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POLICY RECOMMENDATION FOR INTEGRATED SMART HEATING SYSTEM

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Abstract:
In the context of the challenges posed by global climate change and the need for a sustainable energy transition, this study addresses the ways in which innovative strategies contribute to the formulation of public policies aimed at optimising heating systems. This research aims to identify solutions to reduce greenhouse gas emissions and to increase energy efficiency in the field of heating, essential aspects in achieving global sustainability goals to formulate policy recommendations for an integrated heating system.
Adopting a mixed methodological approach, this analysis combines the literature review with a systematic examination of different initiatives and solutions adopted at the urban level to extract patterns of good practice and highlight relevant relationships and differences. The research emphasises the importance of the synergy between innovation, governance, and financing mechanisms in promoting sustainable and effective solutions.
In the light of good practices and lessons learned from cities such as Copenhagen, Stockholm, Helsinki, Vancouver, and Freiburg, the authors' contribution focuses on identifying governance strategies that facilitate the transition to optimised heating systems. These cities demonstrate how the implementation of well-designed public policies can act as a catalyst for the adoption of sustainable heating solutions, highlighting the essential role of public policy in mediating urban development needs and the effective implementation of sustainability initiatives.
The research results show that adopting an integrated and participatory approach involving all relevant actors can speed up the adoption of more efficient heating systems with reduced environmental impact. This underlines the importance of adopting legislative and public policy frameworks that stimulate heating innovation and encourage collaboration between the public, private and community sectors.
Beneficiaries of this research include policy makers, energy professionals, and the academic community, providing them with a solid foundation for the development and implementation of effective public policies. The study concludes that it is essential to develop public policy strategies that promote the adoption of sustainable heating solutions, based on lessons learned from cities that have successfully implemented such initiatives. Thus, progress towards a sustainable energy future can be accelerated, contributing significantly to global efforts to reduce the negative impact on the environment.

Keywords: Public Policy Innovation, Sustainable Heating Systems, Technological Integration. Energy Transition Artificial Intelligence in Energy, Stakeholder Collaboration.

JEL: Q48, R58, O33, Q55

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INTRODUCTION

In the current context marked by the imperative to combat climate change and the need for a global energy transition, energy efficiency and the reduction of greenhouse gas emissions become indisputable priorities. Heating systems represent a critical segment, having a significant impact on energy consumption, on carbon emissions, and, implicitly, on climate change. Recent technological breakthroughs, including advances in artificial intelligence and the Internet of Things (IoT), are opening new horizons for optimising heating systems, turning them into smart and sustainable solutions. However, the large-scale adoption and integration of these technological innovations crucially depends on effective public policy development and implementation.

This research directly addresses the public issue of energy inefficiency and the negative impact of conventional heating systems on the environment, economy, and society. The economic impact manifests itself in high energy costs and dependency, while the social impact includes energy poverty and public health issues related to air quality. From an environmental perspective, inefficient systems contribute to global warming and ecosystem degradation.

The importance of this research lies in its ability to contribute to the transition to a more sustainable energy future through an in-depth analysis of how innovative public policies can facilitate the implementation of smart heating systems. The aim of the paper is twofold: on the one hand, to provide a broad understanding of the challenges and opportunities associated with modernising heating systems through emerging technologies; on the other hand, to identify and analyse public policy strategies that can accelerate the adoption of these innovative solutions. In this sense, the working hypothesis is that a strategic approach, based on intersectoral collaboration and innovation in public policies, can optimise the effectiveness of heating systems, significantly reducing their negative impact on the environment, and improving energy sustainability globally.

Therefore, this research not only addresses an immediate need for energy optimisation and emissions reduction, but also contributes significantly to the existing academic body, providing new directions for public policymaking and promoting a cleaner and greener energy future.

The energy transition and combating climate change are at the center of contemporary global concerns, imposing the need to review and optimise heating systems. In this landscape, emerging technologies such as artificial intelligence (AI) and the Internet of Things (IoT) can fundamentally transform the way energy is produced, distributed, and consumed, promising improved energy efficiency and reduced carbon emissions.

Against the background of these technological developments, understanding how public policy can facilitate or hinder the adoption of innovative technologies becomes crucial. International experiences show that the success of the transition to more efficient and sustainable heating systems significantly depends on the existence of a well-designed public policy framework that stimulates innovation, mobilises investment, and supports collaboration between different actors from the public, private, and civil society sectors.

In this context, the present research aims to analyse innovative strategies in public policies as means of promoting the integration of advanced technologies in heating systems. The study will also assess existing barriers to the implementation of these technologies and explore potential solutions to overcome them, with the aim of contributing to global efforts to achieve a sustainable energy transition.

1. LITERATURE REVIEW

The review of innovation and public policy literature highlights the crucial role of research and development (R&D) in generating innovations, which, in turn, drive technological change. The latter is recognised as the main driver of economic development (Link et al., 2006). In the same vein,

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public/private partnerships are emphasised as essential innovation strategies, offering policy alternatives (Link, 2006).

Landabaso (1997) argues that the promotion of innovation in regional policy and related research and development efforts are essential for regional economic development, directly addressing the need to close the "technology gap" between the regions of the European Union. This "gap" risks widening even more, accentuating the differences in cohesion between regions. The author suggests that regional policy should increasingly focus its efforts on promoting innovation, as a means of creating the conditions for a sustainable and sustained economic development process in less favoured regions.

Edler, Cunningham, and Gök (2016) contribute to this discussion by providing a broad perspective on the impact of innovation policies. Their work, Handbook of Innovation Policy Impact, is a valuable resource for understanding the complex effects of innovation policies and how they can be aligned with overall policy goals.

In the context of the public sector, Arundel, Bloch, and Ferguson (2019) emphasise the importance of advancing innovation, arguing that aligning innovation measures with policy objectives is critical to the success of innovation in the public sector. This is a significant challenge given the often rigid and structured nature of public sector organisations.

Wallace (2017) explores the relationship between environmental policies and industrial innovation, highlighting how strategies in Europe, the US, and Japan help promote green innovation. This work is relevant in the current context, where climate change and sustainability are pressing global issues.

Ansell and Torfing (2014) discuss public innovation through collaboration and design, highlighting the need for a better specification of institutional and policy requirements to support a robust vision of public innovation. They emphasise collaboration, creative problem solving, and design as key dimensions of innovation in the public sector.

The analysis of recent academic literature allowed us to create a dynamic image of the efforts to harmonise technological advances and public policy imperatives in shaping the energy-sustainable urban landscape of the future. This synergy is reflected in the development and implementation of smart energy systems, which promise to radically transform both communities and municipalities, improving energy efficiency, reducing carbon emissions, and promoting the use of renewable energy sources. To map the route towards the horizons of urban sustainability and energy transition, the specialised literature offers a wide spectrum of investigations that shed light on the potential of technological integration in the sphere of public policies, oriented towards building sustainable communities and municipalities. This intersection becomes fertile ground for the emergence of smart energy systems as fundamental solutions to contemporary challenges.

Ceglia et al. (2020) trace a conceptual evolution from smart energy communities to smart energy municipalities, thereby highlighting a framework for understanding and action for the energy transition at the local level. This trajectory underscores the importance of policy adaptability and innovation, suggesting that the success of urban sustainability relies on the ability to integrate advanced technological solutions into an effective governance framework.

In this context, Razmjoo et al. (2022) foreground the development of smart energy systems for communities, emphasising the harmony between technologies, policies, and practical applications. Their work expands the discussion on the need for a synergy between technological innovation and policy approaches that can facilitate a smooth transition to more efficient and sustainable energy consumption patterns.

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Through the work of Lund et al. (2014), the concept of 4th Generation District Heating (4GDH) is presented as an emblematic example of how smart heating networks can be integrated into the sustainable energy systems of the future. This vision proposes a reconfiguration of district heating systems, orienting them towards maximum efficiency and the integration of renewable energy sources.

Furthermore, Dominković et al. (2017) investigate the impact of interconnection of geographically distributed district heating networks on the energy system, showing that this interconnection can lead to increased energy efficiency and better balance of energy demand and supply within cities. This points to a promising path toward urban energy autonomy and system flexibility.
Maier's (2016) analysis of the Reininghaus district as a case study for smart energy systems in urban neighbourhoods illustrates how smart energy solutions can be tailored to meet the specific needs of urban communities, highlighting the positive impact of technological integration on urban sustainability.

The integration of energy systems and the implications of this process for public policies, as explored by Cambini et al. (2020), represents a cornerstone in the discussion of sustainable energy transformation. The authors argue that an integrated approach, combining different energy sources and infrastructures, can lead to significant efficiencies and a reduction in environmental impact. This paper emphasises the essential role of public policies in facilitating and accelerating systems integration, through a legislative and regulatory framework that supports innovation and cross-sectoral cooperation.

Lund et al. (2017) advance the discussion by defining the concept of smart energy and smart energy systems, highlighting how these systems not only optimise energy consumption, but also how they facilitate the integration of renewable sources into the energy network. This research shows that to achieve sustainability goals, energy systems must not only be efficient, but also intelligent, i.e., capable of dynamically managing and balancing energy supply and demand.

Along a similar path, Li, Rezgui and Zhu (2017) focus on the optimisation and improvement of district-level heating and cooling systems, emphasising the integration of renewable sources, storage systems, and smart grid. Their work suggests that a holistic approach, encompassing innovative technologies and advanced energy management, can lead to significant improvements in energy efficiency and carbon reduction.

O'Dwyer et al. (2019) extend this view, exploring how smart energy systems can support the development of sustainable smart cities. They highlight several current developments and trends in this field, such as electric vehicles, smart buildings, and microgrids, showing how their integration into a holistic energy system can help achieve urban sustainability goals.

In a more technological and implementation-focused approach, Fedoruk (2013) examines the integration of smart energy systems and networked buildings, discussing the challenges and opportunities associated with design, control, and operational experience. This PhD thesis provides valuable insights into how technological innovations can be applied in practice to improve energy efficiency and user comfort.

Essentially, these studies emphasise a common point: the need for an integrated and sustainable approach in the development and implementation of smart energy systems. They reflect a consensus in the literature on the importance of synergy between technology, regulation, and community participation in promoting the transition to a cleaner and more sustainable energy future.

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2. RESEARCH OBJECTIVES AND METHODOLOGY

This research aims to identify solutions for reducing greenhouse gas emissions and increasing energy efficiency in the field of heating, essential aspects in achieving global sustainability goals to formulate policy recommendations for an integrated heating system.

This research addressed the intersection of technological innovation and public policy, focusing on how emerging technologies such as artificial intelligence (AI) and the Internet of Things (IoT) have been effectively integrated into the development and implementation of innovative strategies for public health systems. sustainable heating. Adopting a mixed methodology, the study provided a detailed analysis and comparison between various solutions and situations, highlighting patterns of success, significant relationships, and differences between approaches adopted in different contexts.

Qualitative Review of Specialty Literature: In the initial stage of the research process, a qualitative literature review was conducted, identifying, and synthesising previous research exploring the use of AI and IoT in improving the efficiency of heating systems. This review examined studies focused on the challenges, opportunities, and outcomes of implementing emerging technologies in the context of public policies for energy sustainability. The endeavour aimed to build a solid knowledge base, facilitating an in-depth understanding of current trends, research gaps, and the unexplored potential of technological innovations in this field.

Systematic Comparison of Different Situations or Solutions: After establishing the theoretical framework, the research progressed with a systematic comparison of different situations or solutions. This stage focused on analysing how different jurisdictions have integrated AI and IoT technologies into public policy strategies, highlighting innovative approaches, challenges encountered, and the impact of these technologies on the efficiency and sustainability of heating systems. The aim was to identify significant relationships between innovation, governance, and funding, and to determine the most effective strategies for promoting sustainable solutions.

Synergy between Innovation, Governance, and Financing: Analysing the synergy between innovation, governance, and finance was a crucial component of the methodology. The study investigated how the interplay between these three dimensions can facilitate or hinder the adoption and scaling of innovative heating technology solutions. Exploring these dynamics, the research aimed to provide strategic recommendations for the development and implementation of public policies that capitalise on the advantages offered by AI and IoT, guiding the transition to more efficient and environmentally sustainable heating systems.

3. FINDINGS

In the scientific endeavour to decode the interaction between technological innovations and the implementation of smart public policies in the field of integrated heating systems, the research followed a complex analytical route, anchored in a rigorous methodology that combined the review of specialised literature with the analysis of secondary data. This methodological framework enabled an in-depth exploration of the ways in which emerging technologies and innovative governance approaches can contribute to the transformation of traditional energy infrastructures into efficient, sustainable, and resilient systems.

In the specialised literature, a consensus has been identified regarding the potential of technologies such as artificial intelligence (AI) and the Internet of Things (IoT) to revolutionise the heating system by optimising its management and operation. Previous studies, such as those by Lund et al. (2017) and Li, Rezgui, and Zhu (2017), highlighted the ability of these technologies to improve energy efficiency and reduce the carbon footprint of district heating systems, through advanced monitoring and increased adaptability in the face of demand fluctuations and energy supply. The integration of smart technologies into heating systems has demonstrated the potential to optimise energy

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consumption and minimise harmful emissions, thus aligning with sustainable development goals. This transformation, however, requires a detailed understanding of the systemic dynamics and the interactions between different actors and technological components. The success of implementing smart technologies is intrinsically linked to the development and adoption of governance strategies and funding models that support innovation and facilitate cross-sector collaboration. The specialised literature, including the works of Cambini et al. (2020) and O'Dwyer et al. (2019), highlights the need for public policies that provide a stable and predictable framework for investments in green technologies.

Table 1. Key Literature on Policies for Heating Systems

Authors	Year	Key Themes	Main Conclusions/Recommendations
Ceglia et al.	2020	Transition from smart energy communities to municipalities	Emphasises the need for cohesive agendas and technological integration for energy sustainability.
Razmjoo et al.	2022	Development of smart energy systems for communities	Highlights the importance of synergy between technology, policies, and applications for widespread adoption.
Cambini et al.	2020	Energy systems integration and public policy implications	Underlines the role of public policies in facilitating the integration of smart energy technologies.
Lund et al.	2014	4th Generation District Heating (4GDH)	Advocates for the integration of smart thermal grids for increased efficiency and energy sustainability.
Lund et al.	2017	Smart energy and smart energy systems	Stresses the need for a holistic approach in energy planning to optimise resource use and promote sustainability.
Li, Rezgui, Zhu	2017	Optimisation and enhancement of district heating and cooling	Focuses on the integration of renewables, storage, and smart grid technologies for improved system efficiency.
O'Dwyer et al.	2019	Smart energy systems for sustainable smart cities	Discusses current developments, trends, and future directions in smart energy systems for enhancing urban sustainability.
Fedoruk	2013	'Smart' energy systems and networked buildings	Examines the integration, controls, and design through operation experience, suggesting improvements in energy efficiency.

Source: Authors' own processing

The detailed literature review provided an in-depth insight into the interaction between technological innovations and the implementation of smart public policies, highlighting how they can work together to support the evolution of traditional energy infrastructure. Although smart technologies have been observed to present valuable opportunities for improving energy efficiency and reducing environmental impact, the success of their integration into the everyday practice of heating systems is highly dependent on the development of a regulatory and financing framework that is favourable.

Table 2 provides a comprehensive analysis of the integration of smart technologies in district heating systems, covering five key aspects. It covers aspects such as the current state of implementation of smart technologies in heating systems, identified challenges, anticipated benefits, and recommendations for developing effective implementation policies and strategies.

Table 2. Synthesis of Smart Heating Systems: Adoption and Strategies

Data Category	Description	Findings
Implementation Status	Evaluates the degree of smart technology integration within district heating systems.	Observes a disparate level of technology adoption, with urban environments at the forefront of integration.
Identified Challenges	Pinpoints fundamental obstacles to the widespread acceptance and efficient execution of smart heating systems.	Financial, technical, and regulatory barriers are significant, impeding extensive deployment.
Potential Benefits	Emphasises the expected merits of embedding smart technologies into	Foresees improvements in energy efficiency, emission reductions, and augmented adaptability

Data Category	Description	Findings
	heating infrastructures.	and robustness of systems.
Policy Recommendations	Proposes directives to facilitate the embracement and refinement of smart heating technologies.	Calls for enabling policy environments, innovation incentives, and comprehensive stakeholder involvement.
Implementation Strategies	Details viable approaches for the introduction of smart technologies into heating mechanisms.	Underlines the importance of detailed strategic planning, collaborative efforts among stakeholders, and gradual introduction of technological advancements.

Source: Authors' own processing

Table 2 presents a detailed view of the status, challenges, benefits, policy recommendations, and strategies for the integration of smart technologies in district heating systems. It emphasises the importance of overcoming existing barriers through strategic planning, collaborative efforts, and supporting policies to realise the full potential of smart heating systems.

The implementation of smart sustainable heating systems in cities around the world has demonstrated the significant potential to reduce energy consumption and lower carbon emissions. Although direct access to specific savings data is limited, below are examples of cities recognised for their sustainable heating initiatives, reflecting the trends and impact of these technologies (Table 3).

Copenhagen, Denmark: The city aims to become carbon neutral by 2025, and its district heating system plays a key role in that goal. By using high-efficiency heat pumps and renewable energy sources, Copenhagen has been able to significantly reduce the GHG emissions associated with heating.

Stockholm, Sweden: Stockholm's district heating system, which relies on heat pumps and heat recovery from various sources, including waste water, has contributed to a considerable reduction in dependence on fossil fuels. This has enabled the city to realise significant energy savings and reduce its carbon footprint.

Helsinki, Finland: The Smart Kalasatama project in Helsinki is an example of a neighbourhood that uses smart heating and energy solutions, integrating advanced technologies to optimise energy consumption and promote sustainability.

Vancouver, Canada: Vancouver has demonstrated its commitment to becoming a green city with a smart district heating system that uses geothermal energy and heat recovery, aiming to reduce carbon emissions and increase energy efficiency.

Freiburg, Germany: Recognised as a pioneering city in sustainability, Freiburg has invested in heating systems that combine solar thermal energy and biomass, demonstrating a strong commitment to emissions reduction and energy efficiency.

Table 3. Overview of Sustainable Heating Initiatives and Achievements in Global Cities

City	Initiative	Period	Strategic Document	Savings Achieved
Copenhagen	Renewable source district heating system	2010-present	Carbon Neutrality Plan by 2025	Significant CO_2 emission reduction, energy savings due to improved efficiency
Stockholm	Waste heat recovery from wastewater	2015-present	Green City Initiative	Energy consumption savings, reduced reliance on fossil fuels
Helsinki	Smart Kalasatama, integration of smart energy solutions	2013-present	Smart City Strategy	Optimised energy consumption, enhanced heating system efficiency
Vancouver	Centralised geothermal heating system	2012-present	Greenest City 2020 Action Plan	Greenhouse gas emission reduction, savings through the use of renewable energy sources

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City	Initiative	Period	Strategic Document	Savings Achieved
Freiburg	Combination of solar thermal and biomass energy	2000-present	Sustainable Development Policies	Reduced primary energy consumption, decrease in CO_2 emissions

Source: Authors' own processing

These cities exemplify how innovative heating technologies can play a crucial role in the energy transition and efforts to combat climate change. Implementing smart heating systems not only promotes efficiency and sustainability, but also contributes to significant long-term savings by reducing energy consumption and associated operational costs.

4. RESULTS AND DISCUSSION

The research highlights the importance of the synergy between innovation, governance, and financing mechanisms in promoting sustainable and effective solutions. In the light of good practices and lessons learned from cities such as Copenhagen, Stockholm, Helsinki, Vancouver and Freiburg, the authors' contribution focuses on identifying governance strategies that facilitate the transition to optimised heating systems. These cities demonstrate how the implementation of well-designed policies can act as a catalyst for the adoption of sustainable heating solutions, highlighting the essential role of policy in mediating urban development needs and the effective implementation of sustainability initiatives.

Research results show that adopting an integrated and participatory approach that involves all relevant actors can accelerate the adoption of more efficient heating systems with reduced environmental impact. This underlines the importance of adopting legislative and public policy frameworks that stimulate heating innovation and encourage collaboration between the public, private and community sectors.

The analysis of specialised literature and case studies identified in different economically and socially advanced countries led us to develop the following policy objectives:

O1: Integration of Technological Innovations in Heating Systems
O2: Promoting Sustainability in Heating Systems
O3: Increasing Access to Financing for Heating Innovations
O4: Strengthening Knowledge and Capacity in the Field of Sustainable Heating
O5: Formulation and Implementation of Supporting Policies and Regulations
The objectives pursued in this research were designed to guide the development and implementation of public policies to facilitate the transition to smart and sustainable heating systems, reflecting the commitment to innovation, efficiency, and ecological responsibility. By pursuing these objectives, the adoption of heating solutions that are not only technologically advanced, but also aligned with the global imperative of sustainability and reducing environmental impact can be accelerated. The method of achieving the objectives aims at the following directions:

O1: Integration of Technological Innovations in Heating Systems. Creating a policy framework to foster the adoption and integration of innovative technologies such as artificial intelligence (AI) and the Internet of Things (IoT) in heating systems to increase energy efficiency and reduce resource consumption. Encouraging partnerships between the public sector, the private sector, and academic institutions for the development and implementation of advanced technological solutions.

O2: Promoting Sustainability in Heating Systems. Developing strategies to prioritise the use of renewable energy sources and low carbon solutions for heating. Setting targets and performance indicators for monitoring and evaluating progress towards sustainability goals.

O3: Increasing Access to Financing for Heating Innovations. Developing innovative financial mechanisms, including subsidies, tax credits, and dedicated financing programs, to support the

adoption of sustainable heating technologies. Encouraging investments in energy infrastructure and sustainable heating technologies through financial and fiscal stimulus policies.

O4: Strengthening Knowledge and Capacity in the Field of Sustainable Heating. Implementing training and education programs for energy and construction professionals, improving their skills to design, install, and maintain smart and sustainable heating systems. Launching public awareness campaigns on the benefits and importance of adopting sustainable and efficient heating systems.
O5: Formulation and Implementation of Supporting Policies and Regulations Reviewing and updating existing regulations to reflect new technologies and approaches to heating, ensuring that legislation supports innovation and sustainability. Commitment to a continuous dialogue with all stakeholders to ensure that public policies are adapted to the needs of the sector and encourage the widespread adoption of smart heating solutions.

Public Issue: Increasing Greenhouse Gas Emissions from Conventional Heating Systems

Conventional heating systems, mainly based on fossil fuels, are a significant source of greenhouse gas (GHG) emissions, thus contributing to global warming and climate change. This public problem not only exacerbates the global climate crisis, but also leads to energy dependency, energy price volatility, and public health issues related to air quality. In this context, the need to transition to more efficient and sustainable heating systems becomes imperative. In the context of accelerated climate change and the increasing need for sustainable actions at the global level, the transition to smart and sustainable heating systems is a multidimensional challenge that involves significant economic, social, and environmental impacts.

From an *economic perspective*, the adoption of sustainable heating systems promises to reduce long-term costs for consumers by reducing energy expenses, while also helping to stimulate the economy by creating new jobs in the field of green technologies and related sectors. Energy security is improved by diversifying energy sources, thereby reducing vulnerability to fluctuations in international fossil fuel markets. However, the economic challenges are represented by the high initial costs associated with the adoption of sustainable heating technologies and the need for subsidy mechanisms to facilitate the transition, which require considerable budget allocations on their part.

At *the societal level,* addressing air quality issues by reducing emissions of greenhouse gases and other pollutants has a positive impact on public health, reducing the incidence of respiratory and other health conditions associated with pollution. Promoting social equity through their accessibility of sustainable heating technologies to all segments of society is essential, although widespread adoption of these technologies may encounter resistance due to the behavioural changes required and disparities in access among the population.

From an *ecological point of view,* the benefits of the transition to sustainable heating systems are indisputable, contributing to the significant reduction of greenhouse gas emissions and the conservation of natural resources. The use of renewable energy sources and efficient technologies minimises environmental impact and supports long-term sustainability goals. However, the production and implementation of new technologies can have their own environmental impacts, requiring careful waste management and recycling strategies to minimise negative effects.

The adoption and integration of renewable energy sources has been highlighted by the success of cities such as Copenhagen and Freiburg, where the integration of renewable energies into heating systems has demonstrated significant improvements in energy efficiency and sustainability. In this sense, we recommend that Romania develop national strategies to promote and support investments in heating technologies that exploit renewable sources, such as solar, geothermal, and biomass. This would also include facilitating access to financing and incentives for the adoption of these innovative technologies.

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On the other hand, the use of smart energy solutions to improve energy efficiency, exemplified by Helsinki, suggests that the implementation of pilot projects that integrate energy management systems based on artificial intelligence and the Internet of Things can provide valuable ways to optimise consumption and reduce energy losses. Such initiatives should be encouraged and supported through public policies and dedicated funding programs in Romania, promoting technological innovation and collaboration between the public and private sectors.

In addition, the development and adoption of legislative frameworks to encourage the adoption of sustainable heating systems, inspired by Stockholm and Vancouver's green policies and initiatives, are vital to promoting sustainability. This involves developing governance strategies that facilitate the implementation of green technologies and ensure a fair and efficient transition to sustainable heating solutions.

Thus, the adaptation and application of the lessons learned from international good practices in the Romanian context requires an integrated and comprehensive approach, which recognises the essential role of technological innovation, strategic planning, and community commitment in achieving the objectives of energy efficiency and sustainability. Therefore, we recommend that Romania also adopt a holistic perspective in the development of public policies that support innovation and stimulate investments in sustainable energy infrastructure, thus contributing to global efforts to combat climate change and promote sustainable development.

CONCLUSIONS

In the context of the global imperative to respond to climate change and promote a sustainable energy transition, the findings of this study highlight the crucial role of innovative public policy strategies in facilitating the adoption of sustainable and efficient heating systems. Reflecting on lessons learned from cities such as Copenhagen, Stockholm, Helsinki, Vancouver and Freiburg, the research demonstrates that the synergy between innovation, governance, and finance is the foundation for the development of sustainable energy infrastructures.

This analysis underlines the need for an integrated and participatory approach involving all relevant actors in the energy transition process. Such a holistic approach involves not only technological development, but also the development of legislative and public policy frameworks that support innovation and facilitate collaboration between the public, private and local sectors. The importance of adaptive governance is central to this process, ensuring that public policies are flexible enough to incorporate technological advances and respond effectively to emerging challenges.

The study also highlights that public policy serves as an essential mediator between technological development and the sustainable implementation of heating solutions. Creating an enabling environment that encourages investment in sustainable technologies and promotes cross-sector collaboration is crucial to achieving energy efficiency and greenhouse gas reduction goals.

AUTHORS CONTRIBUTIONS

The authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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