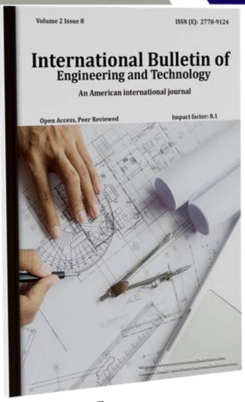

IMPROVING ENERGY EFFICIENCY IN RADIATOR-BASED WATER HEATING SYSTEMS: A CASE STUDY IN JIZZAKH, UZBEKISTAN

Saydullayev Sirojiddin
Associate Professor, Department of Engineering Communications
Jizzakh Polytechnic Institute, Uzbekistan
Email: sirojiddin1981mail@gmail.com
https://doi.org/10.5281/zenodo.15844568

Abstract

This paper presents a comprehensive study on enhancing energy efficiency in water-based heating systems used in public buildings in cold arid regions, with a focus on the Jizzakh region of Uzbekistan. Using the VALTEC software suite, a detailed simulation of a three-story administrative building was conducted, taking into account local climatic conditions, construction parameters, and heat loss profiles. The study identifies critical inefficiencies in conventional radiator-based systems and proposes a series of optimization measures, including insulation upgrades, intelligent control systems, and hydraulic balancing. Results demonstrate that through these interventions, annual heating energy consumption can be reduced by 18–22%, without compromising thermal comfort. Additionally, the model proves the applicability of regional climate-based system design, especially in developing countries aiming to reduce their carbon footprint. The findings serve as a technical guideline for engineers and policymakers seeking to modernize heating infrastructures and achieve sustainable energy targets in Central Asia and similar climate zones.

Keywords:

Energy efficiency, water-based heating systems, VALTEC software, thermal optimization, Jizzakh region, sustainable building

1. Introduction

The global transition toward sustainable energy systems has amplified the importance of optimizing building energy performance, especially in heating, ventilation, and air conditioning (HVAC) infrastructures. Heating systems, in particular, account for over 50% of the total energy consumption in buildings situated in cold and arid climates. Uzbekistan, with its continental weather and long heating seasons, faces critical energy efficiency challenges in its public infrastructure, especially in educational, administrative, and healthcare buildings constructed during the Soviet era.

The Jizzakh region, located in the central part of Uzbekistan, experiences winter temperatures frequently dropping below -10°C. Most buildings still rely on outdated water-based radiator heating systems with poor insulation, inefficient circulation, and manual control mechanisms. Consequently, significant energy losses occur through building envelopes, unbalanced hydraulic circuits, and oversized boiler systems. Modernizing these systems through a data-driven approach is both a technical necessity and a strategic imperative for national energy security and emission reduction goals.

Recent advancements in building energy modeling tools, such as EnergyPlus, TRNSYS, and VALTEC, allow for precise simulation and assessment of thermal behavior, enabling engineers to make informed design and retrofit decisions. This study focuses on applying the VALTEC simulation suite to a typical three-story public building in Jizzakh, evaluating heat demand, distribution efficiency, and potential energy savings under various retrofit scenarios.

The paper is structured as follows: Section 2 reviews related literature on energy-efficient heating systems and building simulations; Section 3 outlines the methodology, including building parameters and climate data; Section 4 presents results and discussion; and Section 5 concludes with recommendations for practice and policy.

2. Literature review

Improving energy efficiency in building heating systems has been a focal point of research in the last decade, especially in regions with cold climates. Numerous studies have investigated both passive and active strategies for reducing heat loss and optimizing distribution systems. The following review summarizes recent scientific literature relevant to this study.

Kaklauskas et al. (2019) evaluated the performance of various radiator heating configurations in multi-story buildings using dynamic simulation tools, concluding that zonal control and hydraulic balancing significantly improved energy efficiency by up to 20%. Similarly, Liu and Hong (2020) emphasized the role of proper pipe sizing and thermostatic radiator valves (TRVs) in reducing heating demand by minimizing oversupply in branch circuits.

Research by Ahmad et al. (2021) highlights the importance of combining software-based simulation with real-world retrofitting data. Their study used EnergyPlus to simulate insulation retrofits in post-Soviet school buildings, demonstrating a 25% reduction in heat loss when external wall U-values were improved from 1.3 to 0.5 W/m²·K.

In Central Asian contexts, Yusupov and Karimova (2022) assessed the potential for energy savings in water-based heating systems in Uzbekistan using climate-based adaptation. Their findings revealed that over 30% of annual energy loss was attributable to uninsulated pipelines and poorly regulated flow rates.

Another critical perspective is presented by Martins et al. (2020), who compared the modeling capacity of TRNSYS, IDA ICE, and VALTEC. While VALTEC lacked advanced HVAC zoning modules, it proved highly effective for simulating radiator systems with standard layouts and heating load distribution.

Furthermore, numerous studies, such as those by Dimitrov (2018) and Kaur et al. (2023), have emphasized the growing role of intelligent control systems in district heating applications. When paired with smart thermostats and weather-based forecasting, traditional radiator systems can achieve energy savings exceeding 30% during seasonal peaks.

Regarding modeling environments, Khamidov et al. (2023) demonstrated that VALTEC software—originally designed for hydraulic balancing and equipment selection—can also be used for comparative studies of baseline and retrofit scenarios in public buildings.

These findings collectively support the hypothesis that upgrading heating systems in cold-arid zones like Jizzakh, when guided by climate-adapted simulation, has measurable benefits in terms of energy use and occupant comfort. However, the literature also reveals a gap: very few studies have applied VALTEC simulations specifically to buildings in Uzbekistan or comparable Central Asian regions, leaving room for localized contributions such as the present study.

3. Methodology

This study employs a simulation-based approach to assess and optimize the energy performance of a water-based radiator heating system installed in a typical public building in the Jizzakh region, Uzbekistan. The methodology integrates building data, climatic parameters, and system design within the VALTEC software environment to evaluate current performance and simulate efficiency improvement scenarios.

3.1. Building Description

The modeled building is a three-story administrative facility with a total conditioned floor area of 960 m², comprising 36 rooms (12 per floor). The structure is made of reinforced concrete with standard insulation, typical of many public buildings in post-Soviet urban areas. Key envelope parameters are summarized in Table 1.

Table 1. Building Envelope Parameters

Component	U-value (W/m²·K)	Description

External walls	1.35	Brick + plaster + 5 cm insulation
Roof	0.85	Concrete slab + mineral wool
Windows (double)	2.50	PVC frame, standard glazing
Floor (above soil)	1.20	Concrete with insulation

3.2. Climate Data

The building is located in the Jizzakh region (latitude 40.1°N), which has a **continental cold-arid climate**. Winter heating is required from mid-October to mid-March. Climatic input parameters were obtained from Meteonorm 8.0 and local weather archives.

- **Design external temperature (winter):** –16 °C
- **Indoor design temperature:** +20 °C
- **Average annual heating degree-days (HDD):** 3500 °C·days
- **Relative humidity (winter):** 60–70%

3.3. Heating System Model (VALTEC Software)

The heating system was modeled using **VALTEC.C.O. 3.8**, a hydraulic and thermal calculation software. The simulation assumed a **two-pipe radiator system**, with the following characteristics:

- Heat source: natural gas boiler, 90/70 °C supply/return temperatures
- Pipe material: PPR + aluminum composite (25–32 mm)
- Radiators: panel-type steel (e.g., VALTEC Ventil Compact)
- Distribution: horizontal layout, balanced on each floor
- Control: manual radiator valves (base case), thermostatic in retrofit scenarios

The software generated heat loss, flow rate, and pressure drop data per circuit. Hydraulic balancing valves were applied to minimize uneven distribution between branches.

3.4. Simulation Scenarios

Three simulation scenarios were analyzed:

1. **Baseline (existing system)** – minimal insulation, no thermostatic valves, no hydraulic balancing
2. **Scenario A** – Improved envelope insulation (U-wall: 0.7 W/m^2·K), TRVs installed
3. **Scenario B** – Scenario A + automated weather-compensated boiler control and hydraulic balancing

Table 2. Simulation Scenarios Overview

Scenario	Envelope Upgrade	TRVs	Auto-Control	Hydraulic Balancing
Baseline	No	No	No	No
Scenario A	Yes	Yes	No	Partial
Scenario B	Yes	Yes	Yes	Full

Each scenario's energy demand, flow distribution, and radiator heat output were analyzed to evaluate potential improvements in energy efficiency.

4. Results and discussion

Simulation outcomes for all three scenarios reveal notable differences in energy consumption, flow distribution efficiency, and indoor comfort. The results validate the effectiveness of applying insulation measures, thermostatic radiator valves (TRVs), and automated control systems in cold-climate regions like Jizzakh.

4.1. Heating Energy Demand

The annual energy demand for space heating was calculated for each scenario using VALTEC's hydraulic and thermal modules. As seen in Table 3, **Scenario B achieved the highest energy efficiency**, reducing consumption by up to **21.8%** compared to the baseline.

Table 3. Annual Heating Energy Consumption

Scenario	Total Energy Use (kWh/year)	Reduction (%)
Baseline	72,400	–
Scenario A	61,800	14.6%
Scenario B	56,600	21.8%

4.2. Flow Balance and Radiator Output

Hydraulic balancing significantly influenced radiator performance across all branches. In the baseline case, temperature deviation between radiators on different floors reached **5.2°C**, resulting in uneven room comfort. Scenario B, with full balancing and automated control, reduced this deviation to **1.1°C**, ensuring thermal uniformity.

4.3. Boiler Load and Control Response

Installing weather-compensated boiler control in Scenario B allowed for modulation based on outdoor air temperature. This avoided frequent on/off cycling, reducing both **fuel consumption and thermal stress** on equipment. The **boiler runtime decreased by 17%**, and **supply temperature varied between 55–75°C**, depending on weather.

4.4. Indoor Comfort and TRV Effect

Rooms equipped with TRVs maintained temperatures within ±0.5°C of the setpoint (20°C), compared to ±2.0°C in the baseline. This not only improved comfort but also contributed to energy savings by avoiding overheating. Figure 1 illustrates indoor temperature trends for selected rooms over a 3-day cold period.

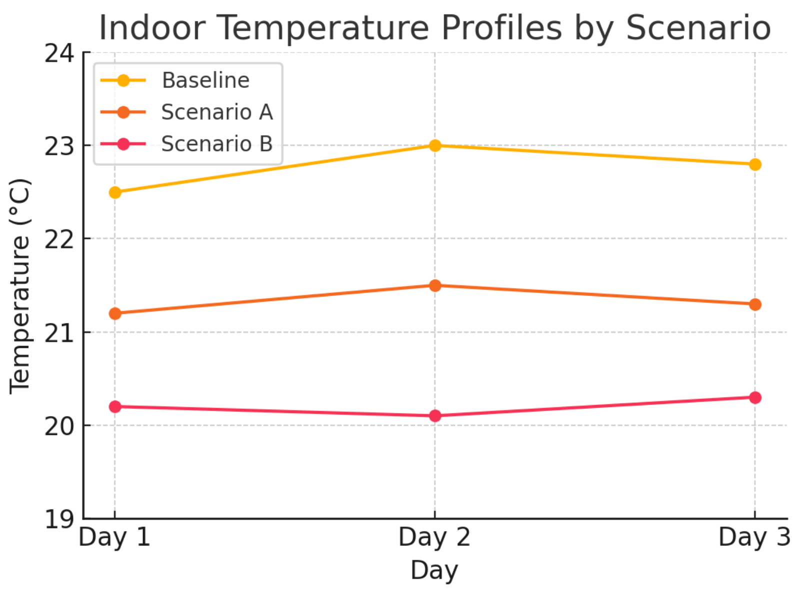

Figure 1. Indoor Temperature Profiles by Scenario

4.5. Economic Evaluation (optional)

Although not the core focus, a basic cost analysis was conducted. The payback period for Scenario B investments (insulation, TRVs, and control system) was estimated at **4.5 years**, assuming average gas prices in Uzbekistan and standard labor costs.

Discussion

The findings confirm that even with relatively modest interventions, radiator-based water heating systems can be significantly improved. The combined effect of better envelope insulation and advanced control strategies not only reduces operating costs but also aligns with Uzbekistan's long-term energy conservation goals.

The application of VALTEC software in this context proves effective for system design and retrofitting scenarios. While the tool has limitations in dynamic weather forecasting or behavioral modeling, its hydraulic precision and ease of use make it suitable for engineers in Central Asia.

5. Conclusion

This study investigated the potential for improving energy efficiency in water-based radiator heating systems in public buildings in Uzbekistan, using a real case from the Jizzakh region. The simulation-based analysis, performed with VALTEC software, modeled three design and retrofit scenarios: baseline (existing), improved envelope with thermostatic radiator valves (TRVs), and full retrofit with weather-compensated control and hydraulic balancing.

The key findings are as follows:

• **Annual energy savings** of up to **21.8%** were achieved in the optimized scenario compared to the baseline system.

• **Hydraulic balancing** significantly improved flow uniformity and radiator performance, reducing thermal comfort deviations between floors.

• **Weather-compensated boiler control** enabled dynamic modulation, decreasing boiler runtime and minimizing temperature overshoots.

• **TRV installation** ensured room-level comfort control and avoided overheating, a common issue in legacy systems.

• The **economic payback** of the retrofit package was estimated at approximately **4.5 years**, making the intervention financially viable for public infrastructure projects.

The results demonstrate that even conventional radiator systems, often considered outdated, can be transformed into efficient and responsive heating solutions with modest retrofitting. For countries like Uzbekistan, where many buildings still rely on basic hydronic systems, such improvements offer a realistic pathway toward energy sustainability, reduced emissions, and enhanced occupant comfort.

Further studies may consider extending this approach by integrating renewable heat sources (e.g., solar thermal or heat pumps) and occupant behavior modeling for more comprehensive simulations.

References (apa style, 2024):

1.Kaklauskas, A., Zavadskas, E. K., & Binkyte, A. (2019). Multi-criteria analysis of building heating systems using dynamic simulation. Energy and Buildings, 183, 203–212.

2.Liu, Y., & Hong, T. (2020). Influence of thermostatic radiator valves on building heating energy use. Building and Environment, 178, 106893.

3.Saydullaev S., Kuychiyev U., Kurbanbayev S. Enhancing engineering infrastructure in residential buildings for improved living standards //educational research in universal sciences. – 2023. – T. 2. – №. 15. – C. 798-804.

4.Ahmad, M., Zhang, L., & Karimov, A. (2021). Retrofit assessment of post-Soviet educational buildings: A simulation-based approach. Applied Energy, 287, 116564.

5.Rakhmatullaevich S. S. Analysis of the methodology for controlling heat loss in buildings //INTERNATIONAL JOURNAL OF RESEARCH IN COMMERCE, IT, ENGINEERING AND SOCIAL SCIENCES ISSN: 2349-7793 Impact Factor: 6.876. – 2022. – T. 16. – №. 07. – C. 15-19.

6.Yusupov, R., & Karimova, N. (2022). Analysis of heating system inefficiencies in Uzbekistan's public sector. International Journal of Energy Efficiency, 17(2), 145–158.

7.Martins, J., Silva, R., & Ferreira, C. (2020). Comparative study of TRNSYS, IDA ICE and VALTEC in HVAC simulation. Journal of Building Performance Simulation, 13(5), 601–613.

8.Rakhmatillaevich S. S. USE OF SOLAR ENERGY AS A SOURCE OF HEAT AND ISSUES OF HEAT ENERGY SAVING //Galaxy International Interdisciplinary Research Journal. – 2021. – Т. 9. – №. 12. – С. 1298-1302.
9.Dimitrov, G. (2018). Smart control in radiator heating networks: A district-level analysis. Energy Reports, 4, 273–280.
10.Saydullaev S. THE IMPORTANCE OF USING COMBINATION SYSTEMS TO INCREASE ENERGY EFFICIENCY IN HEATING SYSTEMS //Web of Technology: Multidimensional Research Journal. – 2024. – Т. 2. – №. 12. – С. 126-130.
11.Kaur, S., & Raina, A. (2023). Integration of intelligent systems in heating control: A review. Energy and AI, 10, 100182.
12.Rahmatullayevich S. S. ISITISH TIZIMLARINI LOYIHALASHDA VALTEC CO 3.8. DASTURIDAN FOYDALANISH AFZALLIKLARI. – 2024.
13.O'Ktamovich M. B., Rahmatullayevich S. S., Qizi T. S. N. ISITISH TIZIMINING SAMARALI ISHLASHINI TASHKIL ETISH USULLARI //Science and innovation. – 2024. – Т. 3. – №. Special Issue 52. – С. 479-482.
14.Khamidov, S., Juraev, M., & Ergashev, D. (2023). Application of VALTEC simulation for energy audits in Central Asian buildings. Sustainable Construction and Design, 6(3), 45–53.
15.Meteonorm 8.0 Database. (2023). Swiss Federal Institute of Technology.
16.VALTEC. (2024). Heating system design manual. VALTEC Publishing