https://doi.org/10.58225/sw.2026.1-82-91

# RENEWABLE BUILDING TECHNIQUES WITH IMPACT ON URBAN INFRASTRUCTURE SUSTAINABILITY

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**Abstract.** The current work investigates the green technologies and their influence in promoting sustainable urban development in Bulgaria under both climate change and urbanization. Although eco-consciousness has increased, EEO adoption is hampered by institutional fragmentation, unstable support measures and scarce involvement of the private sector who owns 93% of the building stock (based on theoretical analysis and official Bulgarian and EU legislative documents). The difficulties are related to absence of long-term financing, change in conditions of the renovation programmer, and insufficient involvement from all actors. However, green technologies offer potential for cutting energy use, addressing climate risks and upgrading infrastructure. Instances include green roofs, passive heating, water conservation systems, smart HVAC and energy-saving facades all of which can reduce levels of energy consumption by 30–50% and $CO_2$ emissions by up to 40%. EU initiatives, such as the new Directive on Energy Efficiency of Buildings, are driving large scale renovation by 2033 providing additional opportunities. On the basis of a SWOT analysis it is concluded that due to standard policy support, social-justice-related aspects and integrated planning, green technologies can be established as one pillar for sustainable modernization in transition economies. Novelty The importance of the study can find expression in its theoretical rationalization of the relationship between construction greening and institutional factors, pointing out strategies directed toward policy, financing, and stakeholder cooperation.

**Keywords:** Opportunities and Obstacles, Construction, Sustainability, Environmental Adaptation, Energy Efficiency, Regulatory Compliance

**Cite this article as:** *M. Yadav, K. Singh, V. H. Abdullayev, F. Moreira, D. D. Barak, R. K. Sharma, S. Kumar, and D. Kumar, "RENEWABLE BUILDING TECHNIQUES WITH IMPACT ON URBAN INFRASTRUCTURE SUSTAINABILITY," SW AzUAC, vol. 1, 2026. https://doi.org/10.58225/sw.2026.1-82-91*
**Article history:** *Received: 20 May 2026 / Revised: 24 June 2026 / Accepted: 04 July 2026*

**Introduction.** Under the current global warming trend and rapid urbanization, the sustainable development of cities is increasingly a matter of concern. In 2050, it is estimated that nearly 70% of the world population will reside in urban agglomerations which currently use approximately 80% of energy produced on earth and produce about 75% of carbon dioxide [1]. In 2019, the construction industry represented one of the most important GHG contributors to global carbon emissions (about 39%) [2]. In this regard, active implementation of “green” technologies into construction industry is

regarded as a response to the challenges and an effective measure to ensure sustainable development goals and environmental burden mitigation, and thus interest in this question has grown relevant [3]. But the uneven development processes and legal tools governing "green" construction continue to hinder creativity. Furthermore, there is very little engagement and investment from the private sector in green projects which in turn hinders the dissemination of environmentally friendly solutions in the industry. Guo et al. performed an empirical analysis on the effect of smart city construction programs on energy preservation and $CO_2$ emission reduction in China, proving that the general realization of smart city programs can make a remarkable contribution to decreasing $CO_2$, raising urban infrastructure's comprehensive energy consumption performance [4]. "The move to a 'new digital normal' will be enabled through the combined benefit of digital energy management technologies, monitoring and predictive analytics," the researchers. The success of these programmes (will be) depends on the conditions and technological readiness to address a range of local regions suggesting in such environments, benefits long-term planning for sustainable development with their own territorial features. Consistent with these results and their study. Figure 1 depicts the applications of eco-friendly technology for sustainability.

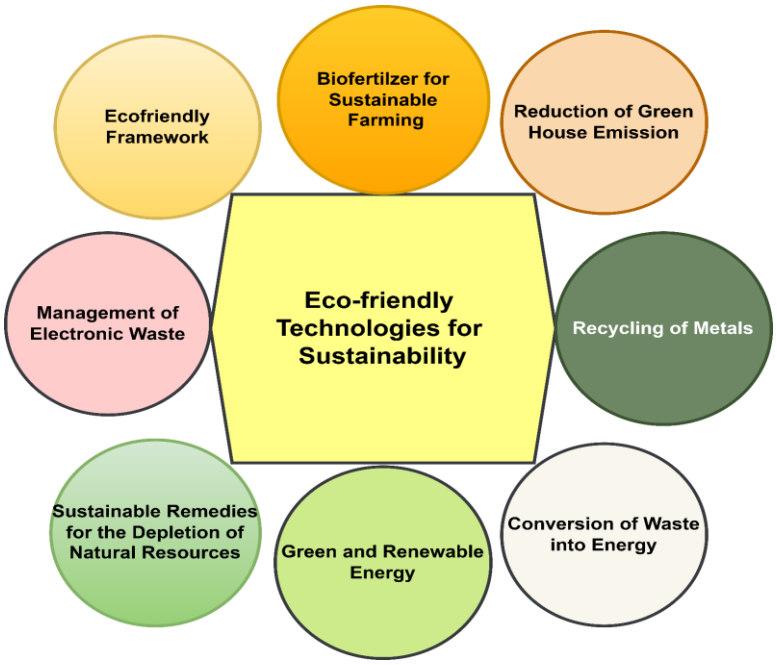


**Fig.1.** Applications of eco-friendly technology for sustainability

Researchers analyzed the influence of smart cities o n th e mo ve to wards green technological innovations. The researchers also proved that building of elements of wise city infrastructure contributes to the surge in environmentally sound technologies [5]. Guo et al. established that the progress of Smart cities influences positively in the adoption of green solutions and also stressed on regions with higher level of technological readiness, they are more attractive to smart city programs [6]. Gil-Ozoudeh et al., prospective of the technological design of green buildings in sustainable urban development had also been researched, the practicality of ecologically oriented architectural engineering was elaborated [7]. The researchers conclude that due to the above a further integration of green technologies in urban planning is needed to enable cities and settlements to adapt themselves better towards the challenges of climate change. The research of researchers analyzed the condition of green projects and initiatives in construction, while concentrating on the European Union (EU) countries experience, and the peculiarities when implementing environmental approaches in Bulgaria. Introduction The Scientists have studied the prospective of sustainable building development,

highlighting that the dissemination of green practices in emerging economies remains incipient. Researchers emphasized the need to apply foreign experience based on local specificity and to establish a national system of stimulation for green construction, which includes educational programs, preferential loans, and work on the development of standards to certify buildings. Other Bulgarian Rodrigues et al. carried out an extended study of the indicators for sustainable urban development in Bulgaria, and pointed out that the main problems remained with low building energy efficiency, irrational use of natural resources, limited access to renewable energy sources and lack of adequate reflection of sustainable solutions within the strategic planning for urban environment [8]. Furthermore, the scientists underlined the requirement for a complex approach to sustainable urban environment creation in particular through innovation construction materials insertion, local energy infrastructure formation, and deepening and spreading inter branch cooperation of public and private institutions. Thus, the aim of the present study was to a detailed theoretical study on the influence of green construction technologies on the sustainable construction of the city (Bulgarian urban environmental studies. practices and challenges). To achieve this goal, the tasks were formulated: to evaluate the role of green technologies in saving energy and infrastructure against climate risks; adaptation of urban environment to determine the institutional and financial constraints that inhibit the information spread on green technologies implementation; research into impact of different factors on stimulation promoting use of green construction, as well as their significance with regard to sustainable cities' development.

**Materials and methods.** The regulatory framework analysis enabled a systematized and conceptualized understanding of the key documents, strategies and projects that guide both climate and construction policy at national levels (in this case Bulgaria and Europe). The analysis of legislation also revealed the degree of legal consistency between European climate objectives and regulation inside construction in Bulgaria. In this way it was possible to consider the field of regulation as a dynamic system that changes and to examine its potential power towards eco-friendly construction practices. Institutional analysis was used as a tool to examine the structure and function of organizations that affect climate and construction policy at national level in Bulgaria. That provides a basis for measuring the degree of participation and influence among individuals from outside Europe but who still play key roles in reshaping industry rules. Such an approach also helps researchers to understand the institutional logic of decision-making: worse even figure mechanisms toward developing a sustainable construction society from managerial and control perspectives.

By means of systematic approach, the green technologies were viewed as parts in its urban complex integrating them into this broad framework of overall sustainable development.Grasping the processes in which architectural, engineering, or environmental measures affect a given urban milieu within a single sharp comprehensive way of thinking, this method achieved major savings and sharply accelerated its previous status. Fig.2 depicts the renewable building techniques with impact on urban infrastructure sustainability and Fig.3 depicts the flowchart of working model for sustainable infrastructure with renewable building techniques.


**Fig.2.** Renewable building techniques with impact on urban infrastructure sustainability

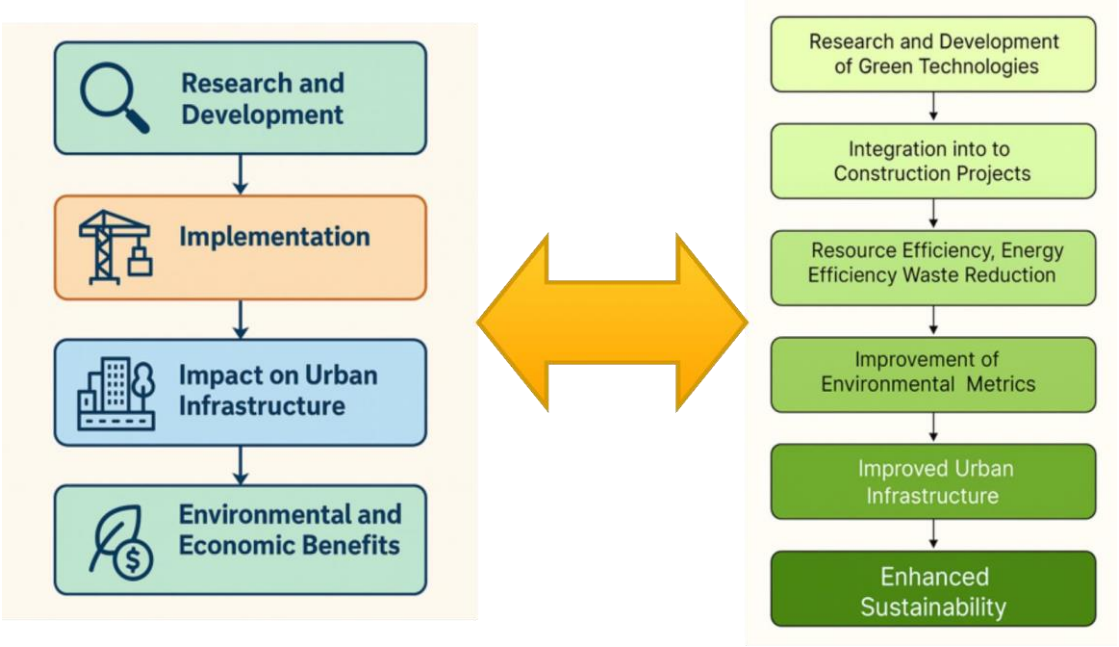


**Fig.3.** Flowchart of working model for sustainable infrastructure with renewable building techniques

This is similar in some respects to the previous item. Under this methodological lens, green technologies become three kinds of tools. They can be used to transform the energy, social and natural subsystems of the city.Therefore, taking strengths, weaknesses, opportunities and threats (SWOT) analysis about where to develop green technologies in construction technology as a guide for theoretical prediction analysis categorized the internal and external factors of construction sustainability that constitute a force. SWOT analysis looked at the way institutions, economy, technology and society interact, all affecting effectiveness of this sector's transition. This way it made possible a framework for studying and expressing in theory about risks and possibilities for the future of programmes that retrofit buildings.

The research team made use of domestic data to analyze the current situation and future outlook for green technology developments. The information about the energy efficiency of the existing residential building stock, how many cases have been realized and the profitability of certain technological areas had been translated. The approach taken by the study's researchers was perhaps

more utilitarian and down-to-earth than that of certain cozy, bureaucratic assessments. This is because with expert views indicating such things as is there a business environment for technology, where do institutional bottlenecks lie—among other empirical evidence gathered on site—the analysis became both down-to-earth and less prone to abstract reasoning. This approach, in turn, was applied to the final stages of theoretical work and made it possible to synthesize the results of various analytical methods into one overarching picture. Regulatory, institutional, systemic and empirical data were integrated through this method, facilitating combined conceptualization of different approaches towards evaluating green technologies ' contributions in modernizing the building sector. And so with the synthetic method, the theoretical construction was coherent and the analysis presented as a whole possessed logical rigor.

**Results and discussion.** Construction progress of green technology is becoming one of the key forces in the sustainable urban environment development, in rapid developing countries in general where city boom. Bulgaria, which is in the phase of the construction industry conversion and European environmental acclimation, is evincing a trend to promote interest in the environment oriented approaches. By early 2025, there are elements of-proof or more in and the construction industry in Bulgaria showing a slow, adoption of green techniques, even existence though their diffusion remains fragmented. For instance, there are as of there are only 54 green buildings in Bulgaria. Architectural Researchers have managed projects that use energy-saving materials, solar water and insulation structures commercial and residential sectors in large cities. The role of environmental certification limited, and it is most frequently used buildings) more from foreign investors than domestic developers. Certification companies that underestimate English Green building certification in Bulgaria The first and only green building certification system currently available in Bulgaria is the English BRE Global and the Building Research Establishment Environmental Assessment Method (BREEAM) standard in the German Council for Sustainable Building. with the DGNB standardisation system, and the counts Studio project among its few members. employs the DGNB scheme.

Construction regulations are experiencing revision and realignment with European standards. This has made methods of construction application of technologies for buildings variable and nonuniform. In keeping with this trend, Bulgaria has ratified a "Long-range national policy to aid recovery of the country's stock of residential and other buildings by 2050", as well as it is carrying out an "Integrated energy and climate plan for the Republic of Bulgaria 2021–2030". These papers all incorporate measures designed to reform construction law and energy-saving standards and support renewable energy sources. While, both the academic and professional communities are only gradually piecing together a unified understanding of green principles in architecture. By 24, according to the National Program for Energy Efficiency in Residential Buildings in Bulgaria, 270 apartments in three multifamily blocks of flats in

Sofia were renovated. Launched in 2015, this project which is entrusted to Ministry of Regional Development and Public Works has now completed the repair of a total 1, 968 units across the country at its close in 24o 'clock . These actions have reduced household heating bills and cut the amount of $CO_2$ given off, thus raising substantially environmental quality. The program emphasized improving structures, especially older ones, via energy conservation methods like insulation, new windows and higher-efficiency heating systems. The National Program extends full grant assistance to condominium associations of multi-family buildings built before 1990, creating a warm relaxing interior environment and enhanced energy efficiency. More than 2,022 sites have now received finance agreements under this program, with roughly two-thirds completed and the rest underway. Beneficial results seen include improved indoor comfort, lower energy bills, and increased satisfaction of the their occupants. Hurdles to its wider adoption include the regulation of homeowner associations and financial frameworks suitable for widespread use.

The outlays for this will be considerable: already in the pipeline are about 200 million leva (over 100 million euros) allocated through 2024 by regional development projects for the energy-

saving renovation of multi-family residential buildings unkindly sited in Bulgaria's coal regions as the country shifts its energy These investments aim at reducing energy use and removing energy poverty as an example by insulation, strengthening the heating system, and a variety of energy-efficient modifications to form a green living environment. At a broader level, the EU program Horizon 2020 provides abundant funding for energy-saving technologies and green solutions in virtually all industries, residential building. Evaluations of energy efficiency investments at EU level suggest strong paybacks over a number of years. Reports often show returns considerably greater than the original investment in terms ofenergy savings and environmental gains. For example, according toa report from the European Institute of Banking and Finance, home-insulation measures offered a payback time as low as two years on average in many countries.

This fact adds more sustainability to the infrastructure. How green buildings can reduce impact of climate fluctuations and heat waves and floods, in particular overheating states of urban cores.The use of green roofs (that decreases air temperature of cities lower by 1-3 degrees Celsius and stormwater storage volume can be reduced by Landscaping & Natural Screens(50-80%): Vertical landscaping & natural screens help make sure you follow us on our social media platforms. restore biological connections within the urban environment favorable to reduced thermal pollution and making densely populated areas more habitable. Such solutions are also some of the adaptation components of cities to climate change, preparing them for climate change without radically restructuring existing structures. The green technologies aesthetic and recreation potential results in a positive impact on the social level, increasing the identity of citizens with their residential location and promoting the growth of local communities.

Regarding the environmental factor, green usage The variety of technologies in construction sector provides a harmonised The foundation helps in integrating the economic development with the natural environment of the global climate agreements being implemented . Focusing on energy savings and renewables According to informaiton, in an effort to limit the harmful impact of the former, Bulgarians are striving to mitigate the negative effects of the latter. construction. The development of sustainable construction practices and encouraging of renewable energy source on the directly decrease the environmental performance of the city (lower gaseous emissions, assist to minimize the ecological footprint).

For Bulgaria, reaching this objective is a technical and institutional challenge. Under the new legislation, there is a requirement that all (whatever their ownership or purpose and regardless of date of construction) buildings are brought up to standard by 2033. This goes for both residential, public and commercial money. The first priority (common action) is to be accorded to the best-performing buildings in terms of energy efficiency, which will require immediate action on improving the thermal performance of these buildings with a particular focus on introduction of electrical heat pumps and electrification of heating systems, despite their continuing high costs and low availability throughout the EU. Among the obligations arising from the directive, Bulgaria, like other EU member states is to develop and submit a national building renovation plan by 2040: a concerted strategy for modernising building stock setting out long-term national glass-by-glass repair mechanisms as well as criteria for choice of buildings and financing sources.

From this, it can be concluded that, notwithstanding its ambitious. targets for modernising the building stock or achieving climate neutrality, the renovation schedule programs faces fundamental systemic limitations. As can fb as one can observe, although a need for green technologies, financial constraint and unwillingness to full Government's support lead to reduction in their active implementation. Furthermore, the absence of a stable government ) regulation and planning tools, and a clear 78 influence of the segmentaare mesopolitical levels. professional talent, provide another shortage of talents for professionals. complexity.

Also, the incorporation of green-GIT green construction technologies- embodied energy address representing construction GDP (Germany) and measure of construction activity (UK), high levels of capital intensity, particularly at the design. specialised materials and engineering

procurement equipment of facilities. Thus, energy-efficient all-encompassing buildings, smart HVAC systems, solar AND photocatalytic facades, geothermal installations, and other innovative solutions require significant investments. For resource scarce economies such opposed to countries that have few domestic investment resources, such as well as Bulgaria, it is a crucial barrier to renovation in mass and climate-related moderisation of the building stock.

In this sense it is of fundamental importance supporting technological and building measures with social support, through the promotion of information campaigns, subsidies and technical assistance programmes as well as flexible financing instruments. Green technologies will only be part of sustainable and inclusive urban development when we uphold the principles of social justice.

By analysing the innovations of energy-efficient technologies in construction, it was proved that they are based on common political and economic objectives and related to certain consequences of the COVID-19 pandemic. The researchers say the EGD is more than environmental regulation instruments- but a comprehensive recipe for sustainable growth, economic incentives and political backing. The research verified these findings and became more pragmatic with the case of Bulgaria – without contextual adjustment of pan-European objectives to the national level, taking into account construction fund peculiarities, PPP interaction specifics or a long-term financing model establishment, green edifice transformation decelerates. Hence, if Bongardt and Torres concentrated on the institutional architecture of the EU -the study demonstrated how these macroeconomic tendencies are reflected in urban infrastructure (in an institutionally volatile country with a transition economy).

Furthermore, where the effectiveness of an individual technological implementation is concerned, empirical analysis of the effect of specific technical solutions on urban sustainability is also an area on which there has traditionally been a scientific interest. The research conducted by Muntean compared the processes of infrastructure construction in Germany, Romania and Bulgaria and particularly emphasised the effects on their economies. The scholar stressed that the sustainability of infrastructure depends on the quality of management and the level of integration between sectors. Thus, this paper elaborated on the latter finding and provided evidence that in countries with low capital, such as Bulgaria, “Institution-based view” of IHaRM would place significant attention on an ability to create institutional infrastructure for securing sustainable form of rules of the game, access to finance and longterm support measures for different renovation programmes. The Case study: a contribution to the future In conclusion the analysis process in this paper, we indicated that private sector (shareholder enterprises), which is superstructure part of socialist market system and has created most housing stock so far as well play an important role in structuring based our past from socioeconomic analysis; it can help us expand and complement the results with systemic measurement of the factors determining building industry’s sustainable development in transition economy.

Yarova et al. evaluated economic benefits of green technologies in Ukraine and indicated the significant energy efficiency (EE) enhancement and CO2 reduction that can be achieved by the state support for sustainable development[9]. The Ukrainian example tows the line of Bulgaria’s present situation concerning the prospect of developing a sound green building sector. Private sector participation in sustainable building is limited in both countries and government intervention is critical. Unlike Ukraine, where the government has supported energy efficiency more strongly, in Bulgaria disarranged legisiation framework and unveiled govenmental support have left a heavy industry footprint on green technologies. According to Yarova et al. Bulgaria could increase green technology adoption by enhancing private sector participation with financial incentives and green certification mechanisms.

Hasanov et al. analysed the permanent link between human development and environmental sustainability in Azerbaijan based on $CO_2$ emissions, and socioeconomic indicators[10]. Azeriinducerat tillväxtgreen, green growth policy increasingly focuses on energy efficient technologies in building, like green in Bulgaria. In terms of reducing energy consumption for building

construction in Azerbaijan, the development and promotion of order‟s green certificates like Green Zoom were successful in commercial buildings but not in residential spaces in Bulgaria. Both face institutional impediments; yet, Azerbaijan's focus on energy-efficient buildings could inform Bulgaria's strategies, especially in urban areas where the commercial properties can be more receptive to refurbishment with sustainable technologies.

Verdiyeva et al. represent the green growth strategy for Azerbaijan based on sustainable economic growth, with the integration of a green technology[11]. What Azerbaijan is actually experiencing matches the aspirations of Bulgaria, where they are trying to modernise their infrastructure with its sustainable development. Azerbaijan has benefitted economically from this plan, making effective use of green technology within commercial real estate. Bulgaria faces significant financial barriers including high start-up costs and limited public private partnerships. Therefore, the results of Verdiyeva et al. for Decision reiterate the call for an effective financing mechanism, one of the chief recommendations regarding Bulgaria s modernisation efforts particularly related to participation[1215].

In many cases, the scope of studies concerning green building in the area of technology energysaving systems, heat recovery system, green roofs into buildings and facade with photocatalysis etc.) however did not go beyond the object only to see them only as example technical solution for green technology or catechize how to encourage construction industry take advantage from new technologies[16-18]. Finally, the scrutiny of green innovations' effectiveness in terms of lowering carbon footprint and raising energy efficiency is a steady point on today's scientific agenda, particularly when considering global climate objectives. But how-to do green technologies in transition economy, where diffusion is confronted to classical and not so stable institutions, remains little known. The study was intended to contribute new knowledge in this respect by providing theoretical analysis backed up with regulatory data from Bulgaria and EU, as well as empirical evidence on existing renovation programmes. This methodological tool enables to connect macroeconomic model of sustainable development with the particular programmes of urban infrastructure modernizing, determine systemic barriers and propose mechanisms ensuring their overcoming.

Overall, the research conducted is a extension of the existing framework, conceptually. adding to the analysis of green technology not purely technical, institutional, and their ratio oflengths thanwhere6. economic and social factors that condition their adoption in the Bulgarian construction industry. This interdisciplinary perspective makes it possible to take into account green as part of an overall system of technologies sustainable urban development, where successful is feasible only when all relevant factors are considered.

**Conclusions**. The main aspects of the development and impact of green technologies on the sustainable development of urban infrastructure were determined based on the study. The results showed that green building applications have a great opportunity in enhancing the energy performance of buildings and contributing to reduce the $CO_2$ emission and climate change. The significance of these solutions is particularly high in middle- and low-income countries with a large share of old housing stock, and where building renovation represents the primary means of raising the resilience of urban areas. In this optic the example of green technologies introduction in Republic of Bulgaria was chosen as an analytical basis. The review of the legal framework has revealed that driving towards mass renovations through the construction fund in Bulgaria is hindered by various institutional issues such as fragmented legislation, missing holistic climate roadmap and unstable financing schemes. In spite of the presence of European directives and support programmes, their transposition to the domestic level is slow and unequal. In addition, the poor participation of the private sector is still a major constraint. These are slowing the translation of climate pledges into action and impede the deployment of new solutions in reality. The SWOT analysis helped to arrange the internal and external factors that contribute for the success or failure of green technologies implementation. Strengths (potential for energy cost reduction, institutional support at EU level,

environmental impact) and weaknesses (institutional fragmentation, high initial economic expenses, lack of specialists) have been pointed out. Key investment opportunities found include increase in availability of capital, growth in sustainable building demand from international investors and potential to establish local production facilities for energy efficient products. Risks were expressed by non-fulfilment of renovation targets, increasing mistrust from the population and increased social division in terms of different opportunities for participation in support programmes. These considerations highlight the compulsion for indivisible solutions, paradise management systems where architectural, engineering and social dimensions formed a single approach for modernising the city environment. This study has several methodological limitations and especially theoretical dependence and secondary data that may not fully illustrate the practical obstacles of implementation of green technologies in Bulgaria. Multi-method research (combining policy analysis with empirical investigations such as surveys, energy audits and case studies) may provide deeper insights into the real effects of green technologies and investigate whether they really meet their goals on a broad scale. Furthermore, panel studies and empirical evidence may contribute to a better assessment of the effectiveness of policies in comparison to social and economic effects on green construction.

**Author Contributions.** All authors contributed to the conception and design of the study, literature review, methodology, data collection and analysis, manuscript preparation, revision, and approval of the final version of the manuscript.
**Funding.** The authors received no specific financial support from any funding agency, commercial organization, or not-for-profit institution for the research, authorship, and/or publication of this article.
**Data Availability.** The data supporting the findings of this study are available from the corresponding author upon reasonable request.
**Declarations**
**Conflict of Interest.** The authors declare that they have no competing interests or conflicts of interest related to this work.
**Ethical Approval.** This article does not involve studies with human participants or animals. Therefore, ethical approval was not required.
**Informed Consent.** Not applicable.


## References

[1]Li, G., Zhang, X., Mirzaei, P. A., Zhang, J., & Zhao, Z. (2018). *Urban heat island effect of a typical valley city in China: Responds to the global warming and rapid urbanization*. *Sustainable Cities and Society, 38*, 736–745. https://doi.org/10.1016/j.scs.2018.01.033
[2]Ahmed Ali, K., Ahmad, M. I., & Yusup, Y. (2020). *Issues, impacts, and mitigations of carbon dioxide emissions in the building sector*. *Sustainability, 12*(18), 7427. https://doi.org/10.3390/su12187427
[3]Fei, W., Opoku, A., Agyekum, K., Oppon, J. A., Ahmed, V., Chen, C., & Lok, K. L. (2021). *The critical role of the construction industry in achieving the sustainable development goals (SDGs): Delivering projects for the common good*. *Sustainability, 13*(16), 9112. https://doi.org/10.3390/su13169112
[4]Guo, Q., Wang, Y., & Dong, X. (2022). *Effects of smart city construction on energy saving and $CO_2$ emission reduction: Evidence from China*. *Applied Energy, 313*, 118879. https://doi.org/10.1016/j.apenergy.2022.118879
[5]Ma, X., Li, J., Guo, Z., & Wan, Z. (2024). *Role of big data and technological advancements in monitoring and development of smart cities*. *Heliyon, 10*(15). https://doi.org/10.1016/j.heliyon.2024.e10852

[6]Guo, M., & Zhou, Y. (2025). *Boosting sustainable urban development: How smart cities improve emergency management—Evidence from 275 Chinese cities*. *Sustainability, 17*(15), 6851. https://doi.org/10.3390/su17156851

[7]Gil-Ozoudeh, I., Iwuanyanwu, O., Okwandu, A. C., & Ike, C. S. (2022). *The role of passive design strategies in enhancing energy efficiency in green buildings*. *Engineering Science & Technology Journal*, *3*(2), 71–91.

[8]Rodrigues, M., Franco, M., Filipova, H., Silva, R. J., Kazandzhieva, V., Nacheva, R., ... & Antonova, K. (2024). *Profile of urban sustainability in Bulgaria*. *Environment, Development and Sustainability*, 1–39. https://doi.org/10.1007/s10668-024-05657-4

[9]Yarova, N., Lipych, L., Gutsul, T., Zhurba, O., & Novytskyi, V. (2025). *Economic benefits of green technologies: Ukrainian experience*. *International Journal of Economics and Financial Issues, 15*(1), 412. https://doi.org/10.32479/ijefi.17624

[10] Hasanov, R. I., Giyasova, Z., Azizova, R., Huseynova, S., & Zemri, B. E. (2024). *Long-term dynamics between human development and environmental sustainability: An empirical analysis of $CO_2$ emissions in Azerbaijan*. *Challenges in Sustainability, 12*(4), 273–280. https://doi.org/10.56578/cis120403

[11] Verdiyeva, P., Dadashova, J., Bayramov, V., & Aliyeva, R. (2025). *Green Growth Strategies for Sustainable Economic Development*. https://doi.org/10.62844/jerf.20

[12] Lata, K., Singh, P., Saini, S., & Cenkeramaddi, L. R. (2024). *Deep learning-based brain tumor detection in privacy-preserving smart health care systems*. *IEEE Access*. https://doi.org/10.1109/ACCESS.2024.3456599

[13] Singh, K., Yadav, M., Barak, D., & Moreira, F. (2025). *Machine-learning-based frameworks for reliable and sustainable crop forecasting*. *Sustainability, 17*(10), 4711. https://doi.org/10.3390/su17104711

[14] Singh, K., Yadav, M., & Yadav, R. K. (2024). *IoT-based automated dust bins and improved waste optimization techniques for smart city*. In *Revolutionizing Automated Waste Treatment Systems: IoT and Bioelectronics* (pp. 167–194). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-6016-3.ch012

[15] Hajimahmud, V. A., Singh, Y., & Yadav, M. (2024). *Using a smart trash can sensor for trash disposal*. In *Revolutionizing Automated Waste Treatment Systems: IoT and Bioelectronics* (pp. 311–319). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-6016-3.ch020

[16] Yadav, M., Hajimahmud, V. A., Singh, K., & Singh, Y. (2024). *Convert waste into energy using a low-capacity igniter*. In *Revolutionizing Automated Waste Treatment Systems: IoT and Bioelectronics* (pp. 301–310). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-6016-3.ch019

[17] Singh, K., Yadav, M., Singh, Y., & Barak, D. (2024). *Finding security gaps and vulnerabilities in IoT devices*. In *Revolutionizing Automated Waste Treatment Systems: IoT and Bioelectronics* (pp. 379–395). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-6016-3.ch023