Journal of Sustainability Perspectives

journal homepage: https://ejournal2.undip.ac.id/index.php/jsp/

Sustainability Initiatives at Shaqra University: A Holistic Approach to Environmental Responsibility

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Article Info

Received:
19 June 2025
Accepted:
25 November 2025
Published:
30 December 2025

DOI:
10.14710/jsp.2025.29887

Abstract. This paper presents a comprehensive evaluation of Shaqra University's sustainability initiatives across infrastructure, water, energy, and education domains. Drawing on institutional data from 2021 to 2025, the study uses a mixed-methods approach combining quantitative indicators with implementation narratives. Key findings include the expansion of green space from 30,000 m² with plans to double by 2030, a five-stage wastewater treatment system enabling 65% reuse for irrigation, and a planned solar energy project expected to supply 22.6% of campus electricity upon completion. Smart building systems currently cover over 38,000 m², and a GHG inventory is planned for 2026 to track Scopes 1 and 2 emissions. The university's academic mission supports sustainability through 43 sustainability-related courses, five active student teams, over 1,600 volunteer hours, and more than $1.3 million in funded research. These efforts reflect Shaqra University's integrated institutional model for environmental responsibility, combining planning, operations, and education in alignment with Vision 2030, the Saudi Green Initiative, and the SDGs. The findings offer a roadmap for universities in arid and semi-arid regions seeking to institutionalize sustainability.

Keywords:

Campus sustainability, energy efficiency, Saudi universities, water reuse, SDGs, GreenMetric

1. Introduction

Higher education institutions (HEIs) are increasingly recognized not only as centres of knowledge, but also as living laboratories for sustainable practices [1,2]. Universities worldwide have begun to model responsible resource management and institutional innovation in campus operations. Over the past two decades, numerous frameworks and metrics have emerged to assess campus sustainability performance. Examples include the Times Higher Education Impact Rankings, AASHE STARS, and the UI GreenMetric World

University Ranking, reflecting a growing demand for evidence-based sustainability indicators [3,4].

Among these, the UI GreenMetric framework stands out for its emphasis on operational sustainability, which is particularly important in resource-constrained contexts. It assesses six categories: infrastructure, energy and climate, waste, water, transportation, and education/research [5]. Studies have found that participation in UI GreenMetric can encourage institutional benchmarking, inter-departmental collaboration, and policy innovation [6,7]. However, despite the global uptake of such tools, their application in the Middle East, particularly in Saudi Arabia, remains limited [8]. Many Saudi universities have only recently begun engaging with structured sustainability evaluations, leading to a gap in both implementation and scholarly documentation.

Globally, campus sustainability has gained significant momentum as universities acknowledge their role in addressing environmental and social challenges [9]. Often likened to “mini-cities” with substantial ecological footprints, universities have unique opportunities to demonstrate sustainable practices at scale. A robust body of literature documents how institutions across the world integrate sustainability into campus operations, academics, and governance [10,11]. Key focus areas include achieving carbon neutrality, improving energy efficiency, reducing waste, conserving water, and adopting circular economy principles [12].

Success in these areas is shown to depend not only on technology and infrastructure changes but also on strong leadership, stakeholder engagement, and supportive governance structures [13,14]. For example, a recent systematic review identified energy management, waste minimization, and environmental management as dominant themes in campus sustainability research, along with an emphasis on holistic, interconnected approaches [15]. This underscores that campus issues such as energy, water, and waste are interlinked and must be addressed systemically.

Universities are also increasingly measuring and reporting their sustainability performance, participating in global rankings, publishing sustainability reports, and undergoing audits to ensure accountability and drive continuous improvement [16,17]. Despite this progress, global reviews still point out gaps and challenges, calling for more cross-institutional comparisons, better data collection and reporting, and innovative financing and policy support for campus sustainability initiatives [18]. In summary, the international higher education sector has largely embraced sustainability as a core mission, yielding a rich literature on strategies and outcomes, but ongoing research and innovation are needed to accelerate change.

In contrast, the Middle Eastern context, and Saudi Arabia in particular, has lagged in documenting sustainability initiatives on university campuses [8,19]. Researchers note that many universities in the Global South lack comprehensive reporting on their sustainability efforts [20]. In Saudi Arabia, campus sustainability initiatives are relatively recent and often not formally captured in the academic literature. Abubakar et al. observed a “dearth of studies on the institutional commitments of universities to sustainable development in Saudi Arabia” [8].

Until the past few years, only a handful of Saudi universities had published sustainability reports or participated in international assessment frameworks [7]. Engagement with global sustainability rankings has also been minimal. For example, as of 2019, only a few Saudi institutions had joined the UI GreenMetric rankings, with just one university debuting in the global top 50. Similarly, participation in networks such as the International Sustainable Campus Network (ISCN) or programs like AASHE STARS has been negligible in the region. As

a result, far fewer case studies and empirical evaluations on Middle Eastern campus sustainability exist compared to the more established literature from North America, Europe, or East Asia [8].

Encouragingly, recent research is beginning to address this gap. Nationally focused studies and surveys have evaluated sustainability practices in Saudi higher education [3,8]. For instance, AlAli and Aboud surveyed faculty across various institutions and reported limited implementation across academic, research, social, and environmental domains [21]. Faculty noted that while "green" initiatives exist, they are typically ad-hoc rather than part of a unified strategy. These findings align with earlier observations that Saudi efforts often concentrate on isolated actions such as awareness campaigns, green buildings, or renewable energy projects, rather than integrated sustainability approaches [20,22]. Persistent barriers include the lack of dedicated sustainability offices, insufficient funding and expertise, limited stakeholder engagement, and the absence of clear policies or monitoring frameworks [23].

On a positive note, the same studies offer recommendations to overcome barriers and strengthen sustainability in Saudi higher education. A widely endorsed recommendation is for universities to establish formal sustainability units or committees responsible for coordinating initiatives. Institutions are also advised to craft clear sustainability visions and action plans aligned with both national and global frameworks. Notably, aligning with the United Nations Sustainable Development Goals (SDGs) provides a universally recognized blueprint for action [24], while Saudi Arabia's Vision 2030 outlines country-specific targets that universities can directly support. Universities are increasingly viewed as key implementation partners in this national agenda, expected to produce research and innovations that advance Vision 2030's sustainability objectives [25].

Mapping campus initiatives to the SDGs and Vision 2030 enhances institutional relevance and enables access to policy or funding support [24,25]. There is also a growing call for knowledge transfer and the adaptation of successful practices to the local context. Some pioneering universities in Saudi Arabia, such as KAUST, IAU, and PSU, have already implemented advanced sustainability projects. These examples, summarized in Table 1, demonstrate the feasibility of such practices in the Saudi context and offer replicable models for other institutions, including those with limited resources. Their success underscores that the previously identified barriers are surmountable through strategic planning and leadership [20,22].

Table 1. National Examples of Campus Sustainability in Saudi Arabia.

University	Initiative(s)	Focus Area(s)	Reference
KAUST	Comprehensive water recycling and reuse system	Water management, infrastructure planning	[26]
IAU	Treated water irrigation for landscape	Water reuse, green infrastructure	[27]
PSU	Solar energy and energy-efficient retrofitting	Clean energy, SDG 7 implementation	[28]

Building on this evolving global and regional context, the present paper offers a focused, evidence-based evaluation of sustainability practices at Shaqra University, a mid-sized public university in Saudi Arabia. This study concentrates on four operational domains where the university's sustainability implementation is comparatively mature: campus infrastructure development, water management, energy systems, and education and research. These focal

areas correspond to urgent environmental priorities in Saudi Arabia's arid climate, including resource-efficient infrastructure, water conservation in conditions of scarcity, and clean energy deployment to reduce emissions. They also align closely with the country's Vision 2030 sustainability goals, such as improving building energy efficiency and increasing renewable energy capacity.

By focusing on infrastructure, water, and energy, this paper examines aspects of campus sustainability that are tangible, measurable, and impactful on environmental performance and operational costs [7]. Case studies of comprehensive sustainability integration in Saudi universities are currently sparse, and a detailed assessment of Shaqra's efforts helps address this gap [3,8]. Through documentation of the university's green infrastructure projects, water reuse initiatives, and renewable energy installations, we contribute a Saudi-based example that can be benchmarked against international best practices [11,15]. This analysis also explores implementation challenges, including technical limitations, stakeholder coordination, and financial planning, within the local institutional context.

Furthermore, by situating Shaqra University's experience within global frameworks and national directives, we assess which approaches transfer effectively from established models, and which obstacles are unique to the local environment [1,13,14]. The study considers whether common challenges noted in the literature, such as gaps in data collection for sustainability reporting, are present at Shaqra, and how national programs under Vision 2030 may offer support mechanisms without direct international equivalents [18]. Ultimately, this integrated evaluation serves as a regional case study and a foundation for comparative learning. It enriches the emerging body of literature on Middle Eastern campus sustainability and illustrates how mid-sized institutions in developing regions can operationalize sustainability in alignment with both the SDGs and national targets [7,19].

2. Methodology

This study adopts a mixed-methods case study approach to evaluate the sustainability initiatives implemented at Shaqra University. To ensure comparability with international practices, the methodology aligns with the UI GreenMetric World University Ranking framework, particularly in its categorization of infrastructure, energy, water, and education dimensions [5]. The analysis is focused on three operational domains where institutional progress has been documented: green infrastructure development, water resource management, and energy systems. These domains were selected due to their strategic importance under Saudi Arabia's Vision 2030 and the availability of institutional data covering performance metrics, targets, and implementation frameworks.

2.1. Data Sources and Collection

Primary data for this study was collected from internal university documents, facility audits, operational reports (2021–2024), infrastructure planning files, and firsthand records provided by the Office of Campus Operations and the university's Sustainability Coordination Team. Additional supporting data was drawn from design schematics of the wastewater treatment system, green space master plans, and solar energy implementation reports. Furthermore, the quantitative data points included total campus area and built-up footprint, green space area (historical and project), daily and annual water consumption and reuse ratios, energy consumption in kilowatt-hours, renewable energy generation and usage share,

as well as the number of smart buildings and square meter coverage.

These data were verified through official Excel spreadsheets maintained by university engineers, including modelling sheets for vegetation growth, solar energy yields, and water treatment efficiency. Time series data for 2021–2025 were used to construct trendlines and projections through 2030. Simple forecasting models were applied using compound annual growth rates (CAGR) where applicable (e.g., green space expansion), and institutional benchmarks were used to establish year-by-year targets (e.g., treated water reuse growth of 7% annually). In addition, data related to sustainability education and research were collected from course specifications, faculty development reports, student affairs documentation, and research office records. These included the number of sustainability-related courses, student volunteer teams and activities, outreach events, and funded research projects categorized under sustainability themes.

2.2. Analytical Framework and Tools

The analysis incorporated both numerical evaluations and implementation assessment. Excel-based models and visual dashboards were used to track progress against internal KPIs, particularly for green infrastructure and water reuse. Custom visualization templates were developed to represent year-on-year improvements and targets, including bar graphs and flowcharts. For water infrastructure, engineering schematics were reviewed to understand the five-stage treatment process. This included filtration, biological treatment, sedimentation, chemical conditioning, and final polishing. Documentation and interviews with operations staff clarified the system's design capacity, current throughput, and planned upgrades. Visuals of the treatment system were recreated to enhance clarity in the results section. Energy performance was analysed through monthly electricity usage logs, compiled over a two-year period, and solar output reports from the engineering department. Smart building implementation was verified through facility inventories and technical specifications of installed BMS systems.

Quantitative indicators such as the percentage of sustainability-related courses and number of volunteer hours were compiled and analysed to assess educational integration. Descriptive data on outreach programs and research funding were also reviewed to provide qualitative context to the university's academic sustainability strategy. Some estimates rely on internal projections due to the unavailability of consistent third-party benchmarks. Where possible, values were cross-referenced with national guidelines and institutional records. However, certain indicators, particularly those related to emerging sustainability practices, are based on localized baselines and expert judgment.

2.3. Institutional and Qualitative Context

Beyond technical metrics, the study also reviewed governance structures, implementation mechanisms, and institutional commitment. Meeting minutes, policy statements, and sustainability planning memos were reviewed to trace the university's internal coordination mechanisms. The existence of a cross-functional team that includes engineering, administration, and student affairs was noted as a key enabler of cross-cutting implementation.

Behavioural and awareness programs, such as water-use signage and appliance labelling, were assessed qualitatively through observation and documentation review. The influence of national programs such as the Saudi Green Initiative and Vision 2030 was also considered in shaping institutional strategy and resource allocation.

2.4. Limitations and Future Tracking

This study does not currently include independent verification of energy and water readings through third-party audits. Furthermore, no formal GHG inventory has yet been conducted, though the university has plans to develop Scope 1 and 2 baselines by 2026. ICT-based sustainability dashboards are under development and, once completed, will enhance future monitoring and reporting precision. The university plans to initiate a greenhouse gas (GHG) inventory by 2026, aligned with international protocols. The planned scope includes Scope 1 (direct) and Scope 2 (purchased electricity) emissions, following the classification standards of the Greenhouse Gas Protocol [29].

3. Results, Discussion, and Implementation

Shaqra University's sustainability program reflects a shift from traditional facility management toward a strategic, data-informed model aligned with the UI GreenMetric World University Rankings, the UN Sustainable Development Goals (SDGs), and Saudi Vision 2030. This section presents the implementation status, measurable outcomes, and forward-looking plans across three core operational areas: green infrastructure, water management, and energy systems.

3.1. Setting and Infrastructure

Shaqra University is a comprehensive public institution located in the central region of Saudi Arabia, operating within an arid climatic zone. This geographical and environmental context presents unique challenges for infrastructure design and land use planning. In response, the university has adopted a proactive, sustainability-oriented development strategy aligned with Saudi Vision 2030 and the principles of the UI GreenMetric World University Rankings.

The university operates two campuses, both situated in suburban areas, allowing for horizontal growth and strategic integration of open and green spaces. The total area covered by Shaqra University's campuses is approximately 4,900,000 square meters. Despite this expansive footprint, the university maintains a low construction density, with a total ground floor building area of 99,147 m^2 and a total multi-story building area of 252,441 square meters. This relatively moderate built footprint reflects the institution's goal of balancing development with environmental preservation as illustrated in Table 2.

Open space accounts for 22% of the university's land area and plays an essential role in regulating microclimates, supporting biodiversity, and offering recreational environments [11,20]. Within these open spaces, the university has systematically developed its green infrastructure. As of 2025, the total designated green area has reached 30,000 m^2, which includes 13,500 m^2 of forest vegetation (primarily native and drought-tolerant tree species) and 16,500 m^2 of planted vegetation such as lawns, shrubs, and ornamental gardens. These vegetated spaces are supported by a treated wastewater irrigation system and serve both ecological and aesthetic functions. This emphasis on vegetation development supports SDG 11 (Sustainable Cities and Communities) and aligns with UI GreenMetric indicators under the "Setting and Infrastructure" category [24,30]. A selection of these green zones and landscape features is illustrated in Figure 1, which captures key examples of forested areas, ornamental gardens, and open lawns developed under the university's green infrastructure strategy.

Table 2. Campus land use at Shaqra University.

Category	Area (m²)	Percentage of Total Campus Area (4,900,000 m²)
Ground Floor Buildings	99,147	2.0%
Forest Vegetation	13,500	0.3%
Planted Vegetation	10,000	0.2%
Open Space	1,078,000	22.0%
Water Absorption	2,000,000	40.8%
Mixed Use (roads, utilities, etc.)	1,699,353	34.7%
Total	4,900,000	100%

Figure 1. Landscapes and green infrastructure at Shaqra University, including native vegetation, irrigated lawns, open fields, shaded courtyards, and campus water features.

Shaqra University has established a defined expansion plan for its landscaped zones. As presented in Table 1 and illustrated in Figure 2, the university aims to increase planted surface coverage by 6,000 m^2 annually from 2026 through 2030, ultimately reaching a cumulative total of 60,000 m^2 by the end of the decade. This initiative is directly aligned with the national Saudi Green Initiative and reflects the university's commitment to doubling its green footprint over a five-year period. The strategy is intended to enhance biodiversity, support carbon sequestration, and improve the ecological resilience and visual quality of the campus environment.

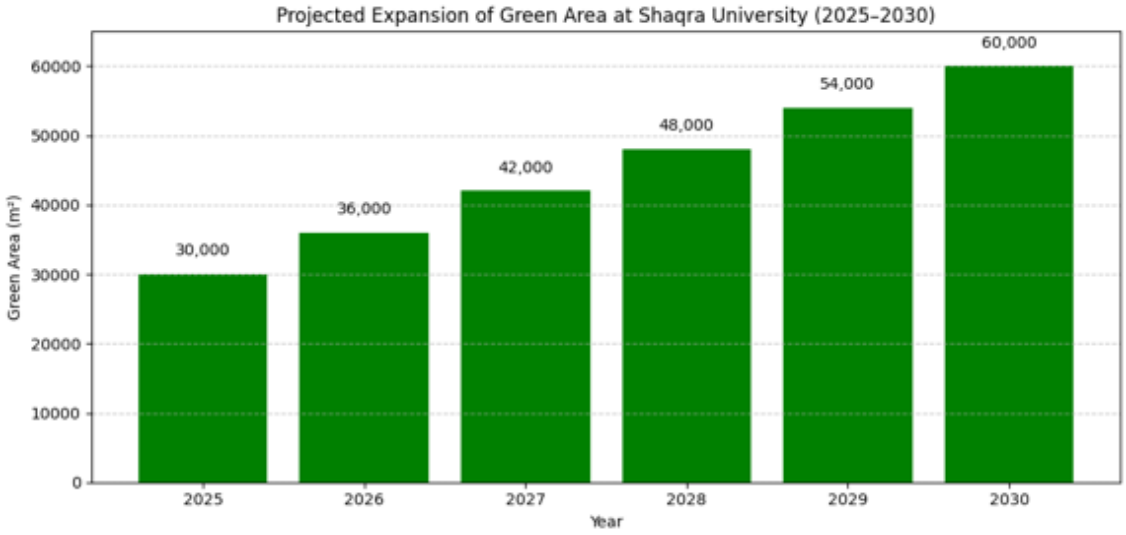

Figure 2. Annual green area expansion targets at Shaqra University, increasing from 30,000 m² in 2025 to 60,000 m² by 2030.

To complement these land use policies, the university has designated 2,000,000 m^2 for water absorption. These zones are composed of permeable soils, unpaved natural buffers, and stormwater infiltration systems that allow for effective groundwater recharge and flood mitigation, which is an essential consideration in arid regions with irregular rainfall.

Moreover, the university's infrastructure planning is grounded in inclusivity and well-being. All newly constructed buildings incorporate universal access design standards, ensuring facilities accommodate individuals with diverse physical needs. Both campuses include dedicated health and safety features such as first aid stations, maternity support services, and gender-inclusive spaces. These efforts reflect a holistic interpretation of sustainability that integrates environmental, social, and institutional resilience. As part of this vision, Shaqra University has enhanced indoor environmental quality through passive design strategies including natural daylighting, high-ceiling atriums, and indoor greenery. These elements help reduce energy demand while promoting thermal comfort, air quality, and visual well-being. Figure 3 provides representative examples. In parallel with physical landscape improvements, the university has also prioritized efficient resource use, beginning with water systems.

3.2. Water Management and Conservation: Institutional and Societal Commitments

In a region defined by extreme water scarcity, Shaqra University has transformed water management from a logistical necessity into a strategic pillar of institutional sustainability. Through an integrated model combining infrastructure, behavioural change, and planning foresight, the university offers a scalable example of how arid-zone institutions can manage limited water resources effectively. These efforts directly contribute to the IWGM 2025 sub-theme, Managing Water: The Story of Our Institution and Society, and reflect national priorities under Saudi Vision 2030 and SDG 6 (Clean Water and Sanitation).

Figure 3. Interior views of Shaqra University showcasing natural lighting, high-ceiling atriums, and indoor greenery.

3.2.1. Infrastructure and Wastewater Reuse Systems

Shaqra University operates an advanced wastewater treatment and purification facility that enables the reuse of treated water across its expanding landscape. Managed by the General Directorate of Projects and Facilities, the system serves the main campus and supplies a growing network of green spaces through a closed-loop irrigation system. The current infrastructure includes a five-stage treatment process that handles wastewater from both residential and academic buildings [3]. Treated water is stored in designated tanks and redirected for irrigation purposes, significantly reducing reliance on freshwater sources, and supporting environmental sustainability in alignment with SDG 6 (Clean Water and Sanitation).

The treatment process follows five technical stages, illustrated in Figure 4. Wastewater is first collected from residential and academic buildings and centralized for treatment. It is then chemically neutralized to balance pH levels and prepare it for biological treatment. Through aeration and bacterial action, organic pollutants are removed. The treated water is subsequently separated from biological by-products and sludge, which is either dried onsite or transported off-campus. The reclaimed water is stored and used to irrigate the university's green zones. This closed-loop system minimizes freshwater dependency and directly supports the university's landscaping efforts by enabling safe and consistent reuse of treated water. Similar wastewater reuse programs have been reported at other Saudi institutions, such as Imam Abdulrahman Bin Faisal University (IAU), further validating the feasibility of such systems in arid higher education environments [28]. Currently, 65% of the campus's irrigated area is maintained using this reclaimed water, with plans to achieve 100% reuse efficiency by 2030. A ring-main pipeline ensures efficient water distribution to forested and planted zones.

The environmental and operational impact of this system is significant. As shown in Figure 1, the area irrigated using treated water has increased from less than 1,000 m² in 2021 to nearly 20,000 m² in 2025, with full irrigation coverage projected by the end of the decade. This shift reduces demand on municipal water sources, lowers operating costs, and enhances the campus's resilience in the face of climate variability. In addition to infrastructure upgrades, Shaqra University is piloting smart water metering technologies to monitor consumption patterns and identify system inefficiencies in real-time. These tools are part of

a broader ICT-driven approach to enhance operational transparency and improve long-term water resource planning [11].

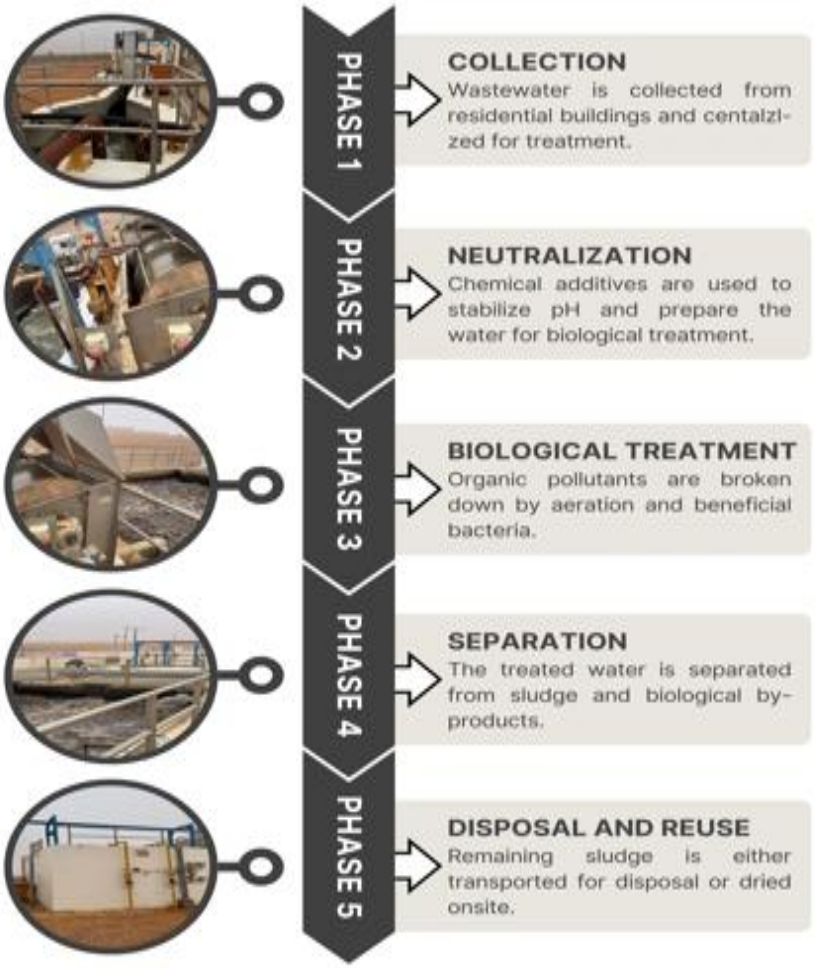

Figure 4. Five-stage wastewater treatment process at Shaqra University, covering collection, neutralization, biological treatment, separation, and reuse.

3.2.2. Efficient Fixtures and Water Conservation Programs

Beyond centralized systems, the university has modernized water infrastructure across its buildings. A recent audit found that 66.6% of washbasins and 46.9% of toilets are equipped with water-efficient fixtures [7]. As shown in Table 3 and Figure 5, implementation rates vary considerably. While awareness signage has reached full deployment, both fixture categories remain below the university's 90% target for 2030, indicating clear opportunities for retrofitting. More than 250 bilingual signs have been installed in restrooms and high-traffic areas, supported by student-led campaigns and campus-wide awareness messaging.

Table 3. Implementation of Water-Saving Devices and Awareness Measures (2025 Audit).

Category	Total Units	Compliant/Installed	Implementation (%)
Toilets	320	150	46.9%
Washbasins	450	300	66.6%
Awareness Signs	250	250	100.0%

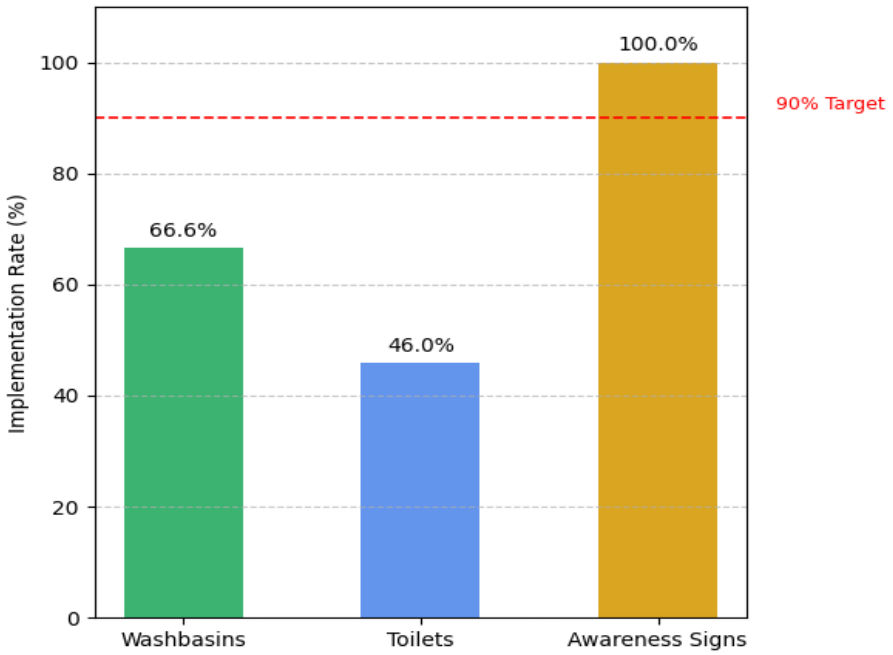

Figure 5. Implementation rates of water-saving fixtures and awareness signs at Shaqra University, benchmarked against the 90% institutional target.

3.2.3. Engagement, Outreach, and Model Sharing

Facilities teams are trained to detect and report leaks, and quarterly inspections are conducted to identify irregularities in consumption. These measures not only reduce water waste but also install a broader culture of accountability and environmental consciousness. These outreach efforts, led by volunteer teams, colleges, and university-wide campaigns, have contributed to a more visible culture of sustainability, and helped embed environmental values within campus life [8,22].

Shaqra University's efforts extend beyond internal operations. The wastewater treatment system and reuse model have been presented to local officials and visiting academic delegations as a practical example of how mid-sized institutions can sustainably manage water in arid environments. This outreach supports knowledge sharing and builds momentum for broader regional adoption of similar systems. The university's green infrastructure also functions as an educational platform, supporting interdisciplinary coursework in environmental engineering, sustainability science, and resource management.

3.2.4. Planning for Smart Water Management

To strengthen water efficiency and operational transparency, Shaqra University is preparing to deploy integrated ICT-based water management systems by 2026. Planned features include real-time consumption monitoring, automated leak detection, and climate-responsive irrigation controls. These technologies will be linked to broader campus energy and climate platforms, enabling predictive maintenance and data-driven resource management [7,16]. This digital transformation is expected to minimize inefficiencies, enhance system responsiveness, and support the university's broader smart campus development strategy.

The water program is grounded in a combination of scientifically designed treatment processes, infrastructure modernization, and institution-wide behavioural engagement.

Through this integrated approach, the university presents a replicable model of resilience in water-scarce environments. By 2030, Shaqra aims to achieve full irrigation using treated wastewater, high-efficiency usage across all buildings, and a smart water control ecosystem that demonstrates how sustainability can be institutionalized through long-term planning and operational innovation.

3.3. Energy and Climate Strategy

Shaqra University has taken foundational steps to enhance energy efficiency and contribute to climate action. Through the adoption of smart building systems, deployment of energy-efficient technologies, and planning for renewable energy integration, the university is building a more sustainable and climate-resilient campus. These efforts align with national energy diversification goals and support SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) [6].

3.3.1. Energy Efficiency and Smart Infrastructure

All major university buildings are equipped with energy-efficient appliances and lighting systems. These include widespread adoption of LED fixtures and reliance on natural lighting in corridors and open-plan spaces to reduce overall electricity consumption. Additionally, Shaqra University has implemented advanced Building Management Systems (BMS) across a total of 38,800 m², covering 100% of all modern buildings on campus. These smart systems enable real-time monitoring of energy consumption, optimize HVAC and lighting usage, and reduce unnecessary energy load.

Operational policies under the General Directorate of Projects and Facilities ensure that these technologies are consistently maintained and aligned with efficiency goals. Together, these interventions have helped reduce baseline electricity demand and improve building performance.

3.3.2. Transition to Renewable Energy

Shaqra University is currently in the planning phase for a large-scale solar energy project. Once implemented, it is expected to generate up to 7.5 million kWh annually. This is projected to cover 22.6% of the university's current electricity consumption, which totals 33.2 million kWh per year. The proposed solar infrastructure will be installed on available open land across the campus, rather than rooftops, with Figure 6 illustrating the designated zones. This initiative reflects the university's commitment to reducing dependence on fossil fuels and supporting national renewable energy targets [11]. The project planning is currently underway, including site selection, capacity modelling, and integration with institutional energy monitoring systems (see Table 4).

Table 4. Planned energy performance summary for Shaqra University's solar project.

Metric	Value
Total Electricity Consumption	33,237,465 kWh/year
Estimated Solar Contribution	7,513,720 kWh/year (22.6%)
Solar Panel Location	Ground-mounted on 1,078,000 m²
Smart Building Coverage	38,800 m²
Electricity Consumption per Capita	~8,000 kWh
GHG Inventory Status	Planned for 2026 (Scope 1 & 2)

The project is based on ground-mounted solar infrastructure. Designated open areas totalling approximately 1,078,000 m^2 have been allocated for solar panel installation. These zones, identified through spatial analysis of campus land use, offer optimal sun exposure, and allow for scalable expansion. The selected deployment areas are illustrated in Figure 6, which highlights the spatial integration of solar technology within the broader campus master plan. This renewable energy initiative represents a critical step in the university's broader sustainability strategy. It contributes directly to Saudi Vision 2030 and national clean energy targets by lowering dependence on fossil fuels, stabilizing future energy costs, and positioning Shaqra University as a leader in sustainable infrastructure within the higher education sector.

Figure 6. Planned solar panel deployment zones at Shaqra University, based on ground-mounted arrays across designated open land.

3.3.3. Electricity Use and Climate Mitigation

Electricity consumption at Shaqra University is currently estimated at approximately 8,000 kWh per capita, based on total annual usage and the university's population. While a formal greenhouse gas (GHG) emissions inventory is not yet in place, several energy efficiency initiatives contribute to reducing operational emissions. These include the adoption of high-efficiency HVAC systems, low-energy LED lighting, and planning for ground-mounted solar infrastructure. In addition to system-level interventions, the university has integrated green building elements into recent facility designs. Features such as natural ventilation, shaded walkways, high-performance glazing, and indoor vegetation help mitigate heat gain, lower cooling demand, and enhance indoor air quality. These measures contribute to long-term energy conservation and user well-being.

To institutionalize its climate response, Shaqra University is preparing to launch a formal GHG monitoring and reporting program by 2026. This initiative will include baseline emissions

data, performance metrics, and alignment with both national targets and international climate reporting frameworks. The inventory will initially cover Scope 1 (direct emissions) and Scope 2 (purchased electricity) sources, serving as a foundation for long-term climate accountability and strategic planning. This step will allow for better environmental performance tracking and support integration into national climate reporting systems [12].

3.4. Education and Research

Shaqra University's commitment to sustainability extends beyond physical infrastructure and operational systems into its core academic mission. Through curricular integration, student engagement, and targeted research funding, the university embeds environmental responsibility across its institutional framework.

At the curricular level, sustainability has been introduced through 43 dedicated courses across environmental science, water management, clean energy, and public health. This represents 3.75% of the university's total course offerings [20,22]. While modest, these efforts mark the beginning of broader alignment with the United Nations Sustainable Development Goals (SDGs) and national priorities. These courses span various disciplines including environmental science, water resource management, public health, and clean energy systems, and are taught across both undergraduate and diploma programs. Although still in the early stages, this integration marks a foundational step toward aligning academic programming with the United Nations Sustainable Development Goals (SDGs). The university is actively working to expand the inclusion of sustainability themes across additional academic departments in the coming years.

Student involvement plays a central role in promoting environmental awareness and social responsibility. Five formally recognized volunteer teams (Ghayam, Sustainable Impact, Himmah, Environmental, and Mulham) have collectively contributed over 1,600 volunteer hours between 2022 and 2025. Their activities have included tree planting, campus clean-up initiatives, awareness campaigns, and public seminars. These student-led efforts foster a campus culture rooted in environmental stewardship.

Experiential learning is further promoted through initiatives such as Takhassusi fi Khidmatik ("My Major in Service of the Community"), which enables students from applied and health sciences colleges to lead sustainability-focused projects. Examples include recycling drives, energy audits, and environmental health exhibitions during Saudi Environment Week. These activities bridge classroom learning with community action [18]. As shown in Figure 7, tree planting and clean-up campaigns account for the majority of student volunteer hours between 2022 and 2025. These efforts are supported by a wide range of co-curricular engagements, including exhibitions, coordination meetings, and gardening projects.

In particular, the College of Engineering plays a central role in advancing sustainability at Shaqra University through curriculum design, applied research, and experiential student projects. Several core and elective courses integrate sustainability themes such as renewable energy systems, environmental engineering, and sustainable infrastructure. Final-year and graduation projects have tackled issues such as solar-powered street lighting, greywater recycling, and energy-efficient HVAC design, translating academic knowledge into practical, locally relevant solutions. Engineering students have actively participated in regional and international competitions, most notably the Shell Eco-Marathon, where they designed and built a fuel-efficient prototype vehicle representing Saudi Arabia on a global stage. Faculty members have led research initiatives in smart building systems, solar integration, and

environmental monitoring, contributing to both scientific advancement and campus-wide innovation.

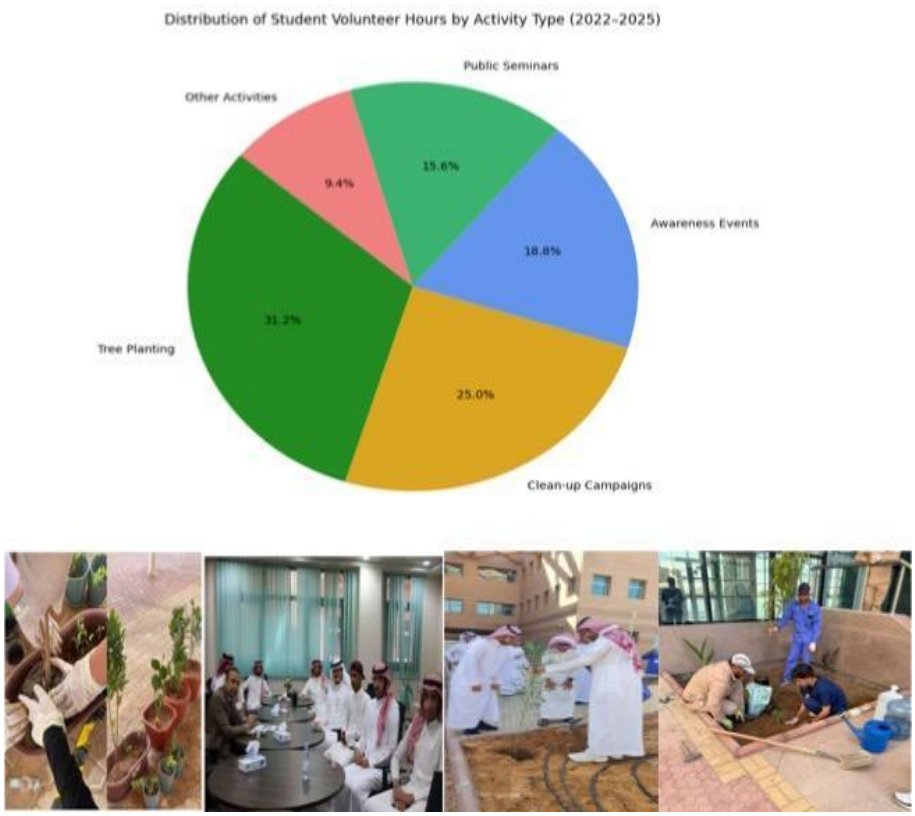

Figure 7. Student-led sustainability activities and volunteer hour distribution (2022–2025), including tree planting, clean-up campaigns, exhibitions, and engagement events.

In 2024, the college co-organized a national conference titled Technologies of Renewable Energy and Modern Communication Systems: Future and Challenges, which brought together over 40 researchers, policymakers, and industry professionals. The event featured keynote sessions, technical panels, and hands-on workshops, including solar installation training in partnership with the National Power Academy. Faculty and students also exhibited energy-focused projects, such as intelligent control systems and low-power automation prototypes. A selection of these efforts is illustrated in Figure 8, which presents engineering students' active engagement in clean energy innovation, sustainable mobility, and applied smart systems through national and international platforms. These contributions exemplify the college's commitment to combining academic rigor with technical leadership in sustainability.

Cultural and co-curricular programming has expanded significantly. From 2023 to 2025, the university organized more than 13 events on environmental themes. These included observances of World Water Day, campus-wide Environment Week campaigns, and collaborative activities with the National Centre for Vegetation Cover. These programs engaged a broad spectrum of students, faculty, and staff across various colleges and administrative centres.

Figure 8. Engineering-led sustainability initiatives at Shaqra University, including student-designed energy systems, mobility prototypes, and national exhibition participation.

Research output in sustainability-related fields has also grown. Between 2009 and 2025, Shaqra University allocated over 1.34 million USD in internal and competitive funding for sustainability-oriented research. Projects have addressed energy optimization, waste reduction technologies, urban greening, and ecosystem service valuation. This research not only advances institutional knowledge but also contributes to national sustainability goals and the broader Saudi research ecosystem.

The university maintains active engagement with external sustainability initiatives. Students have participated in regional competitions such as the Shell Eco-Marathon held in Qatar in 2025. The university has also hosted events such as the National Conference on Renewable Energy. Additional outreach efforts include the Future Generations Environmental Campaign and the Al-Washm Green Forum. These initiatives demonstrate the university's commitment to public engagement and the application of academic work in real-world sustainability contexts. Shaqra University's integration of teaching, research, and outreach demonstrates how mid-sized institutions in Saudi Arabia can effectively operationalize sustainability objectives. By aligning academic initiatives with global frameworks and drawing inspiration from successful national models, the university offers a replicable pathway for embedding environmental responsibility across higher education [8,26].

Table 5: Summary of Education and Research-Based Sustainability Engagement.

Indicator	Value
Total Academic Courses	1,148
Sustainability-Related Courses	43 (3.75%)
Active Volunteer Teams	5 (Ghayam, Sustainable Impact, etc.)
Total Volunteer Hours (2022–2025)	1,600+
Environmental Events (2023–2025)	13+
Sustainability Research Funding	$1.34 million
Student Competitions & Innovation	2+ (e.g., Shell Eco-Marathon, graduation projects)
Academic Conferences Hosted (2024)	1 (National Conference on Renewable Energy)
National and Regional Engagements	3+ (Green Forum, Future Generations, Energy Academy)

These efforts also position the institution to scale its sustainability education in alignment with Vision 2030 and the Sustainable Development Goals (SDGs). This is further illustrated in Table 5, which summarizes Shaqra University's education and research-based sustainability engagement, including curricular integration, student participation, research funding, and the hosting of national events and technical competitions focused on renewable energy and environmental innovation.

4. Conclusions and Future Perspectives

Shaqra University's sustainability initiatives reflect a deliberate shift toward integrated environmental management across both campus operations and academic life. Through strategic investments in infrastructure, renewable energy planning, and water reuse systems, the university has established a strong institutional platform for resource efficiency and environmental responsibility.

The expansion of green spaces, supported by annual growth targets and sustained by treated wastewater irrigation, demonstrates a long-term commitment to microclimate regulation, biodiversity, and ecological resilience. Similarly, the development of smart building systems and the planned deployment of ground-mounted solar infrastructure represent key components of the university's energy transition strategy. These operational measures are complemented by educational and research initiatives, including sustainability-focused courses, student-led projects, and more than 1.3 million USD in funded research. Collectively, these efforts are strengthening institutional capacity for long-term environmental stewardship.

Looking ahead, the university aims to broaden its sustainability focus to include climate reporting, sustainable transportation, and integrated waste management. These emerging priorities will further enhance the university's ability to address environmental challenges while advancing alignment with Saudi Vision 2030, the Saudi Green Initiative, and the global Sustainable Development Goals (SDGs) [6].

Acknowledgment

The author would like to thank the Deanship of Scientific Research at Shaqra University for supporting this work.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors Contribution

Y.A. completed all aspects of this work, including the conceptualization, literature review, data analysis, visualizations, and manuscript writing. The author reviewed and approved the final version of the manuscript.

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