
Green Infrastructure Approaches for Sustainable Planning of Sports and Recreation Facilities: A Case Study of Poznan

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Abstract:

Purpose: The aim of this study is to assess the integration of green infrastructure (GI) and sustainable building practices in sports and recreational facilities in Poznań, with particular attention to energy efficiency, renewable energy adoption, water management, material selection, and ecological site planning. By analyzing municipal investment data, the study seeks to identify patterns, gaps, and best practices that can support the broader implementation of sustainable infrastructure principles in urban recreational settings.

Design/Methodology/Approach: Using a qualitative document analysis of 36 investment projects implemented between 2019 and 2023, the study identifies 17 projects incorporating environmentally conscious measures, including energy-efficient LED lighting, photovoltaic systems, thermal insulation improvements, water management systems, eco-friendly materials, and site-sensitive planning.

Findings: The findings reveal that while GI practices are increasingly adopted across both large-scale and community-focused facilities, their implementation remains uneven. Larger, high-visibility projects tend to lead in sustainability integration, whereas smaller facilities face challenges related to funding, planning capacity, and governance.

Practical Implications: The findings suggest that the integration of green infrastructure and sustainable construction practices in municipal sports and recreational facilities can effectively support broader urban sustainability goals while improving the environmental performance of public infrastructure. The study highlights the need for more systematic approaches to sustainability implementation, including the development of formalized sustainability standards, stronger policy coordination, and post-implementation monitoring frameworks.

Originality/Value: This research contributes to the limited body of literature on the application of green infrastructure in public sports and recreational facilities in mid-sized cities. By focusing on municipal investments in Poznań, the study provides empirical insights into how ecological practices can be mainstreamed within urban recreational infrastructure planning and offers a practical model for other municipalities pursuing sustainable urban development.

Keywords: Sport, recreation, green infrastructure, sustainability, planning, management.

JEL codes: L83, O43, Z21.

Paper type: Research Article.

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1. Introduction

Urban sports and recreational facilities are essential components of sustainable cities, providing spaces that support physical activity, social interaction, and overall community well-being (Wang *et al.*, 2019; Jabbar *et al.*, 2021). Beyond their social and health benefits, these facilities have substantial environmental footprints, consuming energy and water, generating waste, and impacting surrounding ecosystems (Atalay *et al.*, 2024).

In the context of rapid urbanization and climate change, municipal authorities face increasing pressure to ensure that infrastructure development and modernization contribute to environmental sustainability while remaining functional and accessible (Santos *et al.*, 2021). Green infrastructure (GI) has emerged as a critical framework in this regard, encompassing strategies such as energy-efficient lighting and HVAC systems, renewable energy integration, environmentally friendly construction materials, and ecologically sensitive site planning (Gill *et al.*, 2007; Meerow and Newell, 2017).

The adoption of GI in sports and recreational infrastructure aligns with broader international objectives for low-carbon, resource-efficient urban development. Studies indicate that energy-efficient technologies, particularly LED lighting, can substantially reduce electricity consumption and greenhouse gas emissions in both large-scale stadiums and smaller facilities (Fantozzi *et al.*, 2016).

Similarly, the integration of photovoltaic (PV) systems enables partial energy self-sufficiency and reduces reliance on fossil fuels, complementing municipal climate action plans (Lin *et al.*, 2020; Urs, 2025). In parallel, sustainable water management practices – including stormwater retention, artificial irrigation, and permeable surfaces – support low-impact development (LID) principles and improve resilience in recreational areas (Dietz, 2007).

Despite the recognized benefits of green infrastructure, research has consistently noted that its implementation is often uneven. Flagship or high-visibility projects tend to receive priority, while smaller, community-oriented facilities lag in the adoption of sustainable practices due to constraints such as funding, institutional capacity, and planning expertise (Meerow and Newell, 2017; Mell, 2021).

Poznan, the fifth-largest city in Poland, thus provides a compelling context to investigate the application of green infrastructure in municipal recreational facilities.

The city has actively invested in culture, sports, and tourism (Rozmiarek, Malchrowicz-Moško *et al.*, 2022), and in the past it has sought to uphold its reputation as a modern, green, and open city, emphasizing sustainable development not only in cultural initiatives but also in the planning and management of sports facilities (Sobczyk *et al.*, 2022; Malchrowicz-Moško *et al.*, 2021).

Between 2019 and 2023, the city undertook a series of investments in sports and recreational infrastructure, including large-scale facilities such as swimming pools and stadiums, as well as smaller community-focused sites like outdoor fitness installations and sports halls.

Previous studies in Poznan have examined the implementation of sustainable practices in other municipal sectors, highlighting both successes and challenges: for instance, research on martial arts clubs demonstrated variability in environmental management practices, including energy and water conservation, waste management, and sustainable mobility, with many clubs not yet implementing systematic pro-environmental actions (Rozmiarek, 2024).

Similarly, analyses of municipal cultural institutions revealed a range of eco-initiatives – such as energy and water conservation, use of renewable materials, afforestation, and mitigation of urban heat island effects – although these were often fragmented and lacked inter-institutional coordination (Rozmiarek *et al.*, 2022; Rozmiarek *et al.*, 2024).

These findings underscore that even within a single city, the application of sustainability measures can vary considerably across facility types and organizational contexts, reinforcing the value of examining Poznan's sports and recreational infrastructure as a representative case. These projects therefore offer an opportunity to assess how sustainable and ecological construction principles are applied in a mid-sized Central European city, and to what extent these measures are integrated across facilities of varying scale and function.

The aim of this study is therefore to assess the integration of green infrastructure and sustainable building practices in Poznan's sports and recreational facilities, with particular attention to energy efficiency, renewable energy adoption, water management, material selection, and ecological site planning. By analyzing municipal investment data, the study seeks to identify patterns, gaps, and best practices that can inform the broader application of sustainable infrastructure principles in urban recreational settings.

2. Materials and Methods

This study is based on a qualitative research approach, employing document analysis as the primary method. Document analysis is widely used as a systematic procedure for reviewing and evaluating official records and policy-related materials to extract meaningful insights (Bowen, 2009).

In September 2024, a formal inquiry was submitted to the Poznan City Authorities through the Municipal Office regarding infrastructural investments in sports and recreational facilities carried out between 2019 and 2023.

In October 2024, a comprehensive answer of all implemented investments was obtained. The collected dataset consisted of 36 entries describing various projects across multiple types of facilities. The analysis involved a qualitative content analysis aimed at identifying the presence of sustainable and ecological construction principles within each investment. As a result of the analytical process, 17 entries were identified as incorporating elements of green building and sustainable infrastructure.

These included, among others, the implementation of energy-efficient LED lighting, installation of photovoltaic systems, improvements in thermal insulation, modernization of water and energy systems, use of environmentally friendly materials, and integration of renewable energy solutions.

The findings derived from this analysis provide the basis for further discussion on the extent to which sustainable development principles are integrated into municipal sports and recreational infrastructure.

3. Results

After a detailed analysis focusing on the incorporation of principles of sustainable and ecological construction, 17 entries were identified as relevant. Detailed results for these facilities are presented in subsections 3.1 to 3.17.

3.1 Hotel Camping Malta

The Hotel Camping Malta underwent targeted modernization efforts in 2022 and 2023. During these two years, the facility focused on enhancing its technological and operational infrastructure. The main initiatives included the modernization and expansion of the fiber-optic internet network, aimed at improving connectivity and digital services for visitors. In 2023, the scope of modernization was further expanded with the implementation of a parking management system, reflecting an integrated approach to both digital and physical infrastructure improvements.

3.2 Youth Sports Center

The Youth Sports Center underwent a series of infrastructure improvements over the period 2019–2022, reflecting a staged approach to facility modernization. In 2019, design works were carried out for the modernization of Building A, alongside the construction of a new playground, enhancing recreational options for young users. In 2020, the artificial surface of the football field was replaced, improving the safety and performance quality of the sports area.

The following year, 2021, focused on energy-efficient lighting, with the design of LED lighting systems for both the football field and the athletics track. Finally, in 2022, the modernization efforts were extended to the implementation of a parking

management system, integrating operational and functional improvements across the facility.

3.3 Chwiałka Sports Complex

The Chwiałka Sports Complex has undergone a comprehensive modernization program between 2019 and 2023, addressing both recreational and operational facilities. In 2019, major upgrades included the renovation of outdoor swimming pools along with their surroundings and locker-room facilities, reconstruction of spaces within the Chwiałka building, and the implementation of an automated parking system.

In 2020, the modernization efforts focused on interior enhancements, including the equipping of rooms in the Chwiałka building and upgrading of storage areas. The year 2021 marked a significant expansion of infrastructure projects. Renovations continued on the outdoor swimming pools and associated sanitary facilities. Additionally, design work was carried out for the reconstruction of the sauna and service areas of the indoor swimming pool. Energy-efficient LED lighting systems were installed at the ice rink, reflecting the adoption of sustainable technologies.

Further developments included the design for the expansion of the ice rink with a new rink surface, demolition of an old office building accompanied by new parking construction, and continued interior improvements in the Chwiałka building. In 2022, modernization focused on preparatory and design works, including the sauna and indoor pool service areas, as well as the ice rink expansion.

Technical upgrades included the modernization of the server room and installation of photovoltaic panels on the roof, enabling the use of renewable solar energy. Finally, in 2023, implementation efforts were carried out for the photovoltaic system, continued modernization of the Chwiałka complex, upgrades to ventilation systems in both large and small pools, and project work related to the ice rink.

3.4 Malta Regatta Course and Malta Complex

The Malta Regatta Course and the surrounding Malta Complex have undergone extensive modernization between 2019 and 2023, aimed at improving both sporting infrastructure and public amenities. In 2019, the modernization program focused on key infrastructural upgrades, including the renovation of regatta course equipment, engineering facilities, the judges' tower, multimedia building, and the main stands (Phase III).

Additionally, technical documentation was prepared for a pedestrian and cycling path along the northern shore of Lake Malta. In 2020, the modernization efforts continued with upgrades to the judges' tower, multimedia building, rowing starting pontoons, and general regatta course infrastructure. Design works for the

construction of new hangars were also completed. The year 2021 marked a comprehensive expansion of both technical and event-related infrastructure. Work included the modernization of kayak starting machines, projects for decorative spaces and the press center, the ice rink substructure and media, and the scoreboard terrace.

Hangar construction projects were finalized, Lake Malta underwent cleaning operations, and several buildings were demolished to prepare an event area at the Komandoria site. Climate control units and lane ropes were delivered and installed, further enhancing the facility's operational capacity.

In 2022, modernization focused on finalizing preparatory works for the Komandoria event area, installation of rowing starting machines, expansion of the monitoring system, modernization of restrooms in the regatta course service building, and the preparation of a traffic management plan for the Malta Complex. Finally, in 2023, upgrades included the installation of energy-efficient LED lighting along walking paths, modernization of hangars, and construction of the event area following the demolition of the building at Komandoria Street.

3.5 Gołecin Sports Complex

The Gołecin Sports Complex underwent extensive multi-disciplinary modernization from 2019 to 2023, focusing on infrastructure, sports facilities, and operational improvements. In 2019, the development of the Gołecin Sports and Recreation Zone (funded through the Poznan Participatory Budgeting – PBO) began, including the construction of new sports facilities, renovation of the athletics stadium, creation of a connecting road between Lake Rusalka and Warmińska Street, modernization of administrative building interiors, and construction of a new sports field with an athletics track.

Additionally, the speedway track received upgrades to its profile. In 2020, the complex saw continued expansion with the completion of the sports field and athletics track, further modernization of administrative interiors, replacement of the athletics stadium surface, and upgrading of electrical infrastructure, including a cable connecting the substation to the main building's switchgear.

Emergency lighting was adjusted to 5 lux in accordance with fire safety standards, and the area around the new football field and track was landscaped and secured with modernized fencing.

The year 2021 included the installation of a balloon-covered training field and modernization work across two stadiums to improve operational functionality. In 2022, the balloon-covered training field was further enhanced, while design work commenced for the construction of a grandstand with a roof.

A comprehensive monitoring system for the Gołecin Complex was designed, and the speedway track underwent additional modernization. Finally, in 2023, modernization efforts focused on the speedway track, implementation of the grandstand project, site development, general facility modernization, and installation of a container building to support operational needs.

3.6 Indoor Swimming Pool in Rataje

In 2019, the Indoor Swimming Pool in Rataje underwent a comprehensive modernization involving the demolition of the old facility and construction of a new swimming pool. The project incorporated modern construction solutions, with a particular focus on energy-efficient building materials, reflecting a commitment to sustainable and environmentally conscious design.

3.7 Winogrody Municipal Swimming Pool

Between 2019 and 2021, a 25-meter indoor swimming pool with a sports and recreational character was constructed at Osiedle Zwycięstwa. The project incorporated modern construction solutions and energy-efficient building materials, emphasizing sustainable design practices. In addition, a photovoltaic system was installed, enabling the use of renewable solar energy (“clean energy”), which reflects a commitment to environmentally responsible infrastructure development.

The facility represents a significant investment in both community recreation and sustainable sports infrastructure. In 2023, the Winogrody Municipal Swimming Pool underwent a modernization project focused on sustainable energy solutions. Again, photovoltaic panels were installed on the building, enabling the use of renewable solar energy. This upgrade highlights the integration of environmentally conscious technologies into municipal sports infrastructure, reducing energy consumption and supporting long-term sustainability.

3.8 Rataje Water Sports Center

Between 2019 and 2023, the Rataje Water Sports Center underwent comprehensive modernization, focusing on sports, recreational, and operational facilities. In 2019, the main building, including changing rooms, was modernized in accordance with the local building authority (PINB) requirements, and the skatepark was upgraded. In 2020, modernization efforts continued with further improvements to the main building and renovation of the multifunctional “Orlik” sports field. The year 2021 introduced significant infrastructure enhancements.

Electrical networks were extended across the center, a retaining wall was constructed near the basketball court, and a photovoltaic system was installed on the main building to enable the use of renewable solar energy. In addition, unused buildings were demolished, a parking area was created, and a covered tennis court

was built. In 2022, design works were carried out for a beach volleyball court complex, an artificial irrigation system was installed on the tennis courts, and construction continued for the covered tennis court. Further demolition of unused buildings and associated site development were also completed. Finally, in 2023, project work for stormwater management was undertaken, the football field was modernized, and the tennis courts underwent thermal modernization using insulating materials, reducing heat loss and improving energy efficiency.

3.9 Strzeszynek Bathing Area and Facilities

Between 2021 and 2023, the Strzeszynek Bathing Area underwent staged modernization focused on both functional and infrastructural improvements. In 2021, design works were carried out for the construction of a slipway and access road, alongside renovation works at the facility located at Koszalińska Street. These activities continued in 2022, with further development of the slipway and continued modernization of the Koszalińska facility.

In 2023, modernization efforts included additional renovation of the Koszalińska facility and upgrades to the electrical installations, incorporating energy-efficient LED lighting. These measures reflect a commitment to sustainable, environmentally conscious infrastructure upgrades, improving both energy performance and user experience.

3.10 Rusalka Recreational Complex

Between 2019 and 2021, the Rusalka Recreational Complex underwent staged modernization, focusing on enhancing both sports and recreational facilities. In 2019, a slipway and mooring pier were constructed, alongside the development of sports and recreational infrastructure under the project “Sport, Water, and Family at Lake Rusalka” (PBO). In 2020, monitoring systems were installed for the facility and slipway, improving safety and operational management.

In 2021, the modernization continued with upgrades to the surrounding area, including small architectural elements and the installation of energy-efficient LED lighting, reflecting a commitment to sustainable and environmentally conscious infrastructure improvements.

3.11 Sports Field, Playground, and Outdoor Gym at Kobylepole

Between 2019 and 2020, the Kobylepole area underwent the construction of a sports field, playground, and outdoor gym, integrated with a new pedestrian path connecting Primary School No. 55 to Stalowa Street. In 2019, design works were carried out for the pathway and its lighting system. In 2020, the pathway was constructed along with its lighting system, incorporating energy-efficient LED lighting to ensure sustainable operation and reduce energy consumption.

This project demonstrates the integration of modern recreational infrastructure with environmentally conscious design solutions, enhancing community sports and leisure facilities.

3.12 Termy Maltańskie

Between 2019 and 2023, the Termy Maltańskie complex underwent staged modernization, focusing on both operational efficiency and user experience improvements. In 2019, documentation was prepared for systems optimizing media consumption, a pathway from the stands to the pool basins was constructed, an electric drive for the Olympic pool divider was installed, and a glass wall with doors was added in the administrative hall to create a separate space.

In 2020, upgrades included replacement of locker room doors, acquisition of equipment for trampolines and gymnastics (including trampolines, mats, and belts), installation of an electronic scheduling system on display boards, enhancement of underwater sound systems, implementation of a pace-setting device for swimmers, and installation of a variable frequency drive for pool circulation pumps.

In 2021, further improvements were made with the replacement of additional frequency drives, design and modernization of the substation, upgrades to the audible warning system, renovation of the main hall, installation of a new video board, and replacement of lighting with energy-efficient LED systems, reflecting the adoption of sustainable technologies.

In 2022, modernization efforts included rearrangement of the main hall, continued work on the substation, and further upgrades to the audible warning system. Finally, in 2023, the main hall was further reconfigured, and the service elevator under the pool area was replaced to improve operational efficiency and safety.

3.13 Sports Hall at Chojnicka Street

Between 2019 and 2023, the sports hall at Chojnicka Street underwent staged modernization aimed at enhancing its usability for training purposes and improving both indoor and outdoor facilities. In 2019 and 2020, the building was renovated to enable its functional use for sports training. In 2021, the first equipment, including machines and devices for daily operation, was acquired, and the outdoor sports field adjacent to the hall was modernized.

In 2022, the hall's roof covering was replaced, and the lighting system of both the indoor hall and the outdoor sports field was upgraded with energy-efficient LED solutions, reflecting sustainable and environmentally conscious design practices. Finally, in 2023, modernization efforts continued, completing upgrades to the hall and its external sports field, improving operational efficiency, safety, and user experience.

3.14 Stadium at Droga Dębińska Street

Between 2019 and 2023, the stadium at Droga Dębińska Street underwent comprehensive modernization aimed at enhancing both sports infrastructure and operational capabilities. In 2019, energy-efficient LED lighting was installed, providing sustainable and high-performance illumination for the facility. In 2020, the lighting system was further completed, alongside the installation of a heated pitch system and general infrastructure upgrades to improve functionality and safety.

Modernization of the stadium infrastructure continued through 2022. In 2023, the modernization program was expanded to include the construction of a fencing hall, a football field with artificial turf, and a natural grass football pitch with heating. These improvements reflect a holistic approach to stadium development, combining energy efficiency, modern facility standards, and enhanced training and competition conditions.

3.15 Municipal Stadium

Between 2021 and 2023, the Municipal Stadium underwent a modernization program focusing on structural, operational, and safety upgrades. In 2021, work included renovation of resin flooring, water installations, and the IT system, as well as thermal insulation of the exterior walls of the sanitary facilities on the second stand.

In 2022, modernization efforts expanded to the first stand with floor tile installation and expansion joint work, continued upgrades of resin flooring, water installations, and the IT system, as well as refurbishment of staircases, elevators, and structural elements of the third stand. The stadium's roof monitoring system was modernized, and exterior walls of the fourth-stand toilets were insulated, reflecting a focus on structural safety, energy efficiency, and user comfort.

In 2023, renovation continued with further resin flooring upgrades, overall infrastructure modernization, completion of floor tile installation and expansion joints, and enhancements to the smoke extraction system in communication areas. The roof monitoring system and structural elements were further modernized, ensuring long-term safety and operational reliability.

3.16 Atlantis Municipal Swimming Pool

Between 2021 and 2023, the Atlantis Municipal Swimming Pool underwent a modernization program focused on structural, operational, and energy-efficient improvements.

In 2021, renovations included the roof covering and structural elements, the pool hall, changing rooms, and basement facilities, enhancing both safety and

functionality. In 2022, modernization efforts continued with upgrades to the women's, men's, and family changing rooms, including the introduction of a modern access system for improved convenience and security.

In 2023, design work was carried out for the installation of a photovoltaic system on the building's roof, alongside further roof modernization. The photovoltaic installation enables the use of renewable solar energy, reflecting a commitment to sustainable infrastructure and reduced environmental impact.

3.17 Sports and Recreation Community Center in Kiekrz

Between 2022 and 2023, a new sports and recreation community center was constructed at Wilków Morskich Street in Kiekrz. The project utilized modern construction solutions, including energy-efficient building materials, and incorporated a photovoltaic system on the roof, enabling the use of renewable solar energy. The facility reflects contemporary trends in sustainable sports infrastructure, combining functional design with environmentally conscious technologies to support both community activities and energy efficiency.

4. Discussion

The analysis of infrastructural investments in Poznan sports and recreation facilities from 2019 to 2023 demonstrates a clear trend toward the integration of green infrastructure and sustainable construction principles in municipal projects. Out of 36 investment entries identified in official documentation, 17 included explicit elements of environmentally conscious design, reflecting approximately 47% of recorded interventions.

The widespread implementation of energy-efficient lighting across multiple facilities – such as the Strzeszynek bathing area, Chwiałka complex, and Droga Dębińska stadium – demonstrates a consistent commitment to reducing operational energy consumption. The adoption of LED lighting aligns with international studies emphasizing its effectiveness in lowering electricity usage and reducing greenhouse gas emissions in sports facilities (Fantozzi *et al.*, 2016).

In addition, Hong and Rahmat (2022) demonstrated that transitioning to energy-efficient LED lighting in buildings can lead to significant reductions in lighting energy consumption and associated CO₂ emissions, with modelling showing up to an 8-fold reduction in emissions when conventional lamps are retrofitted with LED systems.

Moreover, Katzin (2021) quantified energy savings from retrofitting high pressure sodium lighting with LEDs, showing substantial reductions in overall energy demand linked to lighting systems – a major factor in CO₂ emission reductions in built environments. In the Poznan case, retrofitting older infrastructures with LED

systems not only contributed to energy savings but also extended the service life of lighting installations, thereby reducing material waste.

PV installations, present in facilities including the Atlantis and Winogrady swimming pools and the Kiekrz sports and recreation center, represent a significant step toward decentralized renewable energy adoption within municipal recreational infrastructure. By enabling these facilities to partially generate their own electricity, PV systems reduce reliance on fossil-fuel-based energy and lower operational costs.

This approach reflects broader global trends in sustainable infrastructure, where integrating renewable energy into facility planning is increasingly employed to achieve environmental targets and energy self-sufficiency (Lin *et al.*, 2020). Specifically, the integration of renewable energy technologies into building and infrastructure design is recognized as a critical strategy to improve energy performance, decrease greenhouse gas emissions, and support the development of more self-sufficient and sustainable facilities (Lin *et al.*, 2020).

Modelling studies demonstrate that combining renewable energy systems with storage solutions allows buildings and facilities to enhance energy independence while further reducing dependence on external fossil-fuel power sources (Urs, 2025).

Thermal insulation and building envelope improvements – observed in the Municipal Stadium, Rataje Water Sports Center, and Chwiałka complex – reflect an emphasis on reducing energy losses and improving indoor comfort. The use of modern insulating materials, alongside system upgrades such as heating, ventilation, and water systems, aligns with the principles of sustainable architecture and building performance optimization.

Research shows that increasing the thermal insulation of building envelopes and modernizing ventilation systems significantly improves a building's overall energy efficiency and reduces energy consumption (Gołabeska, 2021). Advanced facade insulation technologies have been demonstrated to enhance thermal performance and occupant comfort while contributing to lower operational energy demand (Cuce, 2025).

Improvements in HVAC systems and mechanical installations are also crucial for optimizing energy use in modern buildings and increasing environmental sustainability (Ferdyn-Grygierek, 2005). Systematic reviews further highlight that combined strategies – integrating high-performance insulation and efficient building systems – are key components in achieving sustainable, low-carbon building performance (Hafez *et al.*, 2023).

Several cases also illustrate a holistic approach to green infrastructure that extends beyond energy efficiency. For instance, the Rataje Water Sports Center and the Strzeszynek bathing area incorporated environmental planning measures such as

stormwater management, artificial irrigation systems, and site-sensitive spatial design. These interventions support water conservation and reduce ecological pressure on urban ecosystems, reflecting the principles of low-impact development and resilient urban design.

LID approaches emphasize the use of natural processes – such as infiltration, retention, and reuse of stormwater – to mitigate the negative hydrological effects of urbanization and improve water cycle balance (Kim *et al.*, 2024). Such strategies are widely recognized as more sustainable alternatives to conventional drainage systems, contributing to reduced surface runoff, improved water quality, and enhanced urban resilience (Yang *et al.*, 2022).

Despite these positive trends, there remain opportunities for improvement. While nearly half of all investments incorporated sustainable measures, several facilities underwent modernization with limited or no explicit ecological interventions, particularly in the earlier years of the 2019–2023 period.

This suggests that sustainable construction is not yet uniformly embedded across all projects and that formalized policies, guidelines, or performance standards could help ensure more consistent adoption of green infrastructure principles. Furthermore, the evaluation of long-term performance metrics, such as energy savings, water consumption reduction, or carbon footprint mitigation, was not available in the current dataset. Future research could integrate post-occupancy evaluations to quantify the environmental and operational benefits of these interventions.

5. Conclusions

This study demonstrates that the integration of green infrastructure principles into the planning and modernization of sports and recreational facilities in Poznan is both evident and progressively expanding. The findings indicate that nearly half of the analyzed investments incorporated elements of sustainable construction, including energy-efficient lighting, renewable energy systems, thermal insulation improvements, and environmentally sensitive site planning.

Importantly, these measures were implemented across facilities of varying scale and function, suggesting a gradual mainstreaming of ecological considerations within municipal infrastructure development. At the same time, the uneven distribution of sustainable solutions and the absence of comprehensive performance evaluation data highlight the need for more systematic approaches, including the adoption of formalized sustainability standards and monitoring frameworks.

Overall, the Poznan case provides empirical evidence that the integration of green infrastructure in sports and recreational facilities is feasible at multiple scales and can contribute to broader urban sustainability goals, while also underscoring the

importance of strengthening policy coherence and post-implementation assessment in future development strategies.

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