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Public Sports Facilities in the Era of Climate Change: Decarbonisation and Sustainable Transition in Toruń, Poland

Publiczne obiekty sportowe w dobie zmian klimatycznych.
Dekarbonizacja i zrównoważona transformacja na przykładzie Torunia

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Abstract: This study examines how public sports facilities can support urban sustainable transition in the context of climate change, with particular attention to decarbonisation, climate mitigation, and social resilience. The analysis focuses on sports infrastructure managed by the Municipal Sports and Recreation Centre in Toruń, Poland, and combines two analytical perspectives: infrastructural and social. The first addresses technical modernisation, energy efficiency, renewable energy integration, and water management, while the second considers the role of sports facilities as multifunctional public spaces supporting social integration, environmental awareness, and urban well-being. The findings reveal substantial differences in the environmental performance of individual facilities, with aquatic facilities achieving the highest scores due to their technical specificity, stronger investment capacity, and greater functional complexity. The study identifies the urgent need for a coherent modernisation strategy for public sports infrastructure, particularly in relation to renewable energy systems, rainwater retention, and long-term cross-sector cooperation between local government, research institutions, and private actors. The article argues that public sports facilities should be understood not only as sites of recreation, but also as strategic components of climate-responsive and socially sustainable urban development.

Keywords: public sports facilities, sports infrastructure, urban sustainability, decarbonisation, renewable energy, energy efficiency, water retention, urban resilience, Toruń, SDG 11 – Sustainable Cities and Communities, SDG 13 – Climate Action, SDG 7 – Affordable and Clean Energy

Streszczenie: W niniejszym badaniu analizuje się, w jaki sposób publiczne obiekty sportowe mogą wspierać miejską transformację na rzecz zrównoważonego rozwoju w kontekście zmian klimatu, ze szczególnym uwzględnieniem dekarbonizacji, łagodzenia skutków zmian klimatycznych i odporności społecznej. Analiza koncentruje się na infrastrukturze sportowej zarządzanej przez Miejski Ośrodek Sportu i Rekreacji w Toruniu i łączy dwie perspektywy analityczne: infrastrukturalną i społeczną. Pierwsza z nich dotyczy modernizacji technicznej, efektywności energetycznej, wykorzystania odnawialnych źródeł energii oraz racjonalnego gospodarowania wodą, druga natomiast, dotyczy roli obiektów sportowych jako wielofunkcyjnych przestrzeni publicznych, które wspierają integrację społeczną, świadomość ekologiczną i dobrostan mieszkańców miast. Wyniki ujawniają istotne różnice w efektywności środowiskowej poszczególnych obiektów, przy czym obiekty wodne osiągają najwyższe oceny ze względu na swoją specyfikę techniczną, większe możliwości inwestycyj-

ne i większą złożoność funkcjonalną. Badanie wskazuje na pilną potrzebę wypracowania spójnej strategii modernizacji publicznej infrastruktury sportowej, w szczególności w odniesieniu do systemów energii odnawialnej, retencji wód opadowych oraz długoterminowej współpracy międzysektorowej między samorządem lokalnym, instytucjami badawczymi i podmiotami prywatnymi. Autorzy artykułu twierdzą, że publiczne obiekty sportowe należy traktować nie tylko jako miejsca rekreacji, ale także jako strategiczne elementy zrównoważonego rozwoju miast uwzględniającego zarówno zmiany klimatu, jak i kwestie społeczne.

Słowa kluczowe: publiczne obiekty sportowe, infrastruktura sportowa, zrównoważony rozwój miast, dekarbonizacja, energia odnawialna, efektywność energetyczna, retencja wody, Toruń, odporność miejska, Cel Zrównoważonego Rozwoju 11 – Zrównoważone Miasta i Społeczności, Cel Zrównoważonego Rozwoju 13 – Działania na rzecz Klimatu, Cel Zrównoważonego Rozwoju 7 – Przystępna i Czysta Energia

Introduction

In the face of the growing challenges posed by global climate change and the new needs of societies, sustainable development is becoming a key issue in the planning and management of sports infrastructure. Important cities that have both a post-socialist heritage and very clear traces of a longer history – its *genius loci* – present their own unique set of challenges and opportunities (Vecco 2020). The development plans for such cities of course follow contemporary trends, but they must be tailored to local conditions and existing infrastructure (Chodkowska-Miszczyk and Lewandowska 2024). One such city is Toruń (one of the two capitals of the Kujawsko-Pomorskie region, Poland), where there is a growing need to adapt sports facilities to low-emission requirements and integrate renewable energy sources (RES). Public sports infrastructure is an important feature of urban public spaces. It is a place for physical activity and a multifunctional social space, and it plays an important role in popularising ecological practices among its users (Mba et al. 2024).

Accordingly, we present an analysis of how urban sports facilities managed by the municipal authority for sports and recreation facilities (in Polish: Miejski Ośrodek Sportu i Rekreacji – MOSiR) in Toruń (Poland, Kujawsko-Pomorskie region – NUTS2) comply with current requirements for innovative, resilient and sustainable

public facilities. This analysis is based on two perspectives: infrastructural and social. The first concerns the technical innovations that have been introduced and the scope of related modernisation works. The second concerns the creation of modern, multifunctional places for social integration and for increasing ecological awareness. The vector of our analyses was established in accordance with the premises of international policies, namely those of the United Nations (UN) and the European Union (EU) (Gillett et al. 2025). The initial stage of the research involved analysing the current state and identifying key areas requiring modernisation, followed by the identification of potential solutions that could improve the energy efficiency of sports facilities and increase environmental awareness among facility managers and users. At the final stage, the article proposes a model for the transformation of sports facilities that takes account of criteria for climate-neutral measures, as well as the social dimension and both historical and cultural heritage of these buildings and the city at large.

1. Theoretical and Conceptual Frameworks

1.1. Sport facilities in the context of climate change and urban development

Fluctuations, risks, and developmental uncertainty characterise today's postmodern reality. Scientists and decision-makers face multiplying challenges. On the one

hand, current demographic and economic issues must be addressed; on the other hand, the effects of climate change and resource scarcity must be mitigated (Singh et al. 2026). These multiplying problems accumulate in cities – multidimensional spaces. After all, cities are the largest consumers of energy, water, and clean air, and producers of pollution and waste (Singh et al. 2026a). They are also attractive places to live and spend free time. Their rich recreational and cultural offerings attract residents and surrounding communities. Specific places that have become a permanent part of the urban landscape, and whose popularity is constantly growing, are elements of sports infrastructure. According to Mamcarczyk (2018), the level of sports infrastructure is correlated with local development, which is coordinated by local government authorities. Their responsibility is to ensure residents' needs for recreation, relaxation, and sport. The relationship between sport, sports infrastructure, and cities continues and will continue, as city authorities see the organisation of sporting events and the construction of sports infrastructure as opportunities to improve competitiveness, build a city's brand, and generate tangible and intangible benefits (Mason 2012). This includes not only the construction and maintenance of sports facilities that fully meet public objectives but also coordinating other activities that address local expectations and needs. It is therefore not surprising that sports facilities are increasingly involved in the process of sustainable urban transition, both through technical improvements and as accelerators of social change (Alberti and da Silva 2026).

In recent years, the "Sports for Climate Action" movement, initiated by the UN and supported by sports entities, has been gaining popularity. In addition to the obvious technical initiatives aimed at climate neutrality and reducing the carbon footprint of sports facilities and events, this project aims to promote pro-environmental practices and attitudes (Gollagher and Fastenrath

2023). In line with the idea of "Sports for Climate Action", the popularity of sport should be exploited to promote mitigation and adaptation solutions at regional, subregional and local levels and should apply equally to professional sport and to local community sport at local sports centres (United Nations Climate Change n.d.). These activities are consistent with the idea of environmental governance, where multi-level, sustainable management of environmental resources and ecosystem services imposes clear requirements, such as prioritising environmental references in the organisation of sports events (Wang et al. 2026).

These locally known sports and recreation facilities are often iconic buildings that constitute key features of urban space (Alaily-Mattar et al. 2025) while also serving as social anchors within communities (Seifried and Clopton 2013). Due to this complexity of roles and functions, those managing municipal sports facilities face a huge transformational challenge, reconciling decarbonisation requirements on the one hand and the needs and expectations of local communities on the other. Infrastructure projects must reduce the emissions of buildings while also taking into consideration the history of the place and the existing cultural heritage (Feliuss et al. 2020). The difficulty of implementing effective technological solutions to meet these complex expectations and needs is further compounded by the fact that sports facilities consume substantial amounts of energy and water, driven by their unique demand profiles and operational requirements. They are also characterised by fluctuations in usage and seasonal increases in user flow. They include different types of spaces with their own specific visual conditions and opportunities for transmission of ecological messages (Mallen and Chard 2012; Elnour et al. 2022). Renovations of buildings, especially those as demanding as sports facilities, allow for technological improvements to be made but also for real savings in material resources and public finances through the use of modern

infrastructural solutions (Karpinska and Śmiech 2020). When considering public expenditure (including the operating costs of public sports facilities) as a redistributive tool for achieving social sustainability, high value should be placed on efforts to reduce the costs of maintaining these facilities and on adapting them to the needs and expectations of all residents, including those with disabilities, families with children, and seniors (Alonso-Morales et al. 2025). As reported by Z. Zhang (2025), the quality of urban sports facilities increases residents' satisfaction with sports and improves the standard of living in cities. Thus, public sports facilities play a huge role in creating friendly, sustainable and resilient urban spaces that strengthen the local community (Aguome et al. 2024). With reference to the theory of cultural attachment, such facilities have even an adaptive role by offering places that are comfortable and safe for various social groups (Hong 2017). Sports facilities have been assessed to constitute a key form of recreational space in the city (Westerholt et al. 2022).

In addition to material gains and tangible socio-cultural benefits, modernisation and pro-ecological works carried out in iconic sports facilities also have an invaluable educational value (Lan and Shizhu 2025). Therefore, information on practices implemented and difficult modernisation actions undertaken should be reliably communicated to users. Transmitting such messages through multisensory experiences that capitalise on the positive emotions associated with sports is an ideal way to effectively encourage and reinforce desirable pro-ecological practices and behaviours over the long term (Bonfanti et al. 2025). Appropriate management and stakeholder relations should act as a "transmission belt" for pro-ecological behaviour. To avoid turning sports facilities into isolated "emerald islands" whose "greenness" fails to permeate the wider urban space (Chodkowska-Miszcuk and Lewandowska 2024), it is necessary to consider the practices of stakeholders and

supply chain participants and to strengthen relationships with those whose activities are closer to the idea of low-emissivity and decarbonisation; this can help embed pro-ecological initiatives in the local system (Lan and Shizhu 2025). This is a fundamental stage in creating the potential for urban transformation, whose core consists of public entities (Elmqvist et al. 2019; Gollagher and Fastenrath 2023). At the same time, it is a milestone in the creation of entrepreneurial ecosystems for the sustainable development of the sports industry (González-Serrano et al. 2021). Of course, the scope and intensity of transformation activities in sports facilities should align with the local context and the city's development strategy, so that the project's final effects are clear to the entire urban community and improve the city's quality of life (Mason 2012).

1.2. Towards decarbonisation of sports facilities

The issue of sustainable construction is gaining importance in Poland, with the growing need to adapt to climate change, effectively manage resources and promote ecological practices. Buildings currently account for over 40% of energy consumption in the EU (European Commission n.d.). Most of this energy is currently supplied by fossil fuels, which cause buildings to generate around 25% of the EU's total greenhouse gas emissions (European Academies Science Advisory Council 2021). Therefore, it is necessary to implement standards to improve their energy efficiency. In accordance with Directive (EU) 2024/1275, each EU member state, including Poland, should prepare a National Building Renovation Plan, which sets out a roadmap for modernising and decarbonising buildings by 2050. To strengthen the energy independence of buildings, it is recommended to install renewable energy systems, including primarily solar photovoltaic systems and solar collectors (Mišík et al. 2024). New buildings are to be zero-emission buildings: from 1 January 2028 for new buildings owned by public institutions, and from 1 January

2030 for all new buildings. These extremely ambitious goals require a territorialised approach at the national level but also, above all, at the regional and local level, as well as cross-sectoral cooperation (Gillett et al. 2025). According to the preliminary draft of the *National Building Renovation Plan* for Poland, buildings with the lowest energy standards, including public buildings, will be modernised first (Ministerstwo Rozwoju i Technologii 2024).

Given the current regulatory framework, it is not surprising that in recent years there has been a noticeable increase in interest in the use of certified building materials and recycling in sports facilities, which are, after all, public buildings. However, there are significant barriers limiting the development of this sector. Many local government units do not have sufficient financial resources to purchase appropriate equipment and devices that would generate real savings not only in financial but also environmental terms, which may lead to the selection of cheaper, but less ecological and less sustainable solutions. The use and implementation of recycled materials is limited by a lack of awareness and a lack of appropriate legal regulations (Bukowski and Fabrycka 2019). Financial constraints and a lack of support from the central government also hinder the development of sustainable construction (Pawlikowska-Piechotka 2016). Moreover, many local government units and those managing sports facilities are not sufficiently aware of the benefits of using certified materials and recycling practices. There is an urgent need for regulatory and financial support from the central government to enable the development of sustainable sports and recreational construction. The market for certified building materials in Poland is still underdeveloped, which leads to higher costs and limited availability of these products (Falaciński and Machowska 2024). Public support for the modernisation of sports buildings is crucial, not only from the point of view of sustainable urban development and the implementation of environmental

governance, but also from the perspective of the functioning of society, because the accessibility of sport for all is becoming a permanent, and even leading, element of broad-based social welfare (Bergsgard et al. 2019). Moreover, the role of sports facilities in building local resilience is growing as multifunctional places. They are important in crisis response plans and counteracting the effects of extreme phenomena (Orr and Kellison 2023).

1.3. The research gap

When considering global challenges related to mitigation and adaptation measures covering various economic sectors, including construction, the building resources used in the sports industry deserve special attention. An in-depth infrastructural and social analysis of sports facilities – which are key to building urban recreational spaces (Westervolt et al. 2022) – is essential to facilitate the achievement of climate policy goals, but also for the urban sustainable development, resilience and social well-being. Cities in Central Europe, including Poland, deserve special attention as they are burdened with a socialist past, including in terms of infrastructure, and are now facing development challenges in terms of decarbonisation needs, social transformations and urban spatial cohesion (Chodkowska-Miszczuk et al. 2023). We therefore present a study that identifies a comprehensive approach to the identified problems. The approach concentrates on the issues of technological projects, but also to the integration of public sports facilities into the settlement fabric and their role in the development of urban society. For this purpose, an empirical analysis was carried out in a medium-sized Polish city, namely Toruń. Recognising the limitations of basing research on case studies, we are confident that the research findings will broaden the current state of the art, particularly given the paucity of research from Central Europe in the global literature. The bidirectional research approach we propose will illuminate the conditions and opportunities

for utilising public sports facilities in urban development strategies. While evidence exists of the importance of sports facilities for recreational and health purposes, there remains a lack of reports on their role in multidimensional development management that aligns with sustainable development policy and creates local resilience. Further exploration of the issues under consideration undoubtedly requires further research, including comparative analyses.

2. Materials, Methods and Research Area

The article presents the results of an analysis that includes an assessment of ten key sports and recreational facilities in Toruń, according to sustainable development criteria. The conclusions drawn from the social research provide the basis for developing recommendations for modernisation strategies that can support local and regional development and contribute to the implementation of European climate policy. In light of the growing role of sport in social life and its impact on public health, well-being, resilience, and environmental governance, this research aims not only to improve infrastructure but also to promote an active lifestyle in harmony with nature.

This study employs a multi-faceted approach that combines both quantitative and qualitative methods to obtain a comprehensive picture of the state of sports infrastructure in Toruń (one of the two capitals of the Kujawsko-Pomorskie region, Poland) and its compliance with low-emission requirements. Toruń is a medium-sized city of approximately 190,000 inhabitants in north-central Poland and is one of the key centres of the Kujawsko-Pomorskie region. Its location between Warsaw, Gdańsk, Poznań and Łódź makes it a convenient point of reference in comparative analyses of medium-sized cities in Poland. The choice of Toruń as the research area was dictated by the diversity of the managed infrastructure, the full availability of technical data, and the city's representativeness in terms of its challenges in adapting sports facilities to EU

low-emission requirements. The research was conducted from January of 2023 to June 30 of 2024 and included ten key sports and recreation facilities managed by MOSiR Toruń and the remaining seasonal sports infrastructure of this municipal body.

MOSiR Toruń is a public body managed by the local government, i.e. Toruń City Municipality, and was established to manage and maintain sports and recreational infrastructure within the city. In the structure of local government entities in Poland, such bodies are established based on resolutions of municipal or city councils in order to carry out public tasks related to organising sports and recreational activities. MOSiR Toruń was established by the Toruń City Council by Resolution No. 72/03 of the Toruń City Council of 6 March 2003. The tasks of this budget unit include administering sports facilities, organising sports and recreational events, providing infrastructure to residents, and implementing programmes promoting physical activity and a healthy lifestyle. MOSiR Toruń includes facilities of various types – from sports halls and stadia, through swimming pools and marinas, to ice rinks and seasonal sports fields. According to the data published on the official website of the unit, MOSiR Toruń administers 20 facilities and numerous local sports fields classified as “other facilities”.

The study encompassed a diverse set of sports and recreational facilities, all under the jurisdiction of MOSiR Toruń, including both facilities subjected to preliminary assessment and those subjected to detailed scientific evaluation. The analysed facilities included “Przystań Toruń”, a modern sports complex equipped with extensive recreational and athletic infrastructure supporting a wide range of physical activities; the Tor-Tor ice rink, primarily used for winter sports and specialized training; a multifunctional sports hall, adapted for the practice of various indoor sports disciplines; a facility dedicated to hosting sports and cultural events, offering versatile infrastructure suitable for both local and professional-scale events; and

the most recently established facility, “Aqua Toruń” (Photo 1).

A detailed technical, functional, and environmental characterization of all facilities is provided in Table 1. The selected set of facilities allowed for a comprehensive analysis of the extent to which sustainable building principles were implemented, including low-emission performance, energy efficiency, the use of renewable energy sources, and modern solutions in water management and green area development within the MOSiR Toruń building stock. This approach enabled a rigorous evaluation of both existing practices and the modernization potential of the assessed facilities.

Additionally, the study encompassed multi-purpose sports fields designed for the practice of various athletic disciplines, as well as swimming facilities equipped with pools of diverse technical specifications. Each facility subjected to empirical evaluation was assessed using an ordinal scale ranging from 1 to 5 points, based on seventeen precisely defined criteria. These criteria included, among others, building thermal insulation, integration of renewable energy sources, modernization of lighting systems, implementation of water-saving solutions, utilization of green roofs, use of environmentally sustainable construction materials, and other aspects related to the sustainable development of sports infrastructure.

The ordinal scale is a measurement tool in which values are assigned to variables according to their relative position within the dataset (Ordinal scale 2010). Ordinal-level measurements allow for the establishment of a logical hierarchy among variables, enabling rigorous comparative analysis and the derivation of scientifically substantiated conclusions, without the need to determine exact distances between successive point values.

The adoption of this methodological approach enables a systematic comparison of individual facilities, the identification of areas requiring modernization, and the evaluation of the degree to which



Photo 1. Aqua Toruń complex: created through modernisation of the “Elana” pool originally built in 1987. The new interior retains the external wall of round windows that has long been a recognisable feature of the local neighbourhood. Toruń, 12/03/2025

Source: Authors

sustainable construction principles have been implemented, including energy efficiency, low-emission performance, and the responsible management of natural resources. Consequently, this approach provides a robust foundation for both empirical analysis and the formulation of strategic recommendations aimed at enhancing the functional and environmental quality of the assessed sports infrastructure.

Ordinal-level measurements, which indicate a logical hierarchy of variables, are entirely sufficient for this analysis and for drawing conclusions.

Explanation: The category of “other facilities” managed by MOSiR Toruń includes diverse sports and recreational infrastructure in various parts of the city. It includes numerous football pitches, basketball courts, volleyball courts (including beach volleyball courts), tennis courts, skate parks, roller skating rinks, athletics tracks and specialised facilities such as an archery range and a pump track. This group also includes elements of waterside recreational infrastructure – city beaches, piers, kayaking areas and outdoor fitness zones. Selected facilities, such as the fencing venue or the go-kart track, operate on a lease basis. These areas play an important role in providing residents with universal access to physical activity in public spaces and provide access to both team and individual sports, and

Table 1. Sports facilities: MOSiR Toruń

This table lists the sports and recreation facilities managed by MOSiR Toruń and identifies their main functional type. It provides an overview of the diversity of the municipal sports infrastructure included in the study, ranging from pools, stadia, and sports halls to marinas, campsites, sports fields, and other dispersed facilities.

	Facility	Classification
1.	Aqua Toruń	Swimming pool
2.	Motoarena	Speedway stadium
3.	Tor-Tor ice rink	Ice rink
4.	Seasonal ice rink	Ice rink
5.	Courts at Skarpa	Tennis courts
6.	Mini Aqua Park	Swimming pool with water fun zone
7.	Municipal stadium	Stadium with athletics field and football pitch
8.	Przystań Toruń	Water sports marina
9.	Orlik sports fields	Sports fields located in eight housing estates in Toruń
10.	Left Bank Pools	Seasonal swimming pools (Kujawska Street)
11.	Pools at Skarpa	Seasonal swimming pools (Przy Skarpie Street)
12.	Szosa Bydgoska swimming pools	Seasonal swimming pools (Szosa Bydgoska Street)
13.	Sports field at Skarpa	Sports field
14.	Szosa Chelmińska sports field	Sports field
15.	Marina and campsite	Recreation and tourism area
16.	Tramp Hotel and Campsite	Tourist area
17.	Hala Olimpijczyk	Multifunctional sports hall
18.	Hockey field	Sports field – field hockey
19.	Szosa Chelmińska Courts	Tennis courts
20.	City beach	Beach
21.	other facilities	Sports facilities

their location promotes an even distribution of infrastructure across the entire city (Mosir Toruń 2024).

Various research methods were used to assess the condition of the facilities. Original questionnaires were used and sent to facility managers to obtain information on possible investments in energy efficiency, the use of renewable energy sources, and recycling practices. Additionally, technical documentation was analysed, and facilities were visually inspected to assess their technical condition and compliance with ecological standards and to prepare original photographic documentation.

Systematic data collection was carried out, and the results were analysed to identify the strengths and weaknesses of sports infrastructure with regard to sustainable development. This approach enabled an assessment of the facilities’ current condition and the formulation of recommendations for

future modernisation activities to improve energy efficiency and increase environmental awareness among facility managers, ultimately presenting a transformation model for sports facilities.

3. Results

The study encompassed ten sports and recreation facilities managed by MOSiR Toruń, which were systematically evaluated for their compliance with contemporary low-emission construction guidelines. In addition, the remaining eleven facilities administered by the authority were included in the research and subjected to detailed scientific observation. This approach enabled a comprehensive assessment of the entire building stock, combining structured evaluation with in-depth analysis of operational and technical characteristics. The point-based assessment of the analysed facilities revealed considerable variation in their level

of compliance with low-emission construction requirements. The highest score was obtained by Przystań Toruń, located on Ks. J. Popiełuszki Street, which achieved 64 points out of a maximum of 85. This result was primarily associated with the implementation of renewable energy systems, the application of water-saving technologies, and the development of green areas surrounding the facility.

The second-highest score, amounting to 61 points, was recorded for the Aqua Toruń complex on Bażyńskich Street. The facility is characterised by high thermal insulation standards, the use of advanced photovoltaic installations, and modern ventilation systems (Photo 2). The third position, with a total of 59 points, was occupied by the Mini Aquapark on Hallera Street, which demonstrated particularly effective solutions in the modernisation of technical infrastructure and water management systems.

The group of facilities with moderate scores included the tennis courts on Przy Skarpie Street, which obtained 55 points, the municipal stadium on Bema Street with 53 points, and the “Tramp” hotel and camping site on Kujawska Street, which achieved 51 points. These facilities demonstrated partial implementation of low-emission solutions, although further improvements are required to meet contemporary sustainability standards.

The lowest-rated facilities included the tennis hall on Szosa Chełmińska, which scored 48 points, Motoarena with 45 points, and the “Olimpijczyk” sports hall on Słowackiego Street, which obtained 44 points. The lowest overall score was recorded for the Tor-Tor ice rink, which achieved 40 points, indicating the greatest need for modernisation measures aimed at improving energy efficiency and reducing environmental impact. A detailed analysis of individual evaluation criteria revealed interesting patterns in the strengths and weaknesses of the examined infrastructure. The best-rated area turned out to comprise the green areas around sports facilities, which received



Photo 2. Photovoltaic panels installed on the roof of the Aqua Toruń complex. Toruń, 12/03/2025
Source: Author.

an average score of 4.1 points, which indicates good development of recreational spaces and good awareness of the importance of green areas in the functioning of sports facilities. The second-highest-rated criterion was the design of sports spaces adapted to the needs of people with disabilities, which obtained an average score of 3.8 points, indicating a relatively good standard of infrastructure accessibility for all users. The use of renewable energy sources took third place with an average of 3.2 points, reflecting the growing interest of managers in photovoltaic installations and other forms of green energy.

At the opposite extreme are areas requiring urgent improvement. The lowest-rated criterion was the use of FSC-certified wood from responsibly managed forests, which received an average of just 1.4 points, indicating an almost total lack of awareness and implementation of such solutions in the surveyed facilities. The recycling of building materials during modernisation and demolition fared little better, with an average score of 1.8 points, indicating insufficient implementation of circular economy practices in the sports infrastructure sector. Green roofs, which serve a retention and thermal insulation function, received an average score of 2.1 points, indicating the limited use of such innovative architectural solutions.

The development plans presented by the managers of individual facilities

revealed clear modernisation priorities. The most frequently mentioned investment was the installation of photovoltaic panels, which was planned in seven of the ten facilities, confirming growing awareness of the potential of renewable energy sources to reduce operating costs and carbon dioxide emissions (Kiss 2022). The second priority was the retention and use of rainwater, which were indicated by the managers of four facilities to be a key investment in terms of climate change adaptation and rational water management. Modernisation of lighting systems to LED technology with motion sensors was the third most frequently mentioned development direction, which results from the relatively short payback period of this investment and ease of implementation (Photo 3; Photo 4).

Environmental awareness is growing in Polish society, which may influence attitudes towards sustainable construction (Kłos 2015). Many people are beginning to see the benefits of using certified building materials and recycling practices. However, there are also attitudinal barriers, such as mistrust in new technologies and higher investment costs. Investments in sports infrastructure can significantly affect local communities (Słocińska 2016). They can improve the quality of life of residents, increasing physical activity and bringing the local community together. However, an inappropriate approach to sustainable development can have negative consequences such as environmental degradation or conflicts of interest in the community.

In planning and implementing infrastructure projects, it is crucial to understand the interactions between various stakeholder groups, such as local authorities, investors, residents and non-governmental organisations. Cooperation and dialogue between these groups can improve understanding of social needs and provide an opportunity to minimise potential conflicts. Social analysis indicates a number of barriers that may hinder the development of sustainable construction. These include financial

constraints, as many local government units have insufficient funds, which limits the possibility of investing in ecological solutions. Insufficient education about the benefits of sustainable construction affects social attitudes and investment decisions, and the lack of regulatory support from the central government may hinder the development of innovative solutions (Photo 3).

4. Discussion

The research results reveal the complex reality of local sports infrastructure in the context of the challenges of energy and climate transformation. Significant differences in the degree to which individual facilities meet low-emission requirements, as expressed by the results ranging from 40 to 64 points, indicate the lack of a coherent modernisation strategy and differences in the availability of financial resources allocated to individual facilities. It is particularly interesting to observe the clear predominance of facilities related to water recreation, which consistently achieved the highest ratings in the analysis.

The predominance of water-based facilities in the ranking may be attributed to a combination of structural, economic, and user-driven factors. Firstly, the functional specificity of these facilities necessitates the implementation of sophisticated technical systems for water heating, ventilation, and air conditioning, which inherently incentivizes facility managers to adopt energy-efficient solutions in order to mitigate the substantial operational costs associated with maintaining large volumes of heated water and controlled indoor environments (Photo 4). Secondly, such facilities typically generate higher revenues from commercial activities, including paid access, swimming courses, and events, providing a stronger financial capacity for investment in modernisation and the integration of advanced technologies. Thirdly, users of aquatic facilities often exhibit elevated expectations regarding comfort, safety, and technical standards, which further motivates



Photo 3. Roof space at Aqua Toruń where further PV modules could not be installed due to lack of funds, Toruń 12/03/2025

Source: Authors.



Photo 4. Rooftop heating and ventilation installation at Aqua Toruń after modernisation. Toruń, 12/03/2025

Source: Author.

facility managers to implement contemporary solutions that enhance user satisfaction and comply with current sustainability and low-emission benchmarks.

Moreover, the technical complexity and multifunctional nature of water facilities often facilitate the integration of renewable energy systems, such as solar thermal collectors or photovoltaic installations, as well as modern water management technologies, including recirculation and filtration systems, which are less feasible in simpler sports facilities. Consequently, the convergence of operational necessity, economic feasibility, and user-driven demand creates favourable conditions for water facilities to achieve higher scores in sustainability and energy-efficiency assessments.

An examination of the modernisation priorities delineated by facility managers elucidates a distinctly pragmatic yet strategically informed approach to the adoption of low-emission solutions. The pronounced preeminence of photovoltaic (PV) systems as the most frequently envisaged intervention reflects not merely an ascendant environmental consciousness, but predominantly the pronounced economic rationality of such measures within the extant climatic conditions and prevailing electricity tariffs in Poland. The relatively abbreviated payback horizon for PV installations, presently estimated at approximately 7–10 years, renders them particularly propitious for municipal

authorities and public facility administrators contending with fiscal constraints (Instytut Energetyki Odnawialnej 2025).

Furthermore, the prioritization of PV technology aligns with broader strategic imperatives encompassing energy autonomy, mitigation of greenhouse gas emissions, and adherence to European Union directives on building decarbonisation. Facility managers increasingly apprehend that investment in renewable energy infrastructure not only curtails operational expenditures but also fortifies municipal assets against volatility in energy markets. Additionally, the deployment of PV installations serves as a conspicuous testament to institutional commitment to sustainability, augmenting public perception and reinforcing municipal leadership in environmental stewardship. This sophisticated synthesis of economic prudence, regulatory compliance, and normative responsibility underscores the cogent rationale underpinning contemporary modernisation strategies within the domain of municipal sports and recreational infrastructure.

Equally important is the interest in rain-water retention, which can be interpreted as a response to the growing problems associated with climate change, including the increasing frequency of extreme weather events (Janardhanan et al. 2020). Investments in retention systems serve a dual purpose: on the one hand, they enable rational management of water resources and reduce

water supply costs, and on the other, they constitute adaptations to climate change by reducing the risk of flooding and improving the microclimate around facilities (Licznar 2013).

The low ratings for some criteria, particularly those related to the use of certified construction materials and the implementation of recycling practices, indicate that significant systemic barriers exist in the Polish sports infrastructure sector. These barriers are multidimensional and include the financial constraints typical of local government bodies, insufficient awareness of available technological solutions among managers, and the lack of adequate regulatory and financial support from central government. Additionally, the Polish market for certified building materials is still underdeveloped, which translates into higher costs and limited availability of related products (Bukowski and Fabrycka 2019).

Particularly worrying is the almost total absence of aspects related to the circular economy, which may result from the lack of appropriate legal regulations requiring the recycling of building materials and the insufficient development of processing infrastructure in this sector. This problem is systemic and goes beyond the capabilities of individual sports facility managers, requiring comprehensive action at the public policy level. Further research and analysis of barriers and potential solutions that can support the development of sustainable sports infrastructure in Poland will be required. Co-action between scientists, practitioners and public administration, along with social participation, is crucial to achieving progress in sustainable sport facilities management (Newig et al. 2023). The effective implementation of sustainability practices in sports facilities requires action to increase public awareness and promote environmental education – initiatives that increase interest in the topic and expand the group of stakeholders (Chodkowska-Miszczyk et al. 2023). Democratisation of decision-making and inclusive

management seem to be the optimal direction for management, consistent with the requirements of the natural environment (Newig et al. 2023). A sustainable sports facility achieves its sporting goals. Furthermore, systematically increasing the importance of sport and sports infrastructure in environmental governance can yield additional benefits, namely, further sustainable changes in both urban structure and local society (Davies 2016).

Conclusions

The research provides valuable insights into the extent to which sports infrastructure meets low-emission requirements and reveals key challenges and development opportunities in this area. The main conclusion from the analysis is the finding that environmental standards within the infrastructure managed by a single entity can be highly heterogeneous, which indicates the need to develop a coherent modernisation strategy that takes into account the specificity of individual facilities while striving to achieve greater uniformity across environmental standards.

The clearly superior assessment results achieved by water facilities provide important indications of which factors contribute to the implementation of low-emission solutions. The experience of these facilities can serve as a model for other units, especially in terms of adopting a comprehensive approach to energy modernisation and the use of synergies between various technological solutions. The management's focus on investments in photovoltaics and water retention indicates a promising direction for modernisation, combining environmental considerations with economic rationality.

For sports facility managers, it is crucial to prioritise investments in renewable energy sources and water retention systems as solutions with the shortest pay-back period and the greatest potential for reducing operating costs. Equally important is the implementation of comprehensive material recycling programmes and the use

of good practices developed in the highest-rated facilities. Particular attention should be paid to opportunities for cooperation between facilities in terms of joint purchases of certified materials and exchange of experiences in implementing low-emission solutions.

From a public policy perspective, the research results indicate the need to increase financial support for the modernisation of sports facilities, particularly in the form of dedicated subsidy programmes that take into account the specificity of this sector. It is also important to develop ecological certification standards for sports infrastructure, which could serve as a point of reference for managers and a tool to motivate them to undertake modernisation activities. Promotion of the use of certified building materials should be supported by the development of the domestic market for such products and appropriate legal regulations.

Directions for further research should include a detailed cost-benefit analysis of implemented low-emission solutions, which would allow financial models to be developed to facilitate managerial decision-making on investment projects. It is equally important to examine the impact that modernisation has on the quality of sports and recreational services and facility-user satisfaction. Through comparisons against similar facilities in other Polish cities, best practices could be identified and nationwide recommendations developed. A long-term assessment of the environmental effects of projects implemented would provide valuable data for optimising future modernisation activities.

It should be emphasised that the present study is a pilot study and covers only MOSiR facilities in Toruń, which is its main limitation. Generalising the presented conclusions to other sports centres in Poland requires that further comparative research be undertaken with a wider geographical scope and encompassing the diverse ownership and management models among sports facilities. Nevertheless, the results constitute a solid

basis for further analyses and can serve as a reference point for similar studies in other regions of the country.

Statements

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