Journal of Sustainability Perspectives

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

Fostering Sustainability through Educational and Research Initiatives at ETUT

*Gurbanmyrat Mezilov[1], Serdar Gedayev[2], Jeren Kulyyeva[3], Nurjahan Mahmudova[4], Atamyrat Altyyev[5], Dovlet Annamuradov[6], Yslam Orazov[*7]*

[1] Rector, Oguz han Engineering and Technology University of Turkmenistan, 744012 Koshi, Ashgabat, Turkmenistan

[2] Department of Microbiology, virology and immunology, Oguz han Engineering and Technology University of Turkmenistan, 744012 Koshi, Ashgabat, Turkmenistan

[3] Extra and Continuous Education Center, Oguz han Engineering and Technology University of Turkmenistan, 744012 Koshi, Ashgabat, Turkmenistan

[4] UI GreenMetric Team, Oguz han Engineering and Technology University of Turkmenistan, 744012 Koshi, Ashgabat, Turkmenistan

[5] Department of Applied Chemistry, Oguz han Engineering and Technology University of Turkmenistan, 744012 Koshi, Ashgabat, Turkmenistan

[6] Department of Ecology and ecological technologies, Oguz han Engineering and Technology University of Turkmenistan, 744012 Koshi, Ashgabat, Turkmenistan

[7] Department of Cyber physical systems, Oguz han Engineering and Technology University of Turkmenistan, 744012 Koshi, Ashgabat, Turkmenistan

*corresponding author: yslam.orazov@etut.edu.tm

Article Info

Received:
05 June 2024
Accepted:
29 November 2024
Published:
03 December 2024

DOI:
10.14710/jsp.2024.25195

Presented in the 10th International Workshop on UI GreenMetric World University Rankings (IWGM 2024)

Abstract. This paper conducts a comparative analysis of sustainability-focused educational initiatives at Oguz Han Engineering and Technology University of Turkmenistan (ETUT) alongside other young universities, including Duke Kunshan University (China), Ashoka University (India), Singapore University of Technology and Design (SUTD), and King Abdullah University of Science and Technology (KAUST, Saudi Arabia). The study examines how these institutions integrate sustainability into their curricula, student engagement, and community outreach efforts, emphasizing the role of emerging universities in advancing sustainability education. Through an in-depth case study of ETUT and a comparative review of global trends, the research highlights innovative approaches aligned with the United Nations Sustainable Development Goals (SDGs). This paper illustrates how young universities leverage their agility to embed sustainability into their operations, curricula, and community interactions, preparing students to address pressing environmental and social challenges in the 21st century.

Keyword:

Sustainability education, emerging universities, comparative analysis,

curriculum development, United Nations Sustainable Development Goals (SDGs), higher education innovation, green campus initiatives, student engagement, community outreach.

1. Introduction

As global awareness of environmental issues intensifies, sustainability has emerged as a cornerstone of modern higher education. Young universities, often more agile in their operations, have the potential to spearhead innovative sustainability initiatives that can shape not only their institutional missions but also the broader educational landscape. This paper aims to explore how these emerging institutions are incorporating sustainability into their educational frameworks, particularly focusing on ETUT as a case study while benchmarking against other young universities.

Sustainability is increasingly viewed as a critical component of higher education, responding to the urgent need for institutions to address complex environmental and societal challenges. With frameworks like the United Nations Sustainable Development Goals guiding educational efforts, universities are tasked with preparing graduates who can navigate and solve pressing global issues such as climate change, biodiversity loss, and social inequity [1]. This responsibility has spurred a demand from students for educational experiences that are not only informative but also transformative, equipping them with the tools necessary for effective engagement in sustainability efforts.

Young universities, established within the last few decades, often possess the flexibility to integrate sustainability initiatives into their core operations without the constraints of longstanding legacy systems [2]. This adaptability allows them to adopt innovative practices more rapidly. Institutions like Nanyang Technological University in Singapore and the University of Tasmania in Australia, have begun to lead by example, implementing strategies for carbon neutrality, waste reduction, and renewable energy use [3]. These initiatives serve as vital components of a holistic educational experience, fostering a culture of sustainability that resonates with students and faculty alike.

Over the past fifty years, higher education has expanded globally, much like luxury retail, with the rise of hundreds of new universities, though many remain absent from global rankings such as the Nature Index or Times Higher Education. These rankings tend to favor elite, research-intensive institutions, while young universities, particularly in developing regions, focus primarily on teaching and educating first-generation students. Since 2000, the higher-education sector has more than doubled, with private universities becoming the fastest-growing segment, especially in developing countries. Notably, many successful young institutions are STEM-focused, as research output and citations enhance their global visibility. However, pioneering non-profit universities, such as India's Shiv Nadar University and O. P. Jindal Global University, along with innovative models like Olin College of

Engineering in the U.S., are introducing new governance and curriculum approaches [25]. Despite their rapid rise and significant investment, the long-term success of these young institutions remains uncertain, as funding and innovation may wane over time.

Curriculum development plays a pivotal role in embedding sustainability into the educational framework. Programs that prioritize sustainability enable students to engage in interdisciplinary learning, critical thinking, and problem-solving [4]. Initiatives such as project-based learning and experiential education allow students to apply theoretical concepts to real-world scenarios, enhancing their understanding and commitment to sustainability. Furthermore, universities are increasingly incorporating sustainability-related content across various disciplines, ensuring that all graduates, regardless of their major, are equipped with the knowledge and skills to contribute to sustainable practices [5].

In addition to internal educational reforms, young universities are engaging with their surrounding communities, positioning themselves as active participants in local sustainability efforts. Community outreach programs facilitate collaboration with local industries, governments, and non-profits, creating living laboratories for sustainable practices [8]. These partnerships not only enhance students' learning experiences but also contribute to the broader societal goal of fostering sustainability awareness and action.

In summary, this comparative study highlights the significant role that young universities like ETUT are playing in advancing sustainability-focused educational initiatives. By examining emerging trends, best practices, and the impact of sustainability on curriculum development, student engagement, and community outreach, the paper underscores the importance of these initiatives in shaping the future of higher education. As emerging universities continue to innovate in their sustainability efforts, they not only contribute to local and global sustainability goals but also prepare future generations to tackle the environmental challenges of the 21st century.

2. Sustainability in Higher Education: Global Trends

Universities worldwide have increasingly focused on sustainability initiatives over the past few decades. Key trends include integrating sustainability into curricula, implementing energy-saving measures, and improving waste management [6, 7]. Efforts to promote sustainability competence have intensified, particularly during and after the COVID-19 pandemic, with an emphasis on active learning and curriculum adaptation to meet evolving global challenges. While European institutions lead in sustainability research and implementation, there is a pressing need for broader engagement across various regions [9, 10].

One significant trend is the adoption of sustainability reporting, with many universities utilizing frameworks like the Global Reporting Initiative. However, despite these efforts, overall levels of reporting remain low (Roque da Rosa et al., 2023). Common initiatives span categories such as transportation, waste management, food and dining, and water and energy conservation. These initiatives not only reduce ecological footprints but frequently provide economic benefits, highlighting the multifaceted advantages of university sustainability programs [6].

In alignment with global sustainability targets, universities are increasingly integrating their educational initiatives with the United Nations' Sustainable Development Goals (SDGs). For instance, young universities in Singapore have begun incorporating sustainable education into their undergraduate curricula, addressing both local and global demands

through interdisciplinary approaches [11]. Similarly, universities worldwide are actively disclosing their sustainability practices, with a notable focus on climate change mitigation and adaptation [12]. A review of environmental sustainability initiatives at Malaysian universities reveals a focus on key areas like energy and water conservation, waste reduction, and climate change mitigation. These initiatives, categorized under the UI GreenMetric framework, include Setting and Infrastructure, Energy and Climate Change, Waste, Water, Transportation, and Education and Research. The analysis highlights the need for improved environmental awareness, efficient resource management, and strategic planning to enhance sustainability outcomes in universities [14]. The University of South Florida has integrated SDGs at the undergraduate level through initiatives such as the Global Citizens Project, which brands events and courses with specific SDGs. Furthermore, the introduction of the Times Higher Education University Impact Rankings has motivated universities to incorporate SDGs across all areas of campus [16]. Collectively, these efforts reflect a growing commitment among higher education institutions to align with global sustainability targets.

Comparative studies shed light on the challenges and opportunities faced by universities in different contexts. Quang Hung Bui et al. (2023) discuss the need for sustainable transition models in developing countries, where balancing economic, social, and environmental goals poses significant challenges. Their proposed model, centered on "Sustainability on Campus," seeks to integrate education, research, and community engagement, aiming to embed sustainable practices at all institutional levels while contributing to national economic goals.

In another comparative analysis, Zou et al. (2015) examine sustainability programs at Indiana University, Bloomington (IUB) in the U.S. and Tsinghua University in China. They find that IUB's program is more detailed and effectively balances environmental, economic, and social aspects of sustainability, while Tsinghua primarily focuses on environmental sustainability with a more general approach. The differences are attributed to national and local contexts, illustrating how cultural, political, and institutional factors shape university sustainability initiatives.

The adoption of sustainability in universities is further explored through various dimensions, such as education and research processes. Gaitán-Ángulo et al. (2022) conducted a bibliometric analysis of publications and examined eight global university rankings, revealing that sustainability is not well integrated into academic programs, especially in Latin America. The study found that only 3.69% of related publications originated from this region, and merely 12% of universities are included in global rankings. This raises critical questions about the prioritization of teaching and research over sustainability and emphasizes the need for policies that better incorporate sustainability into university processes and evaluation systems.

Abo-Khalil (2024) investigates sustainability integration in higher education aligned with the SDGs, focusing on the United Arab Emirates (UAE). By employing both quantitative and qualitative methods, the study examines best practices, educational frameworks, and the impact of global initiatives like the Impact Ranking on fostering SDG-aligned transformations in universities. The research highlights successful sustainability strategies in the UAE and underscores the importance of interdisciplinary approaches and active faculty involvement, offering strategic recommendations to enhance the effectiveness of sustainability education worldwide.

Other studies further explore the integration of sustainability practices in various contexts. Machado et al. (2023) emphasize the role of higher education institutions (HEIs) in modernizing education, showcasing how individuals influenced by HEIs adopt sustainable behaviors that contribute to long-term environmental goals. Similarly, Al Mahameed et al. (2023) focus on Kuwait University, highlighting how social and cultural factors shape the development of sustainability projects within the institution.

In Italy, Sonetti et al. (2020) emphasize the role of universities in promoting education for the SDGs, organizing and describing 18 best practices from Italian universities. Their analysis highlights the importance of addressing practical factors influencing the success of sustainability initiatives. Meanwhile, Stoian et al. (2021) examine the strategic plans of Romanian universities, noting a growing trend toward incorporating sustainability concepts, though the transition to fully sustainable universities remains a future goal.

Amaral et al. (2020) conduct a comprehensive literature review on actions taken by universities to address climate change and reduce environmental impacts. They categorize these initiatives into key areas and recommend establishing an integrated framework to monitor and disseminate the impact of these initiatives, thereby facilitating progress toward sustainable university campuses.

Finally, Reva Şermet's 2023 PhD thesis develops a Sustainability Action Plan for Tekirdağ Namık Kemal University (TNKU), providing a model for other universities to create institution-specific sustainability plans. Lea Marie Quilitz's 2021 thesis explores sustainability efforts in the Universities of Goettingen (Germany) and Uppsala (Sweden), assessing their strategic approaches and challenges.

Overall, these diverse studies illustrate the varying degrees of commitment and success in implementing sustainability initiatives across higher education institutions globally. They underscore the need for continued collaboration and innovation to achieve sustainability goals and address the pressing environmental challenges facing the world today.

3. Case Study: Oguz Han Engineering and Technology University of Turkmenistan (ETUT)

ETUT, founded on July 15, 2016, has quickly established itself as a prominent emerging university in the nation. It comprises five faculties: Chemical and Nanotechnologies, Biotechnology and Ecology, Computer Sciences and Information Technologies, Cyber Physical Systems, and Economics of Innovations. These faculties offer 30 undergraduate programs, serving 4344 students, and one Master's program with 124 students. ETUT employs around 400 faculty and staff members. Since its founding, ETUT has emerged as a regional leader in sustainability. In 2021, the university introduced its Green Engineering Policy (GEP), which drives its commitment to maintaining a pollution-free, environmentally conscious campus. The Green Campus Program, developed to implement this policy, includes initiatives focusing on energy efficiency, waste management, water conservation, and sustainable transportation [24].

3.1. ETUT's Green Campus Program

ETUT's *Green Engineering Policy* aims to incorporate sustainable engineering practices across all university operations, focusing on reducing environmental impact and promoting innovation. The *Green Campus Program*, established to operationalize the GEP, guides the university's sustainability efforts and brings together multiple environmental initiatives under a unified framework. This comprehensive approach has earned ETUT recognition at both the national and international levels for its leadership in sustainability.

3.1.1. Energy and Climate Change Initiatives

As part of the *Green Campus Program*, ETUT has implemented various energy-efficient technologies and climate-conscious strategies. Buildings across campus are equipped with smart automation systems, LED lighting, and energy-efficient appliances. The *Nanoelectronics Research Center* is working on producing green hydrogen through solar power, reducing the university's reliance on fossil fuels. Additionally, the *Ecological Biotechnology Research Center* has developed methods for converting plastic waste into biofuels, while the *Green Chemistry Research Center* focuses on producing sustainable bioethanol from agricultural waste like cotton stalks. These projects demonstrate ETUT's commitment to mitigating climate change through innovative energy solutions.

3.1.2. Waste Management

The *Green Campus Program* also includes ETUT's comprehensive *Zero Waste Program*, which targets waste reduction, reuse, and recycling throughout the university. A structured waste categorization system is in place to separate plastics, metals, glass, paper, and organic materials, which are processed at an on-campus recycling facility. The university is pioneering techniques for converting plastic waste into synthetic fibers and liquid fuel, which can be used in transportation and machinery. Composting organic waste and responsibly managing hazardous waste from laboratories further align with ETUT's goal of minimizing its environmental footprint.

3.1.3. Water Conservation

ETUT places a strong emphasis on sustainable water management as part of its *Green Campus Program*. The university employs various methods to conserve water, including rainwater harvesting through rain gardens, permeable pavements, and cisterns that collect rainwater for irrigation and groundwater replenishment. Water-saving fixtures, such as low-flow showerheads and dual-flush toilets, have been installed across the campus to reduce water consumption by up to 50%. ETUT also operates a water recycling system that repurposes water from fountains and other non-potable sources, supporting its commitment to sustainable water use.

3.1.4. Transportation and Pedestrian Infrastructure

Sustainable transportation is another integral aspect of the *Green Campus Program*. ETUT provides a campus-wide shuttle service and offers a bike rental program, significantly reducing the need for private vehicle use. To further discourage car use, the university limits parking permits, increases their cost, and designates car-free zones. Well-maintained pedestrian pathways encourage walking and cycling, promoting an eco-friendly and active lifestyle among students and staff. The university's focus on alternative transportation methods contributes to its overall reduction in carbon emissions.

3.1.5. ETUT's Achievements in Rankings

ETUT's commitment to sustainability has been recognized globally. In 2023, the university made significant progress in the *UI GreenMetric World University Rankings*, improving its position by over 200 places to reach 432nd globally. This improvement reflects the university's success in integrating energy efficiency, waste reduction, and environmental awareness into its operations. Through the *Green Campus Program*, ETUT demonstrates its leadership in fostering a sustainable academic environment, positioning itself as a model for other institutions in the region and beyond.

3.2. Integrating Sustainability into the Curriculum at ETUT

Oguz Han Engineering and Technology University (ETUT) aims to integrate

sustainability into its curriculum by aligning its courses with the United Nations Sustainable Development Goals (SDGs). This section analyzes the offerings across various departments, evaluating the number of courses and their relevance to sustainability. It highlights the interconnectedness of educational programs and their potential contributions to fostering sustainable practices and innovations.

The analysis was conducted by reviewing the curriculum data from various departments at ETUT. This included the total number of courses, selected courses that specifically address sustainability, their relevance to sustainability, and the related SDGs. The courses were classified according to their contributions to sustainability, using a framework based on the 17 SDGs established by the United Nations. **Table 1** summarizes the key findings of the curriculum analysis, highlighting the number of courses offered by each department, selected courses relevant to sustainability, their contributions, and associated SDGs.

The analysis of the curriculum at the ETUT reveals that the university offers a total of 396 courses across various departments, with numerous selected courses explicitly addressing sustainability. These courses cover a diverse range of topics, including nanotechnology, biotechnology, ecology, and applied chemistry, each linked to specific Sustainable Development Goals (SDGs). Key connections include SDG 2 (Zero Hunger) through Food Biotechnology, SDG 3 (Good Health and Well-Being) in Medical Biotechnology and Molecular Diagnosis, and SDG 7 (Affordable and Clean Energy) in Renewable Energy Technologies. This comprehensive integration demonstrates ETUT's commitment to preparing students to tackle contemporary sustainability challenges through interdisciplinary education and practical applications.

The integration of sustainability into ETUT's curriculum reflects a commitment to preparing students for a future that prioritizes environmental, social, and economic sustainability. The diverse range of courses, each linked to specific SDGs, demonstrates a holistic approach to education. By focusing on real-world applications and innovations, ETUT empowers students to become agents of change in their respective fields.

ETUT's efforts to integrate sustainability into its curriculum are commendable and align well with global sustainability objectives. By continuously refining its courses and encouraging interdisciplinary collaboration, ETUT can enhance its contributions to sustainability education and research, ultimately preparing its students to address the pressing challenges facing our world.

3.3. The Extra and Continuous Education Center

The Extra and Continuous Education Center at Oguz Han Engineering and Technology University of Turkmenistan (ETUT) plays a crucial role in broadening the university's commitment to sustainability. It acts as a bridge between ETUT and the local community, offering programs and initiatives that promote environmental stewardship. Through various educational and outreach efforts, the center engages students and community members alike, fostering a culture of sustainability that extends beyond the university campus. This section will explore the center's mission, educational initiatives, and its direct impact on both students and the local community.

Table 1: Curriculum Analysis – Courses, Sustainability Relevance, and SDG Contributions

No	Departments	Number of Courses	Selected Courses	Key SDGs Supported	Key Contributions
1	Department of Nanotechnology and Materials Science	18	Technology of Smart Materials, Methods for Obtaining Nanomaterials, Fundamentals of Construction Materials, Nano-structured Biocomposites	SDG 9, SDG 12, SDG 3, SDG 17	Focus on advanced materials (nanomaterials, biocomposites) contributing to sustainable industrial processes, healthcare, and global research partnerships.
2	Department of Applied Chemistry	10	Analytical Chemistry, Biochemistry for Engineers, Organic Chemistry, Polymer Chemistry	SDG 9, SDG 12, SDG 3	Emphasizes sustainable chemical practices, biochemistry, polymer chemistry, and biotechnology, contributing to industrial innovation and healthcare.
3	Department of Chemical Technology	14	Chemical Reactors, Modeling Chemical Processes, Design Engineering	SDG 9, SDG 12, SDG 7, SDG 3	Promotes process optimization, energy technologies, and health applications, supporting industrial innovation and resource efficiency.
4	Department of Molecular Biology and Genetics	26	Biochemistry, Genetic Engineering, Molecular Diagnosis, Food and Pharmaceutical Engineering, Clinical Genetics	SDG 3, SDG 2, SDG 15, SDG 9	Focus on genetics, molecular biology, and biomedical applications, contributing to health innovations, food sustainability, and

No	Departments	Number of Courses	Selected Courses	Key SDGs Supported	Key Contributions
			and Genetic Counseling, Plant and Animal Physiology, Synthetic Biology		biodiversity conservation.
5	Department of Biotechnology	14	Fundamentals of Biotechnology, Food Biotechnology, Medical Biotechnology, Agricultural Biotechnology	SDG 3, SDG 2, SDG 12, SDG 9, SDG 6	Contributions to healthcare, food security, sustainable production, and environmental biotechnology.
6	Department of Ecology and Ecological Technologies	27	Biodiversity, Agricultural Ecology, Urban Ecology, Soil Science, Raw Material Resources of Turkmenistan, Meteorology and Climatology, Ecological Engineering, Energy Security and Green Engineering	SDG 13, SDG 15, SDG 6, SDG 12, SDG 7, SDG 11	Emphasizes climate action, biodiversity conservation, water management, and sustainable cities through green engineering and environmental protection courses.
7	Department of Microbiology, Virology, and Immunology	13	Environmental Microbiology, Immunology, Food Microbiology, Medical Microbiology, Industrial Microbiology	SDG 3, SDG 2, SDG 6, SDG 9, SDG 15	Focus on disease prevention, food security, bio-industrial applications, and sustainable environmental practices.
8	Department of Applied Mathematics and Informatics	38	Programming Capabilities in Mathematical Calculations, Systems Analysis and Decision Making,	SDG 4, SDG 9, SDG 11, SDG 13	Provides strong foundations in mathematics and computational skills for technological innovation, urban

No	Departments	Number of Courses	Selected Courses	Key SDGs Supported	Key Contributions
			Analytical Geometry and Linear Algebra, Methods of Teaching Mathematics, Mathematical-Statistical Modeling in Cartography		planning, and climate resilience.
9	Department of Computer Science and Information Technologies	44	Algorithms and Data Structures, Informatics and Programming, Geoinformational Programming, Data Storage and Big Data	SDG 4, SDG 9, SDG 8, SDG 11	Develops essential skills in computing, software engineering, and digital innovation, preparing students for careers in high-demand industries.
10	Department of Artificial Intelligence and Cybersecurity	50	Artificial Intelligence, Cloud Computing Technologies, Geoinformation Technologies, Digital Economy, Machine Learning, Intellectual Analysis of Data, Managing Information Security	SDG 4, SDG 9, SDG 16, SDG 8	Focuses on AI, cybersecurity, and cloud computing, fostering digital economy growth, innovation, and secure information systems.
11	Department of Nano and Biomedical Electronics	15	Laser Medicine and Biomedical Optics, Semiconductor Nanostructures and Nanoelectronics, Sensors and Electrodes	SDG 3, SDG 9, SDG 12, SDG 4	Emphasizes medical technology, nanoelectronics, and sustainable electronics practices, contributing to healthcare and

No	Departments	Number of Courses	Selected Courses	Key SDGs Supported	Key Contributions
					industrial innovation.
12	Department of Physics of High Technologies	18	Electrical and Magnetic Phenomena, Molecular Physics and Thermodynamics, Physics of Nanostructures, Theoretical Mechanics	SDG 9, SDG 7, SDG 12, SDG 4	Focuses on nuclear and quantum physics, clean energy technologies, and sustainable industrial practices.
13	Department of Cyber-Physical Systems	19	Automation of Biomedical Data Processing, Fundamentals of Mechatronics, Robotics, Industrial Automation, Telemedicine, Internet of Things, Industrial Automation	SDG 9, SDG 3, SDG 11, SDG 4	Advances robotics, automation, telemedicine, and smart city solutions, enhancing healthcare and sustainable urban development.
14	Department of Economics of Innovations	19	World Economy and International Economic Relations, International Business, Sustainable Development of Entrepreneurship, Macroeconomics, Technology of Business Planning	SDG 4, SDG 8, SDG 9	Promotes innovation in education and entrepreneurship, fostering sustainable economic growth and industrial innovation.
15	Department of Marketing and Management of Innovations	23	Design Thinking, Marketing of the Innovative Sector and Selling Innovations, Business Ethics, Methods of Managing	SDG 4, SDG 8, SDG 9, SDG 12, SDG 16	Focuses on management, marketing, and sustainable business practices, encouraging innovation and

No	Departments	Number of Courses	Selected Courses	Key SDGs Supported	Key Contributions
			Innovative Projects and Decision-Making, Strategic Management		ethical business standards.
16	Department of Foreign Languages for Technical Disciplines	29	Academic Writing, Formal Semantics, Linguistics, Translation of Technical Texts in English	SDG 4, SDG 9, SDG 17	Enhances technical communication skills, preparing students for global technological advancements and international collaboration.
17	Department of Social Sciences	11	Philosophy, Engineering Pedagogy, Political Studies, History of Turkmenistan	SDG 4, SDG 10, SDG 16	Promotes critical thinking, pedagogy, and governance, fostering informed citizenship and leadership.
18	Language Learning Department	8	English Language, Japanese Language, Turkmen Language and Speech Culture	SDG 4, SDG 10	Offers courses in multiple languages to enhance global communication, cultural inclusivity, and equity in education.
Total		**396 Courses**			

3.3.1. Mission and Objectives

The primary mission of the Extra and Continuous Education Center is to create opportunities for lifelong learning, with a focus on sustainability and environmental awareness. Its goals include:

- Disseminating knowledge on sustainable practices and environmental conservation.
- Encouraging practical engagement in community sustainability projects.
- Providing platforms for professional development in sustainability-related fields.
- Fostering a collaborative spirit among students, faculty, and the local community in addressing environmental challenges.

These objectives align with ETUT's broader aim of nurturing a generation of environmentally conscious professionals equipped to tackle global sustainability issues.

3.3.2. Community Outreach Programs

The center organizes a variety of community outreach programs designed to engage both students and local residents in sustainability efforts.

Workshops and Seminars: Regularly hosted workshops focus on critical topics such as renewable energy, sustainable agriculture, and waste management. These sessions often involve both university experts and external specialists, offering participants practical knowledge that can be applied in everyday life.

School Collaborations: The center works closely with local schools, running environmental education programs that raise awareness of sustainability among younger generations. These programs are tailored to local needs, addressing topics such as water conservation and waste reduction specific to the region (Figure 1).

Green Business Initiatives: Collaborating with local businesses, the center provides training on sustainable business practices, helping companies transition to more eco-friendly operations. These efforts not only support the local economy but also contribute to reducing the environmental footprint of the business sector.

3.3.3. Engaging Students in Sustainability

The Extra and Continuous Education Center provides students with numerous opportunities to apply their academic knowledge in real-world sustainability projects.

Sustainability Projects: Through collaborations between students, faculty, and community members, the center leads various sustainability initiatives that address local environmental challenges. Projects such as the development of community gardens and energy efficiency audits give students practical experience while positively impacting the community.

Volunteer and Internship Programs: Students are encouraged to participate in volunteer work and internships with local environmental organizations and businesses. These experiences enable students to gain hands-on experience in the field, develop professional networks, and contribute directly to sustainability efforts in the region.

Field Trips and Educational Tours: To deepen students' understanding of sustainable practices, the center organizes field trips to eco-friendly facilities, organic farms, and natural reserves. These immersive experiences provide valuable insights into how sustainable principles are implemented in practice.

3.3.4. Future Directions

The Extra and Continuous Education Center aims to expand its reach and impact by continuing to offer cutting-edge educational programs and fostering deeper connections with the local community. Key areas for future growth include:

- Expanding online course offerings to make sustainability education accessible to a global audience.
- Scaling up successful community sustainability projects to address larger environmental challenges.
- Strengthening collaborations with local businesses and government agencies to amplify the impact of sustainability initiatives.

The Extra and Continuous Education Center is instrumental in creating a culture of sustainability at ETUT and within the broader community. By providing continuous

education and practical involvement opportunities, the center not only prepares students for future careers in sustainability-related fields but also fosters a community-wide commitment to environmental stewardship.

Figure 1. Green Festival organized with neighbor school

3.4. The Integrated Olympiad Program

The Integrated Olympiad Program at Oguz Han Engineering and Technology University of Turkmenistan (ETUT) is a cornerstone initiative aimed at cultivating exceptional talent in science, mathematics, and technology. By combining academic excellence with a focus on sustainability, the program seeks to inspire high school students to develop innovative solutions to environmental challenges, positioning them to become future leaders in their fields.

Since its inception, the program has gained wide popularity among high school students across the country. Nearly 30,000 students participated in the first year of the Olympiad (2023), with 23,000 participating in the second year (2024). These numbers highlight the program's growing influence and its role in fostering early interest in sustainability-driven education.

A unique feature of the Olympiad is that all participants who pass the I, II, or III rounds are included in ETUT's prestigious "Talented Descendants of Oguz Han" Golden Fund. Members of this fund enjoy benefits when applying to the university, including special consideration during admission campaigns. Many Olympiad winners and prize-winners have gone on to become students at ETUT and other leading universities both domestically and abroad (Figure 2).

This section explores the objectives, components, and impact of the program in nurturing a generation of skilled professionals committed to sustainability.

Figure 2. The winners of the Integrated Olympiad Program

3.4.1. Objectives of the Program

The Integrated Olympiad Program is built on five key objectives:

1. **Identifying Talent:** To discover high school students with outstanding abilities in science, mathematics, and technology, and offer them a platform to excel.
2. **Fostering Excellence:** To provide these students with the advanced training and resources needed to reach their full potential.
3. **Promoting Sustainability:** To integrate sustainability into the program's curriculum and activities, encouraging participants to develop environmentally conscious solutions.
4. **Encouraging Innovation:** To inspire students to think creatively and apply their knowledge to real-world environmental and technological challenges.
5. **Building Community:** To foster a collaborative network of talented students, mentors, and professionals dedicated to sustainability and scientific excellence.

3.4.2. Key Components of the Program

The Integrated Olympiad Program incorporates several core components that work in tandem to achieve its goals:

- **Competitions:** The program regularly participates in national and international Olympiads and contests that emphasize sustainability in science and technology. Students compete in math and science Olympiads, engineering challenges, and technology competitions, showcasing innovative ideas that address environmental issues.
- **Training Camps:** Intensive training camps are held to prepare students for these competitions. Led by experienced faculty and industry experts, these camps offer advanced instruction in scientific disciplines while incorporating workshops on sustainable practices, allowing students to gain insights into renewable energy, ecological biotechnology, and green chemistry.
- **Workshops and Seminars:** Throughout the year, the program offers specialized workshops and seminars on topics related to both cutting-edge technologies and sustainability. These sessions cover a wide range of issues, from climate change mitigation to sustainable

engineering, encouraging students to apply their skills to pressing environmental challenges.

- **Mentorship and Support:** Participants are paired with mentors, including faculty members, alumni, and industry professionals, who guide their academic and professional development. This mentorship provides personalized support, helping students navigate their education while encouraging innovation and a focus on sustainability.
- **Collaborative Projects:** To reinforce learning and foster real-world application, students engage in interdisciplinary projects addressing sustainability challenges. Whether developing energy-efficient technologies or waste management systems, these collaborative projects contribute to ETUT's sustainability goals while giving students practical experience.

3.4.3. Impact and Outcomes

The Integrated Olympiad Program has a significant impact on both its participants and the broader ETUT community. Some of the key outcomes include:

- **Enhanced Skills and Knowledge:** Through the program, students develop not only advanced proficiency in science, mathematics, and technology but also a deep understanding of sustainability. This prepares them for academic success and future careers in areas where environmental consciousness is essential.
- **Innovation and Creativity:** The program fosters a culture of innovation, pushing students to think critically and devise novel solutions to environmental and technological challenges, often with real-world applications.
- **Networking Opportunities:** Participants build valuable networks with peers, mentors, and professionals, creating a strong community of individuals committed to both scientific excellence and sustainability.
- **Institutional Reputation:** By producing high-achieving students who excel in prestigious competitions, the program enhances ETUT's reputation as a leading institution in sustainability-driven education in science and technology.

3.4.4. The Role of Sustainability in Nurturing Talent

By integrating sustainability into its activities, the Integrated Olympiad Program serves as a platform for students to not only excel in their technical disciplines but also to develop the mindset and skills needed to address global environmental challenges. This commitment to fostering environmentally conscious innovation ensures that ETUT remains at the forefront of sustainability education while nurturing the next generation of talented professionals in science and technology.

The Integrated Olympiad Program exemplifies ETUT's holistic approach to education, where academic excellence and environmental responsibility are intertwined. Through competitions, mentorship, and collaborative projects, the program ensures that students are not only equipped with cutting-edge knowledge but also empowered to create a sustainable future.

3.5. Innovation Technology Competition: Promoting Environmental Awareness and Sustainable Living at ETUT

The Innovation Technology Competition at Oguz Han Engineering and Technology University of Turkmenistan (ETUT) is an annual event that has been held since 2023, serving as a dynamic platform to promote creativity, environmental awareness, and sustainable living skills among the nation's youth. Since its inception, the competition has attracted over

1,000 innovative projects from young minds across the country, each aimed at addressing pressing environmental challenges through technological advancements.

3.5.1. Nurturing Innovation with a Focus on Sustainability

A key objective of the competition is to inspire young innovators to create environmentally friendly solutions in fields such as renewable energy, waste management, sustainable agriculture, and green technology. By incorporating sustainable design principles into their projects, participants are encouraged to develop practical solutions that promote resource efficiency, pollution reduction, and ecosystem protection. The competition not only fosters technological innovation but also instills a deep understanding of the environmental and societal impacts of these innovations.

3.5.2. Fostering Sustainable Skills Among Youth

Through this competition, ETUT equips young people with the essential skills required to lead sustainable lives and become future leaders in sustainability. Participants engage with real-world sustainability challenges, working on projects such as energy-efficient devices, biotechnological innovations for agriculture, and digital platforms promoting environmental education. The competition offers hands-on experience, complemented by workshops, mentorship programs, and collaborations with experts, enabling participants to develop impactful, sustainable solutions.

3.5.3. Impact on Environmental Awareness

The competition's strong focus on sustainability ensures that participants not only gain technical knowledge but also become advocates for environmental stewardship within their communities. By presenting innovative solutions that address environmental concerns, young innovators help raise awareness about eco-friendly practices and inspire others to follow suit. This emphasis aligns with ETUT's broader mission of promoting sustainable development through education and innovation.

3.5.4. Building a Community of Sustainability Champions

ETUT's Innovation Technology Competition has successfully created a community of young sustainability champions. By bringing together passionate individuals who collaborate on sustainability-focused projects, the competition cultivates a network of future leaders dedicated to tackling global environmental challenges. The skills, knowledge, and environmental consciousness instilled in participants will continue to shape a more sustainable future for Turkmenistan and beyond.

ETUT has been shortlisted among the top eight institutions in the *THE Awards Asia 2024* under the category of "Student Recruitment Campaign of the Year." This recognition highlights the university's Innovation Technology Competition, in conjunction with the Integrated Olympiad Program, as a successful and impactful initiative in attracting and recruiting talented students. By integrating sustainability into the core of these programs, ETUT fosters a new generation of students who are not only academically excellent but also committed to addressing global environmental challenges through innovative solutions.

4. Comparative Analysis of Other Young Universities

Over the past few decades, young universities have emerged as critical players in advancing sustainability education and research. With fewer institutional legacies to navigate, these universities often demonstrate greater flexibility in integrating sustainability into their operations, curricula, and community engagement. Many of these institutions,

founded after 2000, have positioned sustainability as a central element of their missions, recognizing its importance in addressing global challenges such as climate change, resource scarcity, and environmental degradation.

Figure 3. Innovation Technology Competition at ETUT

This section provides a comparative analysis of the sustainability initiatives at several young universities worldwide, including Oguz Han Engineering and Technology University (ETUT) in Turkmenistan, Duke Kunshan University (DKU) in China, Ashoka University in India, Singapore University of Technology and Design (SUTD), and King Abdullah University of Science and Technology (KAUST) in Saudi Arabia. The analysis explores key areas such as institutional mission and vision, sustainability-focused courses, notable sustainability initiatives, and collaboration with both local and international stakeholders. By examining these institutions, this comparison highlights best practices and diverse approaches to sustainability, offering valuable insights for emerging universities seeking to integrate sustainability into their educational and operational frameworks.

To provide a clear comparison of the sustainability efforts at each of these institutions, **table 2** offers an overview of their mission, sustainability-focused courses, notable initiatives, and community engagement strategies.

Table 2: Comparative Overview of Young Universities' Sustainability Initiatives

University	Mission and Vision	Sustainability Courses	Notable Sustainability Initiatives	Collaboration and Community Engagement	Common Themes and Diverging Approaches
ETUT	Commitment to Green Engineering Policy	Interdisciplinary courses linked to SDGs, e.g., energy, biotechnology	Green Campus Program (Energy efficiency, Waste Management, Water Conservation, Sustainable Transportation)	Partnerships with local businesses, sustainability-focused competitions	Focus on green engineering, industry collaboration, and student innovation
DKU	Interdisciplinary education addressing global challenges	Integrated Science Series, Environmental Policy	Environmental Research Center, sustainable campus design	Collaborates with local and international institutions	Strong focus on interdisciplinary education and campus sustainability
Ashoka University	Liberal arts institution promoting societal and environmental leadership	Environmental Studies, Agriculture and Sustainability	Centre for Climate Change and Sustainability, campus biodiversity initiatives	Community outreach, school collaborations, green business initiatives	Emphasis on liberal arts education, community-based sustainability efforts
SUTD	Redefining education and design for societal impact	Sustainability by Design, Artificial Intelligence	OASIS initiative, Circular Economy Research	Partnerships with startups, global academic alliances	Design-focused sustainability, industry-academic collaboration
KAUST	World-class institution focused on science and technology to advance global sustainability	Courses linked to marine conservation, energy, and water sustainability	Red Sea Research Center, Solar Energy Research, Zero Waste to Landfill Initiative	Partnerships with global organizations (The Ocean Cleanup, Saudi Green Initiative)	Strong emphasis on scientific research, technology-driven solutions, and global partnerships

Key Analysis Points

- **Mission and Vision**: Each university integrates sustainability as part of its core mission. ETUT emphasizes green engineering, DKU focuses on interdisciplinary solutions to global challenges, Ashoka promotes leadership through liberal arts, SUTD aligns design with societal impact, and KAUST emphasizes research-driven sustainability.
- **Sustainability Courses**: Courses offered across these universities are closely tied to sustainability, though the focus differs. While ETUT centers on technical courses in engineering and biotechnology, Ashoka's courses lean towards environmental leadership, and KAUST emphasizes advanced research on renewable energy and marine sustainability.
- **Notable Sustainability Initiatives**: Each university has flagship initiatives. ETUT's Green

Campus Program demonstrates campus-wide sustainability practices, KAUST excels in energy and marine conservation, while SUTD emphasizes circular economy research. Ashoka's biodiversity initiatives and DKU's environmental policy research are also key highlights.

- **Collaboration and Community Engagement**: Collaboration is integral across all institutions, with Ashoka leading community-based efforts, ETUT and KAUST focusing on research collaborations, and SUTD fostering startup partnerships. DKU has developed international academic partnerships, enhancing its sustainability reach.
- **Common Themes and Diverging Approaches**: While interdisciplinary learning and sustainability-focused innovation are common themes, the institutions differ in their emphasis. KAUST and ETUT highlight technological innovation, while Ashoka focuses more on social sustainability and leadership, and SUTD centers on design thinking and industry collaboration.

4.1. Sustainability at SUTD

The Singapore University of Technology and Design (SUTD) has a mission to redefine design, education, and research for societal impact, aiming to "Trailblaze a Better World by Design." Established in 2009, SUTD focuses on fostering future leaders who integrate technology and design to solve global challenges. The university's design philosophy emphasizes human-centric solutions with measurable outcomes, supported by its mid-term strategy, SUTD Leap, which promotes collaboration between academia and industry. In 2023, 169 Master's and PhD students graduated, and SUTD maintained 82 global partnerships, providing diverse international opportunities.

SUTD offers five undergraduate specializations and nine minors, including "Sustainability by Design" and "Artificial Intelligence." Its adult learning institute, SUTD Academy, provides professional training in areas such as AI, cybersecurity, and sustainability. The university has 13 research centers, has published over 8,100 research papers, and secured $665 million in research funding. In 2021, SUTD launched a comprehensive Sustainability Plan (SSP), focusing on three key areas:

1. **Green Campus Transformation**: Through its OASIS initiative, SUTD has created a living laboratory for sustainable innovation. Collaborations with startups like Noshinom and Seaforms enable projects like food waste upcycling and coral-planting technologies to be tested on campus.
2. **Circular Economy Research**: SUTD advances sustainability research by creating sustainable products and reducing waste. A standout project involves 3D printing food waste into usable products, addressing global food waste issues while driving innovation in the food industry.
3. **Hands-On Sustainability Education**: SUTD incorporates sustainability across its curriculum through new courses, such as "Science for a Sustainable World" and "Design Thinking and Innovation," along with a new Master's program in Sustainable Product Design, preparing students to design sustainable solutions.

SUTD is a leader in sustainability research, publishing over 5,000 papers aligned with the United Nations Sustainable Development Goals (UNSDGs). The DesignerlyAI lab exemplifies the integration of AI in sustainable design. SUTD's strong global and industry partnerships support its efforts, positioning it as a leader in sustainable education and research, driving innovation and preparing students for a more resilient future.

4.2. Sustainability at Ashoka University

4.2.1. Overview of Ashoka University's Commitment to Sustainability

Ashoka University, established in 2014, has rapidly emerged as a leader in fostering sustainability within higher education in India. As a liberal arts institution, its mission is to nurture critical thinking, leadership, and a deep commitment to addressing both societal and environmental challenges. Located in Sonipat, Haryana, the university serves as a model for incorporating sustainability into its institutional ethos, academic programs, and operational practices.

With 132 faculty members and nearly 2,000 students, Ashoka's academic community is diverse, with a focus on interdisciplinary learning. The university offers a robust Environmental Studies program that integrates sustainability into the curriculum, offering courses such as **Agriculture, Food, and Sustainability**, **Environmental Economics**, **Cities, Ecology, and Equity**, and **Environment and Social Exclusion**. These courses prepare students to address real-world sustainability challenges by linking theory with practice. Additionally, Ashoka's **Young India Fellowship** and postgraduate programs emphasize sustainability as a core value, encouraging students to pursue research that contributes to sustainable development.

4.2.2. Sustainable Campus Design and Infrastructure

Ashoka University's campus was designed with sustainability at its core, incorporating natural elements and advanced environmental technologies. The campus, part of the Rajiv Gandhi Education City, currently spans 25 acres, with plans to expand to 100 acres. Its infrastructure includes open corridors for natural ventilation, double-wall structures with brick cladding to reduce heat transfer, and the use of stone 'jaali' designs that bring in natural light while minimizing glare.

This sustainable design extends to the biodiversity of the campus, which has become a hotspot for varied plant life, enhancing its ecological value. The university is also recognized for its energy-efficient building systems, which contribute to significant energy savings.

4.2.3. Energy Management Initiatives

Energy management at Ashoka University focuses on reducing reliance on conventional energy sources and transitioning to renewable energy. In 2023, the university installed **893 kW of solar power**, which now generates approximately 13% of the campus's total energy needs. Alongside this, Ashoka has optimized its energy use through energy-efficient equipment and central air conditioning controls set at optimal temperatures.

The university actively monitors energy consumption across buildings, regularly conducting energy audits to track and reduce its carbon footprint. In 2023, Ashoka's total carbon emissions were **9,323.2 tons of CO_2**, with a per capita emission of **2.24 tons**. These measures reflect the university's ongoing commitment to reducing its environmental impact.

4.2.4. Water and Waste Management

Ashoka University takes a comprehensive approach to water management, adhering to the principles of reduce, reuse, and recycle. Water meters are installed in all buildings, allowing precise monitoring of water consumption for activities like irrigation and laundry. The campus utilizes treated water from its **Sewage Treatment Plants (STP)** for irrigation and cleaning, while 15 rainwater harvesting pits help replenish groundwater supplies. These initiatives are critical in the region, where groundwater levels are critically low.

Waste management at Ashoka follows a similar sustainability ethos. The university has implemented a robust recycling program that includes the segregation of organic and inorganic waste. Food waste from the campus kitchens is composted and used for landscaping, and some is sent to local farms as animal feed. Notably, Ashoka has implemented the **Pad Care Ecosystem**, which recycles sanitary waste and reduces landfill use while saving significant amounts of carbon emissions.

4.2.5. Upcoming Initiatives: The Centre for Climate Change and Sustainability (3Cs)

In recognition of its dedication to sustainability, Ashoka University is preparing to launch the **Centre for Climate Change and Sustainability (3Cs)**. This new initiative will focus on climate action, education, and research, involving students, faculty, and external stakeholders in projects aimed at addressing climate change. The 3Cs will further solidify Ashoka's role as a leader in sustainability-focused education and innovation.

Ashoka University's comprehensive approach to sustainability encompasses its curriculum, campus operations, and community outreach. By integrating sustainable development into every aspect of its mission, Ashoka is nurturing environmentally conscious leaders capable of addressing global challenges. The university's ongoing efforts to expand both academic programs and green initiatives demonstrate its steadfast commitment to a sustainable future.

4.3. Sustainability at DKU

Duke Kunshan University (DKU) integrates sustainability into its curriculum through a comprehensive interdisciplinary model. This approach blends natural sciences, social sciences, and humanities, enabling students to address global environmental challenges across multiple fields. Foundational courses such as *Global Challenges in Science, Technology, and Health* equip students with the skills needed to tackle complex sustainability issues. Key sustainability initiatives at DKU include:

1. **Interdisciplinary Curriculum**: DKU's courses, like the *Integrated Science Series*, emphasize cross-disciplinary studies that explore critical sustainability topics, such as climate science and renewable energy. The interdisciplinary structure prepares students to solve real-world problems using knowledge from multiple academic perspectives.
2. **Environmental Research and Policy Centers**: DKU's *Environmental Research Center (ERC)* and the *International Master of Environmental Policy (iMEP)* program focus on sustainability research, addressing issues like environmental health, policy solutions, and noncommunicable diseases. These centers foster collaborations between students, faculty, and international institutions, directly influencing policy and practice.
3. **Experiential Learning**: DKU promotes hands-on learning through *Signature Work Projects*, where students design research projects that often focus on sustainability themes. This encourages practical engagement with environmental issues and fosters a deeper understanding of the global impact of sustainability initiatives.

DKU's commitment to sustainability extends beyond academics and into campus operations.

4.3.1. Sustainability Strategy at DKU

DKU's sustainability strategy focuses on three core areas: campus design, energy conservation, and water management. The completion of Phase II in 2023 expanded DKU's environmentally friendly campus by 47 acres, enhancing the university's sustainable infrastructure.

1. **Sustainable Campus Design**: The pedestrian-centered campus reduces the need for

vehicles, integrates native plants, and preserves natural areas. These measures optimize resource use and create recreational amenities, promoting a balance between academic and environmental objectives.

2. **Energy Conservation**: DKU prioritizes energy efficiency by incorporating renewable energy sources, such as solar and geothermal power, and installing energy-efficient appliances. These practices have resulted in significantly lower per capita electricity use compared to the regional average, with the university continually exploring new technologies to further reduce its carbon footprint.
3. **Water Management**: DKU has developed a sophisticated water management system that captures and reuses rainwater. The use of permeable pavement and greywater systems ensures sustainable water practices, contributing to DKU's long-term goal of near-circular water management.

4.3.2. Daily Operations

In its daily operations, DKU implements energy-efficient practices, including LEED-certified buildings and air quality monitoring. While the university has made progress, further improvements in air quality monitoring and water consumption tracking could enhance its sustainability efforts.

4.3.3. Food and Waste Management

DKU promotes sustainable food practices by offering diverse dietary options and gathering community feedback. The university is encouraged to expand plant-based options and work with suppliers to minimize environmental impacts. Additionally, waste management practices are in place, with clearly labeled bins for food, recyclable, and residual waste. However, more data collection is needed to improve transparency and reduce food waste on campus.

4.3.4. Environmental Research Center (ERC)

The ERC at DKU is an interdisciplinary hub focused on environmental science and policy. Since its inception in 2016, it has significantly expanded its research and policy outreach. The ERC collaborates with leading institutions to address issues such as environmental governance, green finance, and the Belt and Road Initiative. It also runs executive education programs like the *Blue Pioneers Program*, which trains professionals in marine conservation.

Through its commitment to sustainability in both academic and operational areas, DKU is establishing itself as a leader in sustainable higher education, continuously refining its efforts to contribute to global environmental solutions.

4.4. Sustainability at KAUST

4.4.1. KAUST's Sustainability Commitment

Established in 2009, King Abdullah University of Science and Technology (KAUST) is a graduate research institution focused on addressing pressing scientific and technological challenges in Saudi Arabia and around the world, with specific strengths in food, health, water, energy, and the environment. As a hub for interdisciplinary research, KAUST attracts top minds from over 120 nationalities to live and work in a vibrant campus community, where they collaborate on innovative projects that range from patents and products to startups and international initiatives. KAUST's core mission is to advance science and technology through collaborative research integrated with graduate education, fostering innovation, economic development, and social prosperity in line with Saudi Arabia's Vision 2030.

With an emphasis on the public good, KAUST aims to be a beacon of knowledge and

innovation, linking diverse cultures and inspiring global change. The university's unique attributes include a matrix structure of academic divisions and research centers, extensive laboratory facilities, and an integrated Research and Technology Park that drives knowledge transfer and economic development. This forward-thinking environment encourages collaborative learning, interdisciplinary research, and practical innovation, making KAUST a globally recognized leader in tackling challenges related to sustainability.

4.4.2. Energy Efficiency and Renewable Energy Initiatives

KAUST has made notable advancements in energy management by integrating a comprehensive energy management system that leverages real-time data to optimize consumption and minimize waste across campus. With energy-efficient HVAC systems that adjust automatically based on occupancy and weather, the campus reduces energy use while maintaining comfort. Additionally, KAUST's significant investments in solar energy contribute a substantial share of the university's power, reducing fossil fuel reliance and supporting the transition to clean energy.

4.4.3. Water Conservation and Recycling Efforts

In response to the arid regional climate, KAUST has prioritized water conservation through innovative technologies. The university operates a wastewater treatment plant that converts sewage into treated sewage effluent (TSE), reused for irrigation and other non-potable needs, significantly lowering freshwater demand. KAUST also leads cutting-edge research in desalination to foster more sustainable water management solutions locally and beyond. On-campus water conservation programs include efficient irrigation systems and water-saving fixtures that further enhance sustainable water use.

4.4.4. Waste Management and Circular Economy

Embracing a circular economy model, KAUST has set ambitious zero-waste goals, striving to minimize waste and maximize repurposing. An extensive recycling program processes a wide range of materials to divert waste from landfills, while a dedicated composting facility transforms organic waste from dining services and landscaping into nutrient-rich soil. These initiatives not only reduce landfill use but also support sustainable landscaping efforts on campus.

4.4.5. Research and Innovation for Environmental Sustainability

Sustainability research is central to KAUST’s mission, covering topics from renewable energy to marine conservation. The Red Sea Research Center at KAUST, for example, focuses on preserving the unique ecosystems of the Red Sea through coral reef restoration and pollution control. Research into advanced solar cells and carbon capture technology further enhances KAUST's commitment to renewable energy and climate action, with projects designed to have a lasting impact both regionally and globally.

4.4.6. Global Partnerships and Collaborative Impact

KAUST extends its sustainability influence worldwide through strategic partnerships. Through a Master Research Agreement with Red Sea Global (RSG), formerly The Red Sea Development Company, KAUST supports responsible coastal development and environmental sustainability. This partnership focuses on marine conservation, sustainable food production, waste management, energy conservation, and carbon sequestration, with initiatives like scientific monitoring to track environmental changes—essential for RSG’s goal of achieving a 30 percent net conservation benefit by 2040 through The Red Sea project, one of the world's most ambitious regenerative tourism efforts. Additionally, KAUST’s contributions to the Saudi Green Initiative support national sustainability goals, while its membership in the Green Campus

Consortium promotes sustainable campus practices alongside other global institutions.

4.4.7. Conclusion: KAUST's Role in Advancing Global Sustainability

KAUST's sustainability initiatives form a comprehensive model that integrates energy efficiency, water conservation, waste management, and innovative research. Through its projects and global collaborations, KAUST not only advances the SDGs but also shapes a sustainable future, establishing itself as a key player in environmental research and sustainable development.

5. Key Findings: Common Challenges and Best Practices

This comparative analysis reveals several common challenges that young universities face when embedding sustainability into their institutional frameworks. Despite these challenges, there are notable best practices emerging across institutions.

Common Challenges:

- **Funding and Resource Allocation**: Securing consistent funding for sustainability programs remains a challenge, especially for large-scale projects like renewable energy research. Universities like KAUST mitigate this challenge through partnerships with industry and government.
- **Integrating Sustainability into Curriculum**: While progress has been made, embedding sustainability across all disciplines, not just in specialized courses, is a common challenge. KAUST's research-driven approach and Ashoka's liberal arts curriculum provide contrasting examples of how to achieve this.

Best Practices:

- **Technology-Driven Sustainability**: Institutions like KAUST and ETUT demonstrate how technology-driven sustainability can generate impactful solutions. Their work in green hydrogen, biofuel research, and solar energy highlights the importance of cutting-edge research in addressing environmental challenges.
- **Community and Industry Engagement**: Universities such as Ashoka and DKU excel in connecting with their communities through outreach and research collaborations, making sustainability a practical, real-world concern for local industries and populations.
- **Sustainable Campus Operations**: Initiatives like KAUST's zero-waste program and SUTD's OASIS living lab show how campuses can act as models for sustainability. These universities demonstrate that integrating sustainable practices into daily campus life is achievable and beneficial.

6. Discussion: Implications for Educational Policy and Future Research

The findings of this study have significant implications for educational policy and the future of sustainability in higher education. As global environmental challenges grow more urgent, universities must play a leading role in developing future sustainability leaders.

Educational Policy:

- **Encouraging Interdisciplinary Approaches**: Universities that successfully integrate sustainability into a wide range of disciplines are better positioned to produce innovative solutions to environmental challenges. Policies that support interdisciplinary collaboration, such as cross-departmental research and coursework, are critical for fostering holistic sustainability education.
- **Supporting Technological Innovation**: Institutions like ETUT and KAUST demonstrate the importance of supporting research that focuses on technological solutions to

sustainability issues. Educational policies should encourage investment in research that addresses areas like renewable energy, water conservation, and waste management.

Future Research:

- **Long-Term Impact Assessment**: Future studies should examine the long-term impact of sustainability programs on universities and their surrounding communities. Research into the lasting effects of initiatives like KAUST's energy projects or ETUT's waste management innovations could provide valuable insights into effective sustainability strategies.
- **Regional Comparisons**: More research is needed to explore how regional contexts affect the success of sustainability initiatives. Comparisons between universities in regions like the Middle East (KAUST) and Central Asia (ETUT) could highlight region-specific challenges and solutions in integrating sustainability into higher education.

7. Conclusion

Young universities play a pivotal role in advancing sustainability education and research. Institutions like ETUT, DKU, Ashoka, SUTD, and KAUST have developed diverse and impactful sustainability programs that contribute both locally and globally. From energy-efficient campuses to interdisciplinary education models, these universities are setting benchmarks for how higher education can address pressing environmental challenges.

The initiatives implemented by these institutions reflect the increasing integration of sustainability into university operations, research, and community engagement. KAUST's emphasis on renewable energy research, ETUT's Green Campus Program, and SUTD's circular economy innovations demonstrate how higher education can contribute to global sustainability goals.

Moving forward, the study emphasizes the need for continuous innovation and collaboration. As these universities refine their approaches to sustainability, they will not only shape the future of higher education but also contribute meaningfully to global efforts in addressing environmental challenges.

References

1. Gigauri I, Vasilev V, Mushkudiani Z. In Pursuit of Sustainability: Towards Sustainable Future Through Education. International Journal of Innovative Technologies in Economy. 2022 March;1(37):1-11

2. Ryan A, Tilbury D, Corcoran PB, Abe O, Nomura K. Sustainability in higher education in the Asia-Pacific: Developments, challenges, and prospects. International Journal of Sustainability in Higher Education. 2010 Jan;11(2):106-119.

3. Sen G, Chau H-W, Tariq MAUR, Muttil N, Ng AWM. Achieving Sustainability and Carbon Neutrality in Higher Education Institutions: A Review. Sustainability. 2022;14(1): 1-27.

4. Abo-Khalil AG. Integrating Sustainability into Higher Education Challenges and Opportunities for Universities Worldwide. Heliyon. 2024 May;10(9):1-13.

5. McMillin J, Dyball R. Developing a Whole-of-University Approach to Educating for Sustainability: Linking Curriculum, Research and Sustainable Campus Operations. Journal of Education for Sustainable Development. 2009 July;3(1):55-64.

6. Farag K, Aktas CB. A Survey of the Most Prevalent Sustainability Initiatives at Universities. International Journal of Sustainability in Higher Education. 2024 Jan;25(8):1581-1609.

7. Amaral AR, Rodrigues E, Gaspar AR, Gomes A. A review of empirical data of sustainability initiatives in university campus operations. Journal of Cleaner Production. 2020 March;250:119558.

8. Berchin II, de Amorim WS, Valduga IB, Heerdt ML, de Andreda Guerra JBSO. Sustainable Campuses as Living Labs for Sustainable Development: An Overview of a Brazilian Community University. Universities as Living Labs for Sustainable Development. 2020 Jan:87-102.

9. Smardon R. A comparison of Local Agenda 21 implementation in North American, European and Indian cities. Management of Environmental Quality: An International Journal. 2008 Jan;19(1):118-137.

10. Filho WL, Vargas VR, Salvia AL, Brandli LL, Pallant E, Klavins M, Ray S, Moggi S, Maruna M, Conticelli E, Ayanore MA, Radovic V, Gupta B, Sen S, Paco A, Michalopoulou E, Saikim FH, Koh HL, Frankenberger F, Kanchanamukda W, da Cunha DA, Akib NAM, Clarke A, Wall T, Vaccari M. The role of higher education institutions in sustainability initiatives at the local level. Journal of Cleaner Production. 2019 Oct;233:1004-1015.

11. Mokhtar IA, Chong EYT, Jusuf SK. Incorporating Sustainable Education in the Undergraduate Curriculum: The Experience of a Young University in Singapore. European Journal of Sustainable Development. 2023;12(4):83-94.

12. Nikolaou II, Tsali TA, Trevlopoulos NS, Mathea A, Avlogiaris G, Vatalis KI. Exploring the sustainable reporting practices of universities in relation to the United Nations' 2030 Agenda for sustainable development. Discover Sustainability. 2023 Nov;4(46).

13. Bui QH, Trinh TA, Thi HAL, Ohan NQ, Dinh HUN. Towards a sustainable university transition model for emerging markets, Cogent Business & Management. 2023 Oct;10(3):1-12..

14. Mohamed NH, Noor ZZ, Lee CIS. Environmental Sustainability of Universities: Critical Review of Best Initiatives and Operational Practices. Green Engineering for Campus Sustainability. 2019 April.

15. Zou Y, Zhao W, Mason R, Li M. Comparing Sustainable Universities between the United States and China: Cases of Indiana University and Tsinghua University. Sustainability. 2015 Aug;7(9). 11799-11817

16. Hansen B, Stiling P, Uy WF. Innovations and challenges in SDG integration and reporting in higher education: a case study from the University of South Florida. International Journal of Sustainability in Higher Education. 2021 July;22(5):1002-1021.

17. Gaitán-Angulo M, Gómez-Caicedo MI, Torres-Samuel M, Correa-Guimaraes A, Navas-Gracia LM, Vásquez-Stanescu CL, Ramírez-Pisco R, Luna-Cardozo M. Sustainability as an Emerging Paradigm in Universities. Sustainability. 2022 Feb;14(5):1-23.

18. Machado CF, Davim JP. Sustainability in the Modernization of Higher Education: Curricular Transformation and Sustainable Campus—A Literature Review. Sustainability 2023 May;15(11):1-28.

19. Al Mahameed M, Riaz U, Aldoob MS, Halari A. The Implementation of Sustainability Practices in Arab Higher Education Institutions. Journal of Financial Reporting and Accounting. 2023 Feb;22(3):1161-1185.

20. Sonetti G, Barioglio C, Campobenedetto D. Education for Sustainability in Practice: A Review of Current Strategies within Italian Universities. Sustainability. 2020 June;12(13):1-23. 5246.

21. Stoian CE, Simon S, Gherhes V. A Comparative Analysis of the Use of the Concept of Sustainability in the Romanian Top Universities' Strategic Plans. Sustainability. 2021 Sep;13(19):1-34.

22. Şermet R. Üniversitelerin sürdürülebilirliğine yönelik eylem planı hazırlanması: TNKÜ örneği. Doktora Tezi. Tekirdağ Namık Kemal Üniversitesi / Fen Bilimleri Enstitüsü / Peyzaj Mimarlığı Ana Bilim Dalı. 2023.

23. Quilitz LM. Sustainability at Higher Education Institutions: Paradox or Pioneering? : A Case Study on the Universities of Goettingen and Uppsala. Thesis. Universite de Strasbourg and Uppsala Universitet. 2021.

24. Gedayev S, Orazov Y. Realization of Green Engineering at ETUT. Journal of Sustainability Perspectives. 2023 Dec;3(Special Issue):435-438.

25. Altbach PG. New universities pioneer different approaches to excellence in teaching and governance. Nature. 2019 Oct;574(7779):60.

26. Filho WL, Eustachio JHPP, Caldana ACF, Will M, Salvia AL, Rampasso IS, Anholon R, Platje J, Kovaleva M. Sustainability Leadership in Higher Education Institutions: An Overview of Challenges. Sustainability. 2020 May;12(9):1-19.

27. Gao H, Gu Y. Establishing a Research-Focused Liberal Arts College in China: Duke Kunshan University. Daedalus. 2024 May;153(2):68-82.

28. Chakraborty A, Kumar S, Shashidhara LS, and Taneja A. Building Sustainable Societies through Purpose-Driven Universities: A Case Study from Ashoka University (India). Sustainability 2021 July;13(13):1-20.

29. UI GreenMetric. World University Ranking. Overall Rankings 2023; 2023 [Cited 2023 Dec 5]. Available from: https://greenmetric.ui.ac.id/rankings/overall-rankings-2023.

30. ETUT Sustainability report 2023-2024. Oguz Han Engineering and Technology University (ETUT). Available from: https://www.etut.edu.tm/sustainability.

31. DKU Student Club. 2022 Sustainability Report. Duke Kunshan University (DKU); 2024.

32. SUTD Annual Report 2023-2024. Singapore University of Technology and Design (SUTD). Available from: https://www.sutd.edu.sg/wp-content/uploads/2024/12/SUTD-Annual-Report-2023-2024-1.pdf. 2024.

33. KAUST SDG Highlight Report 2021 & 2022. King Abdullah University of Science and Technology (KAUST). Available from: https://sustainability.kaust.edu.sa/news-center/kaust-releases-its-first-sdg-highlight-report/

34. Mishra BK, Malik N. Ashoka University Sustainability Report – 2023. Available from: https://www.ashoka.edu.in/wp-content/uploads/2024/05/AU-Sustanability-Report-2023.pdf. 2023.