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Review

Urban Energy Transitions: A Systematic Review

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Abstract: Urban energy efficiency and sustainability are critical challenges, as cities worldwide attempt to balance economic growth, environmental sustainability, and energy consumption. This systematic review examines the dynamics of urban energy management, focusing on how local authorities navigate energy transitions through efficiency measures, renewable energy adoption, and policy interventions. Specifically, it seeks to answer the following research question: how do local authorities implement energy-efficient practices and adopt renewable energy technologies to reduce emissions, optimize cost-effectiveness, and influence urban policy-making? The goal of this study is to assess the effectiveness of these approaches in different urban contexts. By reviewing 47 articles, this study identifies the unique characteristics of urban energy management and highlights the need for tailored, context-specific solutions, such as integrating decentralized renewable energy systems, optimizing building energy performance, and developing policy incentives that consider local socio-economic conditions. The findings reveal varying degrees of success among cities, with particular challenges in lower-income municipalities, where financial and institutional barriers hinder the implementation of sustainable energy projects. This study concludes that localized approaches and long-term strategies are essential for achieving sustainable urban energy transitions, offering a comprehensive perspective on the complexities of urban energy systems and their evolving policy landscape. Future research should focus on assessing the long-term impact of municipal energy policies, exploring innovative financing mechanisms for renewable energy integration, and examining the role of digital technologies in optimizing urban energy management.

Keywords: urban energy transitions; energy; energy efficiency; renewable energy; cities; municipal energy policies

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1. Introduction

The global energy landscape is at a critical juncture, with projections indicating a significant surge in energy demand by 2040, expected to reach 736 quadrillion Btu, driven primarily by non-OECD nations [1,2]. This increase presents opportunities for developing economies to enhance their energy systems through efficiency measures and transitions to renewable sources, while developed nations face the challenge of modernizing their aging infrastructures [3–5]. Addressing energy needs at the municipal level is particularly crucial, as urban areas are dense hubs of consumption, innovation, and environmental impact [6]. Urban communities encounter unique challenges, including rapid urbanization, aging infrastructure, limited resources, and diverse stakeholder interests [7,8]. Urban densification has significantly shaped energy demand; for example, cities like New York and London have experienced annual population growth rates of 7.7% and 7.3% over the past decade, placing considerable pressure on their energy infrastructure and efficiency strategies [9,10]. Consequently, innovative solutions are required to improve energy efficiency, enhance infrastructure resilience, and promote environmental sustainability in cities [11].

Cities, which are major contributors to global energy consumption, account for over 70% of global CO_2 emissions, making them key players in the transition toward sustainable energy solutions [12,13]. Integrating renewable energy sources within cities not only reduces emissions but also improves cost-effectiveness and significantly influences urban planning policies [14]. In Copenhagen, the integration of renewable technologies has resulted in an 80% reduction in CO_2 emissions, significantly improving urban sustainability efforts [15]. Similarly, New York has achieved a 19% reduction in emissions through renewable energy adoption while also optimizing municipal energy efficiency [16]. In addition to emissions reduction, these initiatives have led to substantial economic benefits. On average, cities implementing such transitions report a 20% decrease in municipal energy expenditures, demonstrating the financial viability of large-scale renewable integration [17,18]. However, discussions on modernizing energy infrastructures often overlook socio-economic complexities, particularly in developing economies, where governance, stakeholder engagement, and social acceptance remain underexplored [19]. This highlights the need for a holistic approach to address the complexities of urban energy transitions.

This systematic review provides a comprehensive overview of how to integrate energy-efficient practices and renewable energy sources in urban areas. The primary research questions driving this study are as follows: How do local authorities implement and facilitate the integration of energy-efficient practices and renewable energy sources in urban areas? How can these initiatives mitigate emissions, optimize cost-effectiveness, and inform urban policy-making? By conducting a systematic literature review, this research maps current knowledge on urban energy transitions and explores the impact of these initiatives on emission reductions, cost-effectiveness, and policy frameworks. Furthermore, the review identifies mechanisms to drive eco-friendly energy solutions, offering valuable insights into the challenges and opportunities cities face in achieving sustainable energy transitions.

1.1. Purpose and Main Results of the Study

This study examines how municipalities implement energy-efficient practices and integrate renewable energy sources to enhance urban sustainability. Through a systematic review of 47 studies, this research identifies key strategies employed by local authorities to reduce emissions, improve cost-effectiveness, and shape urban energy policies. The findings highlight the diverse challenges cities face, particularly in lower-income municipalities, and emphasize the importance of tailored policy frameworks and long-term planning. This study contributes to the understanding of urban energy dynamics by bridging the gap between technological advancements, governance, and policy-making at the municipal level.

The originality of this study lies in its focus on the role of local authorities in promoting energy-efficient practices and renewable energy integration within urban contexts. By analyzing urban energy dynamics, this study explores how municipalities respond to environmental, economic, and infrastructural challenges in shaping sustainable energy transitions. While much of the literature has focused on national or regional strategies, this review addresses a critical gap by exploring how municipalities faced with unique socio-economic and environmental pressures are implementing solutions tailored to their specific energy needs. By examining emission reductions, cost-effectiveness, and policy-making, this study sheds light on the nuanced approaches cities adopt to navigate the energy transition. Additionally, this study acknowledges the underexplored qualitative dimensions of governance and social acceptance, offering a fresh perspective on how stakeholder engagement influences the success of urban energy initiatives.

1.2. Background

As urban centers face increasingly complex energy challenges, including carbon emissions management, climate change mitigation, rising energy costs, and energy security, energy efficiency and renewable energy integration have become critical components of sustainable urban development [20,21]. Local authorities play a crucial role in addressing these challenges through tailored, context-specific energy efficiency measures and policies [11,22].

1.2.1. Urban Energy Efficiency Practices

Systematic reviews on energy efficiency in urban settings have often focused on national or regional strategies, neglecting the pivotal role municipalities play in driving localized sustainability efforts. For example, the 2009 Copenhagen Accord prompted significant global initiatives to adopt renewable energy and efficiency measures [23], but these initiatives tend to overlook the specific dynamics of urban settlements, where governance structures, local policy frameworks, and infrastructure complexities present distinct challenges [12]. The integration of renewable energy technologies, such as waste-to-energy (WtE) systems, solar energy, and plastic gasification, has demonstrated significant potential for emission reductions in urban environments [24,25]. However, these technological innovations are often hindered by logistical, financial, and institutional barriers that limit their scalability across different urban contexts. Research indicates that while these technologies contribute to environmental sustainability, their long-term impact and operational feasibility require further exploration [22,26].

1.2.2. Barriers to Implementing Energy-Efficient Technologies in Cities

Municipalities face various barriers when implementing energy-efficient technologies. Financial constraints remain a primary challenge, particularly in lower-income cities, where limited budgets restrict the adoption of renewable technologies such as solar and biogas systems [27,28]. Despite the long-term economic benefits of these technologies, the upfront costs are often prohibitive for resource-constrained municipalities [29,30]. In addition to financial challenges, institutional inertia within local governments can impede the adoption of new technologies. As noted by Kaswan [31] and Sparrow [32], resistance to change, driven by entrenched bureaucratic practices and a lack of coordination between stakeholders, can delay or disrupt the integration of energy-efficient practices. Furthermore, a lack of collaboration between utility providers, businesses, and community groups further hampers the effective deployment of energy-efficient solutions [33,34].

1.2.3. Policy Frameworks Supporting Urban Energy Transitions

Policy frameworks are crucial for enabling the successful adoption of energy-efficient technologies in cities. Research highlights the importance of policies that integrate circular economy principles and the Water–Energy–Food (WEF) nexus, which optimize resource use and contribute to broader sustainability objectives [34,35]. However, existing policy frameworks often favor wealthier cities with stronger financial capacities, leaving gaps in support for lower-income municipalities [36,37].

To address these disparities, public–private partnerships and innovative financial mechanisms, such as carbon pricing and renewable energy incentives, have been proposed to make sustainable technologies more accessible in diverse urban contexts [38,39]. These policies not only promote emission reductions and energy efficiency but also ensure that municipalities have the resources to overcome institutional and financial barriers.

2. Materials and Methods

The scope of the selected studies spans various geographic regions, including both developed and developing urban areas, and covers energy systems such as solar, wind, and waste-to-energy technologies. The studies, published between 2009 and 2023, primarily focus on urban settings, with a particular emphasis on municipal-level energy transitions. They address topics such as emission reductions, cost-effectiveness, renewable energy integration, and policy frameworks, providing a comprehensive overview of urban energy initiatives.

The methodology for this systematic review featured two complementary approaches: the snowball method and keyword searches. The snowball method systematically gathers relevant literature by following citation trails from key articles [40–42]. These articles were classified as key based on their foundational role in establishing the scope and direction of this review. Article [40] was selected due to its comprehensive exploration of energy transition models in Africa, aligning with the broader geographical and thematic focus of this study. Articles [41,42] were selected for their significant contributions to understanding energy efficiency and energy poverty in urban environments, which are central to the core themes of this review. This process ensures that the review captures the most relevant literature, reducing the risk of bias while maintaining a clear connection to key themes in energy transitions. Furthermore, this approach helps identify literature that may not be easily accessible through traditional keyword searches [43]. However, to ensure a comprehensive and unbiased review, keyword searches were also conducted at a later stage, allowing for broader coverage and the identification of studies that may not have been captured through citation tracking alone. The combination of these methods facilitated a more thorough examination of energy efficiency and renewable energy integration in urban environments. By leveraging both approaches, this review captured a broader and potentially more relevant set of studies, reducing the limitations of relying solely on either method [44]. This process is illustrated in Figure 1.

The search was conducted using the following search string: ["Energy Efficiency" AND "Renewable Energy" AND "Urban Settlements"]. These terms were selected to capture the literature on urban energy initiatives, focusing on emission reductions, cost-effectiveness, and policy frameworks within the context of local authorities. The search encompassed several academic databases, including Google Scholar, Taylor & Francis Online, ScienceDirect, ProQuest, JSTOR, and Web of Science (WOS). The results of this initial search are detailed in Table 1.

After applying filters to select peer-reviewed, open-access journals in English and eliminating eight duplicate articles, the number of relevant studies was refined to 47, all of which were published in energy-related academic journals. The article filtering procedure was conducted in two stages. First, only peer-reviewed, open-access journals published in English were considered, ensuring high-quality and accessible sources. Second, a detailed assessment was conducted to exclude articles that did not align with the specific focus of this review. Articles addressing broader geographical scales or non-urban contexts were intentionally filtered out to maintain a targeted focus on urban energy efficiency and renewable energy integration. This filtering process was designed to ensure that the selected articles specifically addressed energy initiatives relevant to local authorities and municipalities, with a strong emphasis on emission reductions, cost-effectiveness, and policy implications. This process is further illustrated in Table 2.

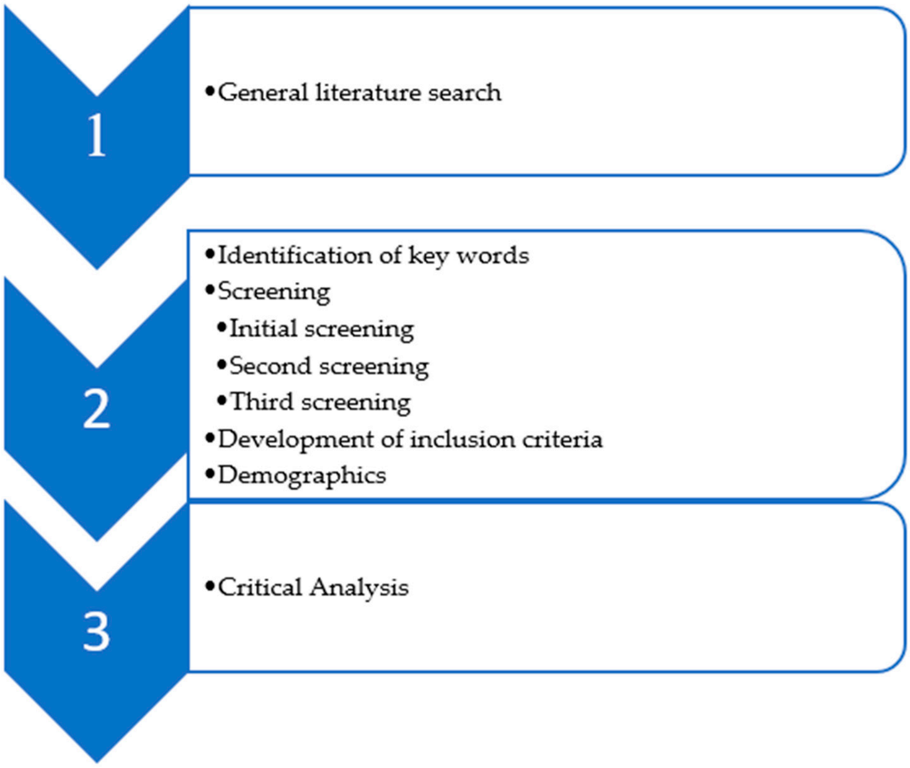


Figure 1. Stepwise snowball structure of the review.

Table 1. Summary of database search results and initial screening criteria.

	Number of Papers Returned from Each Search Engine						
Search Terms	**Google Scholar**	**T & F Online**	**Science Direct**	**ProQuest**	**Jstor**	**Web of Science (WOS)**	**Total**
"Energy" AND "Urban Settlements"	18,200	843	2962	15,781	255	167	24,008
"Efficiency" AND "Urban Settlements"	16,400	593	2184	12,021	1526	59	32,783
"Energy" AND "Efficiency" AND "Urban Settlements"	15,900	296	1462	10,321	740	53	28,502
"Energy Efficiency" AND "Urban Settlements"	5500	94	481	3493	120	16	6554
"Energy Efficiency" AND "Renewable Energy"	1,020,000	17,054	67,685	441,583	13,539	26,882	1,558,557
"Energy Efficiency" AND "Renewable Energy" AND "Urban Settlements"	3100	45	278	2605	47	1	6033

Table 2. Systematic screening stages and final selection of studies.

	Number of Papers Returned from Each Search Engine		
Database	**Initial Screening**	**Second Screening**	**Third Screening**
Google Scholar	3100	450	14
T & F Online	45	6	0
Science Direct	278	69	11
ProQuest	2605	236	21
Jstor	47	13	0
Web of Science (WOS)	1	1	1
Total	6033	1078	47

The study selection process followed the PRISMA 2020 guidelines, ensuring a transparent and systematic approach to identifying relevant studies. The screening and eligibility criteria applied at each stage are detailed in Table 2. For a visual representation of this process, see Figure 2.

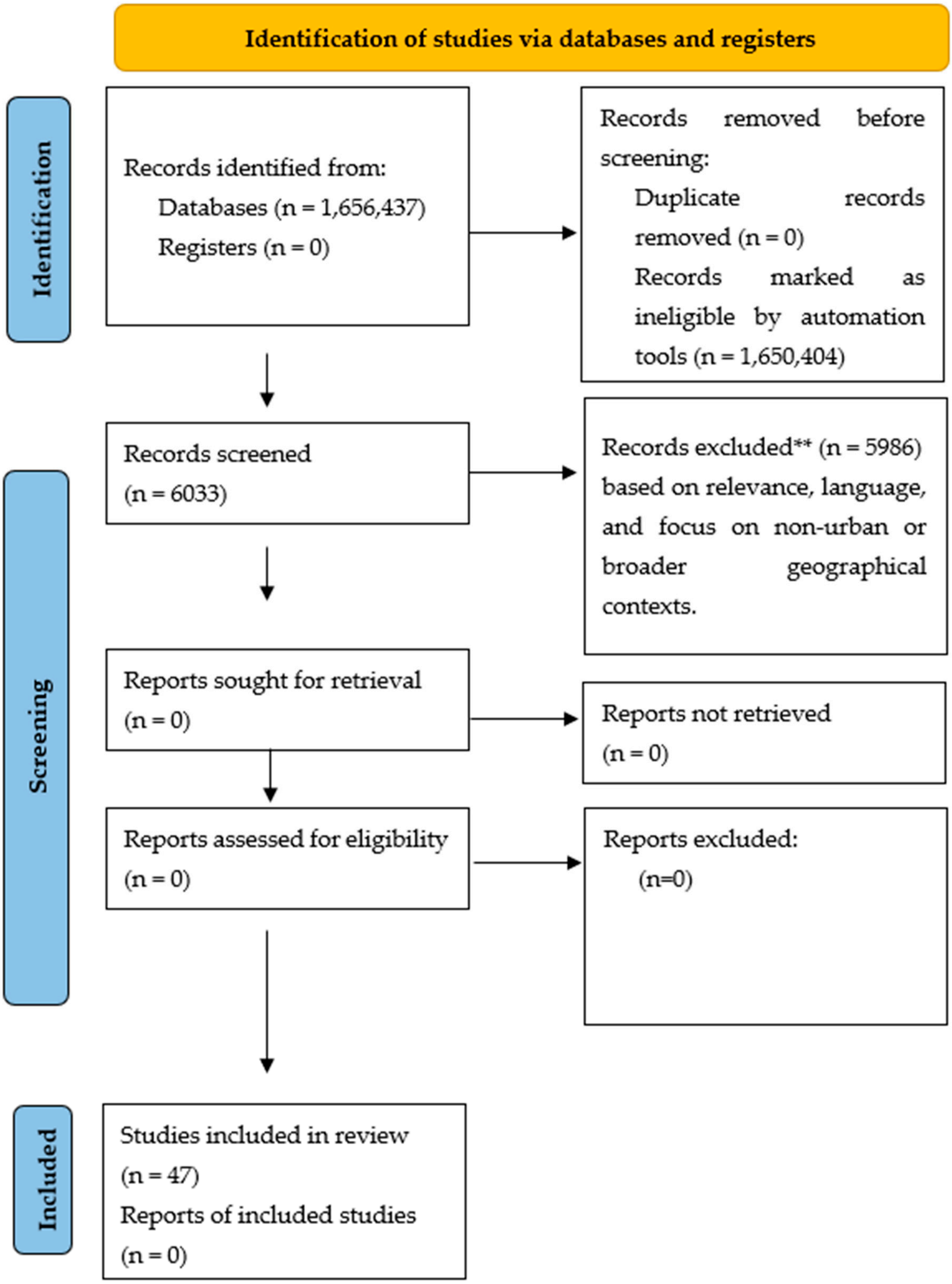
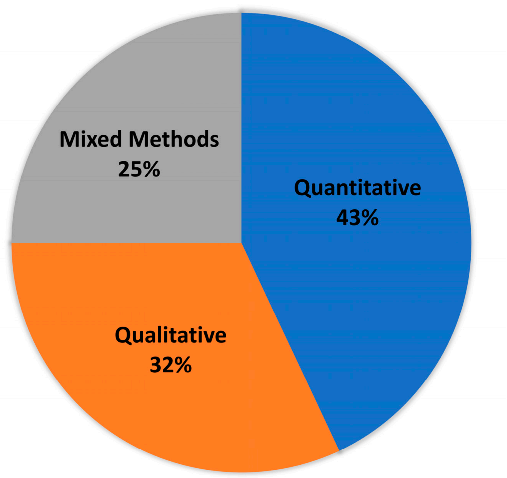
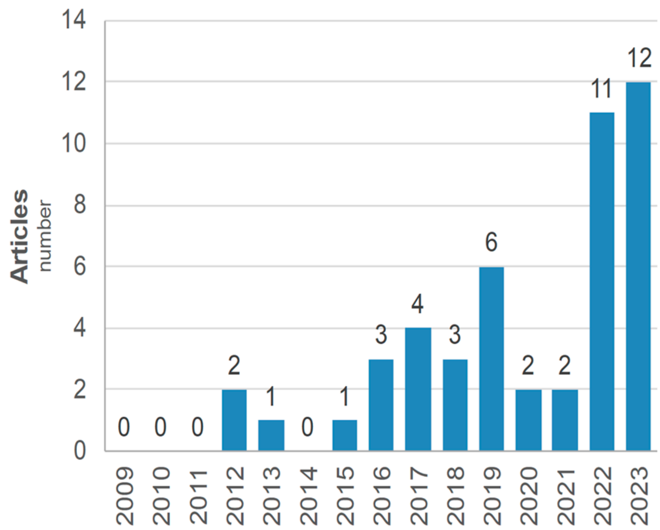


Figure 2. PRISMA 2020 flow diagram illustrating the study selection process.

The methodological aspects of the 47 studies selected after the final screening are summarized in Figure 3. These studies employed various methodological approaches, including quantitative, qualitative, and mixed-methods research, highlighting the diversity of techniques used to assess urban energy transitions.



(a)



(b)

Figure 3. Methodological aspects of studies screened in the third round. (**a**) Distribution of research methodologies by percentage: quantitative, qualitative, and mixed methods. (**b**) Number of studies published per year.

Moreover, the factors driving urban energy efficiency initiatives were analyzed in the final stage of this review. Table 3 categorizes these factors into three key areas: renewable energy integration, energy-efficient practices, and policy frameworks. The sub-factors within each category provide insights into how local authorities can leverage different technologies and policy instruments to achieve sustainability goals.

Table 3. Categorization of key factors in urban energy efficiency and renewable integration.

Factors	Sub-Factors	Insights for Research Questions
Renewable Energy Integration	Solar power	Promotes sustainable practices and reduces harmful emissions in urban areas, indicating potential for local authorities to adopt solar energy as part of their energy mix [45,46].
	Wind power	Impacts emission reductions and cost-effectiveness, suggesting local authorities can explore wind power as a viable renewable source for urban energy systems [47,48].
	Hydroelectric power	Provides clean energy alternatives, offering opportunities for local authorities to leverage hydroelectric power for sustainable energy integration [12,49].
	Biomass	Contributes to emission reductions and cost-effectiveness, highlighting the potential for biomass adoption by local authorities within urban environments [50,51].

Table 3. *Cont.*

Factors	Sub-Factors	Insights for Research Questions
Energy-efficient Practices	Energy-efficient appliances	Influence sustainable practices and cost-effectiveness, aligning with local governance goals for energy efficiency [52].
	Building insulation	Promotes sustainability and informs policy implications for urban infrastructure, underscoring the importance of energy-efficient building practices [53].
	Smart grid technologies	Enhance sustainable practices and inform policy decisions by optimizing energy distribution and consumption in urban contexts [54,55].
Policy Framework	Renewable energy incentives	Facilitate sustainable practices and inform policy implications by promoting renewable energy adoption in urban areas [56].
	Energy efficiency regulations	Promote sustainable practices and inform policy decisions for emission reductions, highlighting the role of regulatory frameworks in energy efficiency [57].
	Carbon pricing	Impacts emission reductions and cost-effectiveness, contributing to policy implications within local governance by incentivizing emission reduction measures [58,59].

These insights underscore the importance of a holistic approach to municipal energy efficiency, incorporating technological, financial, and policy-driven strategies to ensure successful urban energy transitions.

3. Results

The scope of the selected studies spans various geographic regions, including both developed and developing urban areas, and covers energy systems such as solar, wind, and waste-to-energy technologies. The studies, published between 2009 and 2023, primarily focus on urban settings, with a particular emphasis on municipal-level energy transitions. They explore critical topics such as emission reductions, cost-effectiveness, renewable energy integration, and policy frameworks. This comprehensive overview of urban energy initiatives serves as the foundation for the analysis presented in Table 4.

Table 4. Overview of selected studies, methodologies, and research focus.

Authors	Method Used	Data	Study Period	Effect on Energy Efficiency		
				Emissions Reduction	Cost-Effectiveness	Policy Implications
Aboulnaga et al. [60]	Simulation using ENVI-met 3.1 and Design Builder 2.1	Metrological data, urban form data, passive cooling design configurations, and climate change scenarios for 2016 and 2080	2016–2080	✔	✔	✔
Alonso-Marroquin and Qadir [61]	Experimental Analysis	Electricity, ambient sensors	December 2021–February 2023	✔		

Table 4. *Cont.*

Authors	Method Used	Data	Study Period	Effect on Energy Efficiency		
				Emissions Reduction	**Cost-Effectiveness**	**Policy Implications**
Andreotti et al. [62]	Hydrothermal monitoring and simulation	Temperature, humidity, thermal properties, and hydrothermal simulations	2019–2020			
Antuña-Rozado et al. [63]	Qualitative analysis	Demographic, socio-economic, environmental, and stakeholder perspectives data	1987–2019	✔	✔	✔
Bánkuti and Zanatyné Uitz [35]	Practical implementation analysis	Historical data on district heating system, energy savings, cost, and greenhouse gas emissions in Kaposvár	1990s–2013	✔	✔	✔
Barakat and Aboul-naga [64]	Environmentally centered approach and qualitative environmental assessment	Data collection, analyses, and qualitative environmental assessments	Not specified	✔	✔	✔
Besner et al. [65]	Literature Review and Analysis	Key performance indicators, literature-based indices, case study data, and comparative metrics	Not specified	✔	✔	✔
Bieber et al. [4]	Case-study analysis	Population, technology costs/emissions, water/climate, policies, crop yields/land use	2017–2030	✔	✔	✔
Bridge et al. [66]	Conceptual analysis	Seminar series on the UK's low-carbon energy transition policies and geographical impacts	2009–2011	✔	✔	✔
Bruck et al. [67]	Statistical data analysis	CO_2 emissions and energy consumption data from government and European databases	1990–2018	✔	✔	✔

Table 4. *Cont.*

Authors	Method Used	Data	Study Period	Effect on Energy Efficiency		
				Emissions Reduction	Cost-Effectiveness	Policy Implications
Daioglou et al. [36]	Integrated Assessment Modeling	Regional energy system model projections of residential energy demand and building stocks data across 26 world regions	2020–2100	✔	✔	✔
De Rosa et al. [68]	Literature Review	Urban energy consumption and carbon emissions data from building and transportation sectors	2010–2020	✔	✔	✔
Delmastro et al. [69]	Geographical Information Systems (GIS) integrated modeling	Geo-referenced building data, energy consumption data, and socio-economic data	2010	✔	✔	✔
Di Matteo et al. [27]	Energy Analysis, Waste Characterization	Substrate flow rate, biogas yield, and auxiliaries' consumption	Not specified	✔	✔	✔
Ferrante [70]	Literature Review and Case Study	Energy performance data of traditional buildings, analysis of passive cooling techniques, and application examples from previous research	Not specified	✔	✔	✔
Formolli et al. [28]	Systematic Literature Review	Literature on solar accessibility in high-latitude urban environments	2010–2022	✔	✔	✔
Gagliano et al. [71]	Dynamic simulations with DesignBuilder	Thermal properties of building materials, climate data for Catania, Italy, building geometry, and operational schedules	One year (annual simulation)	✔	✔	✔
Jamil and Pearce [72]	Policy Analysis		Not specified	✔	✔	✔

Table 4. *Cont.*

Authors	Method Used	Data	Study Period	Effect on Energy Efficiency		
				Emissions Reduction	Cost-Effectiveness	Policy Implications
Jovović et al. [73]	Random-effects logit model		2000–2020			✔
Karches [74]	Numerical Modeling and Analysis		2020–2023	✔		✔
Kılkış and Kılkış [75]	Exergy Analysis		Not specified	✔	✔	
Koepke et al. [76]	Governance Modalities Framework		1999–2022	✔	✔	✔
Komendantova et al. [77]	Content Analysis		Not specified			✔
Korkovelos et al. [78]	Geospatial Modeling		2018–2030	✔	✔	✔
Kretschmer et al. [79]	Stakeholder Analysis and Interviews		2010–2018	✔	✔	✔
Lazaro et al. [80]	Case study analysis and theoretical exploration	Case studies on urban-rural relationships, circular economy, institutional perspectives, logistics, urban food production, and food waste reduction	Not specified	✔	✔	✔
Leone et al. [37]	Literature Review, Questionnaire Analysis	Questionnaires, literature review, and interviews with project representatives	Not specified	✔	✔	✔
Longe [81]	Qualitative Interviews and Surveys	Structured interviews and Google forms	2019–2021	✔	✔	✔
Malinauskaite et al. [82]	Literature Review and Analysis	National waste management plans, governmental reports, Eurostat, and EU reports	2000–2015	✔	✔	✔
Mastro-lonardo [83]	Multi-stakeholder approach, strategic planning	Accident records, stakeholder feedback	1993–2003, 2020–2022	✔	✔	✔

Table 4. *Cont.*

Authors	Method Used	Data	Study Period	Effect on Energy Efficiency		
				Emissions Reduction	Cost-Effectiveness	Policy Implications
Mata-Lima et al. [24]	Governance Modalities Framework	Literature review, relevant factors on waste and WtE technologies, and synthesis of environmental impacts	Not specified	✔	✔	✔
Mauree et al. [84]	Comprehensive literature review, tool analysis	Selected papers related to urban climate, urban heat island, urban energy demand, urban energy systems, outdoor thermal comfort, and climate change	1979–2019	✔	✔	✔
Midilli et al. [25]	Energy, exergy, and exergetic sustainability analysis	Thermodynamic analysis results from a case study on plastic gasification processes	Not specified	✔	✔	✔
Mika and Goudz [85]	Survey and Meta-analysis	Quantitative Survey Data	2016–2019	✔	✔	✔
Nardecchia et al. [86]	Energy/Exergy Analysis	Building in Rome	2022	✔	✔	
Ochoa et al. [87]	Quantitative analysis	2015 Intercensal Survey (IS) by the National Institute of Statistics and Geography of Mexico (INEGI) and raster images of climate data published by INEGI	2015–2020			✔
Padovan and Arrobbio [88]	Empirical investigation, socio-technical evaluation	Interviews, focus groups	Not specified	✔	✔	✔
Palmas et al. [89]	Integrated Energy Planning	Developed bioenergy assessment method, surveyed experts for sustainable location criteria	Not specified	✔	✔	✔
Papa et al. [90]	Development and application of the Urban Saving Energy Model (UrbanSEM)	Energy consumption data at the neighborhood scale	Not specified	✔	✔	✔

Table 4. *Cont.*

Authors	Method Used	Data	Study Period	Effect on Energy Efficiency		
				Emissions Reduction	Cost-Effectiveness	Policy Implications
Pardo-Bosch et al. [91]	Case study analysis	Developed city business model using Value Proposition Canvas (VPC), Value Creation Ecosystem (VCE), and City Model Canvas (CMC), validated through case study	2020–2021	✔	✔	✔
Persson et al. [92]	Economic and Physical Suitability Analysis	GIS-based improvement of distribution cost model	2015	✔	✔	✔
Qeqe et al. [93]	Econometric Analysis	Data from 2000 to 2018 on electricity prices and household expenditures in South Africa	2000–2018	✔	✔	✔
Sewilam and Nasr [94]	Case study analysis	Historical and observational data related to desalination projects and agricultural practices in the Arab region	1970s onwards	✔	✔	✔
Sezer et al. [95]	Governance Modalities Framework	Data related to urban microclimates and building energy performance	2012–2021	✔	✔	✔
Singh and Hachem-Vermette [96]	Resilience Analysis Methodology	Data related to neighborhood configurations, energy outage scenarios, and infrastructure and energy resilience indicators	Not specified			✔

Table 4. *Cont.*

Authors	Method Used	Data	Study Period	Effect on Energy Efficiency		
				Emissions Reduction	Cost-Effectiveness	Policy Implications
Tlili et al. [97]	Scenario analysis, multi-criteria analysis	French organizations such as RTE, ADEME, and ANCRE, as well as geographic and land/ocean eligibility data for renewable energy installations across France	Not specified	✔	✔	✔
Yigitcanlar et al. [98]	Interdisciplinary Literature Review	Data on neighborhood configurations, energy outage scenarios, and infrastructure and energy resilience indicators to study the sustainable development of smart cities	Not specified	✔	✔	✔

Legend: Emissions Reduction: Articles discussing methods for reducing greenhouse gas emissions in urban areas. Cost Effectiveness: Articles evaluating the economic benefits of sustainable energy practices in urban settings. Policy Implications: Articles addressing the role of policy in supporting sustainable energy initiatives. ✔: Article significantly addresses this aspect. Blank: No reference to this aspect in the article.

3.1. Municipal-Level Emission Reduction Initiatives

Emission reductions in urban settings require an integrated approach that considers technological innovations, urban planning, policy frameworks, human behavior, and sustainability strategies. These interconnected factors shape the evaluation of existing research and help identify both progress and gaps in the literature. Studies show that innovative approaches, such as integrating urban resource management, have significant potential to reduce greenhouse gas emissions. For instance, Bánkuti and Zanatyné Uitz [35] demonstrated how circular economy principles, energy use optimization, and food waste reduction can effectively lower urban carbon footprints. This approach underscores the importance of adopting sustainable energy practices that directly contribute to emission reductions within the energy sector.

Building on the theme of technological advancements, Midilli et al. [19] explore another critical pathway for reducing emissions through plastic gasification, a process with substantial potential to reduce carbon emissions in urban waste management. Their research highlights the potential of a hydrogen-based economy to enhance energy efficiency within waste management systems; however, integrating such technological innovations into existing urban infrastructures remains a complex challenge. Jones and Martinez [49] further argue that the successful integration of such emerging technologies requires policy coherence and multi-stakeholder engagement at the municipal level. The need for a comprehensive approach that combines multiple innovative strategies becomes clear, as cities must balance emission reductions with policy alignment and systemic urban energy practices.

Similarly, the DEng project in the UAE [88] illustrates the importance of urban-specific strategies in residential energy use. This project emphasizes improving thermal performance, reducing air-conditioned air loss, and enhancing construction quality control, all of which contribute significantly to the UAE's Energy Strategy 2050, targeting a 40% reduction in energy consumption. These examples show that tailored solutions in urban residential areas, supported by broader systemic innovations, can have a substantial impact on reducing emissions at the municipal level.

In addition to technological advancements, human behavior also plays a critical role in urban sustainability efforts. Barakat and Aboulnaga [64] demonstrate how understanding building users' interactions with their environment can lead to significant reductions in CO_2 emissions. Sustainable design features that promote energy-efficient behaviors offer an important dimension to emission reduction strategies, emphasizing the need to consider both technological and human factors.

Municipal governments have also launched public awareness campaigns and community engagement programs to promote behavioral changes, such as energy conservation and waste reduction [36,64]. Lacey-Barnacle [52] highlights that community-driven sustainability initiatives tend to yield more persistent behavioral changes, reinforcing the role of civic participation in emission reductions. These initiatives enhance the effectiveness of technological solutions by fostering a culture of sustainability among urban residents.

While these studies highlight diverse strategies for reducing urban emissions, several key research gaps remain. First, there is a lack of long-term evaluations assessing whether emission reduction initiatives sustain their effectiveness over extended periods. Most existing studies focus on short-term energy savings and emissions mitigation, but comprehensive longitudinal assessments are scarce [45]. Second, comparative analyses between different cities and regions are limited, making it difficult to generalize findings across diverse urban settings with varying policy and infrastructure frameworks [29]. Additionally, there is a gap in research addressing the integration of technological advancements with municipal policy measures, as existing studies tend to focus on these aspects separately rather than examining their combined impact [49]. Lastly, although behavioral factors are recognized as critical to emission reductions, further research is needed to explore how social and psychological dynamics influence the success of urban sustainability initiatives [52]. Addressing these gaps will enhance the effectiveness and scalability of municipal emission reduction strategies.

3.2. Enhancing Cost-Effectiveness in Municipal Sustainability Initiatives

The integration of renewable energy and energy-efficient practices is essential for achieving urban sustainability, but cost-effectiveness remains a key consideration for municipalities. Renewable energy plays a critical role in this process, as highlighted by Formolli et al. [28] and Di Matteo et al. [27], who showcase the economic viability of solar energy and small-scale biogas production in urban environments. Solar energy systems provide long-term energy savings and revenue generation opportunities, while biogas facilities contribute to waste management and economic growth. Municipal policies that support financial incentives, such as feed-in tariffs and tax rebates, have been implemented in various cities to enhance the economic feasibility of these technologies [37]. These renewable solutions offer significant cost savings by replacing traditional energy sources and reducing greenhouse gas emissions, making them both economically and environmentally beneficial.

Cost-effectiveness extends beyond renewable energy technologies to include other aspects of urban sustainability. For example, Mauree et al. [84] advocate for sustainable urban design as a means to achieve long-term economic benefits. Investments in energy-efficient planning and renewable energy systems have proven to yield financial returns over time, particularly in densely populated urban areas where energy consumption is high. Longe [37] highlights that expanding affordable electricity access can significantly impact urban sustainability by promoting energy equity and reducing poverty, particularly when supported by governmental policies.

In the realm of waste management, processes such as plastic gasification, as studied by Midilli et al. [25], offer economically efficient alternatives to traditional systems. By integrating renewable energy sources into waste management, cities can reduce energy consumption and operational costs while addressing environmental concerns. Moreover, Bánkuti and Zanatyné Uitz [35] demonstrate how coordinated governance and multilevel collaboration can optimize resource use, leading to significant financial savings. Efficient management of public resources supports broader sustainability initiatives and ensures that cost-effectiveness remains central to urban energy planning.

Technological innovations also play a crucial role in enhancing cost-effectiveness within urban sustainability initiatives. Padovan and Arrobbio [88] demonstrate that improving the thermal performance of buildings through energy-efficient design can significantly lower energy costs. For instance, in the Turin district heating system, optimization measures have led to a reduction in heating expenses by up to 20%, improving both cost efficiency and energy savings. Similarly, Bruck et al. [67] explore the economic benefits of transitioning to renewable energy sources in the transport sector. They emphasize the role of government subsidies and incentives in making these technologies more accessible, further highlighting the importance of public investment in reducing costs and fostering widespread adoption. Finally, advancements in desalination technologies, as demonstrated by Sewilam and Nasr [94], underscore the role of continuous innovation in achieving a cost-effective urban water supply. By improving the energy efficiency of desalination processes, cities can ensure that water resources remain affordable and sustainable. These technological developments reinforce the importance of innovation as a driving force behind cost-effective urban sustainability.

3.3. Municipal-Level Policy Implications

Policy frameworks at the municipal level are crucial for supporting emission reductions, renewable energy deployment, and urban sustainability. Emission reduction policies, in particular, play a central role in advancing sustainable urban development. Municipal governments have adopted diverse policy mechanisms, such as mandatory building energy audits and carbon pricing schemes, to drive energy efficiency [36]. Daioglou et al. [36] and Longe [37] emphasize that policies targeting energy efficiency improvements in buildings, as well as emissions pricing, are necessary to drive down energy consumption and greenhouse gas emissions. Policies must also extend to the transport sector, as Bruck et al. [67] argue, where national and regional policies that promote renewable energy sources can significantly contribute to emission reductions. Similarly, Di Matteo et al. [27] highlight the economic and environmental benefits of waste-to-energy technologies, which are essential for creating sustainable waste management practices.

The deployment of renewable energy sources requires supportive municipal policies that remove legal barriers and incentivize stakeholder engagement. Besner et al. [65] and Korkovelos et al. [78] stress the importance of policy frameworks that prioritize energy access, especially in underdeveloped areas. Additionally, aligning policies with economic realities is crucial for promoting renewable energy sources like solar, wind, and hydrogen. Midilli et al. [25] discuss the need for municipal policies to support hydrogen adoption, a critical step toward reducing reliance on fossil fuels and achieving long-term sustainability goals.

Effective governance frameworks are also vital for building urban resilience. Singh and Hachem-Vermette [96] emphasize the need for evidence-based policies and regulatory oversight to guide sustainable urban development. Collaborative governance frameworks, as discussed by Bánkuti and Zanatyné Uitz [35], optimize resource use and foster resilience through cross-sectoral partnerships. By engaging various stakeholders, cities can better address the challenges posed by rapid urbanization and climate change.

Sustainable waste management policies are another critical area of focus for urban sustainability. Malinauskaite et al. [82] and Kretschmer et al. [79] highlight the importance of long-term planning and collaboration in waste management systems. Innovative technologies like gasification, as explored by Midilli et al. [25], offer cost-effective and efficient waste treatment solutions that align with broader sustainability objectives. Additionally, policy frameworks that integrate waste-to-energy technologies, as advocated by Mata-Lima et al. [24], ensure that waste management practices contribute to both emission reductions and economic development.

To ensure the success of urban sustainability, comprehensive policies must integrate climate adaptation and mitigation strategies across all areas of urban planning, from housing to transportation and infrastructure. Singh and Hachem-Vermette [96] emphasize the importance of resilience-focused policies, particularly in regions vulnerable to climate change. Moreover, financial incentives such as subsidies, tax breaks, and low-interest loans are crucial for encouraging the adoption of energy-efficient technologies and renewable energy systems [37]. Public–private partnerships, as demonstrated by Bánkuti and Zanatyné Uitz [35], can fund and implement sustainable urban projects. Additionally, raising public awareness and engaging communities are key to fostering long-term commitment to sustainability practices [36].

Despite growing evidence supporting the cost-effectiveness of municipal sustainability initiatives, several research gaps persist. First, comprehensive economic analyses comparing different urban sustainability strategies are limited. While studies highlight the financial benefits of renewable energy and waste management solutions [21,22], there is a lack of systematic cost–benefit comparisons between different technological and policy approaches. Second, although financial incentives such as subsidies and feed-in tariffs play a crucial role in promoting sustainable urban projects, further research is needed to evaluate their long-term impact on municipal budgets and energy market stability [37]. Additionally, alternative financing mechanisms, such as outcome-based financing and green municipal bonds, remain underexplored in the literature [31]. Finally, there is limited research on how cities can optimize cost-effectiveness by integrating multiple sustainability strategies within a single urban framework [56]. Closing these gaps will provide municipalities with a clearer understanding of the economic feasibility of different sustainability pathways.

4. Discussion

This systematic review analyzed municipal-level sustainability initiatives, focusing on emission reductions, cost-effectiveness, and policy development, revealing key trends and gaps. Our review of 6033 articles resulted in the selection of 47 studies relevant to urban sustainability. A key gap remains in assessing the actual implementation and long-term effectiveness of municipal policies. The analysis identifies a critical gap in research addressing local authorities' roles in driving sustainability transitions, as much of the existing literature targets broader national or regional levels. By narrowing the scope to municipalities, this review provides essential insights into how governance, policy frameworks, and technological innovations intersect at the urban level. Further empirical studies are needed to track municipal sustainability initiatives over time and evaluate their effectiveness. At the same time, special attention should be paid to the following aspects.

4.1. Limited Scope of Existing Research

One major finding is the relative scarcity of research on municipal-level sustainability efforts, despite cities' pivotal role in global energy transitions. Many studies focus on large-scale national strategies, neglecting the unique challenges and opportunities faced by municipalities. Coaffee [11] and Chourabi et al. [7] emphasized the complexity of cities as entities with diverse stakeholder interests, aging infrastructure, and limited resources. Despite their environmental impact and innovation potential, few studies directly address local-level transitions. Technological advancements, such as plastic gasification and waste-to-energy systems [24,25], demonstrate promise for emission reductions. However, there is a notable lack of long-term studies evaluating the broader impacts of these technologies in urban settings. Morioka and Carvalho [26] underscore the importance of systematic approaches to sustainability, but few others extend these insights to long-term urban impacts. More research is needed to assess whether technological innovations remain effective over time and how they align with municipal energy policies and economic goals.

4.2. Challenges in Implementing Technological Innovations

Technological advancements, such as plastic gasification and waste-to-energy systems [24,25], demonstrate promise for emission reductions. However, there is a notable lack of long-term studies evaluating the broader impacts of these technologies in urban settings. Morioka and Carvalho [26] underscore the importance of systematic approaches to sustainability, but few others extend these insights to long-term urban impacts. More research is needed to assess whether technological innovations remain effective over time and how they align with municipal energy policies and economic goals.

4.3. Cost-Effectiveness and Economic Feasibility

Cost-effectiveness plays a central role in municipal sustainability efforts. Studies demonstrate that renewable energy technologies, such as solar and small-scale biogas, offer financial viability in wealthier cities [27,28]. Solar energy integration, for example, reduces long-term costs while generating significant environmental benefits. However, the initial investment required for waste-to-energy systems or building retrofitting can be prohibitively expensive for lower-income cities [24]. Adaptive policies, including public–private partnerships [38], are necessary to make sustainable technologies more accessible to cities with limited resources.

4.4. Policy Frameworks for Urban Sustainability

Municipal policy frameworks are critical to advancing urban sustainability initiatives. Effective regulations, financial incentives, and strategic planning create an enabling environment for the adoption of energy-efficient technologies. Bánkuti and Zanatyné Uitz [35] stress the need for policies that integrate circular economy principles and the Water–Energy–Food nexus. Chu et al. [34] similarly emphasize the importance of infrastructure development in supporting emission reduction technologies. However, policy challenges specific to lower-income cities where financial and infrastructural limitations are significant require further investigation [36,37]. Digital innovations like blockchain technology may offer future solutions for improving urban energy management, but their application in cities with limited digital infrastructure is still under-researched [25].

4.5. Implications for Israel's Climatic Zones

The implementation of emission reduction strategies must consider the specific climatic conditions of different regions to ensure their effectiveness. In Israel, where climatic zones range from Mediterranean along the coastal plain to arid desert conditions in the southern regions, urban energy strategies must be tailored accordingly. One key area for adaptation lies in improving thermal performance in residential and commercial buildings. Studies emphasize the importance of reducing energy loss through enhanced insulation, efficient cooling technologies, and construction quality control [88]. Implementing stricter building codes that incorporate passive cooling techniques and high-reflectivity materials could significantly reduce cooling energy demand in Israeli cities.

Furthermore, energy-efficient behavioral interventions play a crucial role in emission reductions. Research has shown that public engagement and awareness campaigns lead to lasting changes in energy consumption habits [64]. Given the high reliance on air conditioning in Israel, targeted awareness initiatives and incentives for smart energy use could enhance urban sustainability. Similarly to successful programs in other regions, municipalities could offer incentives for energy-efficient appliances and promote behavioral shifts toward reduced electricity consumption [52].

Another pivotal adaptation involves expanding renewable energy integration. With Israel's abundant solar potential, further streamlining regulatory frameworks to encourage solar panel adoption on residential and commercial rooftops can maximize local energy independence [27,28]. Additionally, exploring advanced waste-to-energy technologies, such as plastic gasification, could support both emission reductions and waste management goals [25]. Urban policies should also promote pilot projects and partnerships to explore the feasibility of these technologies in municipal energy planning.

In addition to these measures, further strategies could enhance urban energy efficiency beyond those commonly cited in this systematic review. The deployment of smart grids and AI-driven energy management systems can optimize real-time energy consumption and reduce peak loads, contributing to overall efficiency gains [99]. Similarly, urban green infrastructure, such as vegetated rooftops and shaded pedestrian zones, has been shown to lower urban heat island effects and reduce cooling demands [100,101]. Another promising avenue involves decentralized energy storage solutions, which allow local energy communities to manage supply and demand more effectively while reducing reliance on centralized power grids [102,103]. Finally, integrating behavioral economics approaches into municipal energy policies—such as nudges and incentive-based interventions—can further drive reductions in energy consumption through subtle but effective behavioral modifications [104]. These complementary strategies provide additional opportunities for Israeli cities to enhance energy efficiency while aligning with global sustainability trends.

In conclusion, municipal policies must align with national sustainability objectives to ensure coordinated action. Research highlights the importance of multi-stakeholder collaboration in achieving long-term emission reductions [35,37]. By adopting policy frameworks that provide financial incentives and infrastructure investments for sustainable urban projects, Israeli cities can effectively transition toward greener, more energy-resilient urban environments.

5. Conclusions

This study systematically reviewed municipal energy policies and their role in urban sustainability. The findings highlight the critical importance of integrating energy efficiency measures, renewable energy adoption, and tailored urban policies to enhance sustainability and energy independence at the municipal level. The findings emphasize the need for strong local governance, financial incentives, and long-term planning to facilitate effective energy transitions.

Additionally, this study underscores the necessity of adapting energy strategies to regional climatic conditions, particularly in Israel, where distinct climatic zones require tailored policy responses. The findings further demonstrate that successful urban energy policies rely on a combination of technological advancements, behavioral interventions, and supportive regulatory frameworks.

By implementing comprehensive and adaptive policy measures, municipalities can play a crucial role in driving sustainable urban energy transitions. Future research should focus on the long-term impacts of these policies and explore additional innovative approaches to further enhance urban energy efficiency and emission reductions.

Directions for Future Research

Building on the identified gaps in the literature, future research should focus on assessing the long-term effectiveness of municipal sustainability strategies, as current studies primarily highlight short-term benefits such as emission reductions and energy savings but lack longitudinal analyses on their sustained impact over time [45]. Additionally, further investigation is required into the integration of emerging technologies, including hydrogen-based energy solutions, advanced waste-to-energy systems, and AI-driven energy management, to understand their feasibility and scalability within urban infrastructures [19,49]. Another critical research direction involves evaluating the adaptability and effectiveness of municipal policies in different urban contexts, particularly in balancing economic feasibility with sustainability objectives and ensuring the long-term success of regulatory measures [31,57]. Furthermore, more studies should explore the role of community engagement and behavioral interventions in enhancing the adoption of renewable energy solutions and energy conservation efforts at the municipal level, as existing research suggests that public participation plays a crucial role in the success of sustainability initiatives [52,55]. Finally, future research should examine cross-sector collaboration in urban energy planning by investigating governance frameworks that facilitate cooperation between municipalities, private sector stakeholders, and local communities, with the goal of optimizing energy efficiency and renewable energy deployment in diverse urban settings [29,60]. Addressing these research gaps will contribute to a more comprehensive understanding of urban sustainability and support the development of more effective, integrated, and scalable energy solutions.

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