УДК 621.482

INTELLIGENT GEOTHERMAL SYSTEMS FOR GREEN URBAN BUILDING HEATING

Aamir U.B. [1] (student)
Scientific supervisor – PhD, Associate Professor Sergienko O.I.[1]
[1]ITMO University
umairbinaamir@yandex.ru

Abstract
Domestic heat pumps have emerged as pivotal technology in the quest for sustainable and energy-efficient heating solutions. As the global emphasis on reducing carbon emissions intensifies, the adoption of heat pumps in residential settings offers a promising pathway to lower energy consumption and mitigate environmental impacts. Improvements in heat pump technology and increasing efficiency of buildings have increased the competitiveness of hybrid heating systems in markets typically dominated by district heating. Current practices often view maintenance as a reactive cost center rather than a strategic lever for sustainability. This research addresses this gap by proposing an integrated framework that combines Reliability-Centered Maintenance (RCM) with circular economy principles and smart technology integration. The Mytishchi retrofit project, which deployed advanced geothermal technologies in a 1980s building, serves as a critical proof-of-concept, demonstrating the technical viability of modernizing heritage infrastructure.
Keywords
Ground source heat pumps, Reliability Centered Maintenance (RCM), Decarbonization, AI, Buildings

ИНТЕЛЛЕКТУАЛЬНЫЕ ГЕОТЕРМАЛЬНЫЕ СИСТЕМЫ ДЛЯ ЭКОЛОГИЧНОГО ОТОПЛЕНИЯ ГОРОДСКИХ ЗДАНИЙ

Аамир У.Б.[1] (магистрант)
Научный руководитель – кандидат технических наук, доцент Сергиенко О.И.[1]
[1]Университет ИТМО
umairbinaamir@yandex.ru

Аннотация
Тепловые насосы становятся ключевой технологией в стремлении к устойчивым и энергоэффективным решениям в области отопления зданий. По мере усиления глобального акцента на сокращении выбросов углерода, внедрение тепловых насосов в жилых зданиях открывает перспективный путь к снижению энергопотребления и смягчению воздействия на окружающую среду. Усовершенствования в технологии тепловых насосов и повышение энерго-эффективности зданий повысили конкурентоспособность гибридных систем отопления на рынках, где пока еще доминирует централизованное теплоснабжение. В настоящее время техническое обслуживание часто рассматривается как реактивный центр затрат, а не как стратегический рычаг для обеспечения устойчивости. Данное исследование восполняет этот пробел, предлагая интегрированную концепцию, которая сочетает в себе техническое обслуживание, ориентированное на надежность (RCM), принципы циркулярной экономики и интеграцию интеллектуальных технологий. Проект модернизации здания 1980-х годов в г. Мытищи, в котором были внедрены передовые геотермальные технологии, служит важным подтверждением концепции, демонстрируя техническую осуществимость модернизации объектов культурного наследия.
Ключевые слова
Геотермальные тепловые насосы, надежностно-ориентированное техническое обслуживание (RCM), декарбонизация, ИИ, здания

Hybrid heating systems with ground source heat pump (GSHP) and district heating and cooling offer flexibility in operation to both building owners and energy providers. The

flexibility can be used to make the heating system more economical and environmentally friendly [4]. AI holds the potential to advance automation for not only service robots, but also in how data is collected, secured and used to increase trust, safety and efficiency [5].

The climatic constraints of the region limit the feasibility of certain renewable options like solar panels, creating a significant challenge for decarbonization. This context underscores the scientific problem: how to significantly enhance the sustainability, efficiency, and environmental performance of existing, conventional heating infrastructure within challenging technical and climatic constraints.

To integrate RCM with smart technology for sustainable use of GSHP, the following steps are proposed:

1) Pilot Application: Utilize the Mytishchi retrofit project as a living laboratory to test and refine the proposed RCM and circular economy framework on its geothermal and ancillary heating systems, validating the model in a real-world, and historically constrained setting.

2) Scalable Model for Heritage & Existing Stock: Promote the validated framework as a scalable model for retrofitting and maintaining heating systems in the vast stock of older buildings across Russia and other regions with similar infrastructure, bridging the gap between heritage preservation and technological sustainability.

This research establishes that intelligent, circular approaches to building heating system maintenance are not only technologically feasible but are essential for achieving deep decarbonization and resource efficiency in the built environment. The proposed RCM framework, enhanced by circular principles and AI, provides a comprehensive model for predictive maintenance and sustainable operation of GSHP systems.

The practical use of these research results is the transformation of central heating systems from static, consuming assets into dynamic, regenerative components of urban infrastructure. The implementation leads to tangible benefits: extended equipment life cycles, significant reductions in material consumption, lower energy use, and decreased greenhouse gas emissions.

References

1. Aridi, M., Pannier, M., R., Lemenand, T. A Comprehensive Review of Life Cycle Assessments for Domestic Heat Pumps: Environmental Footprint and Future Directions // Energy & Buildings. – 2025. – Vol. 336. – P. 115605.
2. Orlov, A.V. Econometric analysis of the influence of factors on the share of energy from renewable sources in the EU. Nizhny Novgorod State Technical University, Russia. – P. 158.
3. Puttige, A.R., Andersson, S., Östin, R., Olofsson, T. Modeling and optimization of hybrid ground source heat pump with district heating and cooling // Energy & Buildings. – 2022. – Vol. 264. – P. 112065.
4. Truong, N.L., Gustavsson, L. Costs and primary energy use of heating new residential areas with district heat or electric heat pumps // Energy Procedia. – 2019. – Vol. 158. – P. 2031–2038.
5. Ossio, F., Salinas, C., Hernández, H. Circular economy in the built environment: A systematic literature review and definition of the circular construction concept // Journal of Cleaner Production. – 2023. – Vol. 414. – P. 137738.