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CONTEMPORARY DESIGN OF SUSTAINABLE CAMPUS SPACES: A CASE STUDY OF THE EXTENSION OF THE WATER CENTRE AT THE WARSAW UNIVERSITY OF LIFE SCIENCES – SGGW

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ABSTRACT

The paper examines the role of sustainable and participatory design in modernising university campuses, focusing on the extension of the Water Centre at the Warsaw University of Life Sciences – SGGW. The study explores integrating pro-ecological strategies, including green roofs, rainwater recirculation, renewable energy systems, and student engagement in spatial planning. The research evaluates how these interventions enhance campus functionality, user well-being, and environmental resilience through a case study approach. The findings indicate that sustainable campus redevelopment improves microclimatic conditions and biodiversity, as well as fostering inclusivity and academic community engagement. The paper contributes to the discourse on ecological urbanism and the adaptation of educational spaces to contemporary sustainability challenges.

Keywords: sustainable design, campus infrastructure, blue-green solutions, university architecture

INTRODUCTION

Modern university campuses face increasing challenges in balancing sustainability with the evolving needs of academic communities. In the context of rapid urbanisation, climate change, and shifting societal expectations, campus spaces must go beyond their traditional educational and research roles to enhance user well-being and promote social inclusion (Jakimiuk et al., 2023; Vaverková et al., 2024). A crucial aspect of contemporary campus planning is the integration of environmentally friendly, energy-efficient solutions and the active involvement of students and staff in the design process (Moscoso et al., 2024).

In response to these challenges, the design team proposed many innovative solutions as part of the project to extend and modernise the Water Centre at the Warsaw University of Life Sciences – SGGW (in short: the Water Centre) (Zagrajek et al., 2023). This study examines the redevelopment and expansion of the Water Centre as a case study in sustainable campus modernisation. The project introduces multiple pro-ecological strategies, including green roofs, rainwater retention and recirculation, photovoltaic panels, and the use of innovative building materials (Stefańska et al., 2023). The redesign also emphasises accessibility,

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with improved facilities for people with disabilities and the creation of diverse communal areas for learning, recreation, and social interaction (Kulpa-Puczyńska, 2022).

Revitalising the surroundings of the Water Centre was also an essential part of the project. Green spaces were designed to encourage biodiversity and adaptation to climate change. A system of pedestrian and cycle paths was introduced, linking the main arteries of the campus, as well as microhabitats for insects and small animals. Greenery was supplemented with shrubs (including formally pruned shrubs) and trees to provide year-round appeal and blue-green infrastructure elements such as infiltration troughs and flower meadows.

Beyond architectural interventions, the revitalisation of the Water Centre's surroundings plays a pivotal role in enhancing campus resilience. Introducing pedestrian and cycling infrastructure, biodiversity-promoting microhabitats, and blue-green infrastructure, such as infiltration troughs and rain gardens, supports climate adaptation while fostering a dynamic, user-friendly environment. These elements align with broader urban sustainability principles, demonstrating how ecological and participatory design can shape modern academic landscapes (Zhong, Schroeder & Bekkering, 2022; Ibiyeye, Shamang & Malachy, 2024).

The interventions implemented in the Water Centre extension are consistent with several established theoretical frameworks. Elements such as biodiverse microhabitats, rainwater management, and natural light optimisation resonate with the principles of biophilic design, which emphasises the integration of natural systems into the built environment to improve health and well-being (Zhong et al., 2022). At the same time, the reuse of materials and reliance on renewable energy sources correspond to the logic of the circular economy, where resource cycles are closed, and waste is minimised (Łacek & Starzyk, 2023). By situating the case study within these frameworks, the paper contributes to bridging design practice with ecological urbanism theory, highlighting how campus redevelopment can serve as a testbed for sustainable innovation.

This paper analyses the impact of these interventions on campus functionality, user experience, and sustainability performance. Emphasis is placed on the role of blue-green infrastructure in improving microclimatic conditions and student engagement in shaping their academic environment. By contextualising this case study within global trends in sustainable campus design, the study contributes to the discourse on resilient and inclusive university spaces.

Science and university facilities

The expansion of science facilities on university campuses presents significant urban, architectural, and environmental challenges. Contemporary processes for modernising such buildings consider functional aspects, user needs and sustainability challenges. The main directions of redevelopment include improving energy efficiency, revitalising common spaces and implementing intelligent building management systems. User participation in the design process and the adaptation of spaces to modern standards of comfort and ergonomics also remain key aspects. The successful modernisation of campus facilities requires a holistic approach, combining advanced technologies, user comfort and sustainability principles. Key strategies include flexible, collaborative spaces, energy efficiency, integrated management systems and optimising environmental conditions.

Recent scholarship increasingly frames campus redevelopment as part of broader sustainability transitions. For instance, biophilic design provides a conceptual lens to evaluate how green roofs, natural ventilation, or vertical greenery influence both environmental performance and user experience. Similarly, the circular economy perspective emphasises adaptive reuse of materials and systems thinking in managing energy and water flows. By engaging these frameworks, the present study positions the Water Centre as not only a functional upgrade but also as a demonstrator of how theoretical concepts can be operationalised in academic infrastructure.

Existing studies of campus redevelopment often emphasise single dimensions of sustainability, such as energy efficiency or user participation. However, fewer works explicitly demonstrate how multiple frameworks can be operationalised in a coherent design process. For example, while biophilic design reviews highlight health and well-being benefits, they rarely address how these strategies interact with circular economy principles of resource reuse. Similarly, ecological urbanism remains largely conceptual without detailed application to campus infrastructure. By synthesising these strands, the Water Centre case contributes to closing this gap and illustrates the combined application of these frameworks in a university setting.

The Massachusetts Institute of Technology's MIT.nano is an advanced research complex dedicated to nanotechnology and materials engineering. The expansion project focused on integrating laboratory spaces with open, collaborative areas, allowing interdisciplinary research teams to use the building flexibly. A key aspect of the upgrade was implementing energy-efficient heating, ventilation, and air conditioning (HVAC) systems and improved thermal insulation, helping reduce the facility's carbon footprint. The design also incorporated high-quality natural lighting and acoustic optimisation of the space, which improved user comfort.

The Nanyang Technological University has comprehensively refurbished its teaching facilities, emphasising climate change adaptation and energy efficiency improvements. The retrofitted buildings received new façades with vertical vegetation, helping to reduce the urban heat island effect. Artificial intelligence-based energy management systems were used, as well as modular teaching spaces that can be adapted to different teaching forms. In addition, the buildings were equipped with natural ventilation systems, which significantly reduced operating costs.

The Groningen Forum is a multifunctional academic facility that combines educational, research, and recreational spaces. Modernisation focused on restructuring the functional layout and creating a more accessible and interactive public space. Green roofs, outdoor terraces, and advanced rainwater retention systems were introduced, significantly improving the microclimate around the building. The open spatial concept has created a conducive environment for individual and collaborative work, increasing student and academic staff satisfaction.

MATERIAL AND METHODS

The Water Centre redevelopment project was analysed as a case study to illustrate the implementation of sustainable and participatory design principles for campus spaces. The execution of the redevelopment concept was the subject of an internal competition for staff, PhD students, and university students. Three mixed teams were selected, including representatives of the above groups in the interdisciplinary community of architects, builders, and landscape architects.

The pre-project research was based on a two-step analysis, including:

1. A two-day workshop with architectural student representatives present, which resulted in a detailed SWOT (strengths, weaknesses, opportunities, and threats) analysis that set the direction of further conceptual work.
2. Detailed analysis of the project documentation, which included a functional and spatial plan, environmental and energy solutions, landscaping, and adaptation of the space to the needs of people with disabilities. The documentation also provided details of the social infrastructure, including new recreational zones, exhibition spaces, and group work areas.

The materials were complemented by consultations with campus users, students, and academic staff, which took the form of pre-architectural competition participants' evaluations in each team. This enabled a broader view in the form of expectations and preferences regarding the designed space to be considered.

A mixed methodological approach was used, combining qualitative and quantitative analyses. The study analysed the design documentation, focusing on the sustainable solutions implemented, their compliance with the urban design guidelines, and the latest pro-ecological and pro-climate trends prevailing in shaping open spaces. An assessment of the preservation state of existing greenery was also carried out, and design guidelines were proposed to increase biodiversity and improve water relations through rainwater management (Wichowski, Rutkowska, Kamiński & Trach, 2019) and nature-based solutions (NbS). At the same time, the anticipated energy savings from the building management system (BMS) were assessed. The Water Centre is a building with modern insulation, built less than two decades ago, which allows a BMS system to operate efficiently without energy loss through the external walls, roof, or foundation. A BMS system is usually designed during the later phases of building development. The conceptual design sets the goals, while the executive design describes and specifies the technical parameters. Because the building management system controls every technical installation in the building, the planned energy savings can be further enhanced through well-organised control of energy flows during the building's operation and maintenance. Kamali, Khakzar and Abdali Hajiabadi (2013) describe a case study of a 20-year-old office building in San Francisco, USA, with a floor area of 66,943 ft². After implementing a BMS regulation system, the building achieved an average annual energy reduction of 50%. The paper by Colmenar-Santos, Terán de Lober, Borge-Diez and Castro-Gil (2013) shows how, only by the optimisation of the system technique regulations, energy savings by a margin of 30% can be achieved in offices and administrative buildings. The functionality of the spaces was analysed in terms of accessibility and their suitability for users. An analysis of the available literature on the revitalisation of science facility spaces supported the ecological and functional assessment with results and studies from several international centres where university spaces have been adapted to meet new requirements. The study also included a comparative analysis that contrasted the implemented solutions with similar projects implemented on campuses in Poland and abroad. This made it possible to determine the effectiveness of the strategies applied in the context of international sustainability standards. The final assessment of the project was based on criteria such as the environmental sustainability of the solutions, the functionality of the space, the impact on the well-being of the users, and the involvement and satisfaction of the students resulting from their participation in the design process.

In terms of qualitative research, the data obtained from workshops and consultations were transcribed and subjected to a thematic coding process. Recurrent categories such as accessibility, comfort, and ecological awareness were identified, and representative quotations were used to support the design directions. Quantitative assessments included two main areas. First, biodiversity was evaluated through direct field observations and species richness counts carried out in designated vegetation patches, both before and after the design intervention. Second, potential energy savings were estimated by benchmarking the projected BMS performance against comparable cases reported in the literature, and by modelling operational scenarios based on building energy demand profiles. This mixed-methods protocol ensured that qualitative insights were systematically integrated with measurable environmental indicators, thus reinforcing reproducibility and transparency.

It is important to note that at the current conceptual stage, precise numerical values for anticipated savings and biodiversity increases could not be generated, as no operational monitoring data were available. Instead, the analysis relied on benchmarking against published case studies and design guidelines, which provide indicative ranges of performance for similar interventions.

RESULTS

Description of proposed landscaping

The landscaping strategy for the Water Centre redevelopment prioritises ecological resilience, climate adaptation, and user well-being through an integrated blue-green infrastructure approach. The design balances urban hardscape – a university plaza facilitating social interaction – with soft landscape zones, including biodiverse green spaces and ecological corridors. Figure 1 illustrates the master plan, highlighting the integration of blue-green infrastructure with circulation routes. The placement of the infiltration troughs and the ribbon path demonstrates how ecological and social functions were combined in the design (Fig. 1).

1 – the Water Centre main building
2 – pavilion with a café and exhibition area
3 – Building 22 (Small Animals Clinic)
4 – Building 23 (Veterinary Medicine and Animal Science faculties' building)
5 – university square with coffee tables
6 – bike racks
7 – ribbon path
9 – quiet zone with benches
10 – green roof (sedum plants)
11 – infiltration ditch (bioswale)
12 – open rainwater channel
14 – microforest
15 – flower meadow
16 – parking area with permeable and green paving
17 – green glass/open-air cinema
18 – wild cherry
19 – new trees
20 – shrubs
21 – tall grass

Fig. 1. Master plan at the original scale of 1 : 500 showing a new complex vision of the Water Centre's surroundings incorporated into the existing campus tissue

Source: own work based on Google Maps (2025).

Key interventions include an autonomous rainwater circulation system consisting of retention basins, infiltration ditches, and an open rainwater channel. These features slow stormwater runoff, enhance water retention, and mitigate flooding risks (McNabb et al., 2024). Additionally, a hierarchical planting system – incorporating micro forests, flowering meadows, and native shrubs – enhances biodiversity while creating habitats for pollinators and small wildlife (Sutkowska et al., 2024).

A network of pedestrian and cycling routes connects the campus and reduces reliance on motorised transport, aligning with sustainable mobility principles (Działek, Jarecka-Bidzińska, Staniewska & Téoule, 2025). Integrating tree belts and vegetative buffers provides additional ecological benefits, such as reducing noise pollution and supporting carbon sequestration (Moscoso et al., 2024).

The project enhances environmental sustainability and social well-being by embedding NbS within the academic landscape, creating a climate-resilient and user-friendly university space.

One of the main pro-climate measures is a closed circulation of rainwater from the newly created university square, the pavilion's roof, and possibly from the green areas. The autonomous water system (with no connection to the sewerage system) contributes to slowing down surface runoff by collecting water while it is still on the roof. Any excess water flows via an open rain channel from the roof of the pavilion to an infiltration ditch (a depression of about 30 cm covered with grass or other vegetation that can withstand temporary flooding, flooded only in the event of excess rainwater). As shown in Figures 2 and 3, the design of infiltration ditches was inspired by precedents from Copenhagen, demonstrating how stormwater management features can double as landscape amenities. A large amount of greenery and the planting of shrubs, trees, tall grasses, and a flower meadow or green roof also contribute to improving the cooling function of the air, which positively affects human well-being during hot weather.

Fig. 2. An example of a rain garden/infiltration ditch from Copenhagen. An excess of stormwater from the roof is collected in a trough with grass vegetation

Source: photo by Barbara Warzecha 2024.

Fig. 3. An example of a rain garden/infiltration ditch from Copenhagen. A surface flow of stormwater can be collected in a trough with vegetation that withstands temporary flooding

Source: photo by Barbara Warzecha 2024.

A few pro-ecological measures have been proposed in the space between the existing and newly built structures. The designed forms of vegetation have been hierarchised into high vegetation (microforest), medium height vegetation (ornamental shrubs, grass garden), as well as low vegetation (green and permeable surface of the car park, green roof of the pavilion, flower meadow). Moreover, the species selection of shrubs allows for additional pro-ecological functions. Furthermore, the shrubs, which are attractive for their fruit, can serve as food for small animals during the winter. Animal sanctuaries with feeders and wintering areas (e.g. for hedgehogs) have been created in the microforest. Shrub belts have been located along urban axes, their species selection allowing them to be left to grow freely or trimmed if they are located next to traffic routes, as necessitated by considerations of safe pedestrian movement. A refuge for insects could become the proposed flower meadow, situated along the ribbon path, away from the main traffic arteries. The microforest acts as an ecological route or space and wraps around the campus site along its boundaries, creating an acoustic barrier from adjacent busy roads.

Mitigation measures for climate change could start here by promoting low-impact pedestrian and cycle transport on campus, improving pedestrian safety (lanes, new pavements, new paths), implementing green paving, and planting trees in the existing car park at the south entrance of the campus.

Architectural interventions

The design for the redevelopment of the existing Water Centre building, together with the development, considers the versatility of solutions, improved acoustics, environmental friendliness, and energy efficiency. Currently, the complex comprises the water park, which is left unchanged, an undeveloped green area, and the university building. The building area is 1,850 m^2, and the total floor area is 5,000 m^2. The building has a teaching, representative, and conference function.

The redevelopment includes extending ancillary functions, constructing a pavilion with an exhibition and educational function, and developing a green area, along with a green terrace. The terrace will be an experimental opportunity for students to design and maintain marsh gardens. The greenery has been tidied up and enhanced with seating areas created along the landscape ‘ribbon’ leading to the pavilion and building. Along the ribbon path will be places for tranquillity, dining, or contact with nature. The traffic network is divided into transit routes and walking paths. Main arteries and side axes provide communication between the campus buildings. New connections have been introduced in place of ‘forecourts’. The redesign of pavements has improved pedestrian comfort and safety. The newly designed plaza between the Water Centre and the pavilion creates an intimate atmosphere and encourages people to meet and linger among the greenery, including in the proposed café. To the pavilion’s rear, additional usable space has been created by moving the fence and gate 20 m into the area around the Water Centre, thus creating a forecourt and meeting place around the pavilion building. Here, in a secluded location, it is also possible to hold outdoor activities or a summer cinema screening, with the back wall of the pavilion acting as a screen.

As a result of pre-design analyses, it was determined that the Water Centre building required an increase in the number of teaching rooms and the planning of an attractive central space, as well as the separation of the conference space to allow independent use of the building. Figure 4 visualises the division into transformation zones, distinguishing between areas of preservation (grey), internal reconstruction (yellow), and structural extension (blue). This diagram clarifies the phased approach adopted to ensure continuity of the Water Centre’s operation during redevelopment. Three transformation zones were planned for the facility: extensions and alterations. Due to the need for the facility to function, the zones have been divided into a no-change zone (grey), where activities can occur almost without interference during construction. A new part (yellow), a conversion zone without interference with the building structure, and a new building extension zone (blue). The projected extent of the changes is shown in Figure 4.

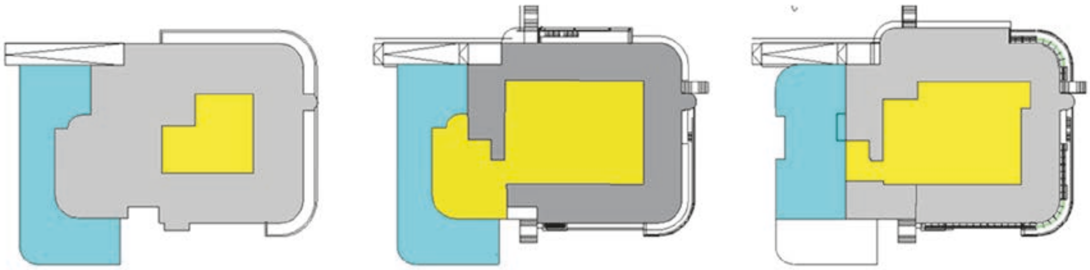

Fig. 4. Diagram of the planned changes to the building depending on the degree of transformation: grey – no change, yellow – reconstruction without interfering with the building structure, blue – extension, interfering with the structure (left: basement, middle: ground floor, right: 1st floor)

Source: own work.

The central space of the building was redesigned to encourage student use. The design includes the replacement of a disused fountain with a multi-purpose grandstand-style staircase acting as an amphitheatre. Among other things, a projection installation has been planned that, together with a skylight shading system and mobile acoustic walls, will allow lectures to take place. The grandstand will be made of wood to make the interior warmer. Under the grandstand, the so-called 'Atelier' has been designed as an exhibition and workshop space for architecture students, fenced off with transparent glass so that the observer can watch the exhibition from outside without disturbing the work inside.

In the common spaces, small-group workspaces have been provided, adapted to the needs of people with visual, hearing, or mobility disabilities. Quiet workspaces, so-called 'learning boxes', have also been designed, which lecturers and students can use to conduct and participate in remote classes.

Currently, the building has two large halls, one small conference and lecture room, specialist labs, and computer labs. The expansion project envisages the addition of three new large lecture/conference rooms and a multi-purpose room that can be divided into smaller practice rooms as required. A mobile wall system has been proposed for the division, which, when folded, will allow the space to be used as a banquet hall. An additional advantage is the proximity of the café and catering facilities.

A café has been designed on the south side of the building, accessible from the car park. The connection between inside and outside will be achieved through a high glass façade topped by a 'green wall'. This provides an independent entrance for conferences held in the new part of the building without interfering with the activity and accessibility of the existing part of the building.

Sustainable solutions

The ventilation and air-conditioning units in the building are intended to provide hygienically adequate fresh air, extract stale air, and maintain the required indoor air parameters for the individual areas. Heat gains in the rooms will be discharged via a cooled ventilation air supply and water underfloor cooling, while the heat demand will be covered by water underfloor heating. All rooms will be provided with mechanical, supply, and exhaust ventilation. Climatic conditions for individual rooms will be determined based on future data from the investor regarding the temperature and humidity levels that should be maintained, as well as the requirements for individual laboratory rooms, applicable regulations, and technological guidelines. The heat source for the building will be a ground heat exchanger in the form of vertical boreholes. Heat pumps will modify the ground heat exchanger facility's medium parameters. In addition, one heat pump will have the capacity to produce hot water and water for cooling purposes. To ensure the uninterrupted operation of the heat pumps as a cooling source, a fan cooler on the building's roof is envisaged. Underfloor heating is envisaged in the open-plan areas; the laboratory and office spaces will have panel radiators.

Cost-reducing solutions

The leading solutions to reduce running costs are energy recovery as much as possible and the use of grey water, as described in detail in the section on pro-environmental solutions. Another solution to reduce running costs is the double curtain wall or double-skin façade in the extension. The space between the two planes of the curtain wall is approximately 60 cm and provides a buffer of air that is insulated in the space between, allowing the rooms it encloses to remain passively warm. In addition, it reduces and eliminates the load caused by solar energy (excessive heating of the façade). In the newly designed south façade, an entirely glazed, double-layered partition and expandable horizontal wooden blinds are designed to support shading as required. In addition, in line with the façade design, vertical panels have been used to reduce light access to the classrooms and save on air conditioning. Meanwhile, photovoltaic glass was proposed in the outer layer of the façade, supporting the extraction of electricity from traditional photovoltaic cells on the roof.

In addition, motion-responsive adaptive lighting will be used around the building to reduce energy consumption significantly (principle of reduction), turning on light only where needed. The biowaste created will be recycled into fertiliser, supporting the maintenance of the greenery around the building and being in line with the idea of recycling (principle of recycling). In addition, materials from the current building, such as bricks, steel, and glass, will be reused in the new design, which fits in with the principle of reuse and minimises the need for new raw materials.

Area versatility

The facility will be fully adapted to the needs of people with disabilities, considering various forms of support and mobility solutions for people with reduced mobility, such as ramps, lifts, and signage at eye level for wheelchair users. There will also be several facilities for the deaf, hard of hearing, blind, and visually impaired. The building will be equipped with systems that work with users' smartphones, enabling them to navigate and use the space in their preferred way. For example, blind and visually impaired people can use a dedicated app that provides voice guidance to help them navigate the facility.

Acoustics

As part of the use of modern materials in the public area, a development has been proposed to form a grandstand-style staircase. Wood has been used as an acoustically insulating material to soundproof this space, reinforced with corrugations to allow early sound reflections to achieve good acoustics. In addition, soundproofing elements in the form of mobile panels and sound-absorbing materials capable of adapting to functional needs have been proposed. A membrane will be spread over the seats, which, together with their wooden finish, will improve the acoustic performance. The design incorporates the use of wooden movable screens, allowing the space to be visually closed off to the presenter.

Pro-environmental solutions

The project uses environmentally friendly solutions inside and outside the building: architecture, landscaping, and ecosystem services. An off-grid (grid-independent) photovoltaic installation was designed, and surplus energy will be stored in batteries for use during reduced production. The stored energy will be used partly for heating and cooling the central heating and water system. Rainwater from the roof will be retained and used for utility purposes, thereby reducing water demand. A room is foreseen on floor −1 for filtering and pumping water to reuse points such as flush toilets, urinals, and outdoor green watering boxes. Surface rainwater from the square and excess water from the green roof are routed through an open rainwater channel with the overwater greenery or through underground pipes to a rainwater basin/garden with vegetation that temporarily tolerates flooding. This self-contained system does not require a connection to the sewer system, and the water is managed in situ.

DISCUSSION

The design outcomes presented in the 'Results' section exemplify how ecological and architectural interventions can be mutually reinforcing. For example, the master plan (Fig. 1) demonstrates integration of blue-green systems with mobility infrastructure, while the building transformation strategy (Fig. 4) shows how functional adaptability was embedded into the architectural fabric. These solutions align with broader frameworks such as the European Green Deal and biophilic design principles, reinforcing the conceptual contribution of the project.

The Water Centre is a specialised building with modern laboratory and field research equipment. It is the only research facility in Poland dedicated to water science. There are laboratories to study the processes that determine water flow under various conditions. Spatial analysis is carried out in computer labs. At the same time, the Water Centre's external garden in the same urban complex includes experimental models of the river, spring, pond, and numerous water structures, as well as a meteorological station measuring current weather conditions.

The construction project was designed in 2005. It is a relatively new building with existing executive documentation. Since then, the following 20 years have been critical in the Polish construction industry due to Poland's accession to the European Union and the consequent entry into force of regulations on sustainable development in the construction industry. Today, two decades later, sustainable development in the construction industry is not just a trend but a conscious design covered by regulation. Directive (EU) 2024/1275 increased the energy performance requirements for new buildings.

It requires all new residential and non-residential buildings to be zero-carbon buildings as of 1 January 2028, as well as for buildings owned by public authorities, and, as of 1 January 2030, for all other new buildings.

The guidelines for the competition project, which included upgrading the Water Centre, addressed the following categories: circular economy, space and function adaptation, energy, greenery with surrounding infrastructure, and site development. The project team's analysis showed the need for changes in all these categories, resulting in the conceptual design of the Water Centre and its surroundings. While the conceptual design allows for the identification of expected benefits, detailed quantitative validation (e.g. measured reductions in energy use, stormwater runoff, or species inventories) will only be possible after implementation. Future monitoring is therefore essential to verify the projected performance and to provide empirical evidence supporting the sustainability claims.

For the conceptual design created based on the competition for the redevelopment of the Water Centre to develop further, it is necessary to carry out a series of analyses and expert opinions that are the starting point for further design work (construction-tender design).

In the case of the circular economy, the analyses and expert opinions should concern the types and quantities of building materials that can be reused, the possibility of storing them during construction (inventory with a list of how many times the material has been used), and the demonstration of appropriate technical parameters to meet construction standards when re-built so that the building can be handed over for use according to Polish construction regulations.

In the case of space and function adaptation, a detailed analysis of the needs of the Warsaw University of Life Sciences – SGGW campus in terms of teaching, auditorium, and laboratory spaces for the next 10–20 years should be carried out, considering the university's development plans. In addition, these analyses should consider the plan for possible phasing of the works to allow the use of the building during construction, renovation, and adaptation works.

As for the design of installations (sewage, water, heating, ventilation, and fire protection), providing, among other things, energy in the designed building should be carefully inventoried and analysed for capacity and possible expansion to meet nearly zero-energy building requirements.

The Directive (EU) 2024/1275 leads member states toward achieving 'nearly zero-energy buildings', which can be described as those with very high energy performance. Buildings like those described need two parameters: minimal energy to operate, and energy sourced from renewable resources generated locally (Starzyk et al., 2024).

Greenery and the surrounding infrastructure and utilities should be carefully analysed and designed according to the reports and EU regulations. The urban layout, which requires thorough sunlight and acoustic analysis around the building, will remain important. The external area of the Water Centre should be integrated with the building and function as one entirely complementary organism.

Solutions importance

The pro-environmental solutions used in the Water Centre expansion project are key to reducing the building's operating costs and improving the quality of life for its users. Integrating energy-saving technologies, such as photovoltaic installations and rainwater retention systems, contributes to a significant reduction in energy and water consumption, directly impacting the facility's operating costs. The introduction of an energy storage system from photovoltaic panels and the use of rainwater for irrigating greenery and flushing toilets exemplify the use of modern technologies to support resource management (Pronk et al., 2021; Dzikuć, Piwowar & Dzikuć, 2022). This approach minimises the load on the urban infrastructure while contributing to the energy self-sufficiency of the campus.

One of the key environmental solutions is using green roofs and rain gardens, which have multidimensional ecological and social functions. In addition to reducing the urban heat island effect, green roofs and other greenery support local biodiversity, improve air quality and provide better microclimatic conditions (Zhong, Schroeder & Bekkering, 2023). For campus users, these benefits translate into increased thermal comfort, reduced noise levels and aesthetic qualities of the environment. As a result, the space becomes more user-friendly, positively impacting users' daily well-being and productivity.

Another innovative design element is using a double-skin façade on the building, which acts as a thermal buffer. The double-skin façade reduces heat loss in the winter months while reducing overheating in the summer (Roostaei Firouzabad & Razi Astaraei, 2024). This passive solution reduces the need for mechanical heating and cooling systems, reducing operating costs and greenhouse gas emissions. In addition, adaptive motion-responsive lighting enhances energy efficiency (Oh & Lim, 2025). The use of recycled materials is in line with the concept of a closed-loop economy, reducing the consumption of raw materials and the generation of waste (Łacek & Starzyk, 2023).

However, the solutions go beyond purely economic aspects. Promoting ecology in an academic environment has essential educational and cultural significance. Elements of blue-green infrastructure, such as rain gardens and microforests, not only improve the quality of life for users but also become spaces for learning and observing ecological processes occurring in urban fauna and flora (Sutkowska, Stefańska, Vaverkova & Matsui, 2024). Such initiatives inspire the academic community to implement similar practices in other areas of life while promoting environmental awareness and responsibility. These elements align with contemporary sustainability frameworks, such as the European Green Deal (European Commission [EC], 2021), and climate adaptation strategies recommended by the Intergovernmental Panel on Climate Change (IPCC, 2023).

CONCLUSIONS

Key lessons for sustainable campus design

The sustainable design of university campuses plays a key role in shaping spaces that minimise negative environmental impacts and enhance the university community's quality of life. The analysis of the Water Centre extension allows for some fundamental conclusions regarding the design of ecological and participatory university spaces.

Integrating blue-green infrastructure as a standard design element is one of the most relevant aspects. Contemporary campuses should use rainwater retention systems, green roofs, rain gardens, and microhabitats to increase biodiversity. Such solutions not only reduce the environmental footprint but also improve the microclimate and the overall comfort of the space. In the case of the Water Centre, rainwater retention and infiltration systems have significantly reduced urban water consumption and increased the site's resilience to extreme weather conditions.

Energy efficiency and the move towards energy self-sufficiency for campuses are also essential elements of sustainable design. The use of low-carbon technologies, such as photovoltaic panels, intelligent energy management systems (BMS), or double-skin façades, allows for a significant reduction in energy consumption, which has a direct impact on reducing operating costs and carbon emissions. In the case of the project in question, implementing these solutions has shown that modern campuses can effectively strive for climate neutrality, which fits with global sustainability goals.

Another critical issue is users' participation - especially students - in the campus design process. Involving the academic community in consultations and design workshops enables spaces to better adapt to users' actual needs, increasing their involvement in the university's life and their sense of responsibility for the shared space. In the Water Centre project, the participatory approach has made it possible to create spaces that better respond to the needs of both students and academic staff.

From a utilitarian perspective, the multifunctionality and flexibility of campus spaces are also extremely important. Today's universities should offer spaces that can be adapted for different activities – teaching, research, and leisure. Modern spaces, such as mobile conference rooms, open amphitheatres or relaxation zones, enable better use of infrastructure and support interdisciplinary interactions. The example of the Water Centre shows that this approach improves the quality of academic spaces, making them more dynamic and open to the changing needs of users.

Campus inclusivity and accessibility cannot be overlooked either. They should be designed with all users in mind, regardless of their physical or sensory abilities. Innovative navigation systems, architectural amenities, and ergonomic working and resting spaces help create an inclusive environment that allows people with different needs to use academic spaces freely.

A final key issue remains the long-term monitoring of the upgrades' impact. Implementing modern technologies and green solutions requires their systematic evaluation, which allows ongoing optimisation and adaptation of projects to new challenges. Implementing space use analysis systems is recommended, allowing the effectiveness of the applied strategies and their impact on academic life to be effectively assessed.

Recommendations for designers and academic institutions

Based on the Water Centre expansion project analysis and its impact on the campus space's functionality, environmental performance and quality, several recommendations can be made for designers and academic institutions planning to upgrade university infrastructure.

The first key recommendation is to incorporate sustainability principles as a central element of the design process. Solutions such as green roofs, rainwater retention systems, or the integration of renewable energy sources should be standard in the design of modern campus buildings. Such technologies not only contribute to lower operating costs but also have a positive impact on the environment and the quality of life of the occupants. It is vital that designers carefully analyse local environmental and social conditions, adapting solutions to the site's specifics.

A second important recommendation is to promote users' participation – especially students – in the design process of campus spaces. Workshops and consultations can provide valuable information about their needs and expectations, allowing the design to be better adapted to the actual requirements of the academic community. Users' participation in the decision-making process also increases their involvement and ownership of the use of the space. Another important aspect is to ensure the inclusivity of the designed spaces. Accessibility for people with different types of disabilities, considering both architectural and digital solutions, should be one of the priorities. Designing inclusive spaces for all user groups fosters a more open and supportive academic environment. It is also recommended that more attention be paid to the quality of communal spaces. These should be conducive to both focused work and social integration. Introducing solutions such as learning box spaces, relaxation areas or multifunctional rooms that can be adapted to different needs increases the functionality of the campus and supports academic activity. Academic institutions should conduct regular analyses of the effectiveness of the technologies used, their level of use, and user satisfaction. Such data can provide a valuable knowledge base to support subsequent modernisation projects.

Proposal for in-depth studies

The Water Centre expansion project opens up a wide range of opportunities for further research into the impact of upgrading university infrastructure on academic life and the realisation of sustainability. As such, several key areas are proposed for further analysis.

The first relevant direction is the long-term evaluation of the impact of the architectural and environmental solutions applied to the daily functioning of the academic community. This research could include an analysis of changes in how students and staff use spaces, an assessment of their satisfaction with the facilities introduced, and the impact of these changes on social integration, psychological well-being, and learning efficiency. It would be exciting to track how modern communal spaces – such as the indoor amphitheatre or individual work zones – affect how users interact and engage in academic life.

A second area of research could be analysing the effectiveness of environmental solutions and their impact on the environment. For example, it is worth investigating how green roofs, rain gardens, and other plantings contribute to improving air quality and rainwater retention or reducing the urban heat island effect. Long-term monitoring of these processes will make it possible to assess the implemented technologies' effectiveness and adaptability to changing climatic conditions.

Another potential research direction is economic analysis, which would assess the impact of the applied technologies on reducing building operating costs. It would be worth tracking the extent to which photovoltaic panels, BMS, or the use of recycled water translate into reduced resource consumption and maintenance expenses. Such a study could also include a comparative analysis with other university buildings with similar solutions.

The impact of a participatory approach on the perception of campus spaces by the university community may also be an interesting issue. The influence of student participation in the design process on their subsequent involvement in university life, sense of belonging, and satisfaction with the designed spaces can be explored.

Ultimately, exploring how campus spaces can be used for innovative research and teaching projects is also proposed. Spaces such as green zones, laboratories or technological installations (e.g. photovoltaics) can become the base for interdisciplinary research projects and practical activities that bring together students and staff from different departments.

In summary, future research into the modernisation of university campuses should include social, ecological, and economic aspects. Long-term monitoring and analysis of implemented solutions will enable the development of knowledge on the sustainable design of academic spaces and contribute to the improvement of future projects of this type.

Study limitations

The analysis provided important insights into the modernisation of campus facilities. However, the study focuses on selected cases, which do not exhaust the entire spectrum of possible approaches to redeveloping academic buildings. The availability of data on the effectiveness of the implemented solutions is limited, especially regarding the long-term operation of the buildings after modernisation. In addition, the analysis does not comprehensively consider economic and political factors that may influence university investment decisions. Another challenge is the lack of long-term user research on their perception of changes to the academic space. Future research should be deepened with an analysis of the long-term effects of retrofitting, including an assessment of user comfort, energy efficiency, and operating costs in the broader context of the operation of university campuses.

The absence of detailed operational data and long-term monitoring directly affects the validity of the presented results. As the study is based on conceptual design and comparative analyses, the findings should be understood as indicative projections rather than definitive evidence of sustainability performance. This limitation means that claims about energy savings, water management efficiency, or biodiversity enhancement cannot yet be empirically verified. Consequently, while the proposed strategies are consistent with best practices and supported by literature benchmarks, their actual effectiveness will depend on future implementation and systematic evaluation.

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Authors' contributions

Conceptualisation: A.S.; methodology: A.S.; validation: K.W. and M.K.; formal analysis: M.K. and M.S.; investigation: M.S. and M.K.; resources: P.N.; data curation: M.S.; writing – original draft preparation: A.S., K.W., M.K., M.S., and B.W.; writing – review and editing: A.S. and K.W.; visualisation: B.W., M.S. and J.K., supervision: A.S.; project administration: A.S.

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WSPÓŁCZESNE PROJEKTOWANIE PRZESTRZENI ZRÓWNOWAŻONYCH KAMPUSU: STUDIUM PRZYPADKU ROZBUDOWY CENTRUM WODNEGO SGGW

STRESZCZENIE

Artykuł analizuje rolę projektowania zrównoważonego i partycypacyjnego w modernizacji kampusu na przykładzie rozbudowy Centrum Wodnego SGGW. Badanie obejmuje integrację proekologicznych strategii, takich jak: zielone dachy, recyrkulacja wody deszczowej, systemy energii odnawialnej oraz zaangażowanie studentów w planowanie przestrzenne. Wykorzystując podejście studium przypadku, oceniono wpływ tych interwencji na funkcjonalność kampusu, dobrostan użytkowników oraz odporność środowiskową. Wyniki wskazują, że modernizacja zrównoważona kampusów nie tylko poprawia warunki mikroklimatyczne i bioróżnorodność, lecz także sprzyja inkluzywności i zaangażowaniu społeczności akademickiej. Artykuł wnosi wkład w dyskusję na temat urbanistyki ekologicznej oraz adaptacji przestrzeni akademickich do współczesnych wyzwań rozwoju zrównoważonego.

Słowa kluczowe: projektowanie zrównoważone, infrastruktura kampusu, niebiesko-zielona infrastruktura, architektura uniwersytetu