IFIJEB
Indo-Fintech Intellectuals: Journal of Economics and Business

p-ISSN: 2808-2443
e-ISSN: 2808-2222
Volume. 4, No. 2, 2024

TRANSFORMING CITIES THROUGH RENEWABLE ENERGY: ANALYZING THE ROLE OF GREEN INFRASTRUCTURE IN DRIVING URBAN ECONOMIC GROWTH

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Article History

Received: 11-06-2024

Revision: 15-06-2024

Accepted: 17-06-2024

Published: 18-06-2024

Abstract. Cities worldwide are experiencing rapid population growth, leading to increased demand for energy, transportation, and other infrastructure. This poses significant challenges in providing sustainable and environmentally friendly energy. This research aims to analyze the role of green infrastructure in driving urban economic growth through the implementation of renewable energy. The method used in this study is a literature review with a qualitative approach. Data were collected from articles published on Google Scholar between 2013 and 2024. The study results indicate that the use of renewable energy and the development of green infrastructure play a crucial role in transforming cities towards sustainability. The main findings show that renewable energy has a positive impact on reducing carbon emissions, while green infrastructure improves the quality of life and drives urban economic growth. Cities in Indonesia, such as Bandung, Surabaya, and Jakarta, have provided tangible examples of success in implementing these strategies.

Keywords: Renewable Energy, Green Infrastructure, Urban Economic Growth, City Transformation

Abstrak. Kota-kota di seluruh dunia mengalami peningkatan populasi yang pesat, mengakibatkan peningkatan permintaan akan energi, transportasi, dan infrastruktur lainnya. Hal ini menimbulkan tantangan besar dalam penyediaan energi yang berkelanjutan dan ramah lingkungan. Penelitian ini bertujuan untuk menganalisis peran infrastruktur hijau dalam mendorong pertumbuhan ekonomi perkotaan melalui penerapan energi terbarukan. Metode yang diguakan dalam riset ini merupakan tinjauan pustaka dengan pendekatan kualitatif. Data dikumpulkan dari artikel-artikel yang dipublikasikan di Google Scholar antara tahun 2013 hingga 2024. Hasil studi menunjukkan bahwa penggunaan energi terbarukan dan pengembangan infrastruktur hijau memainkan peran penting dalam mengubah kota menuju keberlanjutan. Temuan utama menunjukkan bahwa energi terbarukan memiliki dampak positif dalam mengurangi emisi karbon, sementara infrastruktur hijau meningkatkan kualitas hidup dan mendorong pertumbuhan ekonomi perkotaan. Kota-kota di Indonesia, seperti Bandung, Surabaya, dan Jakarta, telah memberikan contoh nyata kesuksesan dalam menerapkan strategi ini.

Kata Kunci: Energi Terbarukan, Infrastruktur Hijau, Pertumbuhan Ekonomi Perkotaan, Transformasi Kota

How to Cite: Harahap, M. A. K., Amory, J. D. S., & Dahri, M. I. (2024). Transforming Cities Through Renewable Energy: Analyzing the Role of Green Infrastructure in Driving Urban Economic Growth. *Indo-Fintech Intellectuals: Journal of Economics and Business,* 4 (2), 448-460. http://doi.org/10.54373/ifijeb.v4i2.1280

INTRODUCTION

On a global scale, population growth in various urban centers has led to significant demands on resources such as energy, transportation systems, and infrastructure. This situation poses complex challenges related to the provision of sustainable energy and environmentally friendly infrastructure. Sustainability becomes a crucial consideration in urban management in the modern era (Kremer et al., 2019). The increased use of fossil fuels as the primary energy source in urban environments significantly impacts climate change dynamics, air pollution, and environmental degradation (Kartal et al., 2022). In this context, transitioning towards renewable energy sources becomes increasingly urgent as a strategic step to mitigate the negative impacts that have occurred and to promote more sustainable practices in urban energy resource management.

Various policies and international agreements, such as the Paris Agreement, exert pressure on countries to incorporate renewable energy as an integral part of efforts to mitigate global climate change. This push underscores the strategic significance of sustainable energy in the context of sustainable urban development. Efforts to implement green energy become increasingly important in guiding the direction of future urban development, integrating ecological, social, and economic aspects to achieve sustainable development goals (Woon et al., 2023). Green infrastructure, involving the implementation of technologies and systems that optimize the use of natural resources with high efficiency levels, encompasses various innovations such as solar panels, wind turbines, and energy-efficient buildings. The primary role of this infrastructure is to reduce carbon footprints and enhance living standards in urban environments (Ashinze et al., 2024).

Investments in the renewable energy sector not only contribute positively to environmental conditions but also open up new and diverse economic opportunities (Clausen & Rudolph, 2020). Besides reducing carbon emissions and negative environmental impacts, these investments have the potential to create new jobs, increase investment flows, and reduce energy costs in the long term. Several cities in Indonesia have successfully implemented renewable energy and green infrastructure initiatives. For example, Surabaya has developed waste-to-energy systems and promoted urban greening programs through widespread city parks. Additionally, Jakarta has started implementing electric buses to reduce air pollution and improve public transportation quality. As quoted from (Iblam, 2023), this could be based on several international media highlighting Jakarta as the 3rd most polluted city in the world. Not only that, the IQAir website also mentions that the air quality in Jakarta is already included in the unhealthy and unfit for life category. On the site it is stated that Jakarta has reached the

threshold of disaster with air quality reaching 177 and the main pollutant 2.5. This means that the concentration value is 105 per microgram cubic metre (M^3). This condition clearly has a very bad impact on society. Because air pollution is also one of the main causes of the onset of various diseases, such as respiratory problems, eye disorders, coughing, lung cancer, cardiovascular, and others. These success stories demonstrate that with the right policies and active participation from the community, cities in Indonesia can make significant strides towards sustainability and greener economic growth (Harakan, 2023).

Technological advancements in the realm of renewable energy, including progress in energy storage, smart grid development, and innovations in electric vehicles, have been pivotal factors in accelerating the transition towards wider adoption of renewable energy and green infrastructure efficiency in urban areas (Ahmad et al., 2021). The involvement and awareness of the community in adopting sustainable principles are crucial in undertaking the transition towards more environmentally friendly development models. Government-led educational efforts and programs that encourage community participation in green initiatives have the potential to enhance understanding of environmental issues and accelerate the acceptance and implementation of renewable energy within urban communities (Adnyana et al., 2023). Referring to the above exposition, this research aims to analyze the role of green infrastructure in driving urban economic growth through the implementation of renewable energy and to explore effective strategies to achieve these objectives.

METHOD

This study is a literature review with a qualitative approach. Data were collected from articles published on Google Scholar between 2013 and 2024. The keywords used in the search included "renewable energy," "green infrastructure," "urban economic growth," and "city transformation." The initial search yielded 59 relevant articles on the research topic. The collected articles were then filtered using strict inclusion and exclusion criteria. Inclusion criteria included direct relevance to the topic, credibility of the source, and significant impact on the research field. Exclusion criteria included duplication, low relevance, and low quality. After the selection process, 25 articles were chosen for further analysis. The selected articles were analyzed descriptively to identify the main themes and trends related to the role of green infrastructure in driving urban economic growth through renewable energy. This analysis involved manual data coding, theme grouping, and interpretation of results focused on explaining and understanding the phenomena. The analysis results were presented in the form of a descriptive narrative providing a comprehensive overview of the contributions of green

infrastructure and renewable energy to urban economic growth. The discussion of the research findings also included comparisons with previous studies and practical implications for policy and urban development. Figure 1 below encapsulates the adopted research flowchart.

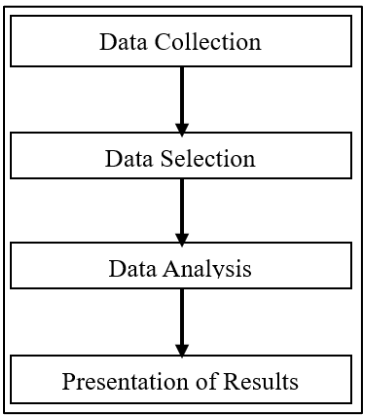

Figure 1. Flowchart methodology

RESULTS

Renewable energy is derived from natural sources that can be replenished sustainably and will not be depleted, such as sunlight, wind, water, biomass, and geothermal heat (Supriyadi et al., 2021). These sources differ from fossil fuels like oil, gas, and coal, which are finite and contribute to climate change and environmental pollution. Renewable energy offers cleaner and environmentally friendly solutions as it does not produce significant greenhouse gas emissions. The use of renewable energy is increasingly important in global efforts to reduce dependence on fossil fuels, minimize negative environmental impacts, and promote sustainable development (Maidasari et al., 2023). Technologies harnessing renewable energy continue to evolve, including solar panels, wind turbines, hydroelectric power plants, as well as geothermal and biomass systems, all contributing to energy source diversification and enhanced energy resilience across various countries.

Green infrastructure encompasses a strategic network of natural open spaces, landscape features, and environmental systems designed to provide various ecological, economic, and social benefits (Monteiro et al., 2020). This infrastructure includes urban parks, rooftop gardens, greenways, urban forests, wetlands, and water features such as rivers and lakes integrated with urban systems. Apart from providing visual beauty and recreational spaces for residents, green infrastructure plays a crucial role in managing stormwater, reducing flood risks, improving air quality, and preserving biodiversity (Ying et al., 2022). It also contributes to climate change mitigation and adaptation by absorbing carbon dioxide and reducing the

urban heat island effect. By integrating natural elements into urban development, green infrastructure helps create healthier and more sustainable environments for communities.

Urban economic growth refers to the increase in a city's economic capacity to produce goods and services, reflected in income growth, job creation, and improved living standards for urban residents (Turok & McGranahan, 2013). This growth occurs through various factors, including increased investment, industrial development, technological innovation, as well as infrastructure and public service improvements. Cities experiencing healthy economic growth tend to have greater attractiveness to businesses and residents, creating a positive cycle that strengthens the local economy. Moreover, urban economic growth encompasses improvements in education, health, and social welfare, all contributing to a better quality of life (Zhang et al., 2023). Thus, urban economic growth is not only characterized by economic indicators but also by overall improvements in the well-being of urban populations.

City transformation is a significant and sustainable process of change in the physical, economic, social, and environmental structure of a city to enhance the quality of life for its residents (Ece Kaya & Erbaş, 2023). This process involves planning and implementing various initiatives such as modern infrastructure development, adoption of smart technologies, energy efficiency improvements, and environmental conservation. City transformation is often driven by the need to address challenges such as rapid population growth, climate change, traffic congestion, and social inequality (James, 2024). Its aim is to create more sustainable, inclusive, and competitive cities by improving public facilities, enhancing accessibility, and creating more green spaces. Thus, city transformation is a holistic effort that combines physical and non-physical aspects to create a better and more sustainable urban environment for all its residents.

DISCUSSION

The research findings indicate that the use of renewable energy and the development of green infrastructure play a crucial role in urban transformation and driving sustainable urban economic growth. Through descriptive analysis of numerous selected articles from Google Scholar, several main themes and emerging trends can be identified, including carbon emission reduction, improved quality of life, economic growth, the success of cities in Indonesia, technological support, and community participation. One of the key findings of this research highlights the positive impact of renewable energy use on reducing carbon emissions. Energy sourced from solar, wind, and biomass plays a central role in reducing dependence on conventional energy sources such as fossil fuels, thereby reducing the amount of greenhouse

gases released into the atmosphere (Hassan et al., 2024). For example, the implementation of solar panels in various urban office facilities and households has proven effective in reducing electricity demand previously met by electricity grids primarily reliant on conventional fossil fuel power plants. This step provides benefits in reducing carbon emissions while significantly reducing energy costs borne by urban residents.

Green infrastructure, in the urban context, plays a vital role in enhancing quality of life, defined in ecological and social dimensions. Comprising elements such as city parks, green corridors, and urban forests, this infrastructure acts as an urban ecosystem balancer and a significant source of benefits for its inhabitants (Myalkovsky et al., 2023). As proven, the presence of these green open spaces not only provides oxygen to dense cities but also offers opportunities for recreation and physical activities that strengthen the physical and mental health of the community. For instance, Bandung, a city that has shown commitment to green infrastructure, has introduced various thematic parks such as Elderly Parks and Singles Parks. The existence of these parks beautifies the urban landscape and creates space for social interaction and communal activities that enhance community bonds and improve quality of life. Urban economic growth is not only influenced by conventional factors but also driven by investments in renewable energy projects and green infrastructure development. Investments in such projects aim to achieve more sustainable environmental goals and provide substantial economic impact. Through the creation of new job opportunities, attraction for investors, and promotion of sustainability-focused economic sectors, renewable energy projects and green infrastructure play a key role in stimulating inclusive economic growth (Sharif et al., 2023). For example, the implementation of solar power plant projects in Bali has successfully provided clean and environmentally friendly energy supply while creating new job opportunities for local communities. In this context, investment in renewable energy yields direct economic benefits and attracts investors interested in sustainability principles, ultimately boosting regional economies.

The success achieved by several cities in Indonesia in implementing renewable energy strategies and green infrastructure confirms that the process of sustainable urban transformation is not impossible but achievable through careful policy adoption and active participation from all layers of society. A striking example is Surabaya, which has shown remarkable achievements by transforming waste issues into renewable energy sources through the establishment of waste-to-energy power plants. Additionally, through aggressive urban greening programs involving the planting of thousands of trees and the development of city parks, Surabaya has successfully addressed environmental challenges by improving air quality

and reducing environmental temperatures in urban areas. This success confirms that through structured frameworks and active community participation, cities can achieve sustainable goals that positively impact urban ecosystems (Liu et al., 2023).

In Jakarta, innovative steps have been taken to address air pollution and traffic congestion challenges, such as the adoption of electric buses and the development of dedicated bike lanes. The implementation of electric buses in the capital city is a tangible example of efforts aimed at reducing carbon emissions and improving efficiency in public transportation systems. Not only does it impact the reduction of dependency on fossil fuels, but the use of electric buses also offers a more comfortable and cleaner travel experience for passengers, contributing to the improvement of the city's quality of life. Furthermore, efforts to develop dedicated bike lanes stimulate the use of sustainable transportation and provide a healthier and environmentally friendly alternative for urban residents. With such innovative measures, Jakarta is moving towards a transformation to more sustainable and quality urban environments.

The role of technology in driving the transition to renewable energy and green infrastructure cannot be overlooked. Innovations in energy storage and smart grid development have opened up new opportunities to integrate renewable energy sources into urban energy systems more efficiently (Khalid, 2024). Technological support enhances energy supply efficiency and stability, while allowing for more targeted energy management at the city level. For instance, in Yogyakarta, the development of energy storage batteries has enabled the storage of solar energy generated during the day for use at night, thereby increasing the efficiency of renewable energy use. The utilization of advanced technology like this enables cities to reduce their dependence on conventional energy sources and stimulate sustainable economic growth while maintaining environmental sustainability for future generations.

Active community participation in sustainable programs plays a crucial role in stimulating and accelerating the urban transformation process. With strong educational efforts and involvement from city residents in green initiatives, the acceptance and implementation of renewable energy and green infrastructure can be significantly enhanced (Chen et al., 2024). A striking example is the success of the "Waste Bank" program implemented in various cities in Indonesia. This program allows residents to exchange the waste they collect for money or daily necessities. In addition to raising awareness about the importance of recycling practices and effective waste management, this program also has a positive impact on reducing the volume of waste ending up in landfills. With sustained participation from the community in initiatives like these, cities can garner broad support for change towards more sustainable and environmentally friendly urban models.

In essence, urban transformation through the adoption of renewable energy and green infrastructure has wide-ranging positive implications for the economic growth of cities and the quality of life of their inhabitants. The experiences of cities in Indonesia affirm that with steadfast commitment and close collaboration between government, private sector, and society, significant and sustainable changes can be realized. Therefore, urban development strategies integrating these sustainable approaches need to be continuously developed and implemented consistently to achieve more robust goals towards a more sustainable and prosperous future for all urban inhabitants. However, the journey towards achieving a green environment is fraught with numerous challenges. One prominent challenge is financial issues. Despite the long-term benefits offered by investments in renewable energy and green infrastructure, high initial costs often serve as a major barrier for many cities to realize such changes (Jones, 2015). This is especially true in countries like Indonesia and India, where budget constraints can hinder the large-scale implementation of green technologies such as solar panels and wind turbines. Governments often struggle to secure funding for replacing conventional power plants like coal-fired power stations with renewable energy sources. These existing power plants require substantial investment to be replaced or upgraded to more environmentally friendly alternatives, while the funds for such large-scale projects are often limited.

In addition to financial challenges, the existing infrastructure also poses significant barriers. Many countries still rely heavily on conventional energy infrastructure that is not environmentally friendly. Transitioning to greener technologies necessitates the development of new infrastructure, which also incurs high costs. For instance, the electrical grid must be adapted to support the integration of renewable energy sources like solar and wind, which have different production characteristics compared to conventional power plants. Countries such as China and South Africa face significant challenges in building the necessary infrastructure to support renewable energy, requiring substantial investment and time. Solving these financial and infrastructural challenges is key to accelerating steps towards the urban future. Strong financial support from the central government and the private sector becomes increasingly urgent. This support provides the necessary financial resources and creates confidence for stakeholders involved in the urban transformation process, thus promoting innovation and more effective collaboration in achieving sustainability goals. Solving these financial challenges is key to accelerating steps towards the urban future.

Regarding steps towards more environmentally conscious cities, the need for structured and clear regulations and policies becomes essential. Regulations that have strength and consistency provide incentives for private investment in renewable energy and green

infrastructure and reduce uncertainties that developers may face. Additionally, capacity building and training for urban stakeholders related to green technology and sustainable practices are crucial components in ensuring the success of such transformations. Adoption of appropriate regulations and investment in capacity building are crucial points in facilitating changes towards greener cities (Nurdin & Baharuddin, 2023).

In evaluating the success of cities in Indonesia, there are a series of lessons that can be taken as a guide for cities worldwide. Firstly, strong leadership roles and sustained commitment from city leaders are vital in driving innovation and sustainability. Secondly, active and inclusive community participation in urban decision-making processes is key to shaping environmentally friendly and inclusive cities. Thirdly, effective collaboration between government, private sector, and civil society in planning and implementing green projects is an essential element in achieving long-term success in realizing transformation towards more sustainable cities. By practicing these principles, cities worldwide can gain a more detailed insight and strengthen their efforts in building a greener and more sustainable urban future.

This research provides a comprehensive perspective on the important role of renewable energy and green infrastructure in driving sustainable economic growth in the urban context. Through careful descriptive analysis and presentation of real-life examples of successful cities in Indonesia, this research emphasizes that transformation towards sustainable cities is not unattainable but can be realized through commitment, collaboration, and appropriate innovation. Therefore, the importance of concrete actions taken by governments, the private sector, and civil society to accelerate the transition towards greener, more inclusive, and sustainable cities becomes increasingly clear. These collective efforts will play a central role in shaping a more sustainable and environmentally friendly urban future for future generations. Table 1 below summarises the key findings resulting from the analysis of the research conducted.

Table 1. Summary of key findings on urban sustainability transformation

No	Finding	Description
1	Utilization of Renewable Energy	Reduces carbon emissions and decreases dependence on fossil fuels. Example: solar panels help reduce electricity consumption and energy costs.
2	Green Infrastructure	Improves urban living quality through green open spaces like city parks and urban forests. Example: Thematic parks in Bandung enhance the city's aesthetics and provide recreational spaces.
3	Urban Economic Growth	Investments in renewable energy and green infrastructure create new job opportunities and attract

		investments. Example: solar power plant projects in Bali generate employment and boost regional economies.
4	Success of Indonesian Cities	Sustainable urban transformation is achievable with appropriate policies and community participation. Example: Surabaya effectively converts waste into electricity, while Jakarta reduces pollution with electric buses.
5	Technological Support	Energy storage technology and smart grid enhance the efficiency of integrating renewable energy into urban energy systems. Example: development of energy storage batteries in Yogyakarta improves solar energy usage efficiency.
6	Community Participation	Education and active involvement of communities accelerate the adoption and implementation of renewable energy and green infrastructure. Example: "Waste Bank" programs raise awareness of recycling and waste management among citizens.
7	Challenges 1	Financial issues and high initial costs often serve as barriers and Clear regulations and stakeholder capacity building are also necessary.
8	Challenges 2	Eco-friendly technologies like solar panels, wind turbines, and energy storage systems require significant initial investment.
9	Challenges 3	Governments often struggle to find funding for renewable energy projects. Funds for large projects are often limited, especially for developing countries.
10	Challenges 4	Many countries still rely on conventional energy infrastructure that is not environmentally friendly. Transitioning to green technology requires building new infrastructure, which is costly, and adapting electricity distribution networks.
11	Lessons for Other Cities	Importance of strong leadership, community participation, and collaboration among government, private sector, and civil society.

CONCLUSION

In conclusion, this research indicates that the use of renewable energy and the development of green infrastructure play a crucial role in urban transformation towards sustainable economic growth. With a focus on reducing carbon emissions, improving quality of life, and fostering economic incentives, the study illustrates how cities in Indonesia have successfully implemented these strategies through active community participation and technological support. Despite financial and infrastructural challenges, collaborative efforts among government, private sector, and society can accelerate progress towards a more sustainable and environmentally friendly urban future.

RECOMMENDATIONS

The recommendations drawn from this research emphasize the need for financial support, clear regulations, and capacity building to facilitate the transformation of cities towards sustainability. Financial support from the central government and the private sector is essential to address the high initial costs of renewable energy and green infrastructure projects. Strong regulations provide incentives for private investment and reduce uncertainty, while capacity building for city stakeholders in green technology and sustainable practices is necessary. Additionally, lessons from the success of cities in Indonesia highlight the importance of strong leadership, community participation, and collaboration among government, the private sector, and civil society. Committed city leaders, active community participation, and inclusive collaboration are necessary to create environmentally friendly and sustainable cities. Therefore, concrete steps need to be taken by governments, the private sector, and civil society to accelerate the transition towards greener, more inclusive, and sustainable cities. This includes increased financial investment, regulatory improvements, capacity building, strengthening city leadership, and enhancing community participation in the city development process. Furthermore, additional commitment from the central government is needed. This includes increased financial investment, regulatory improvements, capacity building, strengthening city leadership, and enhancing community participation in the city development process.

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