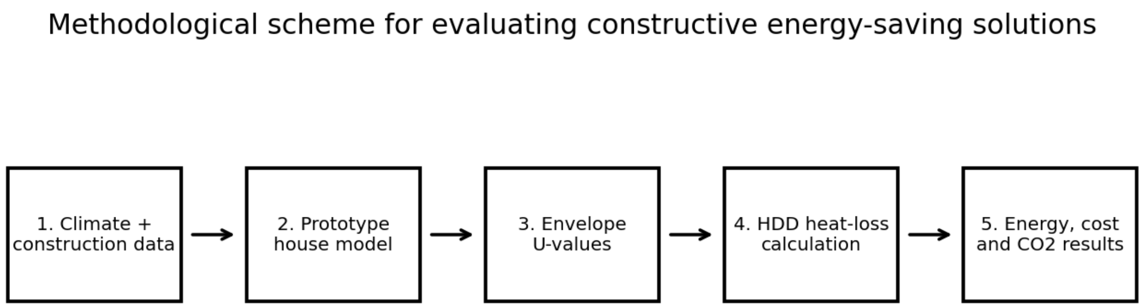


*Figure 7. Methodological scheme of the assessment*

3.1. Interpretation of constructive measures

The highest single-measure effect is obtained from external-wall insulation because walls have both a large surface area and a high baseline U-value. Roof/ceiling insulation is the second most influential measure. Ground-floor improvement, window replacement and airtightness have smaller individual effects, but their combined role is essential because comfort complaints and local cold bridges often remain if they are excluded.

In Fergana's climate, summer comfort should also be considered. Although the article focuses on heating energy, the CDD24 value of 342 °C·day indicates a non-negligible cooling load. Therefore, improved glazing should be combined with solar shading, ventilated roof layers, light exterior finishes and controlled night ventilation. Otherwise, highly insulated buildings may still overheat during July and August.

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3.2. Relation to norms and policy context

The national regulatory context is moving toward stricter building-energy performance. Lex.uz records the conversion of QMQ 2.01.04-2018 “Construction Thermal Engineering” into SHNQ 2.01.04-2018 terminology [5]. In 2026, Uzbekistan also launched a process to align building codes, classification and modernization approaches with international standards [6].

In addition, new requirements from June 2025 introduced mandatory solar panels, solar water heaters and heat pumps for new and reconstructed buildings in Uzbekistan [7]. These policy directions strengthen the practical value of first reducing heat losses through envelope measures and then covering the remaining demand with efficient systems or renewable energy.

3.3. Practical recommendations for Fergana Region

For new low-rise houses, the priority sequence should be: correct orientation and compact shape; continuous wall and roof insulation; thermal-bridge control around ring beams, lintels and window reveals; airtight installation of windows and doors; and roof detailing that prevents summer overheating. For renovation, the most cost-effective first steps are usually attic/ceiling insulation and sealing of uncontrolled air leakage, followed by wall insulation and window replacement when budget allows.

Because the construction market in Fergana is strongly influenced by private and non-state developers, energy-efficiency guidance should be translated into simple checklists, typical wall-roof-floor details and municipal permitting requirements. The results of the model show that the energy-saving potential is high enough to justify such practical standardization.

4. Conclusions

- Fergana’s dry steppe climate creates both winter heating and summer overheating challenges. Based on monthly climate data, the calculated HDD18 value is 2,109 °C·day and CDD24 is 342 °C·day.
- For a representative 120 m² low-rise residential building, the integrated package of wall insulation, roof/ceiling insulation, ground-floor improvement, low-E glazing and reduced air leakage decreases the heat-loss coefficient from 542.7 W/K to 215.4 W/K.
- The annual delivered heating energy decreases from 32,316 kWh/year to 12,826 kWh/year, giving an estimated 60.3% reduction. In specific terms, the demand falls from 269 kWh/m²·year to 107 kWh/m²·year.
- External-wall insulation provides the highest individual saving in the model, followed by roof/ceiling insulation. However, the integrated package is more reliable than isolated measures because it also reduces residual losses and improves thermal comfort.
- For Fergana Region, energy-saving constructive solutions should be integrated into local design practice, private construction guidance and renovation programs. Envelope-first design is recommended before sizing heating, cooling and renewable-energy systems.

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