The Role of Sustainability Evaluation and Certification Systems in University Campus

Master's Degree in Architecture for Sustainability

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الا ای صبح آزادی به یاد آور در آن شادی

کزین شب های ناباور منت آواز می دادم...

To the souls lost on the path of freedom, and to the fearless hearts of my homeland...

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Abstract

This thesis forms the first phase of a broader project aimed at creating a sustainability assessment framework tailored to Italian university campuses, which differ structurally and institutionally from standalone buildings or urban districts. A systematic literature search across scientific databases produced 388 articles; after removing duplicates, 138 remained. Abstract screening identified their sustainability themes based on the SNTool structure, leading to a selection of 44 globally or European-focused studies for full-text review. From these, 258 distinct sustainability indicators and 55 assessment tools were extracted.

A prototype campus assessment was then developed using the 20 most recurrent indicators. Eight stakeholder groups were defined, whose preferences were simulated by AI to rank the indicators. These AI-derived rankings were later cross-checked with a small group of internal stakeholders (students, professors, and technical staff). Average ranks of indicators were converted to weights and applied to get the overall sustainability score of POLITO.

A SWOT analysis produced ten strategic actions, which were again prioritized by stakeholders and examined using Q-sort analysis to identify patterns in stakeholder perceptions and produce three future scenarios. These future scenarios were evaluated in the same way as the current situation to obtain their sustainability scores.

Results show that POLITO performs well overall, with a score of 3.3 on a −1 to 5 scale. This score is even more improvable to 3.6 under the best scenario (scenario 1). Q-sort findings identified two contrasting stakeholder poles—an institutional cluster and a user cluster—underscoring the need to align governance priorities with user needs.

Keywords

SATs (Sustainability Assessment Tools), CSATs (Campus Sustainability Assessment Tools), iiSBE (International Initiative for a Sustainable Built Environment), SBTool (Sustainable Building Tool), SNTool (Sustainable Neighborhood Tool), ITACA (Institute for Innovation and Transparency in Procurement and Environmental Compatibility), LCA (Life Cycle Assessment), Playing cards method, Q-Sort Methodology

1 Introduction

Universities play a critical role in advancing sustainability, not only through their educational and research missions but also by demonstrating sustainable practices on their campuses. As hubs of innovation and centers for developing future leaders, Higher Education Institutions (HEIs) have the potential to influence society's transition towards sustainable development. By integrating sustainability into their operations—such as energy use, waste management, and building design—universities can serve as both role models and testing grounds for sustainable solutions.

However, despite this potential, universities face significant challenges in achieving sustainability goals due to the absence of clearly defined global standards or guidelines specific to university campuses. This lack of standardized frameworks creates obstacles for assessing and benchmarking progress, leaving universities to navigate the complexities of sustainability independently. The development of the ITACA Protocol for universities aims to bridge this gap by establishing a national Italian standard that promotes the adoption of sustainability initiatives in higher education institutions, reinforcing their role as sustainability leaders.

1.1 Background

1.1.1 SATs (Sustainability Assessment Tools):

Sustainable Assessment Tools (SATs) are frameworks to evaluate and measure the sustainability performance of different entities, including universities, corporations, buildings, neighborhoods, and cities. To achieve this, SATs rely on various qualitative and quantitative indicators, which surround the three main pillars of sustainability: environmental, social, and economic performance.

SATs can be divided into various classifications, such as the geographical scale of applicability (global or local), the scale of assessment (urban, neighborhood, building), the indicators' type (qualitative, quantitative, mixed), etc. Whatever categories they belong to, applying them brings about a lifelong sustainability approach for the following organizations, which is ensured through many potentials of SATs, such as:

- Stakeholder Involvement: Many SATs emphasize involving stakeholders (e.g., employees, students, and community members) in the assessment process to ensure comprehensive and meaningful evaluations.
- Certification and Recognition: SATs often provide certifications that allow organizations to showcase their sustainability achievements, such as LEED certification for green buildings or STARS rankings for universities.
- Continuous Improvement: SATs promote ongoing monitoring and reporting, continuously encouraging organizations and institutions to improve their sustainability performance over time.

- Transparency and Reporting: Tools like GRI emphasize transparent sustainability reporting, crucial for accountability to stakeholders and the public.
- Having mentioned the key significant potential, the limitations should be considered too. These limitations can be summarized as:
- Data Availability: Accurate and comprehensive data can be a challenge, especially for smaller organizations or those in developing regions.
- Cost and Complexity: Some SATs, particularly those for buildings and corporations, can be costly and complex to implement, requiring significant resources for data collection and reporting.
- Context Sensitivity: While global SATs offer standardization, they may not always account for local cultural, environmental, or regulatory differences.

1.1.2 CSATs (Campus Sustainability Assessment Tools):

University campuses are like samples of society, with a wide range of activities and infrastructure that mirror real-world systems. They include academic buildings, dormitories, laboratories, dining facilities, and often their transportation networks. This complexity makes universities ideal for assessing sustainability across multiple sectors, from energy use and water management to waste disposal and biodiversity protection.

University campuses also play a pivotal role in educating and shaping the next generation of leaders. Integrating SATs into campus operations and curricula not only improves sustainability on campus but also teaches students practical skills and values they can carry into their careers and personal lives. This creates a ripple effect as students apply sustainable practices in various fields, from business to engineering and public policy.

Furthermore, University campuses are typically designed to last for decades or even centuries. This long-term perspective makes them ideal candidates for implementing sustainability measures that may take time to produce results but have significant long-term benefits.

Finally, University campuses are centers of innovation and experimentation, making them fertile ground for testing new sustainable technologies and practices. They can serve as "living labs" where students, researchers, and faculty develop and experiment with sustainable solutions. SATs can track the effectiveness of these experiments and provide data to guide future initiatives.

1.1.3 iiSBE

iiSBE stands for the International Initiative for a Sustainable Built Environment, a global non-profit organization founded in the early 2000s by sustainable building experts. iiSBE’s core mission is to accelerate the shift towards sustainability in the built environment worldwide. In practice, iiSBE acts as a network and facilitator: it brings together professionals and organizations to share knowledge, reduce duplication of efforts, and establish common standards in building sustainability assessment.

1.1.4 SBTool

A major contribution of iiSBE is the development of the SBTool (Sustainable Building Tool) – a tool for evaluating the sustainable performance of buildings (originating from the late-1990s Green Building Challenge as "GBTool") that can be tailored to local conditions. SBTool has formed the basis for several national rating systems, such as Italy's ITACA Protocol, by allowing local authorities to customize sustainability criteria to their context. (an open and flexible evaluation framework)

1.1.5 ITACA Protocol

ITACA is an acronym for the Institute for Innovation and Transparency in Procurement and Environmental Compatibility, an Italian association of regional governments. In the early 2000s, this institute developed the Protocollo ITACA, a framework for assessing the environmental and energy sustainability of buildings. The ITACA Protocol serves as Italy's green building rating system – similar to international tools like LEED or BREEAM – and was officially adopted in 2004 as a common standard.

Its core purpose is to provide clear criteria and metrics for sustainable construction (e.g., energy efficiency, water use, materials impact), allowing evaluation and certification of new buildings' sustainability performance. Notably, the ITACA system was based on an international model called SBTool, developed from the Green Building Challenge. By adapting this model to the Italian context, ITACA helped implement a unified sustainability evaluation framework across Italy's regions, supporting public policies and incentives for greener buildings.

1.1.6 SNTool

SNTool is an extension of SBTool for assessing the sustainability at the neighborhood and urban scale. It includes a wide range of environmental, social, and economic indicators, allowing a comprehensive evaluation of urban areas. Both tools share the same underlying iiSBE Methodology and philosophy – often summarized as "think globally, act locally" – which provides a common language for assessment while allowing local customization

1.2 Thesis Objective

This thesis is part of a bigger project that aims to develop a version of the ITACA Protocol specifically for university campuses, in the national Italian scale[(2024), *Protocollo ITACA Campus Universitario*, (*Versione 2.0)*]. This thesis contributes to the first phase of the project (scoping and preparatory stage). It defines the thematic areas of sustainability in university campuses based on the SN-Tool's categories, extracts the indicators used in the literature, categorizes them based on the SN-Tool's categories, and in the end chooses the most frequently used of them to test a hypothetical implementation on the POLITO campuses to estimate a sustainability score. Furthermore, It provides with 10 actions and 3 future scenarios to enhance the sustainability score.

1.3 Thesis Structure

The research structure of this thesis is organized into five chapters, each addressing a key aspect of the study:

Chapter 1 – Introduction: Provides the background information about the sustainable assessment tools and their applications in the universities, the assessment tool used in this thesis, and its connection to the context of Italy, also outlines the objectives guiding the study.

Chapter 2 – Literature Review: This chapter first critiques existing HEI sustainability tools and rankings based on the literature (CSATs, STARS, UI GreenMetric, THE/QS/ARWU, THE Impact), showing that they are fragmented, ranking-oriented, heavily focused on environmental operations, and often unfair to dense urban campuses like POLITO. Then shifts from tools to the indicators themselves, reviewing campus-level studies (footprint, nexus, LCA, and indicator frameworks) to see which types of indicators are actually used for energy, water, waste, mobility, buildings, food, education, and research, and which domains emerge as real hotspots. Finally, it synthesizes the main gaps in the literature—tool fragmentation, operational/environmental bias, weak coverage of mobility, infrastructure, food, economic, and governance aspects, and data limitations—and uses these to justify developing an SNTool-based, context-specific indicator framework for the POLITO campus.

Chapter 3 – Methodology: This chapter describes the research design and the methodology, including how to form the research string to select the literature, the parameters considered for removing the redundancy and choosing the relevant papers, and finally how to run the analysis on the relevant papers. Then, describes how based on a set of 20 indicators chosen from the papers, a hypothetical implementation is run on POLITO to estimate its sustainability score, and how this score is improvable through some actions that form three future scenarios, from which the best scenario with the highest sustainability score is chosen c.

Chapter 4 – Results: This chapter Presents the outcomes of the research, including statistical information about the papers reviewed, such as year of the publication, distribution of the geographical area of the empirical study, papers' theme and main focus areas based on the SNTool categories, papers' methodological approach, SATs used in the papers, and redistribution of indicators used by the papers based on the SNTool categories. It also involves graphs and tables of the implementation phase. The radar graph showing POLITO's sustainability position in the current situation and after following each scenario.

Chapter 5 – This hapter discusses the pilot framework's main limitations and proposes improvements. It shows that some common indicators (e.g., "waste treated") have low discriminating power, and that key domains are under-represented due to data and framework gaps—especially the economic pillar and user-centred aspects like study and recreation facilities. It also highlights missing centralized data at PoliTO (e.g., food waste, local procurement, study seats), recommending an expanded sustainability data infrastructure.

The chapter then suggests refining the framework by (i) mitigating open-space bias against dense urban campuses through reuse/rehabilitation indicators, (ii) adding capacity-based metrics such as study seats or study area per student (and recreation space per student), and (iii) aligning priorities with measured gaps via real stakeholder weighting supported by a neutral evidence briefing and iterative validation.

2 Literature Review

2.1 From sustainable development to sustainable university campuses

Since the late 1980s, higher education institutions (HEIs) have been increasingly framed as key actors in the transition towards sustainable development. They not only transmit knowledge but also shape values, behaviours, and professional practices, and therefore have a dual role: reducing their own environmental and social impacts and acting as multipliers of sustainability in society.

Several authors describe the “environmentally sustainable higher education institution” as one that systematically minimizes its environmental footprint while integrating sustainability into institutional systems, education, research, campus management and external engagement. In this perspective, the university campus is viewed as a “microcosm of society” and a “small city”, with complex infrastructures, flows of people and resources, and a wide range of services—making it an ideal living laboratory where sustainability solutions can be tested and demonstrated before being scaled up to urban and national levels.

At the same time, a number of studies highlight that HEIs remain significant contributors to environmental pressures through energy use, mobility, food services, waste, and the construction and operation of large building stocks. This tension between the “transformative” mission of universities and their own operational burdens underpins the need for robust tools and indicators to assess campus sustainability performance in a consistent way.

2.2 Defining sustainable and “green” universities

Despite decades of debate, there is still no universally agreed-upon definition or standard for what counts as an “environmentally sustainable” or “green” university. Freidenfelds et al. Synthesize a large body of work and conclude that a sustainable university should simultaneously address:

- sustainable campus operations (energy, water, waste, mobility, buildings),
- sustainable research and innovation,
- public outreach and cooperation with other institutions,
- sustainable curricula and graduate attributes, and
- transparent sustainability reporting.

In their framework, a “green university” is defined as an institution that actively pursues sustainable development, climate change mitigation, and environmental protection goals while still delivering its core mission of high-quality education and science. This is operationalized through an indicator-based framework built from UN SDGs, World Bank indicators, UI Green Metric, and a national sustainability index, leading to a set of 26 environmental indicators for HEIs.

Other contributions emphasize that HEI sustainability cannot be reduced to environmental aspects alone. Financial and economic resilience, governance quality, equity, and the social and cultural impacts of universities also form essential components of long-term institutional sustainability. Taken together, these studies point towards a multi-dimensional view of sustainable universities that cuts across operations, education, research, outreach, governance, and finance.

2.3 Sustainability assessment tools and rankings for HEIs

2.3.1 Campus sustainability assessment tools (CSATs)

Over the past two decades, numerous campus sustainability assessment tools (CSATs) have emerged, including indicator-based instruments (e.g., AISHE, GASU, SAQ, SUM, uD-SiM), rating systems (STARS, UI Green Metric), and management-oriented frameworks aligned with ISO 14001 or EMAS.

Dawodu et al. identify a wide spectrum of CSATs and extract a set of campus sustainability dimensions—spanning energy, water, waste, mobility, buildings, biodiversity, governance, participation, curriculum, research, and campus life—that should be reflected when designing or evaluating sustainable campuses. Similarly, Alghamdi et al. analyze twelve university sustainability tools and over 400 associated indicators, noting a strong dominance of environmental and operational metrics compared to social and economic aspects.

At a broader scale, Mapar et al. review 27 HEI sustainability tools and systematically code their internal structures, sub-criteria, and indicators, resulting in a database of 239 sub-criteria and 1033 indicators. They map these onto five sustainability dimensions (environmental, social, economic, academic, institutional), seven core elements of HEI implementation (governance, operations, education, research, outreach/collaboration, on-campus experience, assessment/reporting), and 25 thematic areas. Their analysis demonstrates that most tools heavily emphasize governance and operations, while dimensions such as economic performance, assessment/reporting, and on-campus experiences remain weakly operationalized.

Several frameworks focus on specific institutional types. De Lima et al. develop a sustainability evaluation framework for science and technology institutes by integrating and adapting existing models (GRI, ISCN, environmental management systems), with categories covering teaching and research, management, resources, and societal engagement. Freidenfelds et al. similarly construct an indicator set tailored to environmental sustainability in HEIs, drawing on global policy frameworks and existing rankings.

Taken together, this body of work confirms that indicator-based CSATs are the dominant approach to assessing sustainability in universities, but also that they are methodologically fragmented and often biased towards what is easy to measure (resource consumption, infrastructure) rather than towards the broader mission of HEIs.

2.3.2 World university rankings and “green” rankings

In parallel to CSATs, global university rankings (THE, QS, ARWU) have become powerful instruments for shaping institutional strategies. However, these rankings focus almost exclusively on teaching reputation, research output, internationalization, and industry income, and include virtually no indicators of campus environmental performance or contributions to national sustainability transitions.

Horan and O'Regan argue that such rankings are embedded in the corporatization and marketization of higher education; by measuring only research quantity and reputation, they implicitly steer universities away from sustainability performance as a strategic priority. Even the Times Higher Education (THE) Impact Rankings, which link HEI performance to the SDGs, have been criticized for methodological inconsistencies, selective reporting, and risks of double-counting across goals.

Among HEI-specific sustainability rankings, UI Green Metric and STARS are the most widely used. Perchinunno and Cazzolle analyze UI Green Metric and apply a cluster analysis to classify almost 800 participating universities into four levels of sustainability, using categories such as setting and infrastructure, energy and climate change, waste, water, transportation, and education and research. Their results show strong relationships between category scores—particularly waste, water, and education/research—and overall ranking position, and reveal differences associated with campus setting (urban vs suburban vs city centre) and geographical region.

However, other authors highlight significant limitations of these rankings. Sonetti et al. compare UI Green Metric and ISCN against detailed campus data from Politecnico di Torino and Hokkaido University and show that generic indicators and weighting schemes tend to penalize compact urban campuses while favoring large suburban estates. Horan and O'Regan further criticize UI Green Metric and STARS for relying heavily on intensity-based metrics (per capita, per square meter), which can give a misleading impression of progress when campus populations or areas change, and for including overlapping indicators that risk double-counting similar efforts.

On this basis, Horan and O'Regan propose a simplified set of twelve indicators—covering on-site energy use, greenhouse gas emissions (Scopes 1–3), waste, water, commuting, sustainability-related education and research, and management/governance—designed primarily for monitoring sectoral trends rather than producing another league table.

2.4 Indicator-based campus sustainability research

Beyond formal tools and rankings, a growing body of empirical research focuses on developing and testing sustainability indicators at the campus level. Dawodu et al. conduct a systematic review of campus sustainability research and propose a comprehensive set of dimensions and indicators to guide the design of sustainable campuses, emphasizing the need to bridge environmental, social, and educational aspects.

Gu et al. apply a multi-footprint approach (carbon, water, ecological, and nitrogen footprints) to a UK campus and explore the interlinkages between energy, water, and food systems. Their results show that shifting diets, adjusting energy supply, and improving campus operations can have strongly interdependent effects on environmental footprints, underlining the importance of integrated indicators rather than single-impact metrics.

Jürgens et al. propose the first HEI-specific organizational life cycle assessment (O-LCA) method and test it on Leibniz Universität Hannover. Their study identifies transport (especially commuting) as the dominant contributor in most impact categories, followed by infrastructure (buildings and equipment), energy supply, and food services. Scenario analyses suggest that changes in commuting patterns, building stock, and dietary choices can substantially reduce environmental impacts. While O-LCA is methodologically demanding, these findings provide strong evidence that indicators for mobility, infrastructure, and food must be central in any comprehensive campus sustainability framework.

At the conceptual level, studies such as "Assessing the Impacts of Higher Education" argue that the impacts of HEIs extend far beyond their direct footprints: through graduates, research, and regional development, universities shape long-term socio-economic and cultural tracks. However, most operational indicator frameworks remain focused on on-campus impacts and largely ignore these indirect effects, due to measurement complexity.

Financial and economic sustainability is also gaining attention. Analyses of HEI financial performance have proposed indicators related to funding diversification, cost efficiency, long-term solvency, and capacity for strategic investment. Yet economic indicators are consistently under-represented in CSATs and indicator sets compared to environmental metrics.

2.5 Synthesis of gaps and rationale for this thesis

The literature reviewed in Sections 2.2–2.4 reveals several recurrent gaps in how sustainability is currently assessed in higher education institutions (HEIs). These gaps emerge from both systematic reviews of campus sustainability assessment tools and empirical studies on campus footprints, rankings, and institutional frameworks. The main issues, and the specific studies that support them, can be summarized as follows.

2.5.1 Fragmentation of tools and overlapping indicator sets

Multiple reviews show that the landscape of HEI sustainability tools is highly fragmented. Dawodu et al. identify a wide variety of campus sustainability assessment tools (CSATs) and conceptual frameworks, with different structures, thematic scopes, and indicator hierarchies, making it difficult to compare results or transfer lessons between campuses. Alghamdi et al. similarly analyze twelve tools and more than 400 indicators, concluding that their coverage and level of detail vary considerably and that many instruments duplicate similar concepts under different labels.

Mapar et al. extend this analysis to 27 tools and a database of 1033 indicators, confirming that there is a proliferation of frameworks with overlapping scopes and heterogeneous structures, rather than convergence towards a shared core set of indicators for HEIs. De Lima et al. add to this picture by showing how, yet another composite framework (SEIF/STI) needed to be constructed by combining elements from GRI, ISCN, and national environmental agendas, because no single existing tool adequately covered the sustainability dimensions of science and technology institutes.

Therefore, instead of proposing a new tool from scratch, this work responds to the fragmentation problem by extracting and consolidating indicators from 44 campus-related studies into a single bank and then aligning them with the structured macro-areas of SNTool.

2.5.2 Strong bias towards environmental operations and "easy" indicators

Several authors show that existing HEI tools and indicator sets are heavily skewed towards environmental operations and resource flows that are relatively easy to measure. Alghamdi et al. find that most indicators in their sample target energy, water, waste, and buildings, while social, economic, and academic aspects are under-represented. Mapar et al. quantify this imbalance: environmental indicators account for about 29% of their database, whereas economic indicators represent only around 5%; governance and operations together dominate, while education, research, on-campus experience, and assessment/reporting receive fewer indicators than their conceptual importance would suggest.

Financial sustainability studies further highlight that, although long-term financial health, funding diversity, and investment capacity are critical for HEI resilience, such aspects rarely appear in campus sustainability tools.

Since the indicator bank in this thesis is deliberately derived from the existing literature, it inevitably reflects the same environmental and operational bias, and the proposed SNTool-based indicator framework should be read as a literature-derived, empirically grounded starting point that mirrors the current environmental–operational focus of campus sustainability research, while explicitly highlighting the under-represented dimensions that need to be strengthened in future iterations and applications.

2.5.3 Ranking-centered approaches versus campus improvement

A consistent criticism in the literature is that many frameworks are designed primarily for inter-university comparison rather than for guiding improvements on a specific campus. Horan and O'Regan show that the dominant world rankings (THE, QS, ARWU) almost completely ignore campus environmental performance and instead incentivize universities to optimize research output, citations, and internationalization. Even sustainability-oriented rankings such as UI Green Metric and STARS have been criticized for methodological issues, including an over-reliance on intensity metrics (per capita, per square meter), double counting of similar actions under multiple indicators, and embedding strong value judgements about "good" and "bad" energy sources.

Sonetti et al. compare UI Green Metric and ISCN in detail for Politecnico di Torino and Hokkaido University and demonstrate that global rankings can penalise compact urban campuses—even when they have much lower per-capita energy use—because the indicators and scoring thresholds implicitly favor large, estate-style campuses with extensive open space and internal transport systems. Horan and O'Regan therefore propose a small set of twelve indicators designed for national-level monitoring of HEI sustainability transitions, explicitly avoiding the creation of one more league table.

In this thesis, the aim is not to produce a new ranking for Italian universities, but to design a context-sensitive indicator framework that can support internal assessment and decision-making for the POLITO campus. The SNTool-based structure and the subsequent stakeholder-driven prioritization (developed in later chapters) are explicitly oriented towards campus-level learning and improvement, rather than comparative scoring.

2.5.4 Limited attention to campus morphology and local context

Several empirical studies emphasize that campus morphology, climatic conditions, and functional mix fundamentally shape sustainability challenges and opportunities. Sonetti et al. show that indicators related to green space, forest cover, and internal transport systems work very differently for a town-embedded campus such as POLITO, compared to a delimited, park-like campus such as Hokkaido University. Gu et al. and Jürgens et al. similarly treat university campuses as "small communities" whose environmental profiles depend on their spatial layout, commuting patterns, energy systems, and service configurations.

However, most generic tools and rankings still apply one global indicator set and uniform thresholds, with limited sensitivity to whether the campus is urban or rural, compact or sprawling, mono-functional or mixed. This can lead to biased assessments and unrealistic benchmarks for specific campuses.

By grounding the indicator framework in SNTool (which was originally developed for neighborhoods and can be adapted to dense urban fabrics) and by extracting indicators from studies that explicitly treat campuses as small urban systems, the thesis seeks to build a framework tailored to the specific characteristics of the POLITO campus as a town-embedded, multi-site university.

2.5.5 Weak coverage of key environmental hotspots identified by LCA and nexus studies

Organizational LCA and nexus-oriented studies provide important insights into where the main environmental hotspots of HEIs actually lie. Gu et al. quantify interconnected carbon, energy, and water footprints for a UK campus and show that direct energy use and food procurement—especially meat-based diets—dominate the water and carbon footprints, while waste-to-energy systems can produce significant savings. Jürgens et al. apply an O-LCA to Leibniz Universität Hannover and find that commuting and other transport activities are the largest contributors in most impact categories, with infrastructure (buildings and equipment), energy supply, and food services also playing major roles.

Yet many CSATs and indicator frameworks either ignore these domains (e.g., commuting and business travel) or represent them with very few and simplistic indicators. The gap between what LCA and nexus studies identify as hotspots and what tools actually measure suggests that campus sustainability assessment often underestimates the importance of mobility, infrastructure life cycles, and food systems.

in the POLITO framework, the final indicator subset reflects both the literature and the availability of campus data. As a result, several mobility-related aspects partly align with the hotspots identified by LCA and nexus studies (energy, transport). However, no indicators directly addressing campus food provision or dietary patterns could be retained, because first of all, food indicators don't belong to the most frequently used group of indicators in the literature, and secondly, no suitable data are currently accessible. This means that the proposed framework captures some key environmental hotspots while leaving the food-related hotspot outside the scope of this first application, which is explicitly acknowledged as a limitation and a priority area for future extensions.

2.5.6 Underdeveloped integration of economic and financial sustainability

Economic and financial sustainability of HEIs – such as the ability to cover operating costs, maintain and upgrade infrastructure, and invest in teaching and research – has been discussed in the higher education finance literature, which proposes indicators on expenditure, enrolment, efficiency, and attractiveness for investment. However, comparative reviews of HEI sustainability tools consistently report that economic aspects remain weakly operationalized. Alghamdi et al. note that only a small fraction of indicators in their sample address cost, value, or financial performance, and Mapar et al. quantify that economic indicators represent roughly 5% of the 1033 indicators they analyzed across 27 tools, compared to much larger shares for environmental and governance/operations dimensions. This pattern is also visible in the indicator work carried out for POLITO, which is expressed as a limitation in Chapter 5.

2.5.7 Data and institutionalization gaps

Finally, several studies highlight that the practical implementation of comprehensive indicator frameworks is restricted by data limitations and weak institutionalization. Horan and O'Regan test their twelve-indicator set against publicly available data for Irish HEIs and find that, beyond energy use and Scope 1–2 emissions, most indicators (water, waste, commuting, Scope 3 emissions, education, research, governance) lack consistent sector-level datasets. Jürgens et al. report similar constraints for commuting data, detailed building inventories, and neighboring facilities in their HEI LCA, emphasizing that data systems are often not designed with sustainability assessment in mind.

Reviews by Mapar et al. and Alghamdi et al. also note that many tools rely on self-assessment and ad hoc data collection, which limits comparability and long-term monitoring.

the indicator framework for POLITO was therefore shaped from the outset by a dual constraint: on the one hand, indicators had to be supported by the international literature and fit within SNTool macro-areas; on the other hand, they also had to be measurable with the data that are currently available for the campus. In practice, this means that the final set corresponds to the intersection between frequently used indicators in the literature and data-rich domains at POLIT. Indicators for which no meaningful data could be obtained – for example, those related to food services – remain outside the operational framework. This does not solve the data gap identified in the literature, but documents it explicitly and clarifies which additional data would be required to move towards a more complete sustainability assessment in future iterations.

3 Methodology

Figure 1 shows the methodology's flowchart. The final goal is to extract the indicators for the sustainability assessment of POLITO's university campus from the 44 articles that were selected for the final analysis, and then pick some of these indicators for the implementation phase.

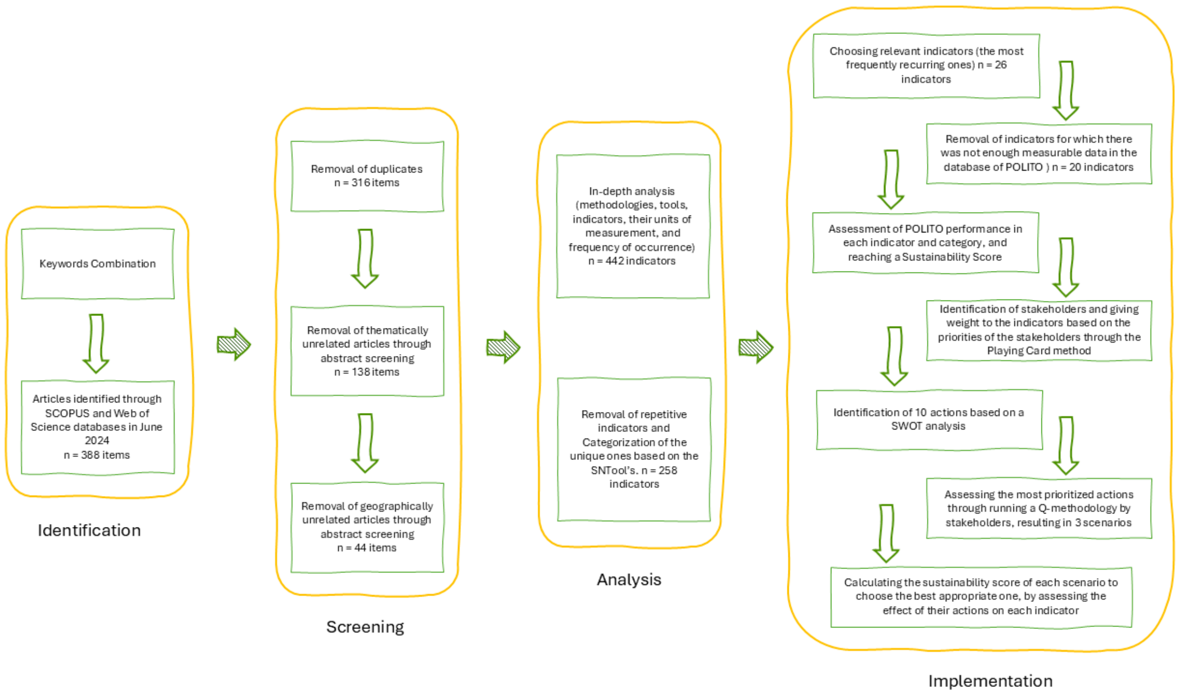


Figure 1. Flowchart of Methodology

3.1 Identification

To source the academic literature, search strings were formed using relevant keywords from the WEB of SCIENCE and SCOPUS databases. The search was designed to focus on three core themes: sustainability assessment, university campuses, and indicator frameworks, considering various related terms to ensure a comprehensive range of literature, yet with a focus on articles on university campuses, ensuring relevancy.

The beginning of the search time frame was considered 2015 to be aligned with the launch of the Sustainable Development Goals of the United Nations, and the end of it was June 2024 when this thesis started.

Finally, the following search string was applied to both databases:

TITLE (("sustainability" OR "sustainable") AND ("assessment" OR "framework" OR "evaluation" OR "monitoring" OR "tools" OR "rating" OR "index" OR "method" OR "methodology" OR "indicators" OR "standard" OR "metrics" OR "protocol" OR "certificate") AND ("campus" OR "university buildings" OR "high education institutions" OR "high education infrastructures" OR "high education buildings" OR "academic buildings")) OR KEY (("sustainability" OR "sustainable") AND ("assessment" OR "framework" OR "evaluation"

OR "monitoring" OR "tools" OR "rating" OR "index" OR "method" OR "methodology" OR "indicators" OR "standard" OR "metrics" OR "protocol" OR "certificate") AND ("campus" OR "university buildings" OR "high education institutions" OR "high education infrastructures" OR "high education buildings" OR "academic buildings")) AND ALL ("indicators" OR "KPIs" OR "Key Performance Indicators")

This search led to the identification of 388 peer-reviewed articles.

3.2 Screening

After the initial identification, duplicate articles were removed, leaving a total of 316. The next stage involved screening these articles based on their titles and abstracts to determine their relevance. For an article to be considered eligible, it needed to focus specifically on sustainability assessments of university campuses or buildings. All relevant details, including the authors, title, year, citations, geographical focus, thematic content, abstract, DOI, document type, and source, were recorded in an Excel spreadsheet for tracking purposes. As a result of this screening, 178 articles were excluded, leaving 138 that were deemed relevant.

For the in-depth analysis, the geographical scope of the articles served as the main selection criterion. This decision was rooted in the fact that sustainability practices are affected by local factors such as environmental conditions, cultural norms, economic circumstances, and social expectations (Violano & Cannaviello, 2023). Consequently, the analysis focused primarily on articles within the European context, yet considering global perspectives to not neglect the international standards, benchmarks, shared challenges, and learning from the global successful cases. Finally, this selection process produced a final set of 44 articles for detailed analysis, covering both European and global contexts.

3.3 Analysis

The last phase of the academic literature review involved analyzing the selected articles to identify and categorize the sustainability indicators they used. Each article was reviewed in depth, and a new Excel spreadsheet was created to document the following information:

- Categories and sub-categories: each indicator extracted from literature was assigned to a category and a sub-category according to the SN-Tool framework.
- Units of measurement: The measurement unit for each indicator was recorded. If the unit was not mentioned in the article, it referred to the original assessment tool that the article used for that indicator.
- Frequency of use: The frequency with which each indicator appeared across the selected sources was tracked to identify the most commonly used indicators. In total, 442 indicators were identified across the academic literature. After eliminating duplicates, 258 unique indicators were classified and analyzed.

3.4 Implementation

In this phase, a list of twenty frequently recurring indicators was selected from the literature, restricted to those for which measurable data were available in the Politecnico di Torino (PoliTo) Green Team database. This set was then used to carry out an illustrative implementation for the PoliTo campuses in the city of Turin. For each indicator, campus performance was calculated using Green Team data. Subsequently, a panel of eight stakeholder roles was asked to rank the indicators by their priority to derive a set of weights. The final indicators' scores and indicators' weights were normalized. Weights are used to understand the importance of each category of sustainability in the stakeholders' viewpoint and also to obtain the final sustainability score. The weight of each category would be the sum of the weights of indicators in that category. Then, a SWOT analysis was conducted to formulate a set of improvement actions, which were then ranked by the same stakeholder roles. The ranked actions were finally analysed using Q-sort to identify converging patterns in stakeholder preferences and to derive three strategic scenarios. From each scenario, the three most representative actions were chosen to test their application on the indicators set. After applying each scenario to the indicators, the amount of increase/decrease in the indicator value was calculated. The new values were then normalized, and the average of the indicator values in each category was taken for the value of that category. By multiplying each category's value by its assigned weight and then summing across categories, a sustainability score was obtained for each scenario. The scenario with the highest score was selected as the best. Because the real external stakeholders could not be reached easily, their viewpoints were approximated by AI, constructed through targeted prompting.

3.4.1 Stakeholder Identification

A long list of potentially relevant stakeholders for the PoliTo campuses was first compiled and then screened to distinguish between those with direct, specific interests in campus sustainability decisions (first-level stakeholders) and those with more general, indirect or institutional interests (second-level stakeholders). First-level stakeholders are expected to be directly exposed to the impacts of campus sustainability actions and to participate in, or be strongly affected by, related decision-making. Second-level stakeholders, by contrast, mainly play enabling, regulatory, advisory, or service roles, and are more difficult to frame as carriers of fully autonomous interests with respect to the campus. Table 1 summarises the stakeholder categories considered in the project, indicating their level, typology, and main resources or contributions.

Table 1. Stakeholders engaged in the project

Stakeholder	Level	Typology	Resource
University Administration	First	Special interests	Funding, policy support, strategic vision
Professors and Academic Staff	First	Special interests, Experts	Expertise, data analysis, innovative solutions
Student Unions or Representative Bodies	First	Special interests	Volunteering, ideas, awareness campaigns
Technical and Support Staff	First	Special interests, Experts	Operational insights, maintenance expertise
Local Government and Authorities	Second	General interest, Political, Bureaucratic	Regulations, funding, technical guidance
Private Sector: Energy Providers and Renewable Energy Companies	Second	Experts	Technology, Implementation and services, sponsorships
Private Sector: Transportation Providers	Second	General interest	services
Private Sector: Waste Management and Recycling Service Providers	Second	Experts	Technology, Implementation and services, sponsorships
Experts and Consultants: Environmental and Sustainability Consultants	Second	Experts	Specialized knowledge, tailored advice
Funding Agencies	Second	Experts	Grants, financial resources
Organizations Setting Standards for Sustainable Campus Certifications (e.g., LEED, ITACA Protocol)	Second	Special interests, Experts	Evaluation frameworks, certifications

3.4.2 Power-Interest Grid

After identifying the relevant stakeholder categories, they were positioned in a power–interest grid. The power–interest grid is a conceptual tool that maps stakeholders according to two dimensions: their relative ability to influence decisions (power) and their degree of concern or involvement in the outcomes (interest). Each stakeholder category was qualitatively scored on these two dimensions and plotted in a two-axis matrix. Grouping stakeholders within this matrix supports the definition of differentiated engagement and communication strategies by indicating which actors should be closely involved, kept satisfied, or simply kept informed during the implementation of sustainability actions. The resulting power–interest grid for the project is shown in Figure 2.

3.4.3 Indicators selection

The selection of indicators followed a structured procedure. In the first step, starting from the pool of indicators identified in the literature review, two parameters were considered in parallel: (i) the frequency with which each indicator recurred across the reviewed sources, and (ii) the availability of reliable, measurable data for that indicator in the PoliTo Green Team database. Recurrence in literature was used as the primary signal to reflect the state of the art; however, a limited number of indicators with lower recurrence were also retained when robust campus-level data were already available, and the indicator was deemed relevant for operationalisation. This combined filtering generated an initial shortlist, reported in Appendix 1.

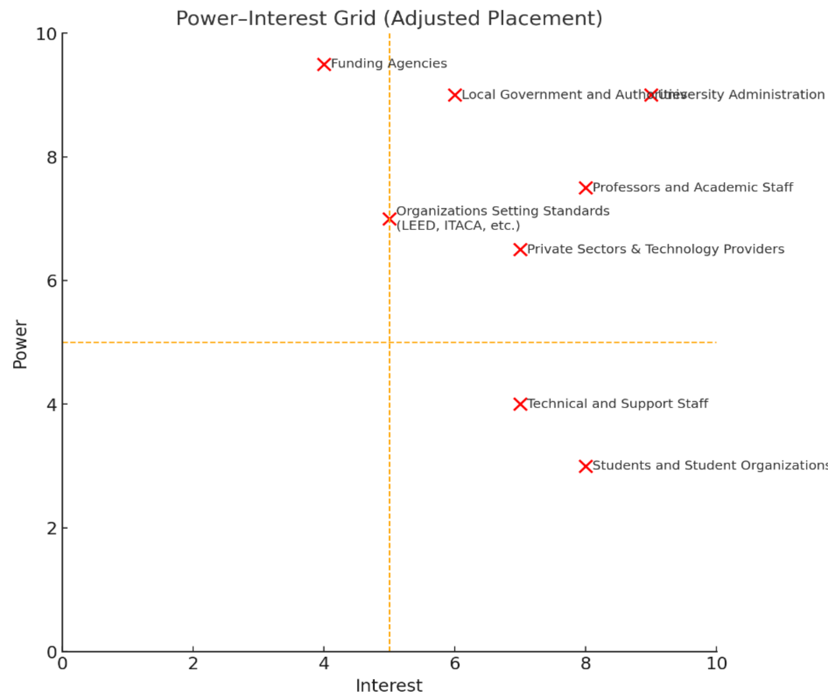


Figure 2. Power-Interest grid

In a second step, this shortlist was further reduced by applying additional criteria, namely: (i) measurability at the campus scale, (ii) coherence with the ITACA/SBTool structure and SNTool categories, and (iii) the need to keep the overall number of indicators manageable at the scale of the thesis. On this basis, a final set of twenty indicators was defined, summarised in Chapter 4. These twenty indicators constitute the operational backbone of the subsequent assessment, weighting exercises, and scenario analyses developed in the following sections.

3.4.4 Indicators Assessment

The next step was to measure POLITO's Performance for each of the 20 selected indicators. Benchmark values were obtained from the corresponding assessment tool (mostly UIGM and STARS) and, where necessary, calibrated to the climatic, urban, and organisational context of Turin, under the supervision of the Green Team. PoliTo's current value was then calculated using the database of the Green Team. The three values (benchmark 0, PoliTo, and benchmark 5) were finally visualised through simple bar charts for each indicator; these are presented and discussed in Chapter 4.

3.4.5 Normalization

At this stage, a performance score is assigned to the value or scenario of each indicator. This process is named “normalization”. Indicators are normalized in the interval (-1,+5), where -1 corresponds to a negative performance and +5 to an excellent performance. The better the performance, the higher the normalized score.

The values of quantitative indicators are normalized through linear functions of two kinds:

H.I.B. (Higher Is Better) and L.I.B. (Lower Is Better).

For each indicator, the normalization function depends on two parameters: the thresholds assigned to scores 0 and 5. These parameters are named “benchmarks,” and they define the value or scenario of the indicator associated with the “minimum acceptable performance” (score zero), and the “excellent and ideal performance” (score five).

For HIB (Higher is Better):

- If **Vi < V0** → Normalized = **-1**
- If **Vi = V0** → Normalized = **0**
- If **Vi ≥ V5** → Normalized = **5**
- If **V0 < Vi < V5** → Normalized = a linear value between **0…5**

The linear formula:

(Vi-V0)/(V5-Vi)*5

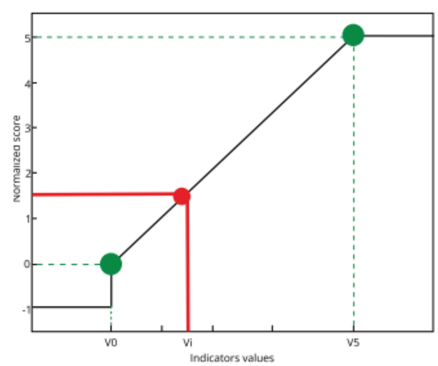


Figure 3.Higher is better normalization chart

For LIB (Lower is Better):

- If **Vi > V0** → Normalized = **-1**
- If **Vi = V0** → Normalized = **0**
- If **Vi ≤ V5** → Normalized = **5**
- If **V5 < Vi < V0** → Normalized = a linear value between **0…5**

The linear formula:

(V0-Vi)/(Vi-V5)*5

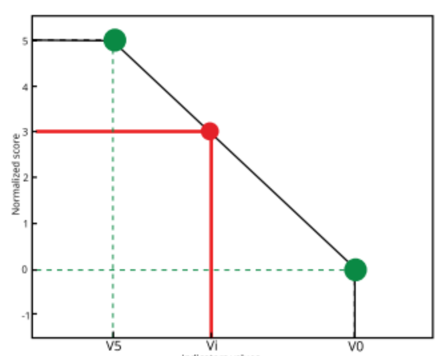


Figure 4.Lower is better normalization chart

Table 2. Normalized values in the range of -1 to 5

Indicator	Value	Normalized	Normalized Average in Category
Area on campus covered in planted vegetation	7.00	-1	-1
Open space area/total campus population	4.3	-1	
Annual heat energy consumption per square meter	51.77	4.89	2.65
Annual electricity consumption per square meter	57.88	4.07	
Amount of electricity generated/consumed from renewable energy sources per total amount of electricity generated/consumed, (E-Renewable/E-Total)	6.15	-1	
Water consumption (Potable water use per person)	16.09	4.8	3.65
Water conservation program and implementation	25	2.5	
Organic waste treatment	100	5	4
Inorganic waste treatment	100	5	
Availability of containers for sorted waste	0.3	2	
Bicycle parking spaces /total campus population	0.03	2.3	3.98
Total vehicles (cars and motorcycles)/total campus population	0.01	5	
Users using more sustainable commuting options	0.04	4.64	
Publicly shared facilities	0.75	1.9	2.29
Sustainability courses/total courses-subjects	54	2.7	
Percentage of university budget for sustainability efforts	31	5	5
Annual scope 1 & 2 greenhouse gas emissions from building operations per person	0.18	4.81	3.48
Annual greenhouse gas emissions (electricity) per square meter	14.3	3.57	
Annual greenhouse gas emissions (thermal) per square meter	10.4	5	
Area on campus for water absorption / total open area	5	0.54	

3.4.6 Assigning Weight to the Indicators

The Playing Card Method is a participatory approach used in sustainability assessments and multi-criteria decision-making to assign weights to indicators. It allows stakeholders to prioritize indicators by distributing limited resources (such as points or cards) among them. Each indicator is written on a separate card. Cards are arranged in order of importance, from the least to the most important, based on stakeholders' perspectives. If two indicators are equally important or closely related, they are placed horizontally (or in the same cell of the table), meaning they share the same ranking. If there is a significant difference in importance between two indicators, white cards are placed between them. The number of white cards reflects the degree of difference. More white cards indicate a larger gap in priority. At the end of the process, indicators fall into three possible arrangements:

Successive Placement → Indicators are ranked one after another with no white cards (gradual difference).

White Card Separation → Indicators are separated by one or more white cards (large difference in priority).

Shared Ranking → Two or more indicators are placed in the same cell (equal importance).

This method ensures a structured yet flexible way to capture stakeholder preferences and assign meaningful weights to sustainability indicators.

3.4.7 Playing Cards Method in This Thesis

In the absence of real stakeholders sitting around a table discussing how to assign weight and priority to the indicators, the Playing Cards Method was applied with the aid of AI. It was asked to play the role of each stakeholder one by one and come up with an individual Playing Cards table for each of them, reflecting their specific priorities and logic, while considering all the rules of the game. This involved using white cards to indicate a significant difference in priority (each white card adds 1 unit of priority) or the same cells for the same priorities. The position of each indicator in the table reflects its priority. For example, the students put the indicator "*Area on campus planted in green vegetation*" at the bottom of the table (the most prioritized) in row 15, so this indicator's score, based on the students' point of view, is 15. Figure 5 shows how the students arranged the cards. The logic behind this lies in their operational and day-to-day needs, which can be summarized as below:

- Most important factors that affect their daily tasks: daily well-being, health, green space, sustainable mobility, and living costs (water, energy, transport).
- Least important: budget indicator and institutional reporting (since these do not directly affect them).
- Middle priority: waste management (because it impacts their daily experience on campus, but less than mobility and comfort may create issues).
- Ultimately, climate change and GHG emissions have a symbolic importance for the student generation, and they are not directly bound to their urgent needs.

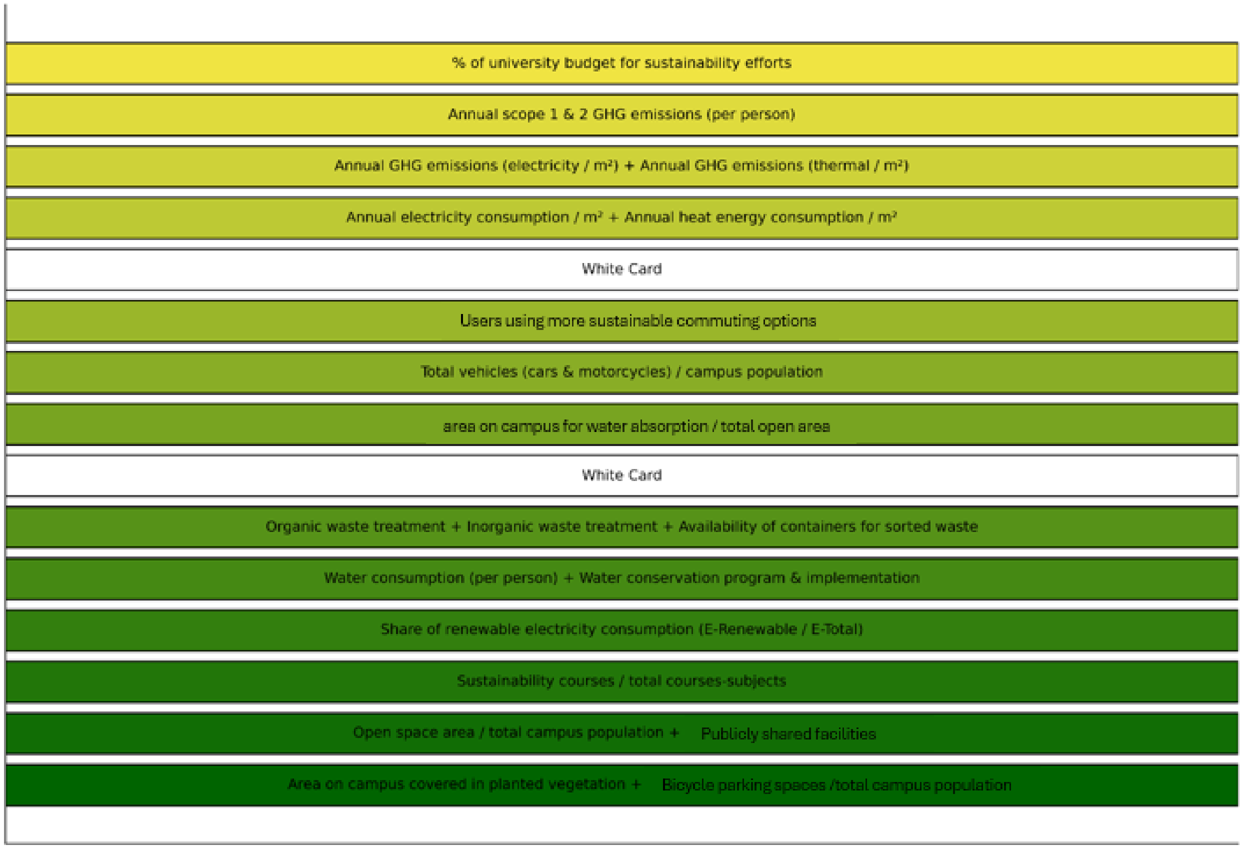


Figure 5. Playing cards ranking for the stakeholder "student"

The individual playing-card layouts for each stakeholder role are reported in *Appendix 3*.

In this research, eight stakeholder groups (University Administration, Students, Professors, Technical and Support Staff, Local Government, Standard-Setting Organizations, Private Sector & Technology Providers, and Funding Agencies) were identified.

To achieve a final consensus ranking:

- The ranking position of each indicator from each stakeholder was collected.
- Average ranks were calculated to establish an overall order.
- Based on the differences in average ranks, the following rule was applied:
  - If the indicators have equal ranks → they are placed in the same row (shared ranking).
  - If the difference > 1→ a white card is inserted between them. (Each one unit of difference is equal to one white card)
  - If the difference ≤ 1→ indicators were placed successively without a white card.

The rationale behind this arrangement is that it is proportional to the average rank difference among indicators. Many indicators increase their ranks gradually, while many others have equal values.

Table 3. Indicators' ranking

Indicator	Students	Funding Agencies	Local Government	Private Sector & Tech Providers	Professors	Standards Organizations	Technical & Support Staff	University Administration	Mean Rank
Area for water absorption / total open area	8	5	5	2	3	5	7	2	4.63
Area on campus covered in planted vegetation	15	4	4	1	3	4	6	1	4.75
Users using more sustainable commuting options	6	1	8	3	7	1	9	4	4.88
Open space area / total campus population	14	5	5	2	4	5	7	2	5.50
Publicly shared facilities	14	5	5	2	4	5	7	2	5.50
Total vehicles (cars & motorcycles)/ campus population	7	2	9	4	8	2	10	6	6.00
% of university budget for sustainability efforts	1	15	1	8	1	8	1	15	6.25
Bicycle parking spaces /total campus population	15	3	10	5	9	3	11	5	7.63
Sustainability courses/ total courses-subjects	13	15	3	7	15	7	2	3	8.13
Organic waste treatment	10	7	12	9	2	11	14	7	9.00
Inorganic waste treatment	10	7	12	9	2	11	14	7	9.00
Availability of containers for sorted waste	10	7	12	9	2	11	14	7	9.00
Water consumption (per person)	11	8	7	10	5	10	13	8	9.00
Water conservation program & implementation	11	8	7	10	5	10	13	8	9.00
Annual electricity consumption / m2	4	9	2	12	11	12	15	10	9.38
Annual heat energy consumption / m2	4	9	2	12	11	12	15	10	9.38
Annual GHG emissions (electricity/m2)	3	12	14	15	13	15	4	12	11.00
Annual GHG emissions (thermal/m2)	3	12	14	15	13	15	4	12	11.00
Share of renewable electricity consumption (E-renewable / E-total)	12	11	13	13	12	13	5	9	11.00
Annual scope 1 & 2 GHG emissions (per person)	2	13	15	16	14	16	3	13	11.50

This procedure ensures that the final table not only represents the aggregated priorities of all stakeholders but also mirrors the dynamics of a real participatory process.

Figure 6. Final consensus

Area for water absorption / total open area
Area on campus covered in planted vegetation
Users using more sustainable commuting options
Open space area / total campus population + Publicly shared facilities
Total vehicles (cars & motorcycles)/ campus population
% of university budget for sustainability efforts
White Card
Bicycle parking spaces /total campus population
Sustainability courses/ total courses-subjects
Organic waste treatment + Inorganic waste treatment + Availability of containers for sorted waste + Water consumption (per person) + Water conservation program & implementation
Annual electricity consumption / m2 + Annual heat energy consumption / m2
White Card
Annual GHG emissions (electricity/m2) + Annual GHG emissions (thermal/m2) + Share of renewable electricity consumption (E-renewable / E-total)
Annual scope 1 & 2 GHG emissions (per person)

3.4.7.1 Non-normalized weight

This represents the raw score assigned to each indicator based on the number of cards it receives. It is simply the total number of cards allocated to an indicator before any adjustments are made. However, this raw score does not yet account for the total distribution of all weights.

3.4.7.2 Normalized Weight

This adjusts the non-normalized weight so that all weights sum to a standard value, typically 100% (or 1). It helps compare indicators on a relative scale rather than absolute card counts. For example, if an indicator has a non-normalized weight of 5, and the total of all non-normalized weights is 44, then:

Normalized Weight = (5/44) × 100 = 11.36%

This means the indicator holds 11.36% of total importance.

3.4.7.3 Total

Total is the sum of normalized weights multiplied by the Number of cards (should be 100% or 1.0, depending on how it is calculated). It serves as a check to ensure the distribution is complete.

Table 4. Indicators final weights

indicators and white cards (Final Consensus)	Number of cards	Position	Non-normalized weights	Normalized weights	Total
Area for water absorption / total open area	1	1	1.0	0.44	0.44
Area on campus covered in planted vegetation	1	2	2.0	0.88	0.88
Users using more sustainable commuting options	1	3	3.0	1.32	1.32
Open space area / total campus population + Publicly shared facilities	2	4,5	4.5	1.98	3.96
Total vehicles (cars & motorcycles) / campus population	1	6	6.0	2.64	2.64
Percentage of university budget for sustainability efforts	1	7	7.0	3.08	3.08
White Card	1				
Bicycle parking spaces /total campus population	1	9	9.0	3.96	3.96
Sustainability courses / total courses-subjects	1	10	10.0	4.41	4.41
Organic waste treatment + Inorganic waste treatment + Availability of containers for sorted waste+Water consumption (per person) + Water conservation program & implementation	5	11,12,13,14,15	13.0	5.73	28.63
Annual electricity consumption / m^2 + Annual heat energy consumption / m^2	2	16,17	16.5	7.27	14.54
White Card	1				
Share of renewable electricity consumption (E-Renewable / E-Total)+Annual GHG emissions (electricity / m^2) + Annual GHG emissions (thermal / m^2)	3	19,20,21	20.0	8.81	26.43
Annual scope 1 & 2 GHG emissions (per person)	1	22	22.0	9.69	9.69
SUM	**21**	**227**			**100.00**

3.4.7.4 Final Sustainability Score

To obtain the final sustainability score, having calculated the weight and the normalized score of each indicator, we need to calculate the weight and the normalized score of categories too. To that, it is needed to take the average of the indicators' scores for the category's score and the sum of the indicators' weights for the category's weight. The category's weighted score, then, is the multiplication of these two numbers, and the final sustainability score is the sum of all categories' weighted scores.

Table 5. Categories' final weights

Indicator	POLITO's Performance	Normalized Performance	Normalized Weight	Category's Score	Category's Weight	Category's Weighted Score
Area on campus covered in planted vegetation	7.00	-1.0	0.88	-1	2.86	-2.86
Open space area/total campus population	4.3	-1.0	1.98			
Annual heat energy consumption per m^2	51.77	4.9	7.27	2.65	23.35	61.96
Annual electricity consumption per m^2	57.88	4.1	7.27			
Amount of electricity generated/consumed from renewable energy sources per total amount of electricity generated/consumed, (E-Renewable/E-Total)	6.15	-1.0	8.81			
Water consumption per capita	16.09	4.8	5.73	3.65	11.46	41.83
Water conservation program and implementation	25	2.5	5.73			
Organic waste treatment	100	5.0	5.73	4	17.19	68.76
Inorganic waste treatment	100	5.0	5.73			
Availability of containers for sorted waste	0.3	2.0	5.73			
Bicycle parking spaces /total campus population	0.03	2.3	3.96	3.98	7.92	31.52
Total vehicles (cars and motorcycles)/total campus population	0.01	5.0	2.64			
Users using more sustainable commuting options	0.04	4.6	1.32			
Publicly shared facilities	0.75	1.9	1.98	2.3	6.39	14.70
Sustainability courses/total courses-subjects	54	2.7	4.41			
Percentage of university budget for sustainability efforts	31	5.0	3.08	5	3.08	15.40
Annual scope 1 & 2 greenhouse gas emissions from building operations per person	0.18	4.8	9.69	3.48	27.75	96.57
Annual greenhouse gas emissions (electricity) per m^2	14.3	3.6	8.81			
Annual greenhouse gas emissions (thermal) per m^2	10.4	5.0	8.81			
Area on campus for water absorption / total open area	5	0.5	0.44			
			100.00		100.00	3.28

3.4.8 SWOT Analysis as a Synthesis Tool

SWOT analysis was used as a qualitative synthesis step to complement the quantitative indicator-based assessment. Building on the results of the stakeholder weighting and performance evaluation, a SWOT matrix was constructed to organise key internal factors (strengths and weaknesses related to campus performance, governance, and facilities) and external factors (opportunities and threats linked to policies, funding schemes, urban constraints, and climate trends). This exercise provided a structured bridge between the numerical diagnosis and the formulation of actions and strategies by highlighting the conditions that may support or hinder the transition towards a more sustainable campus.

3.4.9 Q-sort Methodology

Q-sort is a mixed-method research approach designed to systematically explore subjective viewpoints. Participants are provided with a set of statements (Q-set) and are asked to rank them along a continuum from “most important/agreeable” to “least important/agreeable”, following a forced distribution. The resulting Q-sorts can then be analysed, for instance, through factor analysis or by comparing score patterns, to identify clusters of shared perspectives.

In this thesis, Q-sort was used to prioritise strategic actions derived from the SWOT analysis. A set of ten action statements was formulated, each corresponding to a possible line of intervention for improving campus sustainability (Appendix 4). These statements were then used as the Q-set. Eight stakeholder roles were again simulated through AI-based profiles, and each role was asked to complete a Q-sort by arranging the ten actions from highest to lowest priority according to its own perspective, under a forced quasi-normal distribution. The resulting Q-sorts were subsequently compared to identify converging trends in priorities and to support the extraction of a limited number of overarching strategies, as discussed in Chapter 4.

The Q-sorts were first intercorrelated using the Pearson product–moment coefficient, resulting in an 8×8 correlation matrix. On this matrix, a centroid factor analysis – the most commonly used extraction technique in Q-methodology – was applied to identify shared patterns of prioritisation among the stakeholders.

3.4.10 Pearson Correlation Matrix

To examine how similarly or differently the stakeholders prioritised the ten sustainability strategies in the Q-sort exercise, a Pearson correlation matrix was computed between all pairs of Q-sorts. Each correlation coefficient ranges from −1 to +1, where values close to +1 indicate that two stakeholders ranked the strategies in a very similar way (perfect positive correlation), values around 0 indicate no clear linear relationship, and values close to −1 indicate opposite prioritisation patterns (perfect negative correlation). The matrix, therefore, provides a synthetic picture of convergence and divergence among stakeholder viewpoints and forms the basis for identifying clusters of shared perspectives.

3.4.11 Extracting Strategies

For each extracted factor, an idealised Q-sort (factor array) was computed, indicating the position of each action on the −2 to +2 scale from "least" to "most representative". These factor arrays were visualised as pyramids and later interpreted to characterise the main strategic viewpoints emerging from the stakeholder panel.

3.5 Strategy impact assessment

After identifying three strategic viewpoints through the Q-sort analysis, an impact assessment was carried out to compare their potential contribution to campus sustainability. For each factor, the three actions with the highest priority in the factor array were selected.

In the first step, the links between each action and the twenty indicators were mapped in an action–indicator matrix. For each action, its expected effect on the relevant indicators was estimated, starting from the current baseline values. For example, an action aimed at increasing on-site photovoltaic generation was translated into a percentage increase in the share of renewable electricity, a corresponding reduction in electricity purchased from the grid, and a decrease in electricity-related greenhouse-gas emissions.

On this basis, for each indicator $i$and each strategy s, a new "after-implementation" value $V_i^s$was obtained by applying the estimated percentage change(s) associated with the three actions included in that strategy to the baseline value V_i^0. Indicators not directly affected by any of the actions retained their baseline values.

In a second step, these updated indicator values were converted into normalised performance scores using the same H.I.B./L.I.B. functions and benchmark values (0 and 5) described in Section 3.4.5. Let P_i^sdenote the normalised performance of the indicator $i$under strategy $s$on the [−1, 5] scale. For each SNTool/ITACA category c, a category score $P_c^s$was then computed as the arithmetic mean of the scores of the indicators belonging to that category:

$$P_c^s = \frac{1}{n_c} \sum_{i \in c} P_i^s$$

where $n_c$is the number of indicators in category c.

Finally, the category scores were aggregated into a single **strategy sustainability score** by applying the category weights derived from the stakeholder-based weighting procedure (Section 3.5). Let $w_c$be the normalised weight of category c(with $\sum_c w_c = 100$); the overall score for strategy s, S^s, is given by:

$$S^s = \sum_c w_c \cdot P_c^s$$

In this way, each strategy receives a composite score on the same [−1, 5] scale used for the baseline assessment, reflecting both its impact on indicator performance and the relative importance attributed by stakeholders to the different sustainability categories. The strategy with the highest aggregated score is interpreted as the most effective option within the assumptions of this framework.

4 Results

4.1 Year of Publication

This section presents the literature review results, including categorizing the screened papers by the year of publication, the geographical area, and the thematic focus.

Figure 2 shows the articles' distribution according to the year of publication. This demonstrates a growing interest in sustainability issues related to university campuses. The decline in 2024 could be linked to the timeframe of this research, which does not cover the whole year, but until June 2024.

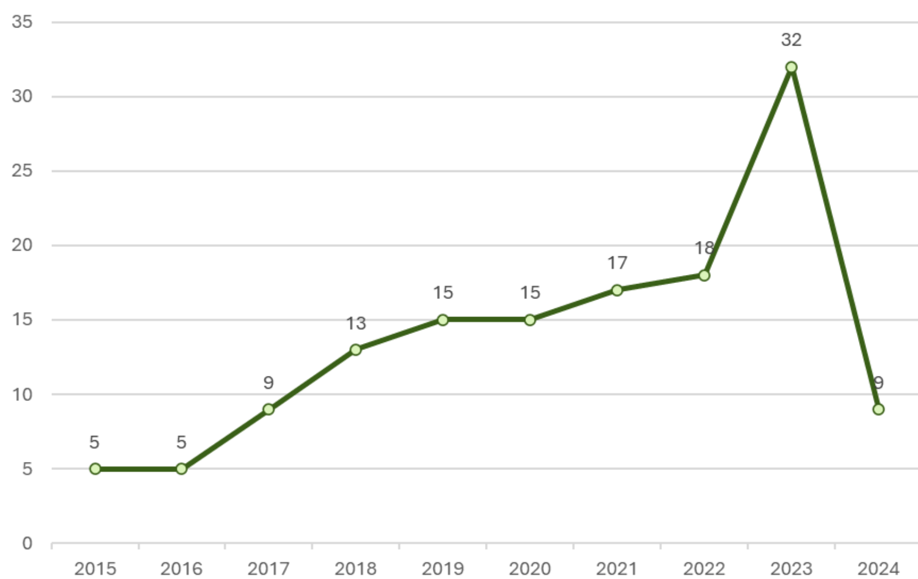


Figure 7. Distribution of articles by year of publication

4.2 Geographical Area

As mentioned in the methodology section, the second screening was to sift and sort the 138 articles deemed thematically relevant to the analysis, based on the Geographical area in which their empirical data was gathered, and the research was conducted. Figure 3 shows the distribution of articles by their geographical area. As illustrated, Asia is the biggest producer of literature over the time limit of this research, contributing to 46% of the articles, followed by Europe and South America with 19% and 14% of the articles, respectively. Additionally, 12% of the academic articles adopt a global perspective.

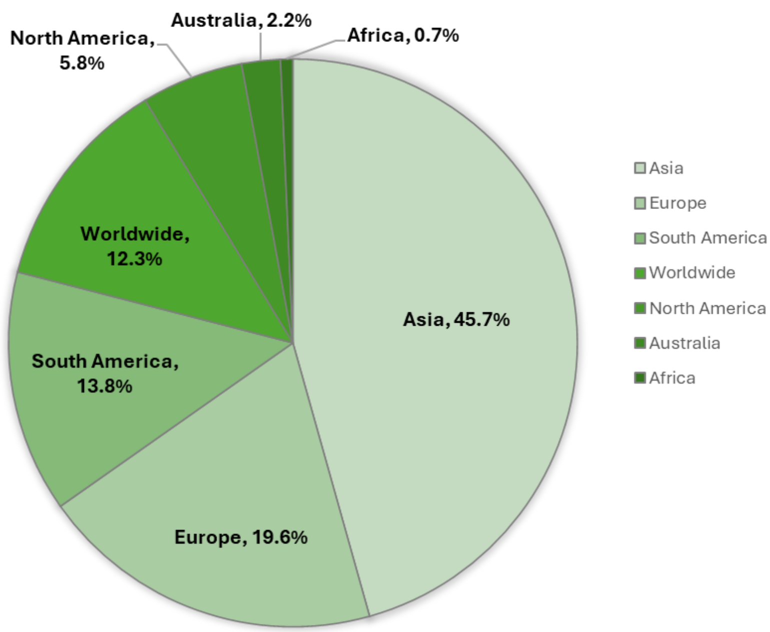


Figure 8. Distribution of articles by geographical area

4.3 Theme

A third analysis was also conducted to categorize the 138 screened articles based on their themes. The SNTool framework (iiSBE Italia, 2023) was the reference for this categorization. Its categories are as follows:

- A- Use of Land and Biodiversity
- B- Energy
- C- Water
- D- Solid Waste
- E- Environmental Quality

- F- Transportation and Mobility
- G- Social Aspects
- H- Economy
- I- Climate Change: mitigation and adaptation
- J- Governance

Figure 4 demonstrates the number of articles fitting in each category. Since most articles adopt a comprehensive approach in their sustainability assessment, there is not such a significant difference among most criteria. Still, three categories emerge as the most addressed: Energy, Climate change mitigation and adaptation, and social aspects, aligning with two pillars of sustainability assessment topics; People and Plant. While the third pillar, Profit which is represented by the Economic category here is the least regarded, appeared in only 42 articles. However, it is still justifiable. Firstly, because in comparison with education, research, or social involvement economy is not the first priority of universities in general. Secondly, since many of the HEIs, regarded in this research, are state universities, their financial stability is for granted through the state budgets. Finally, because there is not a standard methodology to assess financial sustainability (Cernostana, 2018).

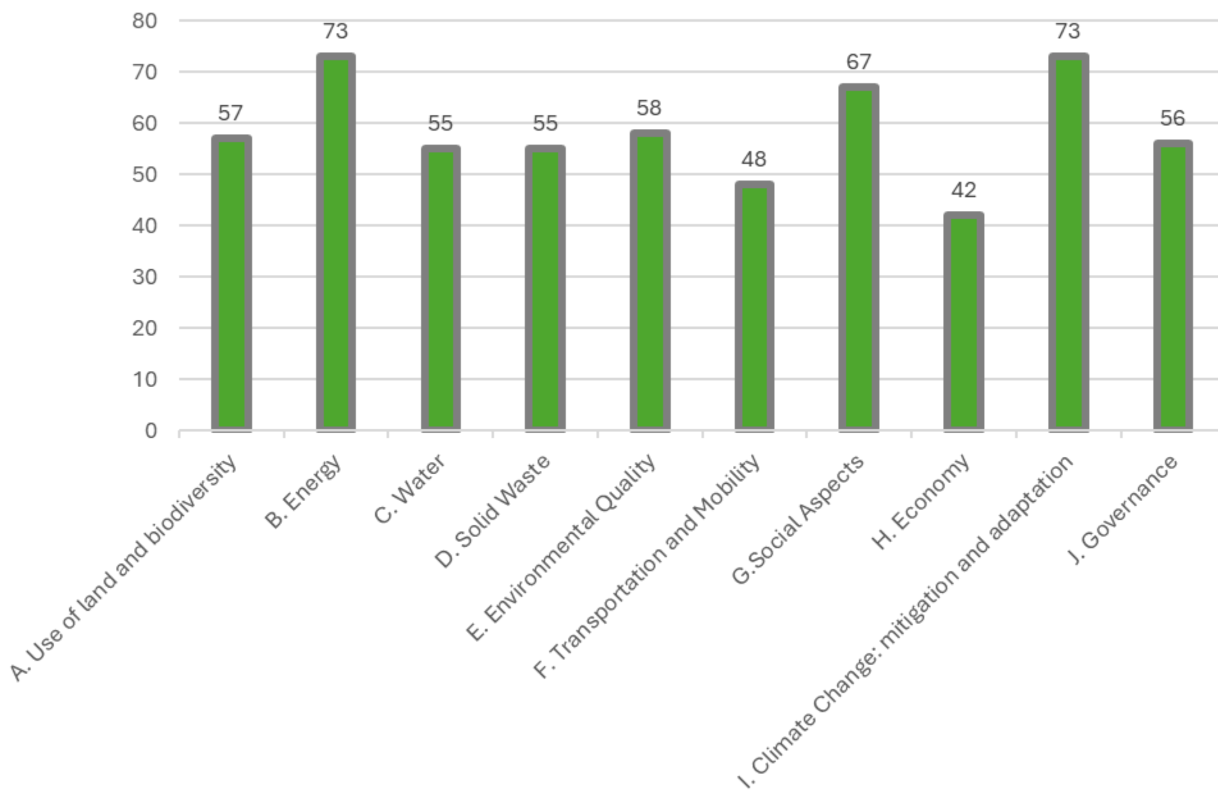


Figure 9. Distribution of articles according to the SNTool's categories

4.4 Methodological Approach

The next screening was done to understand the methodological approach that the final 44 articles had in their assessment. The prevailing methodology was qualitative with almost half of the articles (21 articles) representative. Mixed and Quantitative were adopted by 11 and 12 articles, respectively. Some articles mentioned their methodology somewhere in the abstract or in the body. For those that did not mention, the data type of article was considered. If the whole data (variables) that the article used consisted of numerical values, representing real amounts that can be added, subtracted, divided, etc. then the methodology would be quantitative. Otherwise, if the data was Categorical, representing groupings of some kind, the methodology would be qualitative. Considering that the categorical data is sometimes recorded as numbers, but the numbers represent categories rather than actual amounts of things. For example, yes or no outcomes (binary values). Finally, the methodology would be mixed if the article used both kinds of data.

Another scale to decide on the methodological approach of articles is the tools they use. According to Bihari Singh et al (2023), "Three categories separate these tools: quantitative, qualitative, and mixed techniques." Based on this categorization, tools such as GMID (Graz Model for Integrative Development), AMAS (Adaptable Model for Assessing Sustainability), SAQ (Sustainability Assessment Questionnaire), STAUNCH (Sustainability Tool for Auditing Universities Curricula in Higher Education), and ACUPCC (American College & University Presidents' Climate Commitment) are placed in the Qualitative category. On the Other hand, tools such as Ecological Footprint Analysis (EFA), Graphical Assessment of Sustainability in Universities Tool (GASU), Three-Dimensional University Ranking (TUR), uD-SiM Model, and Green Report Card are quantitative methods. Finally, mixed methods can be named University Environment Management System (UEMS), and Sustainability Tracking, Assessment, and Rating System (STARS).

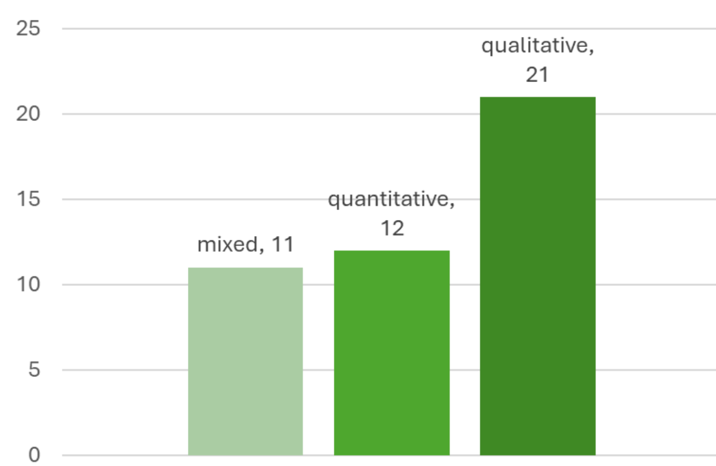


Figure 10. Methodological approach of the final 44 articles

4.5 Sustainability Assessment Tools

Finally, the last screening was to determine the tools employed by the 44 articles. According to that, Stars, with 12 articles represented, was the most employed tool, followed by UIGM (UI Green Metric), with 10 articles in second place. The third most frequent tools were SAQ (Sustainability Assessment Questionnaire) and GASU (Graphical Assessment of Sustainability in University), with 6 indicative articles out of 44 articles reviewed.

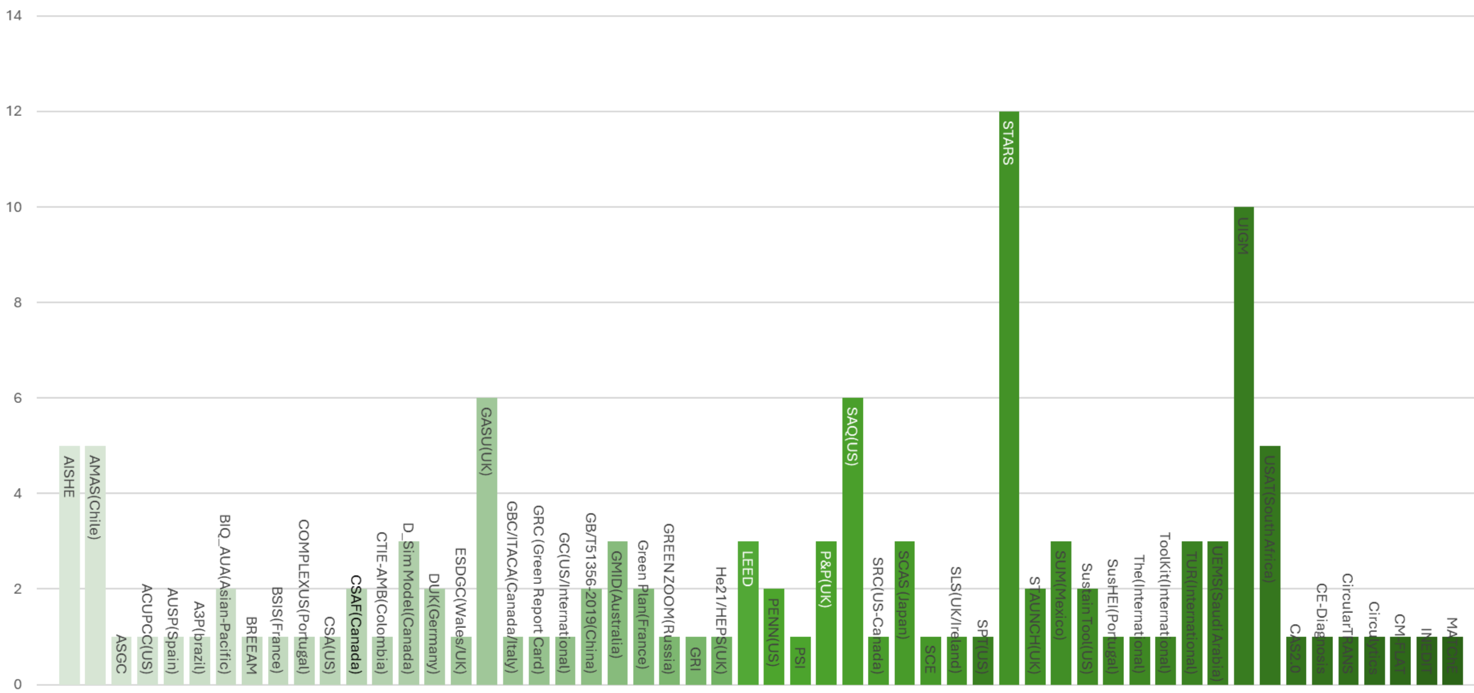


Figure 11. Distribution of tools used by the 44 article

After screening the articles, in-depth analysis was solely focused on the 44 academic articles with global and European geographical domains. The articles selected for in-depth analysis are reported and coded in Table 1.

Table 6. Articles selected for in-depth analysis (44 articles)

Code	Title	Authors
A1	What does environmentally sustainable higher education institution mean?	(Freidenfelds et al., 2018)
A2	A Smart Campus' Digital Twin for Sustainable Comfort Monitoring	(Zaballos et al., 2020)
A3	Assessing the impacts of higher education institutions on sustainable development-an analysis of tools and indicators	(Findler et al., 2019)

A4	A review of empirical data of sustainability initiatives in university campus operations	(Amaral et al., 2020)
A5	A clustering approach for classifying universities in a world sustainability ranking	(Perchinunno & Cazzolle, 2020)
A6	Analyzing research trends of universities' carbon footprint: An integrated review	(Ma et al., 2023)
A7	Campus sustainability research: indicators and dimensions to consider for the design and assessment of a sustainable campus	(Dawodu, Dai, et al., 2022)
A8	Sustainability Assessment of Higher Education Institutions: A Systematic Literature Review	(Singh et al., 2023)
A9	Assessment tools' indicators for sustainability in universities: an analytical overview	(Alghamdi et al., 2017)
A10	Comparative analyses of sustainable campuses as living laboratories for managing Environmental quality	(KılkıŞ, 2017)
A11	Sustainable evaluation systems in higher education institutions	(Mendoza-Cavazos, 2016)
A12	Air quality monitoring on university campuses as a crucial component to move toward sustainable campuses: An overview	(Ramírez et al., 2023)
A13	Analysis of financial sustainability indicators of higher education institutions on foreign direct investment Empirical evidence in OECD countries	(Alshubiri, 2021)
A14	A comparison on the evaluation standards of sustainable campus between China and America	(Zhu et al., 2022)
A15	A sustainability evaluation framework for Science and Technology Institutes: An international comparative analysis	(Lima et al., 2016)
A16	True green and sustainable university campuses? Toward a clusters approach	(Sonetti et al., 2016)
A17	Strategic Environmental Assessment in higher education: Portuguese and Brazilian cases	(Ramos et al., 2015)
A18	Quantification of interlinked Environmental footprints on a sustainable university campus: A nexus analysis perspective	(Gu et al., 2019)
A19	Sustainability assessment tools for higher education: An empirical comparative analysis	(Berzosa et al., 2017)
A20	Carbon footprint in Higher Education Institutions: a literature review and prospects for future research	(Valls-Val & Bovea, 2021)
A21	Are distance higher education institutions sustainable enough? - A comparison between two distance learning universities	(Casado-Aranda et al., 2020)
A22	Assessing sustainability and its performance implications: An empirical analysis in Spanish public universities	(Blasco et al., 2019)

A23	A framework for implementing and reporting United Nations sustainable development goals in Spanish higher education institutions	(González-Torre & Suárez-Serrano, 2022)
A24	Adequacy of existing circular economy assessment tools for higher education institutions	(Valls-Val et al., 2023)
A25	Justification of educational institutions Environmental reconstruction in accordance with the UI Green Metric rating and Environmental standards	(Tichomirova & Sukhinina, 2021)
A26	Key Performance Indicators for Smart Energy Systems in Sustainable Universities	(Kifor et al., 2023)
A27	The Building Certification System-A Tool of Sustainable Development of University Campuses	(Hanga-Fărcaş et al., 2023)
A28	Sustainability Assessment Tools in Higher Education Institutions: Comprehensive Analysis of the Indicators and Outlook	(Mapar et al., 2022)
A29	Sustainable mobility patterns to university campuses: Evaluation and constraints	(Ribeiro et al., 2020)
A30	Closing the loop: A case study on pathways for promoting sustainable waste management on university campuses	(Jakimiuk et al., 2023)
A31	Measuring financial sustainability of private higher education institutions	(Cernostana, 2018)
A32	The classification of the university for type of campus setting in a world sustainability ranking	(Montrone et al., 2020)
A33	Environmental performance of universities: Proposal for implementing campus urban morphology as an evaluation parameter in Green Metric	(Marrone et al., 2018)
A34	Envisioning green solutions for reducing the ecological footprint of a university campus	(Genta et al., 2019)
A35	Reducing the carbon footprint in college mobility: The car commuters' perspective in an Italian case study	(Crotti et al., 2022)
A36	Smart digital campus UniTO: data gathering and visualisation to support sustainability and indoor comfort	(Accardo et al., 2023)
A37	Developing a practical framework of sustainability indicators relevant to all higher education institutions to enable meaningful international rankings	(Horan & O’regan, 2021)
A38	“Reaching for the STARS”: A Collaborative Approach to Transparent Sustainability Reporting in Higher Education, the Experience of a European University in Achieving STARS Gold	(Kirrane et al., 2020)
A39	Life cycle assessment of higher education institutions – method and case study	(Jürgens et al., 2023)

A40	Analysis of the energy usage in university buildings: The case of Aristotle university campus	(Pappi et al., 2015)
A41	Multi-Dimensional Assessment of a Bavarian and Czech University: A Case Study of Sustainability Implementation	(Herzner & Hommerová, 2022)
A42	Assessment of Sustainability Governance in Higher Education Institutions-A Systemic Tool Using a Governance Equalizer	(Niedlich et al., 2020)
A43	Performance based core sustainability metrics for university campuses developing towards climate neutrality: A robust PICSOU framework	(Jiang & Kurnitski, 2023)
A44	Imagining a Carbon Neutral University	(Violano & Cannaviello, 2023)

4.6 Indicators

Through the in-depth analysis of the 44 articles, 442 indicators were identified and classified according to the categories and sub-categories of SNTool (iiSBE Italia, 2023). After removing the repetitives 258 indicators remained, which were classified as follows: 8 indicators corresponded to the "Use of Land and Biodiversity" category, 46 indicators to the "Energy" category, 10 indicators to the "Water" category, 20 indicators to the "Solid Waste" category, 2 indicators to the "Environmental Quality" category, 17 indicators in the "Transportation and Mobility" category, 66 indicators in the "Social Aspects" category, 30 indicators in the "Economy" category, 22 indicators to the "Climate Change: mitigation and adaptation" category, and 29 indicators to the "Governance" category. Finally, 8 indicators did not fit into any of the proposed categories, which were assigned to a new category named "others". From these results, it is evident that similarly to the main themes of the screened articles, Energy accompanied by climate change mitigation, and social aspects emerge as the main analytical focus in academic literature. The only contradiction with the main themes is the "economy" category, which, although it had the minimum number of articles represented, has the third largest number of indicators. This contradiction is justifiable since almost all the economic indicators were unique, and there were no repetitive or duplicate indicators to be eliminated, while in other categories, there were many repetitive indicators, which, after the removal, resulted in the number of indicators mentioned above.

Table 7. Indicators retrieved from academic articles

No.	Category	Sub-Category	Indicator	Unit	Reference
1	A-Use of Land and Biodiversity	A.1 Use of Land	Area of protected reserves and sites	m2	A10
2		A.2 Green Urban Areas	Total number of trees on campus	Number	A10
3			open space area/total area	%	A5, A22, A33
4			area on campus covered in trees	m2	A5, A22, A33

5			area on campus covered in planted vegetation	m2	A5, A22, A33
6			percentage of natural and virgin areas used to build the campus	%	A 33
7		A.3 Biodiversity and ecosystems	Landscape management	%	A21, A38
8			Biodiversity	Yes/No	A21, A38
9	B-Energy	B1. Energy infrastructure	Self-sufficient heat energy amount	%	A1
10			Self-sufficient electricity amount	%	A1
11			Energy-efficient appliances are replacing conventional appliances	Yes/No	A22
12			smart building implementation	Yes/No	A5, A22, A33
13			Renovation of the areas with significant energy losses	%	A26
14			Type I * energy-efficient equipment	%	A26
15			Type II *** energy efficient equipment	%	A26
16			Equipment automation Smart energy solutions' implementation (Automation) to reduce energy losses	%	A26
17			Balance between supply and demand	%	A26
18			Energy-efficient appliances usage	%	A5, A33
19			Building certified space	%	A37
20		B.2 Energy consumptions	Heat energy produced/consumed per square meter	MWh/time unit/m2	A1
21			Heat energy produced/consumed per administrative and scientific personnel	MWh/time unit/ number of personnel	A1
22			Electricity produced/consumed per square meter	kWh/time unit/m2	A1
23			Electricity produced/consumed per student	kWh/time unit/ number of students	A1
24			Electricity produced/consumed per administrative and scientific personnel	MWh/time unit/ number of personnel	A1
25			Annual energy consumption	MWh and MWh/student	A3, A10, A18
26			Building energy consumption	Btu/m2	A21, A38
27			Indirect (supply chain) energy consumption (water supply energy	MWh	A18

			consumption, wastewater treatment energy consumption, waste disposal energy consumption)		
28			Total electricity usage/total campus population	kWh per person	A5, A22, A26, A33, A43
29			Energy report to assess areas with higher energy losses and optimal improvement measures	Yes/No	A26
30			Reduce heat demand (by 50%)	%	A26
31			Report assessing and reducing energy conversion losses	Yes/No	A26
32			Report assessing and reducing storage losses of the energy system	Yes/No	A26
33			Site energy use per unit of floor area	kWh/m2/y	A26
34			Energy used/floor space	kWh/m3	A26
35		B.3 Renewable energy	Heating energy efficiency	%	A26
36			Cooling energy efficiency	%	A26
37			Reduce energy consumption	kWh/m2/year	A26
38			Increase the energy efficiency	kWh/m2/year	A26
39			Heating use	kWh/pers. a	A1, A43
40			Primary energy use	kWh/m2	A43
41			Grid electricity	kWh	A37
42			On-site fossil fuels	kWh	A37
43			Energy source per unit area	kWh/m2	A37
44			Energy source per student and staff	kWh/Fulltime Equivalent	A37
45		B1. Energy infrastructure	Building Energy Efficiency	%	A44
46		B.3 Renewable energy	Amount of heat generated/consumed from renewable energy sources per total amount of heat energy generated/consumed	%	A1
47			Amount of electricity generated/consumed from renewable energy sources per total amount of electricity generated/consumed,	%	A1
48			Average share of renewable energy	%	A10, A21, A26, A38, A44
49			number of renewable energy sources on campus	Number	A5, A22, A26, A33

50			the ratio of renewable energy produced/energy usage	%	A5, A22, A26, A33
51			Total of renewable energy purchased from the grid (for example: electricity from RES with green tariffs and gas)	%	A26
52			The share of fluctuating RES (for example solar, wind, wave, etc.)	%	A26
53			Renewable energy export	kWh/m2	A43
54			On-site renewable electricity	kWh	A37
55	C- Water	C.2 Water consumption	use of water-efficient appliances	%	A5, A22, A33
56	C. Water	C.2 Water consumption	Cold/hot water consumption per square meter	m3 /time unit/m2	A1
57			Cold/hot water consumption per student	m3 /time unit/number of students	A1
58			Cold/hot water consumption per administrative and scientific personnel	m3 /time unit/number of personnel	A1
59			Annual water consumption	m3 and m3/student	A3, A10, A18, A43
60			Water use compared to a baseline	m3/person, m3/m2, m3/hectares	A21, A38
61			Annual water reduction target	m3/year	A10
62			WFP2: associated with energy (WFP associated with direct energy consumption, WFP associated with energy needed for the water supply and wastewater treatment)	m3	A18
63			WFP3: associated with food procurement (meat, vegetable/fruit, dry stored/frozen)	m3	A18
64			Treated water consumed	m3	A5, A22, A33
65	D- Solid Waste	D.1 Solid waste collection infrastructure	Sewerage disposal	Yes/No	A5, A22, A33
66	D. Solid Waste	D.2 Solid waste management	Availability of containers for sorted waste	number /m2	A1
67		D.2 Solid waste management	Annual waste generated	Tonnes and Tonnes/student	A3, A10
68			Average diversion (recycling) rate	%	A1, A10

69			Hazardous chemicals usage in labs	Tonnes	A10, A43
70			organic waste treatment	Yes/No	A5, A22, A33
71			inorganic waste treatment	Yes/No	A5, A22, A33
72			toxic waste handled	Yes/No	A5, A22, A33
73			efficiency for compost=total amount of biodegradable waste produced in one day divided by the total amount of waste generated on campus in one day	%	A26
74			Efficiency for plastic=	%	A26
75			Waste minimization and diversion	Yes/No	A21, A38
76			Construction and demolition waste diversion	%	A21, A38
77			Hazardous waste management	Yes/No	A21, A38
78			Recycled waste streams	kg	A43
79			Electronic waste	€/pers. a	A43
80			Organic/food waste	kg/pers. a	A43
81			Composting of organic waste	Tonnes	A10
82			Toxic waste treatment	Yes/No	A5, A33
83			Recycling program for university waste	Yes/No	A5, A22, A33
84			program to reduce the use of paper and plastic on campus	Yes/No	A5, A22, A33
85	E- Environmental Quality	E.1 Air quality	Outdoor air quality	%	A21, A38
86	E. Environmental Quality	E.1 Air quality	Indoor air quality, category I and II spaces	%	A2, A43
87	F- Transportation and Mobility	F.1 Performance of mobility service	Distance traveled to HEI (classified by mode of transport – personal cars, public transport, bicycles, etc.)	km/time unit	A1
88	F. Transportation and Mobility	F.1 Performance of mobility service	Average share of SOV (single occupancy vehicle) commuters	%	A10
89			Average share of public transport	%	A10
90			Total vehicles (cars and motorcycles)/total campus population	%	A5, A22, A33
91			shuttle service	Yes/No	A5, A22, A33
92			Parking area/total campus area	%	A5, A22, A33
93			Campus fleet	%	A21, A38

94			Student commute modal split (percentage of students that use more sustainable modes)	%	A21, A38
95			Employee commute modal split	%	A21, A38
96			Ratio of parking space (including underground parking) per person	m2/person	A43
97		F.2 Green mobility	Distance traveled by environmentally friendly vehicle (including electric cars, bikes, etc.) against total HEI distance	%	A1
98		F.2 Green mobility	Total number of zero-emission vehicles/total campus population	%	A5, A22, A33
99			Zero-emission vehicles (ZEV) policy on campus	Yes/No	A5, A22, A33
100			Transportation program designed to limit or decrease the parking area on campus for the last 3 years	Yes/No	A5, A22, A33
101			Number of transportation initiatives to decrease private vehicles on campus	Number	A1, A5, A22, A33
102			Support for sustainable transportation	Yes/No	A5, A22, A33
103		F.3 Safety in mobility	pedestrian path policy on campus	Yes/No	A22
104	G- Social Aspects	G.1 Accessibility	Affordability and access	%	A21, A38
105	G. Social Aspects	G.2 Housing	Average share of campus housing	%	A10
106		G.3 Availability of public and private facilities and services	open space area/total campus population	m2/student	A5, A22, A33
107		G.3 Availability of public and private facilities and services	presence of existing public transport near to the universities	%	A33
108			presence of green and public spaces near to the university buildings	%	A33
109			presence of existing services near to the university buildings	%	A33
110			Auditoriums and other learning space	m2/student	A43
111			Teaching laboratory	m2/student	A43
112			Office & meeting rooms per staff	m2/person	A43
113			Total space per person (staff +students)	m2/person	A43
114			Self-learning and group working spaces (informal learning seats)	%	A43

115			Sports facility per person (staff+ students)	m2/person	A43
116		G.4 Education	Student educators program	%	A21, A38
117		G.4 Education	Outreach materials and publications	Yes/No	A21, A38
118			Employee educators program	%	A21, A38
119			Continuing education (share of continuing education courses in sustainability to total continuing education courses, if the institution has at least one certificate program that meets some criteria)	%, Yes/No	A21, A38
120			Sustainability-oriented courses/credits	%	A10, A38, A21
121			Sustainability-oriented degree programs	Number	A10
122			Sustainability-oriented theses/projects	Number	A10
123			Sustainability courses/total courses-subjects	%	A5, A22, A33
124			sustainability research funding/total research funding	%	A5, A22, A33
125			Number of scholarly events related to environment and sustainability	Number	A5, A22, A33
126			number of student organizations related to environment and sustainability	Number	A5, A22, A33
127			existence of a university-run sustainability website	Yes/No	A5, A22, A33
128			existence of published sustainability reports	Yes/No	A5, A22, A33
129			Energy sustainability educational programs for staff and students	Yes/No	A26
130			Increased environmental/sustainability education	Yes/No	A26
131			programs for local community about the importance of energy efficiency and clean energy	Number	A26
132			Promote a public pledge toward 100% renewable energy beyond the university	Yes/No	A26
133			Sustainability Learning outcomes	Yes/No, %	A21, A38

134			Undergraduate Program	Yes/No	A21, A38
135			Graduate Program	Yes/No	A21, A38
136			Immersive experience	Yes/No	A21, A38
137			Sustainability literacy assessment	Yes/No	A21, A38
138			Incentives for developing (sustainability) courses	Yes/No	A21, A38
139			Campus as a living laboratory	Yes/No	A21, A38
140			Sustainability-oriented publications	Number	A5, A10, A22, A33
141			Sustainability-based researchers	Number	A10
142			Living Lab research projects	Number	A10
143			Funding research on energy sustainability	%	A26
144			Research and scholarship	%	A21, A38
145			Support for sustainability research	Yes/No	A21, A38
146			Direct access to research	Yes/No	A21, A38
147		G.5 Social inclusion	Social Security affiliation 3 years after graduation	%	A22
148		G.5 Social inclusion	Percentage of students with grants from the General Administration	%	A22
149			Dropout rate for graduates	%	A22
150			Gender ratio for full professors	%	A22
151			Variation of the ratio between incoming students and graduates	%	A22
152			Women and men in health Sciences and Engineering and Architecture	%	A22
153			Student Orientation	%	A21, A38
154			Student life	Yes/No	A21, A38
155			Outreach campaign	Yes/No	A21, A38
156			Employee orientation	%	A21, A38
157			Staff professional development and training	Yes/No, %	A21, A38
158			Community service	%, Yes/No	A21, A38
159			Efficiency proxy measured by university-life expectancy (ULE) and defined as the total number of years a student can expect in the future	Number of years	A13
160			Endogenous growth proxy measured by gross enrolment tertiary ratio	%	A13

			(GETR) and expressed as a percentage of the population eligible for the same level of education in a given school year		
161			Support for underrepresented groups	Yes/No	A21, A38
162			Trademark licensing	Yes/No	A21, A38
163		G.7 Health	Wellness Program	Yes/No	A21, A38
164		G.7 Health	Workplace health and safety	Yes/No	A21, A38
165		G.8 Food security	Average radius of food procurement	km	A10
166		G.8 Food security	Average share of local food purchase	%	A10
167			Food and beverage purchasing	%	A21, A38
168			Sustainable dining	Yes/No	A21, A38
169		G.9 Cultural Heritage	percentage of historical buildings reused with changing functions	%	A33
170	H- Economy	H.1 Economic Performance	Percentage of university budget for sustainable effort (in a year)	Local currency /%	A5, A22, A33
171	H. Economy	H.1 Economic Performance	Annual energy cost savings	Local currency	A10
172			Size of funds for Living Lab projects	Local currency	A10
173			Annual water cost savings	Local currency	A10
174			Government expenditure on education, total	%	A13
175			Government expenditure on education, total (percent of government expenditure) (GEGT)	%	A13
176			Current education expenditure total (percent of total expenditure in public institutions) (CET)	%	A13
177			Economic stability measured by rate of inflation calculated from the annual percentage change in consumer prices (CP)	%	A13
178			Market size measured by the growth rate of per capita GDP (GPC)	%	A13
179			Degree of openness measured by the sum of nominal export and import	%	A13
180			Operative cost over revenues	%	A22
181			Personnel cost over revenues	%	A22
182			Cost recovery rate per student	%	A22
183			Sustainability of the annual activity	%	A22

184			Dependence on the Autonomous Community	%	A22
185			Dependency on the General Administration	%	A22
186			Current ratio	%	A31
187			Quick ratio	%	A31
188			Total assets turnover	%	A31
189			Fixed assets turnover	%	A31
190			Accounts receivable turnover	%	A31
191			Days payable outstanding	%	A31
192			Debt to equity	%	A31
193			Equity ratio	%	A31
194			Net profit margin	%	A31
195			Return on equity (ROE)	%	A31
196			Return on assets (ROA)	%	A31
197		H.2 Employment	Number of faculty/students engaged	Number	A10
198		H.3 Innovation	Number of clean technology start-ups	Number	A10
199			A catalog of exemplary practice and open-ended innovation credits available for selection	Yes/No	A21, A38
200	I-Climate Change: mitigation and adaptation	I.1 Climate change mitigation	Annual Scope 1 and 2 (electricity and district heating) CO2 emissions	Tonnes	A10
201			Annual Scope 3 (car, bus, train, ship, and plane) CO2 emissions	Tonnes	A10
202			Carbon Footprint Scope 1: fossil fuel consumption for heating (natural gas consumption), fossil fuel consumption for transport (diesel consumption, petrol consumption)	Kg CO2e	A18
203			Carbon Footprint Scope 2: indirect emissions caused by electricity (electricity grid, electricity on site)	Kg CO2e	A18
204			Carbon Footprint Scope 3: emissions caused by water supply, emissions caused by wastewater treatment, emissions caused by food procurement (emissions caused by meat procurement, emissions caused by fruit procurement, emissions caused by dry stored and frozen food procurement), emissions caused by	Kg CO2e	A18

			waste disposal (green waste, general waste, recyclable waste)		
205			Total carbon footprint per total population of the institution	tCO2e per people	A3, A5, A10, A22, A26, A33, A43
206			Greenhouse gas emissions	TCO2e per people	A21, A38
207			Carbon offset	tCO2/pers. a	A43
208			Carbon footprint of building materials for new construction and major renovation	kgCO2eq/m2	A43
209			Carbon footprint from work trips, business trips, inside campus transport	tCO2/pers. a	A1, A43
210			CO2 emissions associated with energy category per student, administrative, and scientific personnel	tonnes CO2/person	A1
211			CO2 emissions associated with water category per student, administrative and scientific personnel (excl. hot water preparation CO2 emissions since included in the category "Energy")	tonnes CO2/person	A1
212			CO2 emissions associated with waste category per student, administrative, and scientific personnel	tonnes CO2/person	A1
213			Greenhouse gas emission reduction program	Yes/No	A5, A21, A26, A33
214			Number of greenhouse gas emission reduction program	Number	A26
215		I.2 Adaptation to climate action: heatwaves and increase of temperature	Area of green roofing and gardens	m2	A10
216		I.3 Adaptation to the climatic action: pluvial flood	Capacity for stormwater runoff absorbance	m3	A43
217		I.5 Adaptation to the climatic action: drought	Share of recycled water amount per total water consumption	%	A1
218			Water conservation program implementation	Yes/No	A5, A22, A33
219			water recycling program implementation	Yes/No	A5, A22, A33
220			Rainwater management	Yes/No	A21, A38

221			area on campus for water absorbance	m2	A5, A22, A33
222	J-Governance	J.2 Management and community involvement	Community partnerships	Yes/No	A21, A38
223			Inter-campus collaboration	Yes/No	A21, A38
224			Participation in public policy	Yes/No	A3, A21, A38
225			Involving the stakeholders	Yes/No	A3, A26
226			Participatory governance	Yes/No	A21, A38
227			Diversity and equity coordination	Yes/No	A21, A38
228			Assessing diversity and equity	Yes/No	A21, A38
229			Employee compensation	Yes/No	A21, A38
230			Assessing employee satisfaction	Yes/No	A21, A38
231		J.3 Public buildings cooperation	Assessing sustainability culture	Yes/No	A21, A38
232			Have a policy for ensuring that all renovations or new buildings are following energy efficiency standards	Yes/No	A26
233			Number of implemented green building elements in construction and renovation policies	Number	A26
234			Have a plan to upgrade existing buildings to higher energy efficiency	Yes/No	A26
235			Have a process for carbon management and reducing carbon dioxide emissions	Yes/No	A26
236			Have an energy efficiency plan in place to reduce overall energy consumption	Yes/No	A26
237			Have a policy for clean energy and divesting investments from carbon-intensive energy industries, notably coal and oil	Yes/No	A26
238			Have a policy development for clean energy	Yes/No	A26
239			Have an internal energy assessment?	Yes/No	A26
240			Have a certified energy management system (EMS) ISO 50001, for instance	Yes/No	A26
241			Audits of the EMS organized in the last five years, other than certification audits	Yes/No	A26
242			Number of local initiatives in the field of resource consumption reduction (separately for thermal energy, electricity, transport, water consumption, and waste	%	A1

			management) per total number of initiatives		
243			Investment volume separately for improvement of energy efficiency of buildings, to reduce water consumption, heat loss prevention	Euro/time unit	A1
244			Sustainable investment	%	A21, A38
245			Number of green procurement procedures per total number of procurements	%	A1
246			Sustainability coordination	Yes/No	A21, A38
247			Sustainability planning	Yes/No	A21, A38
248			Committee on Investor Responsibility	Yes/No	A21, A38
249			Investment Disclosure	%	A21, A38
250			elements of green building implementation as issues reflected in construction and renovation policy	Yes/No	A5, A22, A33
251	Others	Purchasing	Sustainable procurement	Yes/No	A21, A38
252			Electronics Purchasing	%	A21, A38
253			Cleaning and janitorial purchasing	%	A21, A38
254			Office paper purchasing	%	A21, A38
255		Building	Building operations and maintenance	%	A21, A38, A44
256			Building design and construction	%	A21, A38, A44
257		Thermal Comfort	General thermal comfort, category I and II spaces	%	A43
258		Thermal Comfort	Ensuring thermal comfort for users in all classrooms and laboratories of a university.	Yes/No	A2, A26

4.7 Implementation Results

The implementation of the framework produced a final set of twenty campus sustainability indicators and enabled their application across the four main PoliTo campuses in Turin. The initial assessment provided a baseline picture of relative campus performance. The subsequent SWOT analysis generated ten specific improvement actions, which the stakeholder roles ranked according to their perceived urgency and impact. Q-sort analysis of these rankings revealed three coherent strategic directions, representing the dominant patterns in stakeholder preferences and forming the basis for the proposed sustainability roadmap for PoliTo.

4.7.1 Implementation Indicators

The selection procedure described in Chapter 3 resulted in a final set of twenty sustainability indicators for PoliTo campuses (Table 8). The indicators cover all main SNTool categories, from land use and energy to water, waste, mobility, economy, and climate change mitigation/adaptation, and are measurable using data available in the PoliTo Green Team database. This set constitutes the operational framework to benchmark campus performance and to identify strengths, weaknesses, and priority areas for action.

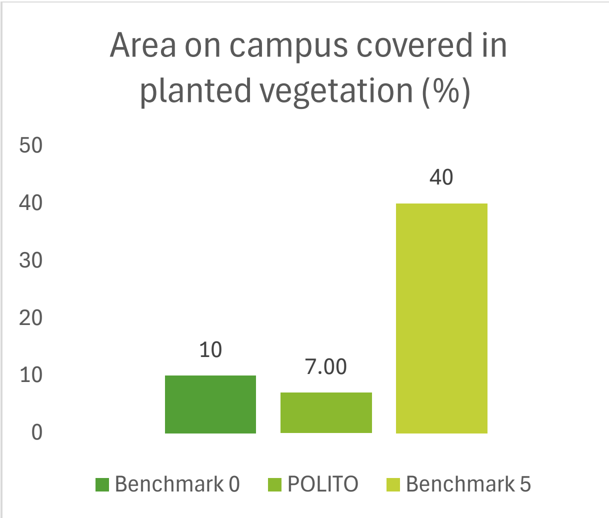
Table 8. Final list of implementation indicators

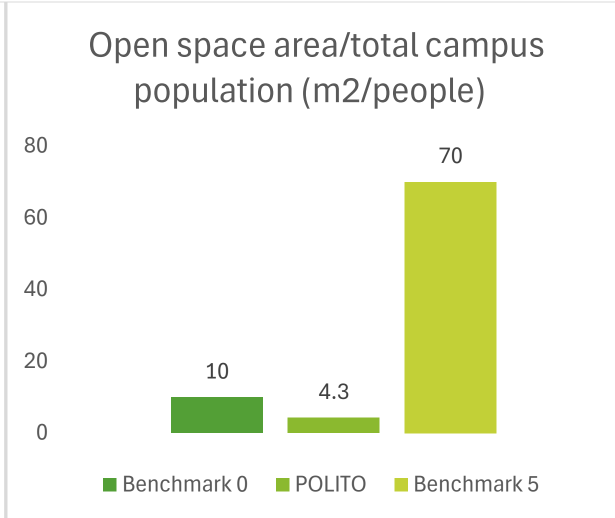
No	Category	Sub-Category	Peer indicator of SN-Tool	Indicator	Unit	Source	Bench mark 0	POLITO	Bench mark 5
1			A2.1	Area on campus covered in planted vegetation	%	UIGM (2024)	10	7.00	40
2	A-Use of Land and Biodiversity	A.2 Green Urban Areas	A2.2	Open space area/total campus population	m^2 per capita	UIGM (2024)	10	4.3	70
3	B-Energy	B.2 Energy consumption	B2.3	Annual heat energy consumption per square meter	kWh per square meter	Article A1	130	51.77	50
4			B2.6	Annual electricity consumption per square meter	kWh per square meter	Article A1	180	57.88	30
5		B.3 Renewable energy	B3.6	Amount of electricity generated/consumed from renewable energy sources per total amount of electricity generated/consumed, (E-Renewable/E-Total)	%	Article A1	10	6.15	30
6	C. Water	C.2 Water consumption	C2.1	Water consumption per person	m^3/person/year (liters/person/day to match with SNTool unit)	Article A43, STARS	54	16.09	14.5
7			C2.6	Water conservation program and implementation	%	UIGM (2024)	0	25	50
8	D. Solid Waste	D.2 Solid waste management	D2.1	Organic waste treatment	%	UIGM (2024)	0	100	85
9			D2.2	Inorganic waste treatment	%	UIGM (2024)	0	100	85
10			D2.3	Availability of containers for sorted waste	number per 1000 m^2	Article A1	0	0.3	0.8
11	F. Transportati	F.1 Performanc	F1.2	Bicycle Parking spaces / Total campus population	Number per capita	SNTool	0	0.03	0.072

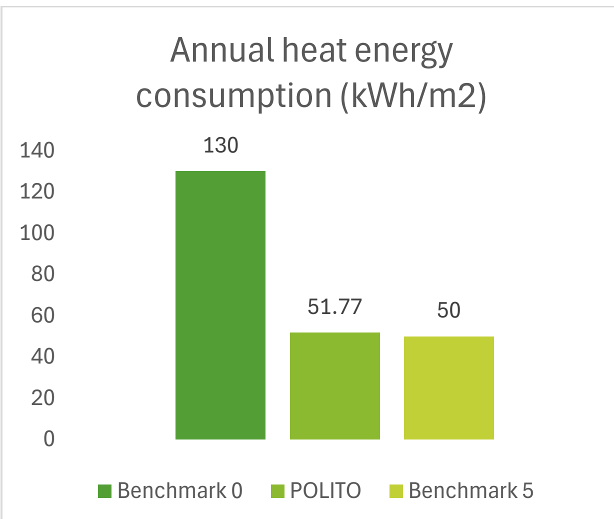
	on and Mobility	e of mobility service							
12			F1.3	Total vehicles (cars and motorcycles)/total campus population	number per capita	UIGM (2024)	1	0.01	0.045
13			F3.2	Users using more sustainable commuting options	Points	STARS	0	5.57	6
14		G.3 Availability of public and private facilities and services	G3.5	Publicly shared facilities	Points	STARS	0	0.75	2
15		G.4 Education	G4.1	Sustainability courses/total courses-subjects	%	UIGM (2024)	1	54	100
16	H. Economy	H.1 Economic Performanc e	H1.1	Percentage of university budget for sustainability efforts	%	UIGM (2024)	1	31	15
17	I. Climate Change: mitigation and adaptation	I.1 Climate change mitigation	I1.1	Annual scope 1 & 2 greenhouse gas emissions from building operations per person	tones/p erson	STARS	4.7	0.18	0
18			I1.6	Annual greenhouse gas emissions (electricity) per square meter	kg/m2	STARS	25	14.3	10
19			I1.7	Annual greenhouse gas emissions (thermal) per square meter	kg/m2	STARS	35	10.4	15
20		I.5 Adaptation to the climatic action: drought	I3.3	Area on campus for water absorption / total open area	%	UIGM (2024)	2	5	30

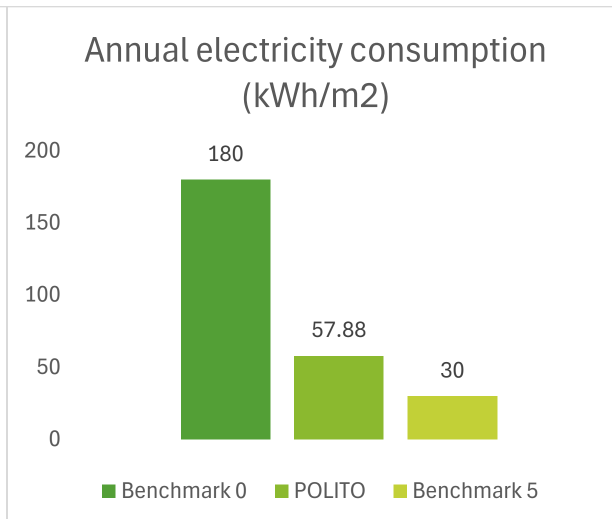
4.7.2 Assessment of Implementation Indicators

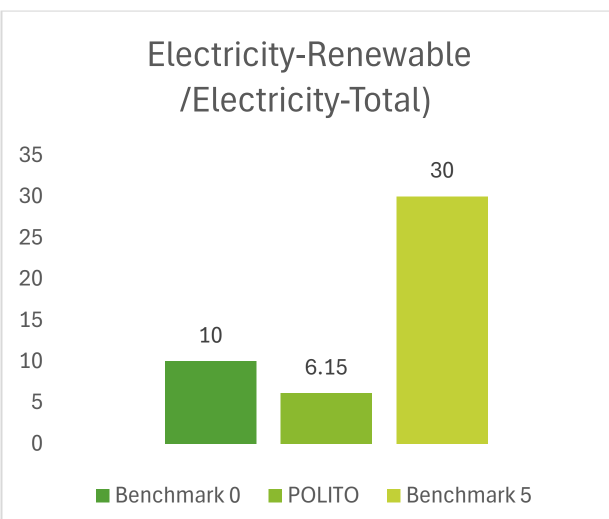
The graphs listed under Figure 11 compare PoliTo's current performance with the benchmark values of 0 and 5 for each indicator. The full dataset used to produce the graphs is provided in Appendices 2 and 5. For land use and green areas, PoliTo performs below the desired benchmark, especially in terms of open space per capita, while in energy and greenhouse-gas indicators, the campus is already positioned closer to the best-practice values.

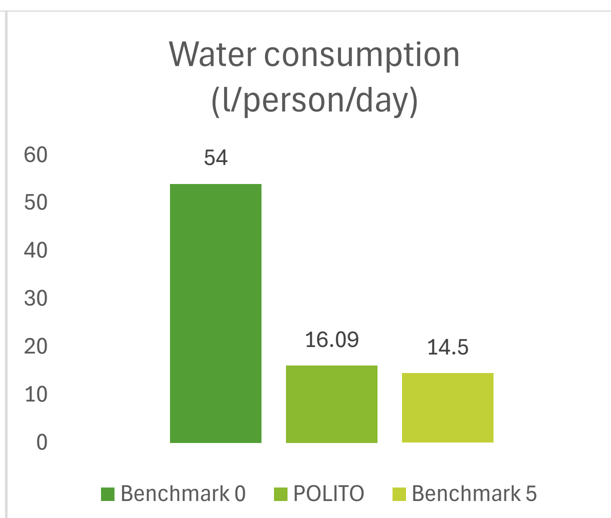

Area on campus covered in planted vegetation (%)
50
40
30
20
10
0
10
7.00
40
Benchmark 0
POLITO
Benchmark 5

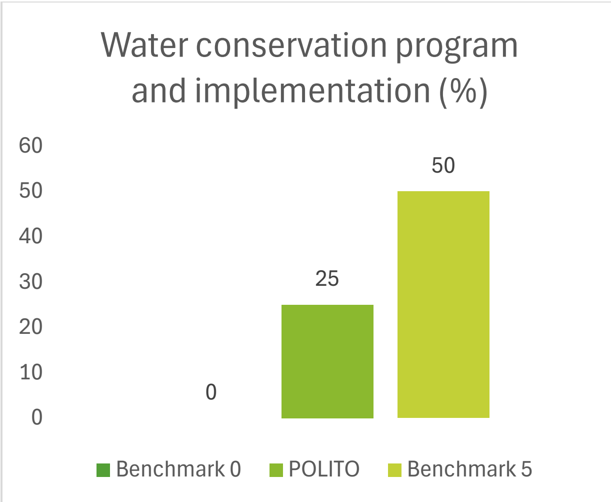

Open space area/total campus population (m2/people)
80
60
40
20
0
10
4.3
70
Benchmark 0
POLITO
Benchmark 5

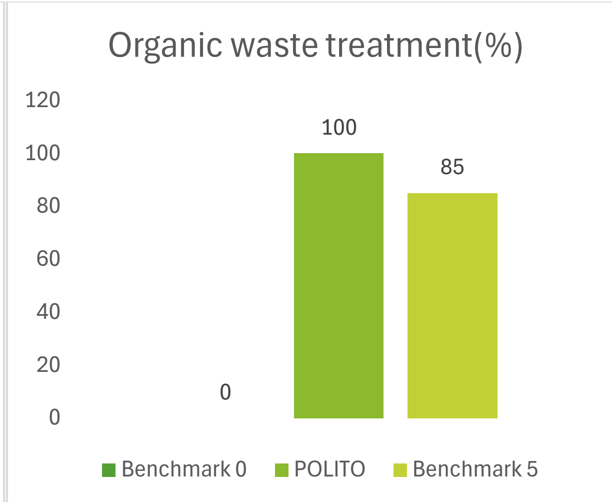

Annual heat energy consumption (kWh/m2)
140
120
100
80
60
40
20
0
130
51.77
50
Benchmark 0
POLITO
Benchmark 5

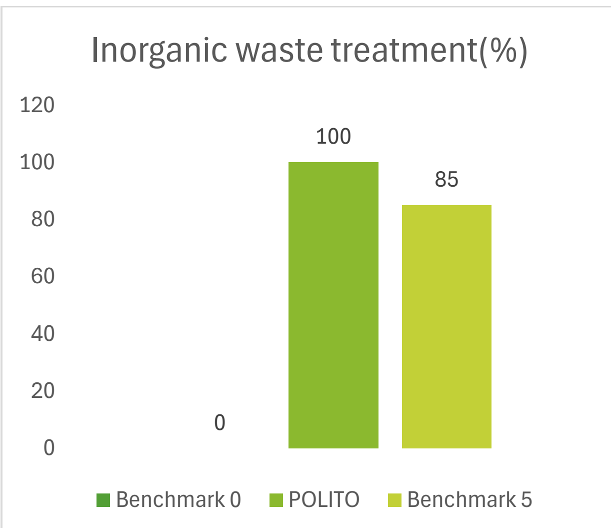

Annual electricity consumption (kWh/m2)
200
150
100
50
0
180
57.88
30
Benchmark 0
POLITO
Benchmark 5

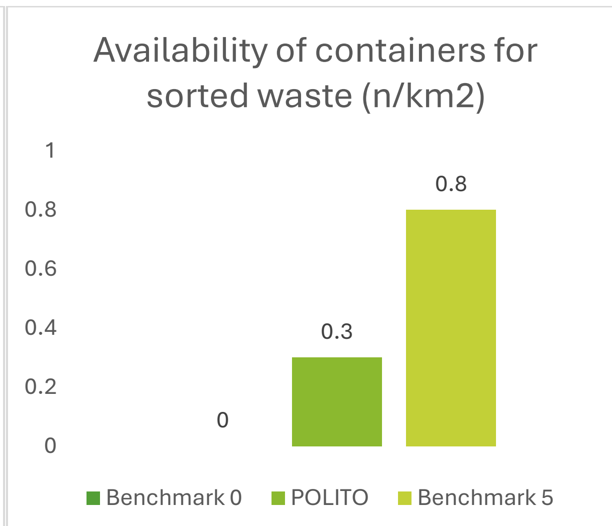

Electricity-Renewable /Electricity-Total)
35
30
25
20
15
10
5
0
10
6.15
30
Benchmark 0
POLITO
Benchmark 5

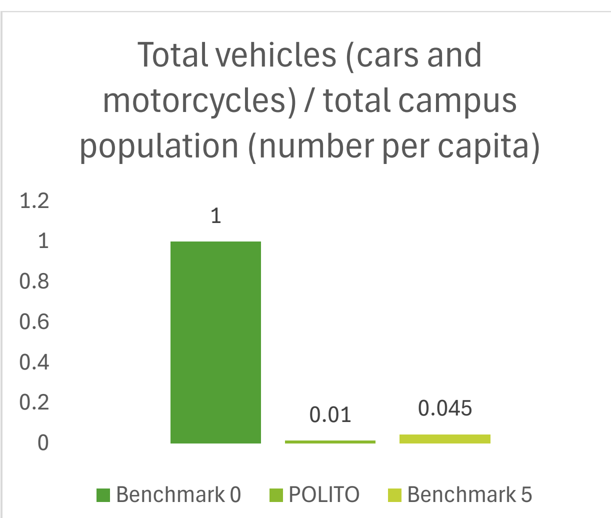

Water consumption (l/person/day)
60
50
40
30
20
10
0
54
16.09
14.5
Benchmark 0
POLITO
Benchmark 5

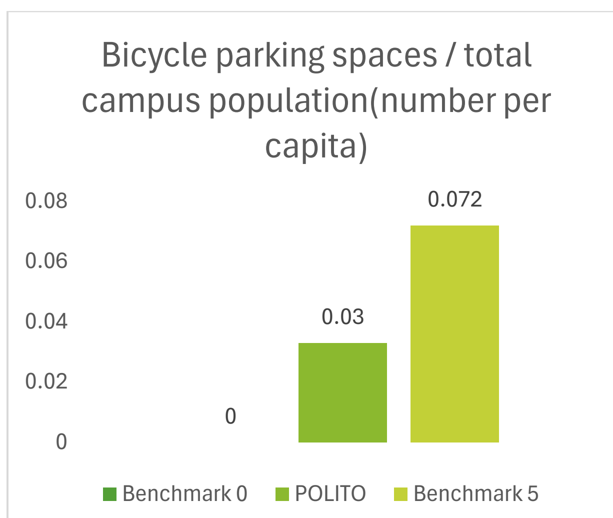

Water conservation program and implementation (%)
60
50
40
30
20
10
0
0
25
50
Benchmark 0
POLITO
Benchmark 5

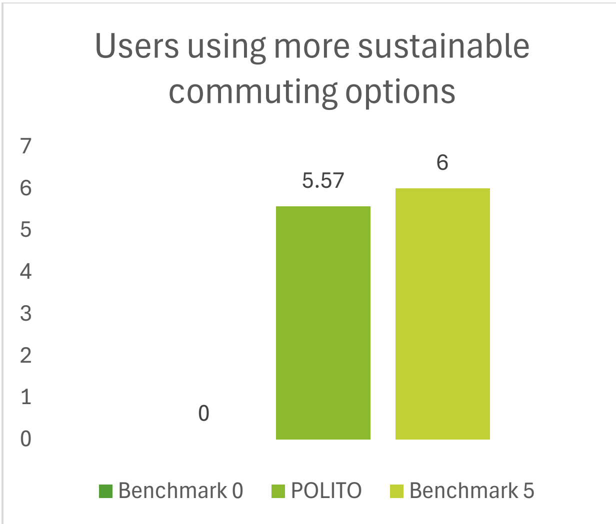

Organic waste treatment(%)
120
100
80
60
40
20
0
0
100
85
Benchmark 0
POLITO
Benchmark 5

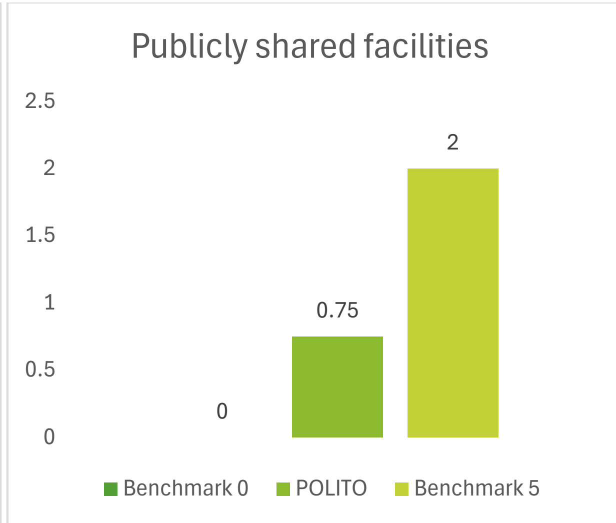

Inorganic waste treatment(%)
120
100
80
60
40
20
0
0
100
85
Benchmark 0
POLITO
Benchmark 5

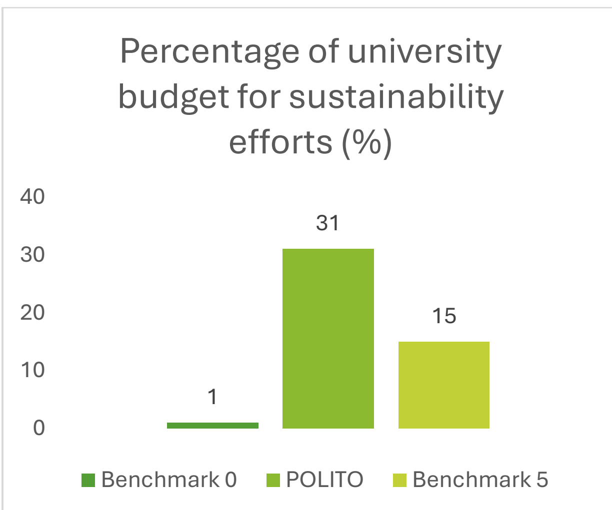

Availability of containers for sorted waste (n/km2)
1
0.8
0.6
0.4
0.2
0
0
0.3
0.8
Benchmark 0
POLITO
Benchmark 5

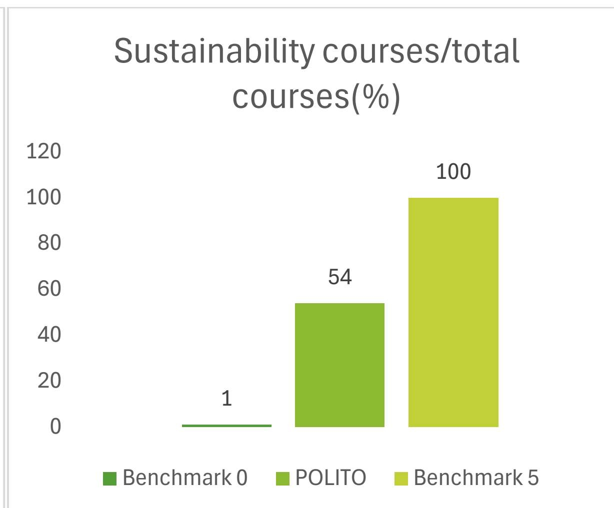

Total vehicles (cars and motorcycles) / total campus population (number per capita)
1.2
1
0.8
0.6
0.4
0.2
0
1
0.01
0.045
Benchmark 0
POLITO
Benchmark 5

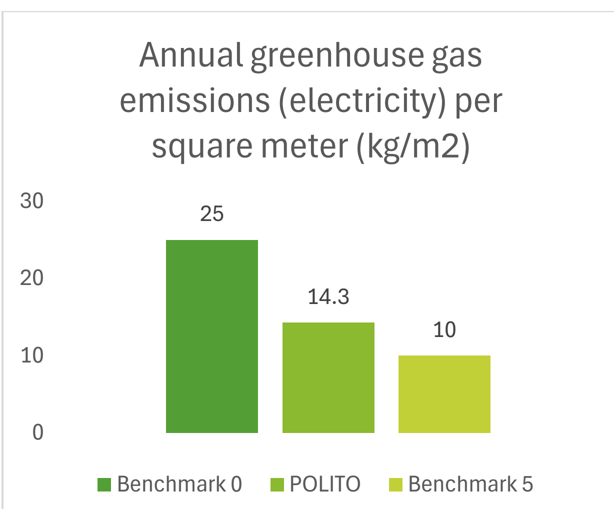

Bicycle parking spaces / total campus population(number per capita)
0.08
0.06
0.04
0.02
0
0
0.03
0.072
Benchmark 0
POLITO
Benchmark 5

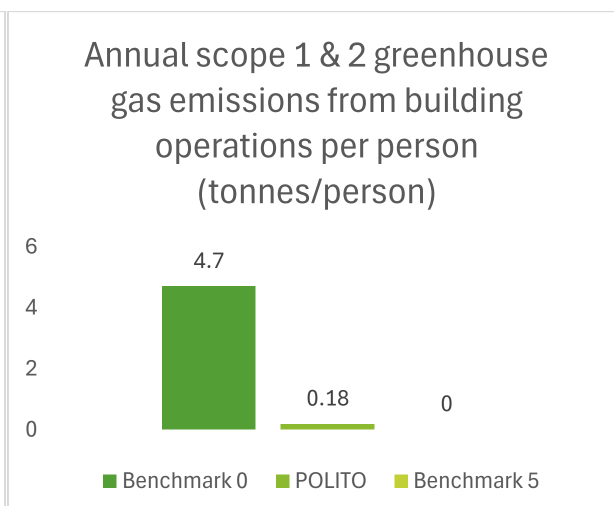

Users using more sustainable commuting options
7
6
5
4
3
2
1
0
0
5.57
6
Benchmark 0
POLITO
Benchmark 5


Publicly shared facilities
2.5
2
1.5
1
0.5
0
0
0.75
2
Benchmark 0
POLITO
Benchmark 5


Percentage of university budget for sustainability efforts (%)
40
30
20
10
0
1
31
15
Benchmark 0
POLITO
Benchmark 5


Sustainability courses/total courses(%)
120
100
80
60
40
20
0
1
54
100
Benchmark 0
POLITO
Benchmark 5


Annual greenhouse gas emissions (electricity) per square meter (kg/m2)
30
20
10
0
25
14.3
10
Benchmark 0
POLITO
Benchmark 5


Annual scope 1 & 2 greenhouse gas emissions from building operations per person (tonnes/person)
6
4
2
0
4.7
0.18
0
Benchmark 0
POLITO
Benchmark 5

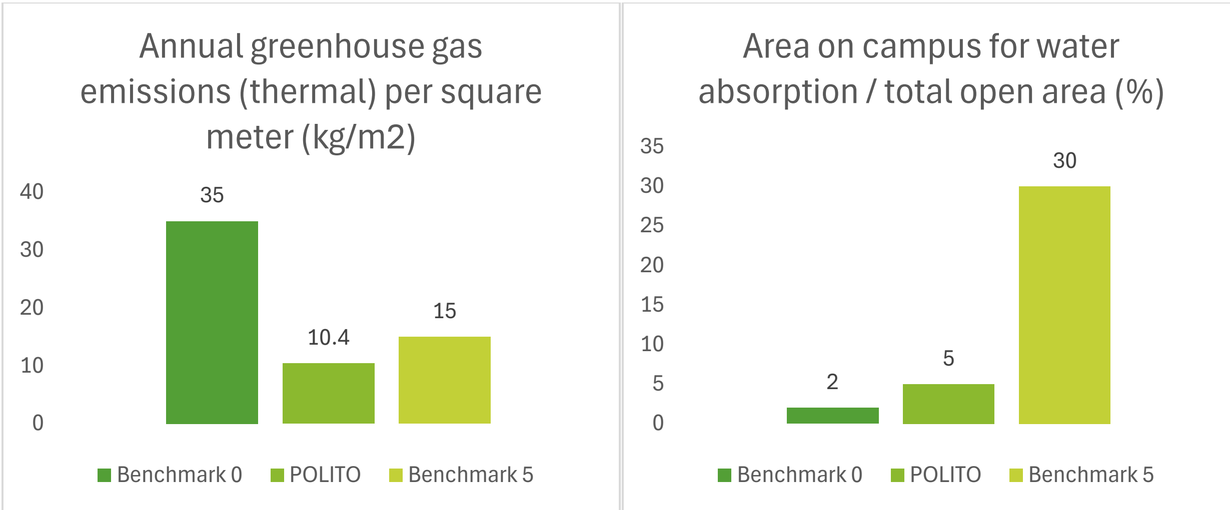


Figure 12. POLITO performance compared to benchmarks

4.7.3 POLITO's Current Performance

Figure12 provides the current overview of PoliTo's sustainability performance across the SNTool categories, comparing the normalised score of each category within the benchmark values. It shows that Use of Land and Biodiversity is clearly the weakest area, with PoliTo scoring lower than the minimum threshold and far from the desired benchmark, while Energy and Climate change mitigation and social aspects achieve only intermediate values, indicating room for improvement. Water also lies in a mid-range position, performing better than the minimum but still below the high benchmark. By contrast, Solid Waste, Transportation and Mobility, and Economy are clustered close to the high benchmark, suggesting that waste management, sustainable mobility, and budget allocation for sustainability are relatively strong dimensions on campus.

Table 9. Normalized score of Categories

Indicator	POLITO's Performance	Normalized Performance	Category
Area on campus covered in planted vegetation	7.00	-1.0	-1.0
Open space area/total campus population	4.3	-1.0	
Annual heat energy consumption per m^2	51.77	4.9	2.7
Annual electricity consumption per m^2	57.88	4.1	
Amount of electricity generated/consumed from renewable energy sources per total amount of electricity generated/consumed, (E-Renewable/E-Total)	6.15	-1.0	
Water consumption per capita	16.09	4.8	3.7
Water conservation program and implementation	25	2.5	
Organic waste treatment	100	5.0	4.0
Inorganic waste treatment	100	5.0	
Availability of containers for sorted waste	0.3	2.0	
Bicycle parking spaces /total campus population	0.03	2.3	4.0
Total vehicles (cars and motorcycles)/total campus population	0.01	5.0	
Users using more sustainable commuting options	0.04	4.6	
Publicly shared facilities	0.75	1.9	2.3
Sustainability courses/total courses-subjects	54	2.7	
Percentage of university budget for sustainability efforts	31	5.0	5.0
Annual scope 1 & 2 greenhouse gas emissions from building operations per person	0.18	4.8	3.5
Annual greenhouse gas emissions (electricity) per m^2	14.3	3.6	
Annual greenhouse gas emissions (thermal) per m^2	10.4	5.0	
Area on campus for water absorption / total open area	5	0.5	

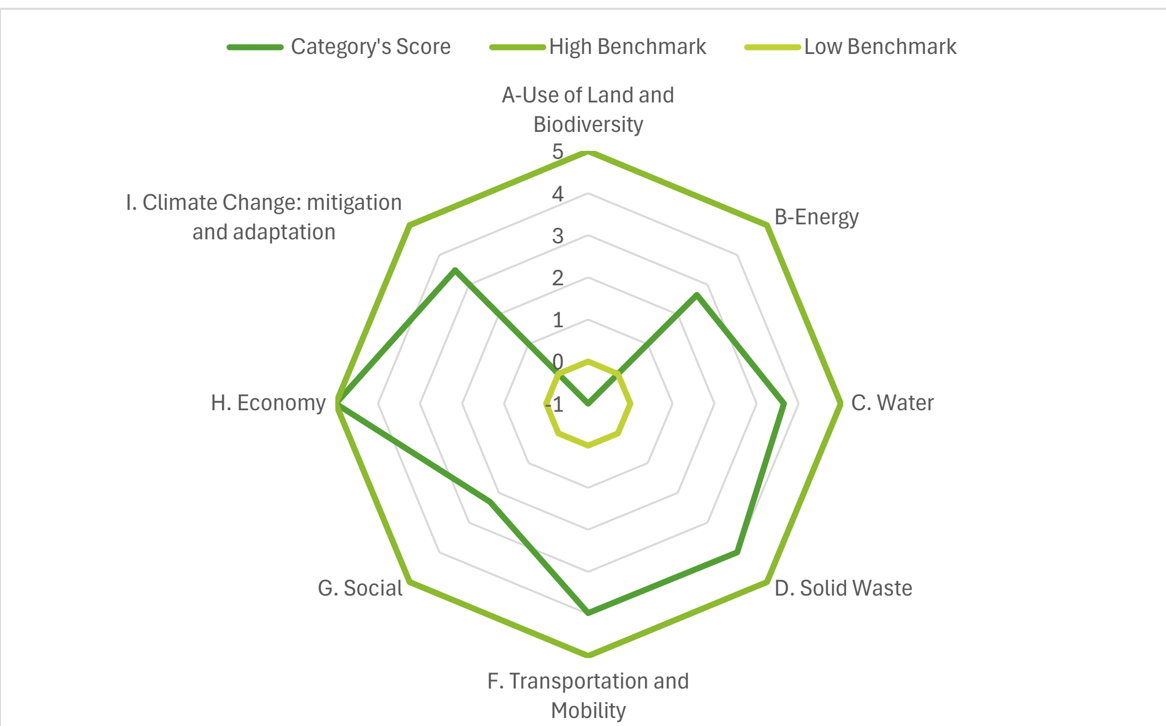


Figure 13. Radar chart of the current POLITO's performance

4.7.4 Final consensus on Implementation Indicators

In total, eight stakeholder roles were simulated through the playing-cards exercise, each producing a separate ranking of the twenty indicators (full layouts are reported in Appendix 3). When these rankings are aggregated into a single consensus table, a clear structure emerges. Indicators directly linked to climate-change mitigation and energy performance (annual scope 1 & 2 GHG emissions per person, GHG emissions per square metre, and energy-consumption indicators) systematically occupy the highest-priority positions in the consensus ranking. A second cluster of indicators with intermediate priority includes resource-oriented aspects such as water consumption and conservation, waste treatment and sorting infrastructure, and the share of sustainability courses in the academic offer, and bicycle parking provision. By contrast, indicators related to land use and transportation, such as, overall vehicle numbers and planted vegetation or water absorption areas, tend to appear towards the lower end of the ranking, indicating that, from the perspective of the simulated stakeholder panel, they are comparatively less critical than climate, energy, and everyday resource-use issues. This consensus ranking is then used to derive the final set of indicator weights applied in the final sustainability score of PoliTo campuses.

Figure 14. Total consensus of the cards

Area for water absorption / total open area
Area on campus covered in planted vegetation
Users using more sustainable commuting options
Open space area / total campus population + Publicly shared facilities
Total vehicles (cars & motorcycles)/ campus population
% of university budget for sustainability efforts
White Card
Bicycle parking spaces /total campus population
Sustainability courses/ total courses-subjects
Organic waste treatment + Inorganic waste treatment + Availability of containers for sorted waste + Water consumption (per person) + Water conservation program & implementation
Annual electricity consumption / m2 + Annual heat energy consumption / m2
White Card
Annual GHG emissions (electricity/m2) + Annual GHG emissions (thermal/m2) + Share of renewable electricity consumption (E-renewable / E-total)
Annual scope 1 & 2 GHG emissions (per person)

4.7.5 Assigning Weight to Implementation Indicators

In the weighted assessment, the sum of all weighted scores amounts to 328 points. When this value is divided by the total weight (100), it yields an overall composite score of 3.28 out of 5, which represents PoliTo's aggregated sustainability performance across the twenty indicators.

Table 10. Final Sustainability Scores

	POLITO's Performance	Normalized Performance	Normalized Weight	Category's Score	Category's Weight	Category's Weighted Score
Area on campus covered in planted vegetation	7.00	-1.0	0.88	-1	2.86	-2.86
Open space area/total campus population	4.3	-1.0	1.98			
Annual heat energy consumption per m^2	51.77	4.9	7.27	2.65	23.35	61.96
Annual electricity consumption per m^2	57.88	4.1	7.27			
Amount of electricity generated/consumed from renewable energy sources per total amount of electricity generated/consumed, (E-Renewable/E-Total)	6.15	-1.0	8.81			
Water consumption per capita	16.09	4.8	5.73	3.65	11.46	41.83
Water conservation program and implementation	25	2.5	5.73			
Organic waste treatment	100	5.0	5.73	4	17.19	68.76
Inorganic waste treatment	100	5.0	5.73			
Availability of containers for sorted waste	0.3	2.0	5.73			
Bicycle parking spaces /total campus population	0.03	2.3	3.96	3.98	7.92	31.52
Total vehicles (cars and motorcycles)/total campus population	0.01	5.0	2.64			
Users using more sustainable commuting options	0.04	4.6	1.32			
Publicly shared facilities	0.75	1.9	1.98	2.3	6.39	14.70
Sustainability courses/total courses-subjects	54	2.7	4.41			
Percentage of university budget for sustainability efforts	31	5.0	3.08	5	3.08	15.40
Annual scope 1 & 2 greenhouse gas emissions from building operations per person	0.18	4.8	9.69	3.48	27.75	96.57
Annual greenhouse gas emissions (electricity) per m^2	14.3	3.6	8.81			
Annual greenhouse gas emissions (thermal) per m^2	10.4	5.0	8.81			
Area on campus for water absorption / total open area	5	0.5	0.44			
			100.00		100.00	3.28

4.8 SWOT Analysis

The SWOT analysis summarised in Table 10 combines the indicator-based findings with contextual information on PoliTo and its urban setting. On the strengths side, the campus shows very good performance in resource-efficiency and operational aspects, including low heat and electricity consumption per square metre, low potable-water use per person, 100% treatment of organic and inorganic waste, high availability of containers for sorted waste, a high share of zero-emission vehicles and a very low number of private vehicles and parking area per capita. The curriculum also includes a relatively high share of sustainability-related courses, and student services are supported by the EDISU organization as a point of strength.

Conversely, the weaknesses highlight structural and spatial limitations: limited planted green areas and low open space per capita, a modest share of renewables in the energy mix, and shortages in study spaces and inclusiveness of extracurricular programmes, particularly for international and older students. Among the opportunities, EU and national policies, research programmes, and scholarship schemes can support further investments in renewable energy, green areas, sustainable mobility, and environmental education. However, threats such as high retrofit costs, dense urban fabric, climate-change impacts, and potential managerial or budgetary resistance may slow down implementation, with the additional risk that PoliTo could lag behind other European universities in green campus rankings if these challenges are not addressed.

Table 11. SWOT analysis

Strengths	Weaknesses
◆ Low annual heat energy consumption per m^2 (efficient performance)	◆ Limited area on campus covered in planted vegetation
◆ Low annual electricity consumption per m^2	◆ Low open space per capita for the campus population
◆ Low potable water consumption per person	◆ Low share of renewable energy in the total energy mix
◆ 100% organic waste treatment	◆ Shortage of study halls compared to the number of students
◆ 100% inorganic waste treatment	◆ Some extracurricular programs are available **only in Italian**, limiting accessibility for international students
◆ High availability of containers for sorted waste	◆ Some extracurricular programs are **restricted by age**, excluding older students
◆ High share of Zero Emission Vehicles (ZEV) per capita	
◆ Very low number of vehicles per capita	
◆ Low parking area ratio (reducing land take)	

🔹 High percentage of sustainability courses within the curriculum	
🔹 Presence of EDISU organization: managing dormitories, canteens, and student services; organizing cultural events, festivals, and sports competitions	
Opportunities	**Threats**
🌱 EU-funded scholarships for students with financial difficulties (benefiting many international students)	⚠️ High retrofitting costs for integrating renewable energy and greening existing buildings
🌱 EU and Italian policies supporting renewable energy transition can increase the campus renewable share	⚠️ High urban density and limited available space in Turin
🌱 Potential to expand green areas and roof gardens in new projects	⚠️ Climate change impacts (heatwaves, water scarcity) increase pressure on energy and water systems
🌱 Access to European research projects (e.g., Green Deal, Horizon Europe) to strengthen sustainable mobility	⚠️ Managerial or budgetary resistance may delay sustainability upgrades
🌱 Collaboration with stakeholders (students, staff, city of Turin) to optimize resource consumption	⚠️ Risk of falling behind other European universities in green campus rankings
🌱 Potential to enhance educational programs to foster environmental awareness	

4.8.1 Suggested Actions Based on SWOT Analysis

On the basis of the SWOT analysis, ten strategic actions were defined to translate the identified strengths, weaknesses, opportunities, and threats into concrete lines of intervention. These actions, which also constitute the Q-sort statements, are summarized below:

- Strengthen and expand the share of renewable energy (Preserve & enhance strengths). (By 2030, increase the share of electricity produced by on-campus photovoltaic systems at the main campus to twice (from 6.15% to at least 12.30%), by installing additional PV capacity on existing buildings.)

- Develop green spaces to compensate for the lack of open space per capita (Address weaknesses). (By 2030, double the share of green areas within the total open area at Politecnico di Torino, by converting existing asphalted surfaces into locally vegetated, permeable spaces.)

- Improve and expand study facilities and multifunctional spaces for students (Address weaknesses). (By 2030, upgrade and expand campus facilities, such as on-site spaces for meetings or events, facilities that help people meet their basic needs, such as a community garden, food bank, child care center, or health clinic, facilities that provide cultural services, for example, a library, computer lab, resource center, museum, or gallery, and facilites that provide recreational services, for example, a gym, or athletic field.)
- Strengthen and internationalize educational and research programs related to sustainability (Preserve & enhance strengths). (By 2030, enhance PoliTO's sustainability-related education and research offer by: increasing the share of courses explicitly focused on sustainability from 54% (2024 baseline) to at least 80% of all courses…)

- Maintain and enhance sustainable mobility (Preserve & enhance strengths). (By 2030, consolidate and enhance sustainable mobility at Politecnico di Torino by: Initiatives reducing the number of daily trips to campus made by private cars to 0, and increasing the bicycle parking spaces to at least 50% compared to 2024.)

- Preserve low water consumption patterns (Preserve & enhance strengths). (By 2030, consolidate and enhance equipment (Water Sense bathroom faucets/accessories) that leads to at least a 10% reduction in water consumption per person)

- Enhance and innovate waste management systems to establish a "Zero Waste Campus" model (Preserve & enhance strengths). (By 2030, implement an integrated "zero waste" system at Politecnico di Torino that: (i) achieves a high separate collection rate for organic waste, with at least 100% of total organic waste being sent to composting or anaerobic digestion; (ii) achieves a high separate collection rate for recyclable inorganic waste, with at least 100% of total inorganic waste being separately collected and sent to authorised recycling facilities; and (iii) doubles sorted-waste collection points clearly labelled (at minimum: residual, organic, paper, plastic/metal, glass) from 0.3 per 1000m2 to 0.6.)

- Expand international and multilingual extracurricular programs to increase student inclusivity (Address weaknesses). (Address the weakness of activities being limited to Italian and certain age groups.)

- Leverage support organizations (such as EDISU) to improve student services and attract more students (Preserve & enhance strengths). (Preserve and expand this strength as a competitive advantage in student recruitment.)

- Consolidate and enhance equipment (Water Sense bathroom faucets/accessories) that leads to at least a 10% reduction in water consumption per person.

Individual Q-sort pyramids for each stakeholder role, based on these ten actions, are reported in Appendix 4.

4.9 Pearson Correlation Matrix

The correlation matrix (Table 11) reveals a clear structure in how stakeholders prioritised the ten strategies.

- Funding Agencies and Organizations Setting Standards showed a correlation of **+1**, meaning their Q-sorts were completely identical. Both groups represent institutional actors with a strong emphasis on policy, regulation, and resource management.
- Funding Agencies, Organizations Setting Standards, Professors, and the Private Sector all displayed very high positive correlations (0.75 to 0.83), forming a clear institutional–policy cluster.
- Students and Technical/Support Staff had a positive correlation of +0.67, showing that their perspectives are relatively aligned, with a stronger emphasis on operational and day-to-day needs.
- Students had consistently negative correlations with institutional actors (–0.25 to –0.33), revealing that their priorities are often the inverse of those emphasized by funding, policy, and academic authorities.
- University Administration is statistically aligned with the institutional–policy cluster rather than occupying an intermediate position between the two groups. It has moderate to high-positive correlations with Funding Agencies, Standard-setting Organisations, Professors, and Private Sector providers ($r \approx 0.58$) and a weaker positive correlation with Local Government ($r \approx 0.33$), while its correlation with students is clearly negative ($r \approx -0.58$) and almost neutral with technical and support staff ($r \approx -0.17$). This pattern indicates that the administration tends to reproduce institutional priorities more than everyday user concerns, and that a clear gap exists between its priorities and those expressed by students.

The Pearson correlation matrix clearly highlights a division of stakeholders into two opposing poles:

- An institutional cluster (funding, regulation, professors, private sector) that shares very similar priorities.
- A user cluster (students and technical staff) that focuses more on inclusivity, services, and operational issues.

Overall, the analysis reveals that the largest gap exists between students and institutional stakeholders, emphasizing the need for strategies that reconcile governance priorities with

Table 12. Correlation matrix

Click the drop-down menu and select a correlation type. The table below will update in real-time to display the corresponding correlation matrix.

Select a correlation type: Pearson

Show excluded

Respondent	Funding Agency	Local Government and Authorities	Organizations Setting Standards	Private Sectors & Technology Providers	Professors and Academic Staf	students	Technical and Support Staff	University Administration	
Funding Agency	1.00	0.50	1.00	0.8333	0.8333	-0.25	-0.1667	0.5833	•••
Local Government and Authorities	0.50	1.00	0.50	0.75	0.5833	-0.0833	-0.25	0.3333	•••
Organizations Setting Standards	1.00	0.50	1.00	0.8333	0.8333	-0.25	-0.1667	0.5833	•••
Private Sectors & Technology Providers	0.8333	0.75	0.8333	1.00	0.75	-0.3333	-0.4167	0.5833	•••
Professors and Academic Staff	0.8333	0.5833	0.8333	0.75	1.00	-0.3333	-0.3333	0.5833	•••
students	-0.25	-0.0833	-0.25	-0.3333	-0.3333	1.00	0.6667	-0.5833	•••
Technical and Support Staff	-0.1667	-0.25	-0.1667	-0.4167	-0.3333	0.6667	1.00	-0.1667	•••
University Administration	0.5833	0.3333	0.5833	0.5833	0.5833	-0.5833	-0.1667	1.00	•••

user needs.

4.10 Centroid Factors:

Table 13. Centroid factors

Participant	Factor 1	Factor 2	Factor 3
Funding Agency	0.86044	0.32176	0.35683
Local Government and Authorities	0.58638	0.22266	-0.23533
Organizations Setting Standards	0.86044	0.32176	0.35683
Private Sectors & Technology Providers	0.94587	0.12699	-0.26075
Professors and Academic Staff	0.88146	0.11114	0.07584
students	-0.47856	0.93383	-0.15252
Technical and Support Staff	-0.40932	0.33222	0.17217
University Administration	0.68031	-0.12323	0.27999

Factor extraction

A three-factor centroid solution was retained in order to explore the underlying structures in stakeholder viewpoints. Factor loadings for each role are reported in Table X. Loadings close to ±1 indicate a strong association with a given factor, whereas values around 0 suggest no clear alignment.

4.10.1 Factor 1 – Institutional–policy perspective.

Factor 1 is clearly dominated by institutional actors. Funding Agencies, Standard-setting Organisations, Private Sectors & Technology Providers and Professors and Academic Staff all display very high positive loadings on this factor (between 0.86 and 0.95), while Local Government and Authorities and University Administration also load positively at medium-to-high levels (around 0.59 and 0.68 respectively). In contrast, Students and Technical & Support Staff have negative loadings on this factor (approximately −0.48 and −0.41). This pattern mirrors the institutional–policy cluster already identified in the correlation matrix: Factor 1 represents a viewpoint that emphasises governance, investment and long-term transition measures, and it is almost the opposite of the user-based perspective embodied by campus users.

4.10.2 Factor 2 – User-centred, everyday perspective.

Factor 2 is strongly defined by Students, who show a very high positive loading (about 0.93), and to a lesser extent by Technical and Support Staff (around 0.33). All institutional actors have either small positive or negative loadings on this factor. Factor 2 therefore captures a predominantly user-centred perspective, in which strategies are prioritised according to their impact on everyday experience: comfort, access to green and open spaces, mobility, inclusiveness and the immediate usability of campus facilities and services.

4.10.3 Factor 3 – Residual/secondary nuance.

The third factor shows comparatively low loadings for all stakeholder roles (generally below 0.40, with some positive and some negative values). No stakeholder clearly “loads” on Factor 3 in a dominant way. As a result, this factor is interpreted as a residual or secondary nuance rather than as a fully distinct viewpoint. It appears to capture minor differences within the institutional group and between internal university bodies and external actors, but its explanatory power is limited compared with Factors 1 and 2.

Overall, the factor structure confirms the existence of two main, contrasting perspectives: an institutional–policy factor, shared by funding, regulatory, and academic actors and aligned with University Administration, and a user-centred factor, led by students and supported by technical staff. The weak third factor suggests that most of the variance in Q-sorts is already accounted for by this fundamental divide between institutional priorities and everyday campus experience.

4.11 Varimax

Varimax is an orthogonal rotation technique commonly applied in factor analysis. Its purpose is to simplify the factor structure by maximizing the variance of the squared loadings within each factor. This makes the results easier to interpret, as each stakeholder tends to load strongly on one factor and weakly on others, creating a clearer distinction between clusters. Overall, the varimax-rotated solution confirms the existence of two dominant and clearly separated viewpoints: an institutional, university-centred policy factor (Factor 1), shared by funding bodies, standard-setting organisations, professors and the university administration, and a user-centred everyday factor (Factor 2), led by students and supported by technical staff. A third, more implementation- and city-oriented factor (Factor 3) is mainly associated with local government and private-sector providers, capturing secondary nuances related to urban and practical feasibility. Together, these three factors explain most of the variance in Q-sorts and highlight the structural gap between institutional priorities, external implementation logics, and the daily experience of campus users.

Table 14. Varimax

No	Participant	Factor Group	Factor 1	CHNG	Factor 2	CHNG	Factor 3	CHNG
1	Funding Agency	F-1-1	0.92021	-0.05977	-0.04896	0.37072	0.34932	0.00751
2	Local Government and Authorities	F-3-2	0.30797	0.2784	-0.02353	0.24618	0.59447	-0.82979
3	Organizations Setting Standards	F-1-2	0.92021	-0.05977	-0.04896	0.37072	0.34932	0.00751
4	Private Sectors & Technology Providers	F-3-1	0.50621	0.43966	-0.25293	0.37991	0.81151	-1.07226
5	Professors and Academic Staff	F-1-3	0.68289	0.19857	-0.2468	0.35794	0.51752	-0.44168
6	students	F-2-1	-0.14508	-0.33347	1.04894	-0.11511	0.05478	-0.2073
7	Technical and Support Staff	F-2-2	-0.06246	-0.34686	0.46433	-0.13211	-0.29674	0.46891
8	University Administration	F-1-4	0.61212	0.06819	-0.38562	0.26239	0.18167	0.09832

4.12 Strategies Derived from Q-sort Factors

4.12.1 Factor 1 – Resource efficiency and academic transition

The first factor array presents a view that integrates environmental performance with the university's academic mission. Actions related to renewable energy are placed at the top of the distribution. Strengthening and internationalising sustainability-related educational and research programmes together with enhancing waste management have the second priority. In this configuration, actions such as improving study facilities, leveraging EDISU and similar support organisations, and expanding international extracurricular programmes fall in the negative positions (−1 or −2), indicating that they are seen as less representative of this strategy. Overall, Factor 1 reflects a resource-efficiency and transition-oriented perspective, where the priority is to consolidate the university's environmental performance (energy, mobility) and its academic leadership in sustainability, while student services and extracurricular activities are secondary.

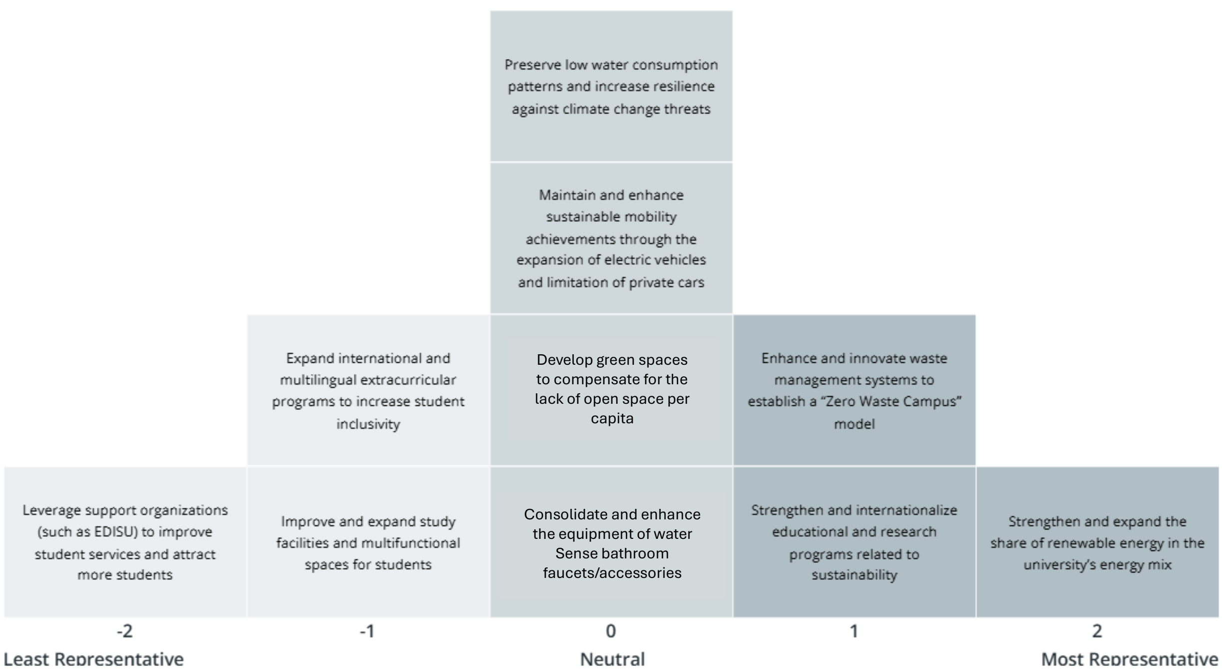


Figure 15. Composite Factor 1, Resource efficiency and academic transition

4.12.2 Factor 2 – Student-centred campus experience

The second factor array is clearly student-centred. The most representative action is improving and expanding study facilities and multifunctional spaces for students (+2), followed by maintaining sustainable mobility and expanding green spaces (+1). These priorities highlight the importance of everyday campus experience: having adequate places to study, move around comfortably and participate in inclusive activities. Actions related to water efficiency, waste, and sustainability education tend to occupy neutral positions (0), while strengthening the renewable energy share, and especially fostering strategic collaborations with internal and external stakeholders are located at the negative end of the scale. Factor 2 therefore represents a user-centred perspective, in which strategies are judged primarily by their immediate impact on student life rather than by their contribution to long-term institutional transition.

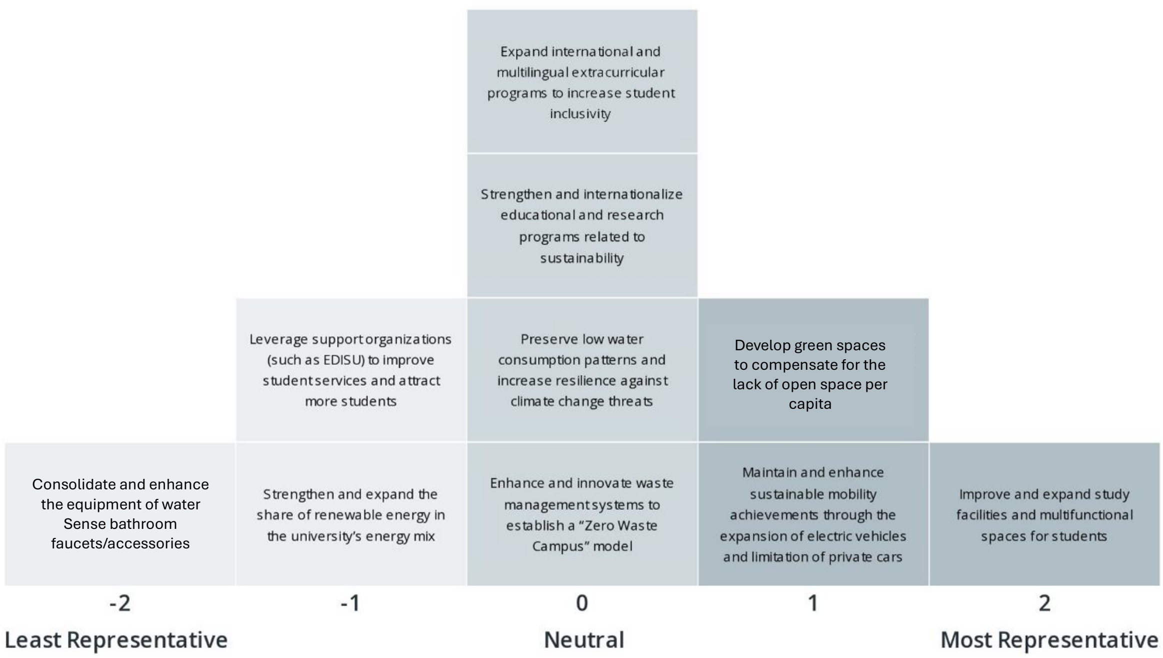


Figure 16. Composite Factor 2, Student-centred campus experience

4.12.3 Factor 3 – Low-carbon infrastructure and resource management

The third factor array emphasises infrastructural change and coordinated implementation. Here, strengthening and expanding the share of renewable energy in the university's energy mix are among the most representative actions (+2), closely followed by maintaining and preserving low water consumption patterns, and innovating sustainable mobility(+1). Actions linked to green spaces, study facilities, sustainable education, and waste management occupy neutral positions, while leveraging support organisations, extra-curricular activities, and water saving equipments are consistently placed at the least representative levels (−1 or −2). Factor 3 can thus be interpreted as a low-carbon infrastructure, which prioritises systemic changes in energy, water and mobility and pays comparatively less attention to student services and campus life enhancements.

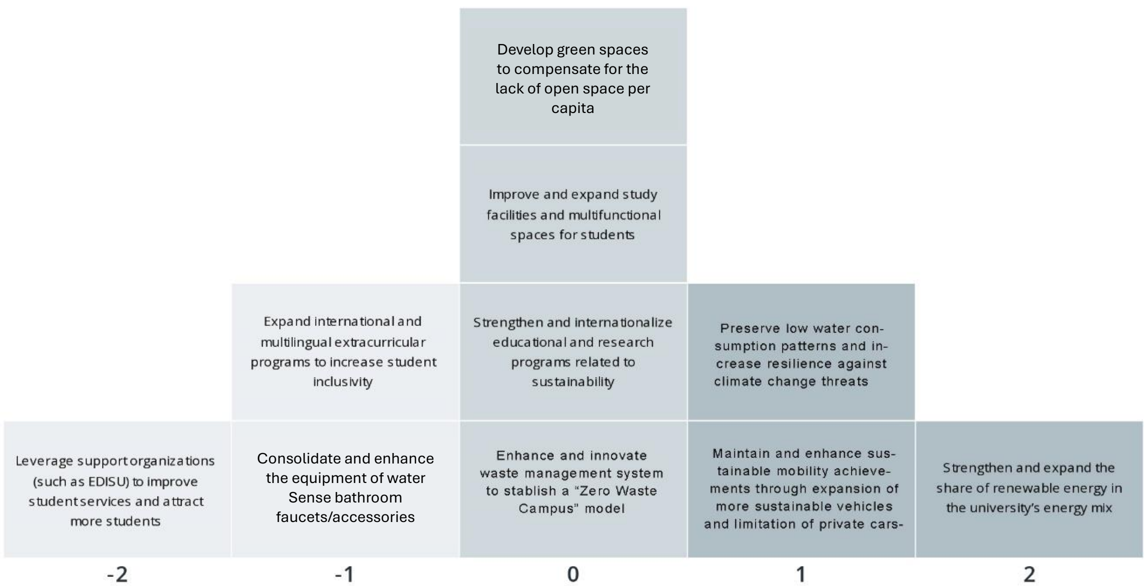


Figure 17. Composite Factor 3, Scenario: Low-carbon infrastructure and resource management

Taken together, the three factor arrays reveal three distinct strategic viewpoints emerging from the Q-sort exercise:

- a resource-efficiency and academic transition perspective (Factor 1),
- a student-centred campus experience perspective (Factor 2), and
- a low-carbon infrastructure and resource management (Factor 3).

These factors summarise how different stakeholder roles, when considered jointly, structure their priorities among the ten proposed actions and provide a qualitative basis for discussing which combinations of strategies could form a coherent roadmap for a more sustainable PoliTo campus.

4.13 Comparative performance of the three strategies

Tables 15, 16, and 17 summarise the category-level and overall scores obtained for the three strategies. All strategies improve PoliTo's baseline performance, but to different extents and in different areas. Strategy 1, which focuses on: resource efficiency and academic transition, produces the largest gains in the Energy and Climate change categories, and achieves the highest aggregate score $S^1 = 3.58$, indicating the strongest overall contribution to campus sustainability under the assumed conditions. Strategy 2 built around student-centred improvements, primarily raises scores in the Social and Mobility categories, and to some extent on land-related indicators, resulting in a more modest overall improvement; 3.37. Strategy 3, oriented towards low-carbon infrastructure and water, delivers balanced gains in Energy and Mobility and attains an intermediate aggregate score between Strategies 1 and 2 with a score of 3.48. The complete calculation to get the percentage of contribution of each action to the indicators is shown under Appendix 5.

Table 15. Action-indicator matrix, Strategy 1

Action description / Indicator	Planted vegetation area	Open space / campus population	Annual heat energy per m²	Annual electricity per m²	Renewable electricity share	Water use per person	Water conservation program	Organic waste treatment	Inorganic waste treatment	Containers for sorted waste	Bicycle parking spaces per capita	Vehicles / campus population	Users using more sustainable commuting options	Publicly shared facilities	Sustainability courses / total	Budget for sustainability (%)	GHG operations per person	GHG (electricity) per m²	GHG (thermal) per m²	Water absorption area / open area
By 2030, increase the share of electricity produced by on-campus photovoltaic systems at the main campus to twice (from 6.15% to at least 12.30%), by installing additional PV capacity on existing buildings.				-6.63%	100%												-5.60%	-8.70%		
By 2030, enhance PoliTO's sustainability-related education and research offer by: increasing the share of courses explicitly focused on sustainability from 54% (2024 baseline) to at least 80% of all courses..															26%					
By 2030, implement an integrated "zero waste" system at Politecnico di Torino that: (i) achieves a high separate collection rate for organic waste, with at least 100% of total organic waste being sent to composting or anaerobic digestion; (ii) achieves a high separate collection rate for recyclable inorganic waste, with at least 100% of total inorganic waste being separately collected and sent to authorised recycling facilities; and (iii) doubles sorted-waste collection points clearly labelled (at minimum: residual, organic, paper, plastic/metal, glass) from 0.3 per 1000m2 to 0.6.										100%										
Polito's Performance before Action	7.00	4.3	51.77	57.88	6.15	16.09	25	100	100	0.3	0.03	0.01	5.57	0.75	54	31	0.18	14.3	10.4	5
Polito's Performance after Action	7.00	4.3	51.77	54.30	12.30	15.3	25	100	100	0.6	0.03	0.01	5.57	0.75	80	31	0.17	13.0	10.40	5
Benchmark 0	10	10	130	180	10	54	0	0	0	0	0	1	0	0	1	1	4.7	25	35	2
Benchmark 5	40	70	50	30	30	14.5	50	85	85	0.8	0.072	0.045	6	2	100	15	0	10	15	30
Normalized	-1	-1	4.89	4.19	0.58	4.80	2.50	5	5	3.75	2.3	5	4.64	1.88	3.99	5	4.82	3.99	5.00	0.54
Score in Category		-1			3.22		3.65			4.58			3.98		2.93	5				3.59
Weight of Category	2.86		23.35			11.46		17.19			7.92			6.39		3.08	27.75			
New Final Score of Category		-2.86			75.1513		41.829			78.7875			31.5216		18.73835	15.4				99.49436
																				3.58

Figure 18. Radar graph, Strategy 1

Table 16. Action indicator matrix, Strategy 2

Action / Indicator	Planted vegetation area	Open space / campus population	Annual heat energy per m^2	Annual electricity per m^2	Renewable electricity share	Water use per person	Water conservation program	Organic waste treatment	Inorganic waste treatment	Containers for sorted waste	Bicycle parking spaces per capita	Vehicles / campus population	Users using more sustainable commuting options	Publicly shared facilities	Sustainability courses / total	Budget for sustainability (%)	GHG operations per person	GHG (electricity) per m^2	GHG (thermal) per m^2	Water absorption area / open area
By 2030, upgrade and expand campus facilities, such as on-site spaces for meetings or events, facilities that help people meet their basic needs, such as a community garden, food bank, child care center, or health clinic, facilities that provide cultural services, for example, a library, computer lab, resource center, museum, or gallery, and facilites that provide recreational services, for example, a gym, or athletic field.														63.20%						
By 2030, double the share of green areas within the total open area at Politecnico di Torino, by converting existing asphalted surfaces into locally vegetated, permeable spaces.	100%																			
By 2030, consolidate and enhance sustainable mobility at Politecnico di Torino by: – Initiatives reducing the number of daily trips to campus made by private cars to 0; – increasing the bicycle parking spaces to at least 50% compared to 2024.											50%		8%							
Polito's Performance before Action	7.00	4.3	51.77	57.88	6.15	16.09	25	100	100	0.3	0.03	0.01	5.57	0.75	54	31	0.17	14.3	10.4	5
Polito's Performance after Action	14.00	4.3	51.77	57.88	6.15	16.09	25	100	100	0.3	0.05	0.01	6.00	1.25	54		0.17	14.3	10.4	5
Benchmark 0	10	10	130	180	10	54	0	0	0	0	0	1	0	0	1	1	4.7	25	35	2
Benchmark 5	40	70	50	30	30	14.5	50	85	85	0.8	0.072	0.045	6	2	100	15	0	10	15	30
Normalized	0.66667	-1	4.89	4.07	-1.00	4.80	2.50	5.00	5.00	1.90	3.40	5.00	5	3.10	2.68	5	4.81	3.57	5.00	0.54
Score in Category		-0.1667			2.65		3.65			3.97			4.4667		2.89	5				3.48
Weight of Category		2.86			23.35		11.46			17.19			7.92		6.39	3.08				27.75
New Final Score of Category		-0.4767			61.9553		41.829			68.187			35.376		18.467	15.4				96.57
																				3.37

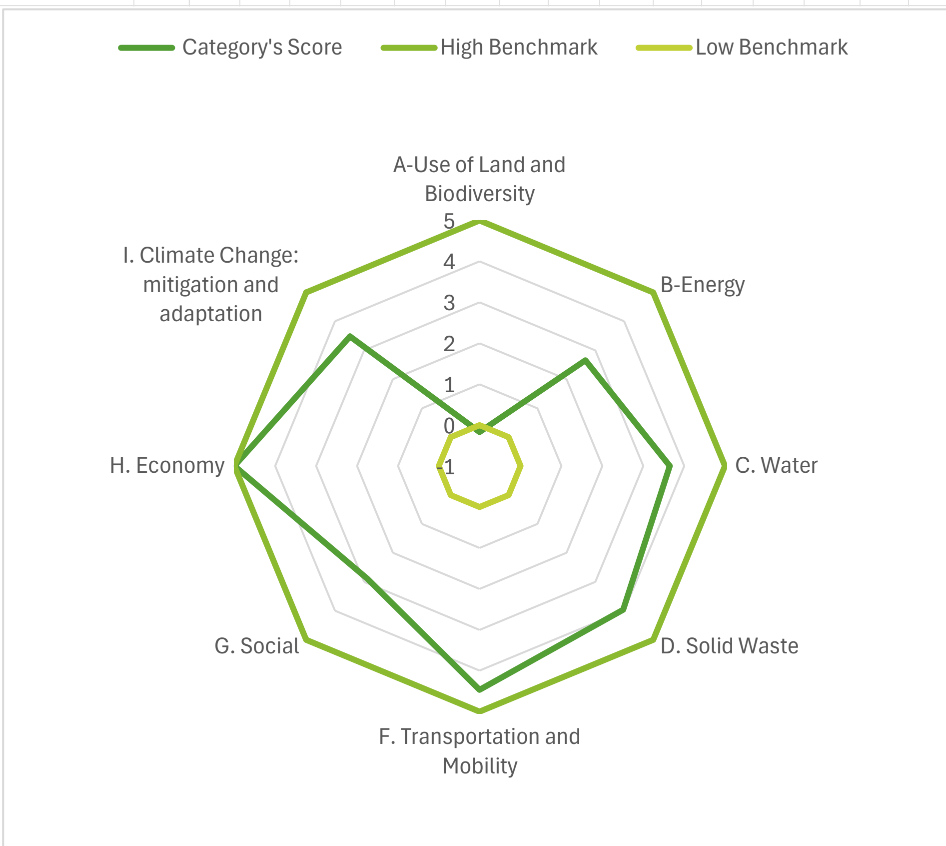


Figure 19. Radar graph, Strategy 2

Table 17. Action indicator matrix, Strategy 3

Action / Indicator	Planted vegetation area	Open space / campus population	Annual heat energy per m²	Annual electricity per m²	Renewable electricity share	Water use per person	Water conservation program	Organic waste treatment	Inorganic waste treatment	Containers for sorted waste	Bicycle parking spaces per capita	Vehicles / campus population	Users using more sustainable commuting options	Publicly shared facilities	Sustainability courses / total	Budget for sustainability (%)	GHG operations per person	GHG (electricity) per m²	GHG (thermal) per m²	Water absorption area / open area
By 2030, increase the share of electricity produced by on-campus photovoltaic systems at the main campus to twice (from 6.15% to at least 12.30%), by installing additional PV capacity on existing and new campus buildings.				-6.63%	100%												-5.6%	-8.7%		
By 2030, consolidate and enhance equipment (Water Sense bathroom faucets/accessories) that leads to at least a 10% reduction in water consumption per person;						-6%														
By 2030, consolidate and enhance sustainable mobility at Politecnico di Torino by: – Initiatives reducing the number of daily trips to campus made by private cars to 0; – increasing the bicycle parking spaces to at least 50% compared to 2024.											50%		8%							
Polito's Performance before Action	7.00	4.3	51.77	57.88	6.15	16.09	25	100	100	0.3	0.03	0.01	5.57	0.75	54	31	0.18	14.3	10.4	5
Polito's Performance after Action	7.00	4.3	51.77	54.30	12.30	15.1	25	100	100	0.3	0.05	0.01	6.00	0.75	54	31	0.17	13.0	10.40	5
Benchmark 0	10	10	130	180	10	54	0	0	0	0	0	1	0	0	1	1	4.7	25	35	2
Benchmark 5	40	70	50	30	30	14.5	50	85	85	0.8	0.072	0.045	6	2	100	15	0	10	15	30
Normalized	-1	-1	4.89	4.19	0.58	4.93	2.50	5	5	1.9	3.40	5	5	1.88	2.68	5	4.82	3.99	5.00	0.54
Score in Category		-1			3.22		3.71			3.96			4.47		2.28	5				3.59
Weight of Category	2.86			23.35		11.46			17.19			7.92		6.39		3.08	27.75			
New Final Score of Category		-2.86			75.148		42.562			68.044			35.383		14.543	15.4				99.494
																				3.48

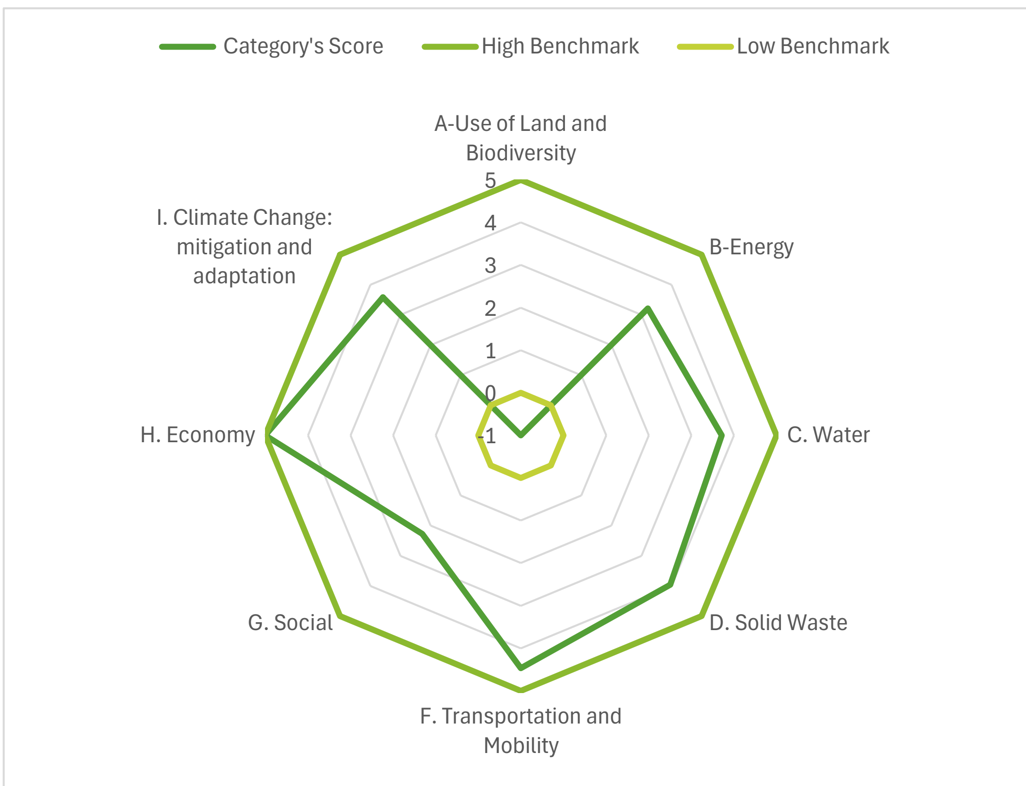


Figure 20. Radar graph, Strategy 3

5 Discussion and Conclusions

5.1 Limitations

5.1.1 Share of waste treated has a limited discriminating power

The indicator “share of waste treated”, which is widely used in studies on university sustainability, adopted originally from the UI GreenMetric (UIGM), has a limited discriminating power: according to the available documentation, practically 100% of both organic and inorganic waste is already “treated” by authorised municipal operators. As a result, the standard “waste treated” indicator overestimates performance and does not fully capture circularity, because high performance on “waste treated” mainly reflects the existence of a formal waste management service, but tells very little about how much waste is actually separately collected and recycled or composted. In other words, the wording “treated” can be somewhat self-congratulatory, because it hides the difference between disposal and circular management of materials.

5.1.2 Economic dimension remains under-represented in the pilot framework

Although the literature review already highlighted the weak operationalization of economic sustainability in many HEI tools, the POLITO pilot implementation confirms this limitation in practice: In the literature-derived indicator bank, 26 economic and financial indicators were identified, but they originate from only four out of the 44 reviewed articles, with one study contributing eleven indicators, two others six each, and one study three. This means that the apparent numerical weight of economic indicators in the database is driven by a small cluster of specialized contributions rather than by broad consensus across campus sustainability studies. When moving to the final set of twenty indicators selected for the POLITO framework – based on relevance, frequency in the literature, and data availability at campus scale – almost all of these economic indicators were filtered out, and the pilot framework ultimately includes just one explicitly economic indicator. As a result, the proposed SNTool-based framework remains predominantly environmental–operational, with a minimal economic component that prevents this dimension from being completely absent but does not provide a comprehensive picture of financial sustainability. The concentration of economic indicators in a few sources, and their marginal role in the final POLITO set, are therefore acknowledged as structural limitations and point to the need for future work on campus-level economic indicators (e.g., costs, value retention, or life-cycle investment) that are both conceptually robust and practically measurable.

5.1.3 Study facilities as a “blind spot” of the indicator set

A further limitation of existing campus sustainability assessment tools concerns their treatment of space for learning and physical well-being. Although STARS and UI GreenMetric are among the most widely used frameworks for higher-education institutions, neither of them includes explicit quantitative indicators for study space area per student or sports and recreation space per student; spatial metrics are generally limited to open space per capita or total campus area. STARS does contain a related indicator on publicly shared facilities, which asks whether the institution provides publicly accessible cultural and recreational spaces (e.g. libraries, computer labs, museums, gyms, athletic fields, fitness trails or playgrounds). However, this credit is essentially binary (yes/no) and bundles several facility types into a single item: as soon as one or more of these facilities exist, the institution receives the full score, regardless of their size, capacity or adequacy relative to the campus population. As a result, the presence of such an indicator does not meaningfully distinguish between campuses with severe shortages of study and sports spaces and those that offer generous, well-distributed facilities. In the specific context of PoliTo, where the shortage of dedicated study areas and sports infrastructure is already a recognised issue, indicators such as “study space (m^2) per FTE student” and “sports and recreation space (m^2) per FTE student” would therefore be highly discriminating and potentially decisive, capturing a critical dimension of student well-being and campus liveability that current tools do not adequately reflect.

5.1.4 Gaps in PoliTo’s own data infrastructure

In addition to the limitations of external assessment frameworks, the analysis was also constrained by gaps in PoliTo’s own data infrastructure. Several indicators that are conceptually straightforward and metrically well-defined could not be used simply because the necessary data is not systematically collected or centrally stored. Examples include waste separation rates at campus level, the volume of food waste from canteens and self-service facilities, the share of food procured from local markets, or even basic capacity measures such as the number of study seats available across libraries and study halls.

Moreover, the overall number of indicators employed in this thesis had to be deliberately limited: at the scale of a master’s dissertation, it was not feasible to manage a much larger set, especially given the difficulties of identifying robust references, validating indicator definitions, and estimating the feasibility and impacts of the proposed actions.

It is therefore recommended that PoliTo invest in expanding and systematising its sustainability-related data collection, particularly for operational and user-centred dimensions. Such an effort would not only improve the quality of future campus assessments but also substantially reduce the time and effort required by students and researchers working on similar projects.

5.2 Interpretation of results and recommendations

5.2.1 Mitigating the Open-Space Bias Against Dense Urban Campuses

The baseline assessment highlights a clear imbalance among sustainability domains. In particular, “Use of Land and Biodiversity” emerges as the weakest category, with performance falling below the minimum threshold. This suggests that the main sustainability bottlenecks for a town-embedded, compact campus such as PoliTo are not necessarily in the domains where generic campus tools traditionally show the worst performance, but rather in space-related and ecological dimensions that are structurally constrained by the urban context.

The implementation confirms that land-use and open-space indicators can disadvantage urban campuses due to structural spatial constraints. As suggested in the literature for the Italian context (Marrone P. et al), this gap could be partly balanced by introducing an indicator that captures the sustainability value of reusing and rehabilitating existing building stock—an approach widely adopted by Italian universities and aligned with resource conservation and avoided demolition. In the POLITO case, such an indicator would acknowledge sustainability contributions that are not reflected by land-availability metrics.

A suggested indicator could be Share of reused/rehabilitated floor area.

$$\text{Reused GFA Share} = \frac{\text{GFA of Refurbished or Reused Buildings}}{\text{Total Campus GFA}}$$

Or, as suggested by Marrone P. et al, percentage of historical buildings reused with a changing function.

5.2.2 Introducing a Capacity-Based Indicator for Study Facilities

To address the “blind spot” identified in the indicator set, the framework could be strengthened by adding at least one capacity-based study facilities indicator that captures the adequacy of learning spaces relative to the campus population. A suitable option is the introduction of an indicator such as Study seat capacity per capita (or per Full-Time Equivalent), which is commonly used in library and learning-space programming and directly reflects the availability of places for individual and group study. For example:

$$\text{Study seats per 1,000 FTE students} = \frac{\text{Total publicly available study seats}}{\text{FTA students}} * 1{,}000$$

This metric is easy to understand, comparable across campuses, and sensitive to overcrowding conditions. Furthermore, it is aligned with established library performance guidance (e.g., ISO 11620 / IFLA), which defines “number of user seats … per 1,000 members of the library’s population to be served” as a standard indicator.

In parallel, a complementary spatial indicator can be used to capture the physical dimension of learning environments:

$$\text{Dedicated study area (m}^2\text{) per FTE student} = \frac{\text{Total dedicated study area}}{\text{FTA students}}$$

Together, these indicators would allow the assessment to move from a “presence-based” logic to an “adequacy-based” logic, ensuring that improvements in learning facilities translate into measurable gains within the sustainability evaluation.

A similar approach could be extended to physical well-being by introducing sports and recreation space (m^2) per FTE student, which would better represent the campus capacity to support health and daily activity compared to generic open-space metrics.

5.2.3 Rebalancing Stakeholder Priorities Toward Evidence-Based Gaps

A third implication concerns the interaction between measured performance and stakeholder priorities. The aggregated ranking assigns systematically higher priority to energy and climate-related indicators, while land-use and some mobility/space indicators tend to appear towards the lower end of the consensus table. This tension is important: it indicates that even when ecological/space-related weaknesses are objectively visible in the baseline, decision-making may still gravitate towards energy and emissions because they are both more legible (data-rich) and more directly aligned with climate commitments.

In future iterations, priorities should be elicited from real stakeholders using a short, neutral evidence briefing (baseline gaps in land-use/mobility/space in comparable units) before the weighting exercise, and—ideally—validated through a second weighting round with controlled feedback to improve consistency.

In this thesis, however, stakeholder preferences were AI-simulated rather than elicited from real participants. Introducing an evidence briefing in a simulated setting could have produced an unverifiable influence on the simulated votes, potentially amplifying the effect beyond what would occur in practice. Therefore, the study intentionally avoided additional decision-shaping inputs and minimized confounding parameters to reduce the overall risk of error.

Appendix

5.3 Appendix 1

Table A 1. Indicators retained after the first screening

No.	Category	Sub-Category	Indicator	Unit	Source	Benchmark 0	Benchmark 5	POLITO
1	A- Use of Land and Biodiversity	A.2 Green Urban Areas	Open space area/total campus population	m2 per capita	UIGM (2024)	10	70	4.3
2			area on campus covered in planted vegetation	%	UIGM (2024)	10	40	7
3	B-Energy	B.2 Energy consumption	Total electricity usage divided by total campus population	kWh per person	UIGM (2024)	2424	279	421.34
4			Annual heat energy consumed per square meter	kWh per square meter	Article A1	130	50	51.77
5			Annual electricity consumption per square meter	kWh per square meter	Article A1	180	30	57.88
6			Energy consumption per person	kWh per person	STARS	17895	1282	831.57
7		B.3 Renewable energy	The ratio of renewable electricity to the total electricity	%	Article A1	10	30	6.15
8	C. Water	C.2 Water consumption	treated water consumed	%	UIGM (2024)	1	75	>75%
9			Potable water use per person	liters/person/day	STARS, Article A43	54	14.5	16.09
10			Potable water use per square meter	liters/m2/day	STARS	4.7	0.55	2.21
11			Water conservation program and implementation	%	UIGM (2024)	0	50	25
12	D. Solid Waste	D.1 Solid waste collection infrastructure	Program to reduce the use of paper and plastic on campus	Number	UIGM (2024)	1	10	>10
13			Organic waste treatment	%	UIGM (2024)	0	85	100
14			Inorganic waste treatment	%	UIGM (2024)	0	85	100

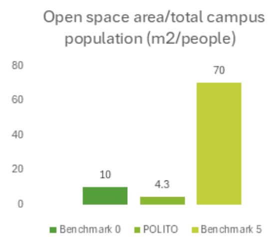
15			Availability of containers for sorted waste	Number/m2	Article A1	0	50	60
16	F. Transportation and Mobility	F.1 Performance of mobility service	Total vehicles (cars and motorcycles)/total campus population	Number per capita	SNTool	0	0.072	0.03
17			Bicycle parking spaces /total campus population	Number per capita	UIGM (2024)	0.002	0.02	0.03
18			Users using more sustainable commuting options	Points	STARS	0	6	5.57
19	G. Social Aspects	G.3 Availability of public and private facilities and services	Publicly shared facilities	Points	STARS	0	2	0.75
20		G.4 Education	Sustainability courses/total courses-subjects	%	UIGM (2024)	1	20	54
21		G.9 Cultural Heritage	Percentage of historical buildings reused with changing functions	%	article	25	75	70
22	H. Economy	H.1 Economic Performance	1.18 (SI.6) Percentage of university budget for sustainability efforts	%	UIGM (2024)	1	15	31
23	I. Climate Change: mitigation and adaptation	I.1 Climate change mitigation	Annual greenhouse gas emissions (electricity based) per square meter	kg/m2	STARS	25	10	14.3
24			Annual greenhouse gas emissions (Thermal based) per square meter	kg/m2	STARS	35	15	10.4
25			Greenhouse gas emissions per person	Tones per capita	STARS	4.7	0	0.16
26		I.5 Adaptation to the climatic action: drought	area on campus for water absorption	m2	UIGM (2024)	2	30	5

5.4 Appendix 2

The full dataset used to produce graphs in Figure 11 is provided here.

Indicators Assessment

Open Space Area per Capita



1.15. The total open space area divided by the total campus population (SI.5)

Please provide the open space area per person on your campus. The areas included in the calculation of open space here are those within the campus. If there is a campus forest used for research, it can be considered under forest vegetation, but for this indicator, it cannot be included.

Formula: ((1.5-1.6)/(1.12+1.14))

Please select one of the following options:
[1] ≤ 10 m^2/person
[2] > 10 – 20 m^2/person
[3] > 20 – 40 m^2/person
[4] > 40 – 70 m^2/person
[5] > 70 m^2/person

UIGM gide line

$$\text{Open space per capita} = \frac{169{,}695}{39{,}414} = 4.3\ \text{m}^2/\text{person}$$

University Profile

Username : polito.it
University Name : Politecnico di Torino
University Leader : Rector: Stefano Corgnati

PIC Profile

PIC Name : Valentina Colaleo
PIC Position : Sustainability Division
Email : valentina.colaleo@polito.it

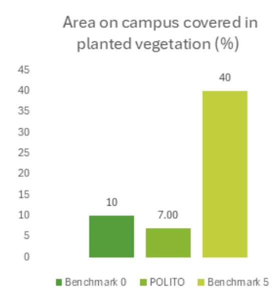
Setting and Infrastructure

Question		Answer
1.1()	Type of higher education institution	[2] **Specialized higher education institution**
1.2()	Climate	[5] **Mediterranean**
1.3()	Number of campus site	4
1.4()	Campus setting	[3] **Urban**
1.5()	Total campus area (m^2)	169695
1.6()	Total campus ground floor area of buildings (m^2)	81936
1.7()	Total campus buildings area (m^2)	291602
1.8(SI.1)	The ratio of open space to total area.	[2] **> 1 - 80%**
1.9(SI.2)	Total area on campus covered in forest vegetation (please provide total area in square meters)	[1] **<= 2%**
1.10(SI.3)	Total area on campus covered in planted vegetation (please provide total area in square meters)	[1] **<= 10%: 7 m2**
1.11(SI.4)	Total area on campus for water absorption besided forest and planted vegetation (please provide total area in square meters)	[2] **> 2 - 10%: 5 m2**
1.12()	Total number of regular students (part time and full time)	38013
1.13()	Total number of online students (part time and full time)	0
1.14()	Total number of academic and administrative staff	2611
1.15(SI.5)	The total open space area divided by total campus population.	[1] **<= 10 m2 / person**
1.16()	Total university's budget (in US Dollars)	375029455
1.17()	University's budget for sustainability effort (in US Dollars)	116260891
1.18(SI.6)	Percentage of University's budget for sustainability effort	[5] **> 15%**
1.19(SI.7)	Percentage of operation and maintenance activities of building in one year period	[5] **100%**
1.20(SI.8)	Campus facilities for disable and maternity care	[5] **Facilities exist in all buildings and are fully operated**
1.21(SI.9)	Security and safety facilites	[5] **Security infrastructure is available and fully functions and security accidents, crime, fire, and natural disasters is less than 10 minutes**

UIGM questionnaire, provided by Green Team

Indicators Assessment

Area of Planted Vegetation



1.10. Total area on campus covered in planted vegetation (SI.3)

Please provide the percentage of the area on campus covered in planted vegetation **excluding** forests to the total campus area. Lawns, gardens, green roofs, internal planting, and vertical garden can be counted, for vegetation purposes. Please select one of the following options:
[1] ≤ 10% (provide the total area in square meters)
[2] > 10 - 20% (provide the total area in square meters)
[3] > 20 - 30% (provide the total area in square meters)
[4] > 30 - 40% (provide the total area in square meters)
[5] > 40% (provide the total area in square meters)

UIGM gide line

University Profile

Username : polito.it
University Name : Politecnico di Torino
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PIC Profile

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PIC Position : Sustainability Division
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Setting and Infrastructure

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1.7()	Total campus buildings area (m^2)	291602
1.8(SI.1)	The ratio of open space to total area.	[2] **> 1 - 80%**
1.9(SI.2)	Total area on campus covered in forest vegetation (please provide total area in square meters)	[1] **<= 2%**
1.10(SI.3)	Total area on campus covered in planted vegetation (please provide total area in square meters)	[1] **<= 10%: 7 m2**
1.11(SI.4)	Total area on campus for water absorption besided forest and planted vegetation (please provide total area in square meters)	[2] **> 2 - 10%: 5 m2**
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1.15(SI.5)	The total open space area divided by total campus population.	[1] **<= 10 m2 / person**
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1.21(SI.9)	Security and safety facilites	[5] **Security infrastructure is available and fully functions and security accidents, crime, fire, and natural disasters is less than 10 minutes**

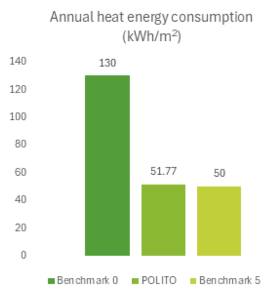
UIGM questionnaire, provided by Green Team

Indicators Assessment

Thermal Energy Consumption (kWh)

2023	Type	january	february	march	april	may	june	july	august	september	october	november	december	overall 2023
Sede centrale	TLR	1,375,416	1,086,281	881,853	223,124	10,755	20,607	11,683	2,665	6,829	262,491	907,706	1,442,186	6,231,596
Cittadella	TLR	1,230,994	972,219	789,257	199,696	9,625	18,443	10,457	2,385	6,111	234,929	812,394	1,290,754	5,577,264
Energy Center	TLR	57,580	72,200	58,480	16,650	-	-	-	-	-	-	-	62,940	267,850
Castello del Valentino	TLR	109,910	278,410	291,820	97,550	-	-	-	-	-	55,090	209,290	390,460	1,432,530
Sede centrale	CH4	9,600	8,424	6,649	1,379	-	-	-	-	-	1,732	7,857	10,797	46,437
Energy Center	CH4	86	53	43	21	21	-	1,112	-	-	1,133	1,646	2,020	6,136
Mirafiori	CH4	108,985	83,446	46,170	13,608	-	-	-	-	-	8,050	62,333	79,544	402,136
Overall CH4 (m^3 converted into kWh)	**CH4**	118,670	91,923	52,862	15,009	21	-	1,112	-	-	10,914	71,837	92,362	**454,710**
Overall TLR (kWh)	**TLR**	2,773,900	2,409,110	2,021,410	537,020	20,380	39,050	22,140	5,050	12,940	552,510	1,929,390	3,186,340	**13,509,240**

Green Team



1.4()	Campus setting	[3] **Urban**
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1.13()	Total number of online students (part time and full time)	0
1.14()	Total number of academic and administrative staff	2611

UIGM questionnaire, provided by Green Team

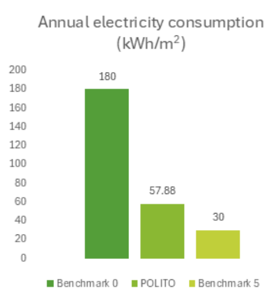
$$\text{Annual Heat Energy Consumption} = \frac{454710 + 13509240}{291,602} = \mathbf{51.77}\ \text{kWh/m}^2$$

Indicators Assessment

Electricity Consumption (kWh)

Campus	january	february	march	april	may	june	july	august	september	october	november	december	overall
Sede centrale	588,335	549,538	582,523	511,861	555,527	629,418	761,231	582,857	668,203	639,803	609,317	583,552	7,262,163
Cittadella	526,558	491,835	521,356	458,114	497,195	563,328	681,300	521,656	598,040	572,622	545,337	522,277	6,499,620
Castello del Valentino	75,229	68,651	70,840	52,360	52,261	59,246	73,777	60,203	56,012	61,468	63,668	61,655	755,370
Lingotto	60,341	54,193	57,821	47,720	50,132	50,470	57,383	51,340	53,016	60,616	68,897	62,281	674,210
Mirafiori	75,628	67,333	74,463	60,934	66,086	72,121	70,128	59,059	64,066	69,714	69,579	75,175	824,286
Architettura Morgari	9,338	8,353	9,586	6,263	9,402	10,280	9,526	8,666	8,871	9,642	8,861	8,665	107,453
Energy Center	42,426	32,081	33,045	26,719	30,998	42,099	54,145	45,172	49,287	48,163	47,947	31,617	483,699
	1,377,855	1,271,984	1,349,634	1,163,971	1,261,601	1,426,962	1,707,490	1,328,953	1,497,495	1,462,028	1,413,606	1,345,222	**16,606,801**

Green Team



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1.14()	Total number of academic and administrative staff	2611

UIGM questionnaire, provided by Green Team

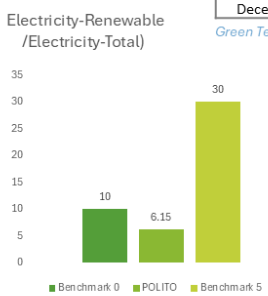
$$\text{Annual Electricity Consumption per m}^2 = \frac{16,606,801}{291,602} = \mathbf{57.88}\ \text{kWh/m}^2$$

Indicators Assessment

Renewable Electricity Production (kWh)

Month	Year	PV Cittadella	PV Incubatore	PV Aule P	Castelfidai	PV Aule R	PV Energy Center	PoliTO PV autopro	Unit
January	2023	28,565.40	828.95	1,605.90	8,194.80	1,194.20	941.68	41,330.93	kWh
February	2023	44,065.00	1,339.21	2,383.00	10,713.30	1,791.50	4,618.73	64,910.74	kWh
March	2023	70,057.30	2,462.81	4,485.90	17,643.10	3,514.50	2,971.64	101,135.25	kWh
April	2023	64,360.60	3,097.71	5,601.10	19,403.90	4,697.50	3,205.71	100,366.53	kWh
May	2023	66,378.40	2,828.77	5,437.80	16,931.80	4,995.60	2,951.62	99,523.99	kWh
June	2023	61,244.70	3,143.14	6,155.10	18,297.30	5,805.90	2,049.68	96,695.83	kWh
July	2023	62,540.00	3,671.32	6,744.90	26,549.80	6,516.80	3,560.38	109,583.20	kWh
August	2023	82,249.30	3,467.12	6,488.70	25,628.50	5,889.80	2,872.72	126,596.14	kWh
September	2023	64,795.30	2,420.83	4,843.60	21,496.90	4,852.00	5,537.09	103,945.72	kWh
October	2023	47,059.10	1,539.70	3,125.80	15,330.50	3,211.10	2,275.38	72,541.58	kWh
November	2023	39,426.60	1,132.78	2,226.50	13,892.30	2,424.30	2,207.36	61,309.83	kWh
December	2023	27,431.40	785.10	1,481.20	10,485.00	1,726.20	1,607.02	43,515.93	kWh
								1,021,455.66	

Green Team



$$\text{Ratio of Renewable Electricity} = \frac{1{,}021{,}455.659}{16{,}606{,}801} = 6.15\ \%$$

Indicators Assessment

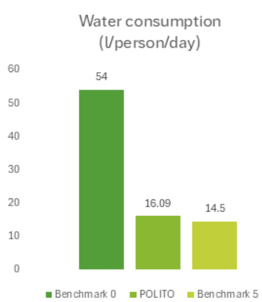
Municipal Water Suply (m3)

Trimester	Year	Sede centrale	Cittadella	Castello del Valentino	Energy Center	Mirafiori	Overall PoliTO water supply	Unit
First	2023	10,990.51	9,836.49	757.00	592.00	27,287.00	49,463.00	m^3
Second	2023	14,918.22	13,351.78	737.00	514.00	11,411.00	40,932.00	m^3
Third	2023	44,517.20	39,842.80	577.00	514.00	3,933.00	89,384.00	m^3
Fourth	2023	16,696.06	14,942.94	410.00	514.00	4,541.00	37,104.00	m^3
							216,883.00	

Green Team

Drinking Water Consumption (l)

Month	Year	Aula Magna	DENERG	Aule P	Aule M/N	North corridor	South corridor	iTO drinking w	Unit
January	2023	4,247.00	299.00	1,129.00	25,223.00	2,263.00	3,777.00	36,938.00	l
February	2023	4,922.00	584.00	1,051.00	45,931.00	3,163.00	4,364.00	60,015.00	l
March	2023	13,564.00	1,682.00	4,660.00	67,870.00	5,882.00	5,573.00	99,231.00	l
April	2023	9,759.00	1,215.00	2,884.00	40,649.00	1,985.00	3,355.00	59,847.00	l
May	2023	20,102.00	1,848.00	5,972.00	67,401.00	0.00	7,560.00	102,883.00	l
June	2023	17,746.00	1,639.00	3,505.00	40,197.00	1,963.00	6,845.00	71,895.00	l
July	2023	12,270.00	218.00	1,761.00	39,884.00	3,065.00	6,312.00	63,510.00	l
August	2023	1,979.00	40.00	367.00	39,288.00	1,163.00	1,596.00	44,433.00	l
September	2023	5,966.00	133.00	1,367.00	43,697.00	2,022.00	5,843.00	59,028.00	l
October	2023	19,235.00	263.00	6,045.00	49,049.00	4,344.00	10,077.00	89,013.00	l
November	2023	13,511.00	296.00	3,623.00	30,131.00	3,088.00	8,901.00	59,550.00	l
December	2023	0.00	0.00	0.00	15,050.00	0.00	7,100.00	22,150.00	l
								768,493.00	



$$\text{Ratio of Renewable Electricity} = \frac{(216{,}883*1{,}000)+768{,}493}{39{,}414*365} = 16.09\ \text{l/person/day}$$

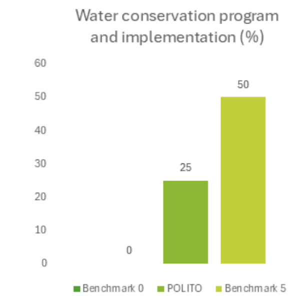
Indicators Assessment

Water conservation program and implementation

Water

Question		Answer
4.1(WR.1)	Water conservation program and implementation	[3] **1 - 25% water conserved**
4.2(WR.2)	Water recycling program implementation	[5] **> 50% water recycled**
4.3(WR.3)	Water efficient appliance usage	[5] **> 80% of water efficient appliances installed**
4.4(WR.4)	Consumption of treated water	[5] **> 75% treated water consumed**

UIGM questionnaire, provided by Green Team



4.1. Water conservation program and implementation (WR.1)

Please select a condition describing your current stage in a program that is systematic and formalized, and supports water conservation (i.e., for lakes and lake management systems, rain harvesting systems, water tanks, bio pore, recharge well, etc.) in your university, from the following options:

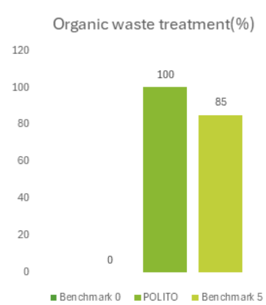
[1] None. Please select this option if the conservation program is needed, but nothing has been done.
[2] Program in preparation
[3] 1 - 25% water conserved
[4] > 25 - 50% water conserved
[5] > 50% water conserved

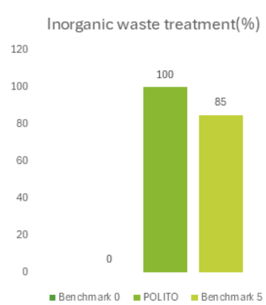
Indicators Assessment

Waste Treatment

3.3()	Total volume organic waste produced (ton)	2.04
3.4()	Total volume organic waste treated (tons)	2.04
3.5(WS.3)	Organic waste treatment	[5] **Extensive (> 85% treated)**
3.6()	Total volume inorganic waste produced (tons)	194.3
3.7()	Total volume inorganic waste treated (tons)	194.3
3.8(WS.4)	Inorganic waste treatment	[5] **Extensive (> 85% treated)**

UIGM questionnaire, provided by Green Team





3.5. Organic waste treatment (WS.3)

The method of organic waste (i.e., garbage, discarded vegetable, food, and plant matter) treatment in your university. Please select an option that best describes your university's overall treatment of the bulk of organic waste:

[1] Open dumping
[2] Partial (1 - 35% treated)
[3] Partial (> 35 - 65% treated)
[4] Partial (> 65 - 85% treated)
[5] Extensive (> 85% treated)

3.8. Inorganic waste treatment (WS.4)

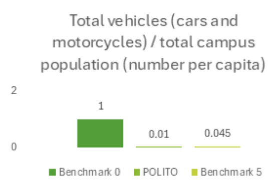
Please describe the method of non-toxic inorganic waste (i.e., rubbish/garbage, trash, discarded paper, plastic, metal, electronic, etc.) treatment in your university. Please select an option that best describes your university's overall treatment of the bulk of the inorganic waste:

[1] Burned in the open area
[2] Partial (1 - 35% treated)
[3] Partial (> 35 - 65% treated)
[4] Partial (> 65 - 85% treated)
[5] Extensive (> 85% treated)

Indicators Assessment

Total Vehicles per Capita

Transportation		
Question		Answer
5.1()	Number of cars actively used and managed by University	25
5.2()	Number of cars entering the university daily	479
5.3()	Number of motorcycles entering the university daily	30
5.4(TR.1)	The total number of vehicles (cars and motorcycles) divided by total campus population.	[5] **< 0.045**
5.5(TR.2)	Shuttle service	[5] **Shuttle service is provided by university, regular, and environment friendly. Or shuttle use is not possible (not applicable)**
5.6()	Number of shuttles operated in your university	0
5.7()	Average number of passengers of each shuttle	0
5.8()	Total trips of shuttle services each day	0
5.9(TR.3)	Zero Emission Vehicles (ZEV) policy on campus	[3] **Zero Emission Vehicles are available, but not provided by university**
5.10()	Average number of Zero Emission Vehicles (e.g. bicycles, cano, snowboard, electric car, etc.) on campus per day	1200



5.4 The total number of vehicles (cars and motorcycles with combustion engines) divided by the total campus' population (TR.1)

Please provide the total number of vehicles divided by the total campus' population.

Formula: (5.1+5.2+5.3)/(1.12+1.14)

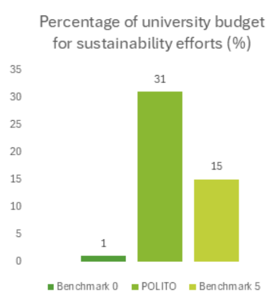
Please select one of the following options:
[1] ≥ 1
[2] > 0.5 - 1
[3] > 0.125 - 0.5
[4] > 0.045 - 0.125
[5] < 0.045

$$\text{Vehicles per capita} = \frac{25+479+30}{39{,}414} = 0.013$$

Indicators Assessment

Budget for Sustainability

1.16()	Total university's budget (in US Dollars)	375029455
1.17()	University's budget for sustainability effort (in US Dollars)	116260891
1.18(SI.6)	Percentage of University's budget for sustainability effort	[5] **> 15%**
1.19(SI.7)	Percentage of operation and maintenance activities of building in one year period	[5] **100%**



1.18. Percentage of university budget for sustainability efforts (SI.6)

Please provide the percentage calculation of the sustainability budget (infrastructure, facilities, personnel cost, research, programs and others related to the sustainability efforts) to the total university budget. Please select one of the following options:
[1] ≤ 1%
[2] > 1 - 5%
[3] > 5 - 10%
[4] > 10 - 15%
[5] > 15%

$$\text{Ratio of Sustainability Budget} = \frac{116{,}260{,}891}{375{,}029{,}455} = 0.31$$

Indicators Assessment

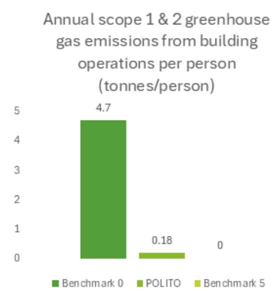
Annual scope 1 & 2 GHG emissions from building operations per person
Annual Emissions from Electricity Consumption & Thermal Energy Consumption

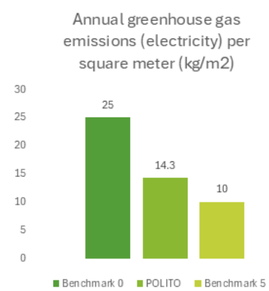
$$\text{Scope 1\&2} = \frac{7{,}150.71}{39{,}414} = \mathbf{0.18}\ tco_2/\text{person}$$

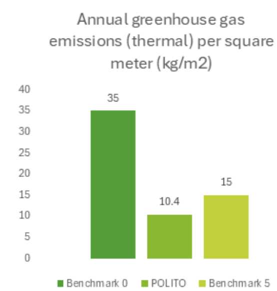
$$\text{Electricity Emissions} = \frac{4{,}099.73 * 1000}{291{,}602} = \mathbf{14.3}\ kg/m^2$$

$$\text{Thermal Emissions} = \frac{2{,}987 * 1000}{291{,}602} = \mathbf{10.4}\ kg/m^2$$

Scope	Quantity	Unit	Related CO_2 emissions	Unit
1 - mobile combustion >> PoliTO cars using PETROL------ scope1	538.67	l of fuel	1.47	tCO_2
1 - mobile combustion >> PoliTO cars using DIESEL------ scope1	13,646.72	l of fuel	36.63	tCO_2
2 - electrical energy consumption-------scope2	17,595,388	kWh	4,099.73	tCO_2
2 - thermal energy consumption--------scope2	14,790,501	kWh	2,987.68	tCO_2
3 - waste generated operations ---- Scope 1	auto-calculated		25.20	tCO_2
			7,150.71	



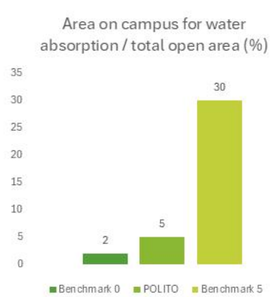




Indicators Assessment

Ratio of Campus Area for Water Absorption

1.8(SI.1)	The ratio of open space to total area.	**[2] > 1 - 80%**
1.9(SI.2)	Total area on campus covered in forest vegetation (please provide total area in square meters)	**[1] <= 2%**
1.10(SI.3)	Total area on campus covered in planted vegetation (please provide total area in square meters)	**[1] <= 10%: 7 m2**
1.11(SI.4)	Total area on campus for water absorption besided forest and planted vegetation (please provide total area in square meters)	**[2] > 2 - 10%: 5 m2**



1.11. Total area on campus for water absorption besides the forest and planted vegetation (SI.4)

Please provide the percentage of the total area of ground surfaces (i.e., soil, grass, concrete block, synthetic field, etc.) dedicated for water absorption to the total campus area. A larger water absorption area is desirable. Please select one of the following options:

[1] ≤ 2% (provide the total area in square meters)
[2] > 2 - 10% (provide the total area in square meters)
[3] > 10 - 20% (provide the total area in square meters)
[4] > 20 - 30% (provide the total area in square meters)
[5] > 30% (provide the total area in square meters)

5.5 Appendix 3

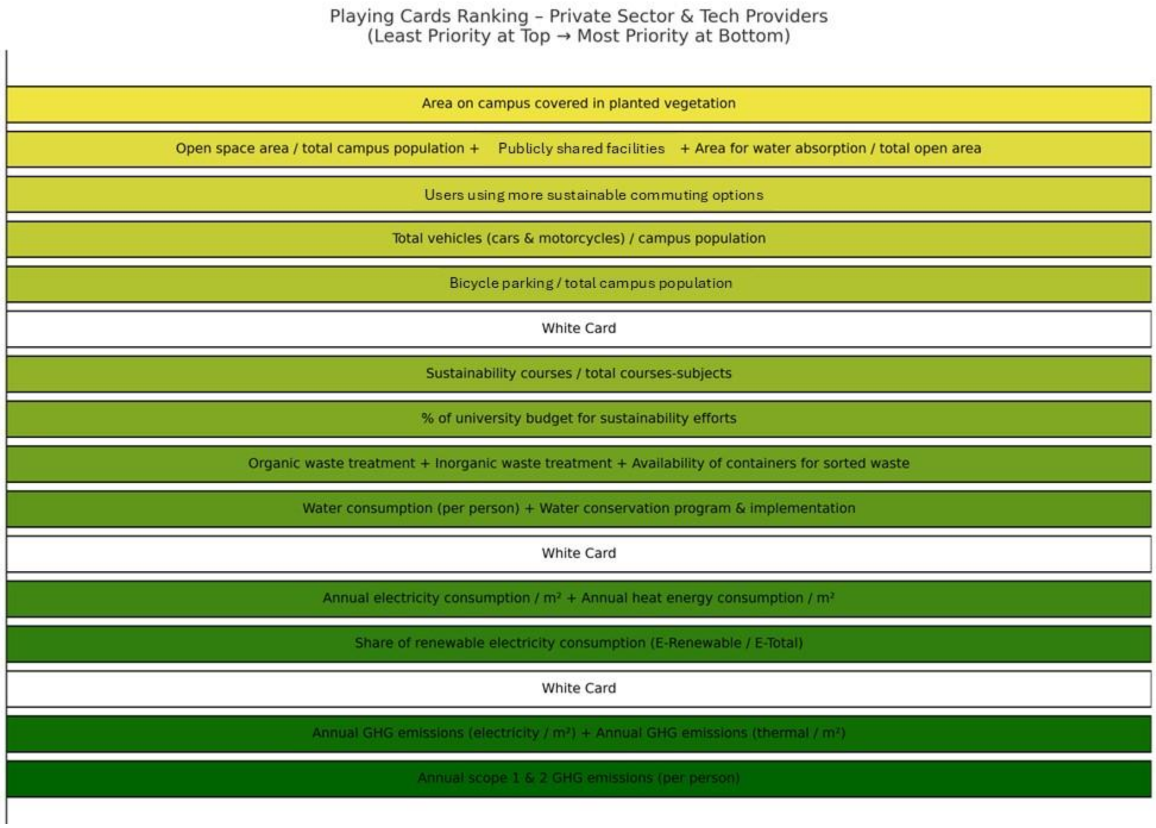


Figure A 1. Playing cards of private sector

Logic for Private Sectors & Tech Providers:

- High priority: indicators that generate market demand for technology or services → energy consumption, renewable energy share, GHG emissions.
- Medium–high priority: smart water systems and waste treatment solutions → These also create technological and service opportunities (such as smart metering, efficient fixtures, and waste systems), but they are usually not as central in terms of attention and funding as energy and carbon.
- Medium priority: budget allocation (signals potential contracts) and sustainability courses (indirectly relevant for the future workforce).
- Low priority: green areas, open space, bicycle parkings (since they do not directly create technological or service demand).

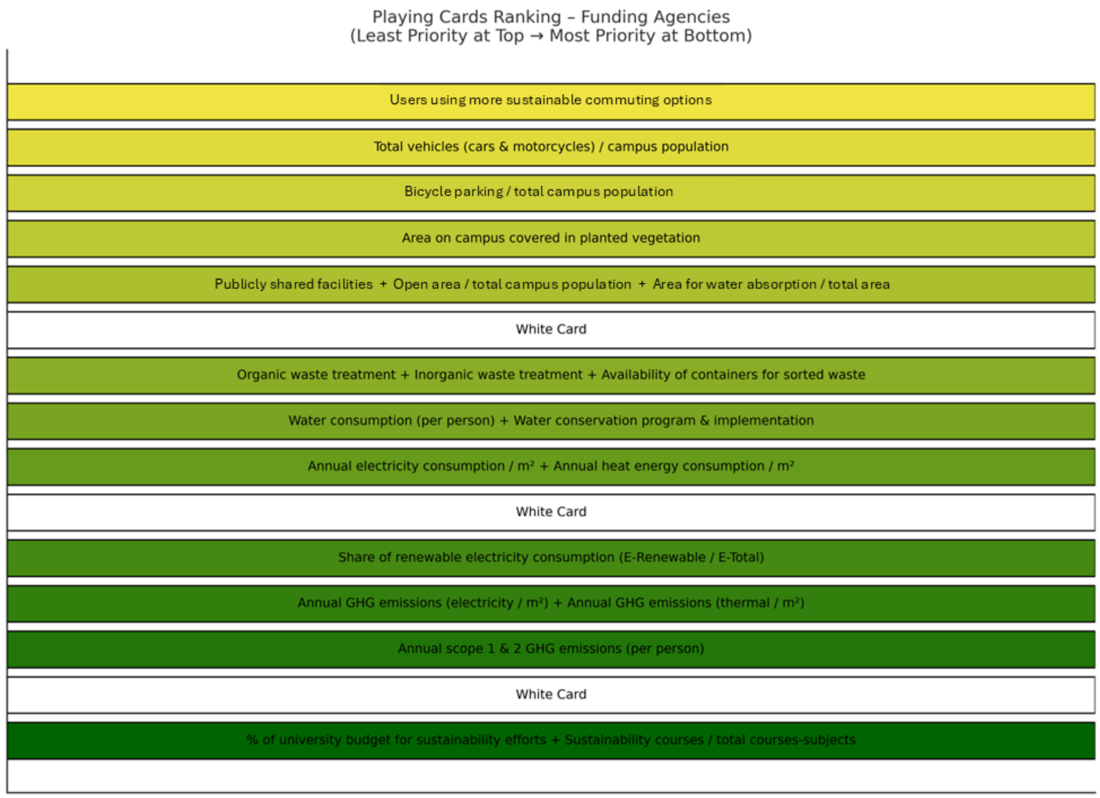


Figure A 2. Playing cards of Funding Agencies

Logic for Funding Agencies:

- High priority: Since they are paying, they care more about indicators that demonstrate clear, measurable sustainability outcomes and institutional commitments → GHG emissions, renewable energy share, sustainability budget allocation, and sustainability courses as a sign of long-term cultural change.
- Medium priority: water and waste (important for ESG, Environmental-Social-Governance, reporting, though not always the main funding driver. They are considered as part of a broader resource-efficiency package in which GHG and Energy usually come first, because most funding programmes and political targets are framed explicitly in terms of carbon reduction and renewable energy, which provide clearer, more communicable "headline impacts" for accountability and reporting).
- Low priority: campus comfort metrics (open space, green area, parking), because they do not directly demonstrate return on investment or regulatory compliance. They do not strongly justify funding decisions and have a weaker link to impact and accountability.

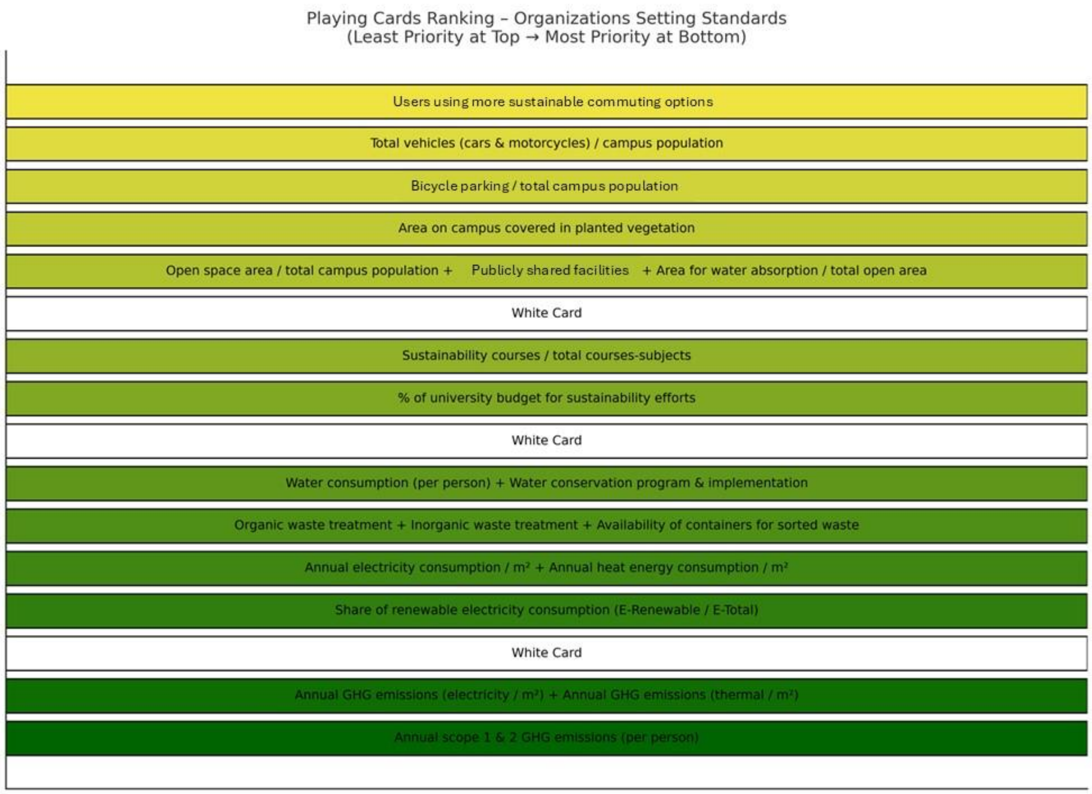


Figure A 3. Playing cards of organizations setting standard

Logic for Organizations Setting Standards:

- High priority: indicators that are directly measurable, comparable, and align with certification/reporting schemes → GHG emissions, renewable energy, waste treatment, water efficiency.
- Medium priority: sustainability courses and budget allocation (they show institutional effort, but they are not core technical metrics in rating and certification schemes).
- Low priority: comfort-related campus indicators (parking, open space, green areas) because these are contextual and not standardized internationally.

Figure A 4. Playing cards of university administration

University Administration's Main focus :

- Costs and budget control
- Energy efficiency and building performance
- Compliance with standards and sustainability reporting

Logic for University Administration:

- GHG indicators: intensity (per m^2) and scope (per person) are placed in two separate levels, since for administrators, the scope is more important in the reports.

- Water consumption and water-conservation programmes are still of high priority (because of operating costs and EU/PNRR (National Recovery and Resilience Plan) requirements)

- Low-priority indicators: Student comfort–oriented indicators (e.g., open space and green area, publicly shared facilities), since they are constrained in any way by a lack of land in dense urban campuses like POLITO, are seen as secondary compared to financial and operational performance.

Figure A 5. Playing cards of professors

Logic for Professors:

- Sustainability courses, Top priority, it's their teaching mission.
- GHG indicators, Energy consumption, and renewable share of energy are often seen as more institutional/reporting issues rather than immediate academic needs, but are still important in terms of research and innovation.
- Mobility (Medium priority) → relevant for daily life, but not central to their academic role.
- Water performance of buildings → important as good infrastructure for labs and teaching, but more as a support condition.
- Budget allocation (Lowest priority) → perceived mainly as the responsibility of the University Administration, not professors. Student comfort indicators are not a primary concern for the professors.

Figure A 6. Playing cards of technical and support staff

Logic for Technical & Support Staff:

- High priority: operational indicators directly tied to their daily work (they operate, fix, and are directly held accountable for in case of any issue or failure) → energy consumption, water consumption, waste treatment, and availability of sorted waste containers.
- Medium priority: mobility and parking (these affect their daily commuting, but are less central to their technical responsibilities).
- Low priority: budget, sustainability courses, and high-level GHG indicators (too abstract for their role).
- Green/open spaces: considered only in terms of maintenance workload, not for sustainability value (mainly create additional maintenance work and are not a key performance responsibility for them).

Figure A 7. Playing cards of local government

Logic for the Local Government:

- High priority: Indicators that are directly linked to urban and environmental policy goals → GHG reduction, renewable energy, mobility policies, and waste separation.
- Medium priority: water efficiency (since they connect with broader city programs).
- Low priority: internal budget allocation (as local government does not manage university finances), and detailed building consumption per m^2 (considered institutional and technical issues).
- Symbolic but important: green areas and open space (linked to urban livability and alignment with municipal plans).

5.6 Appendix 4

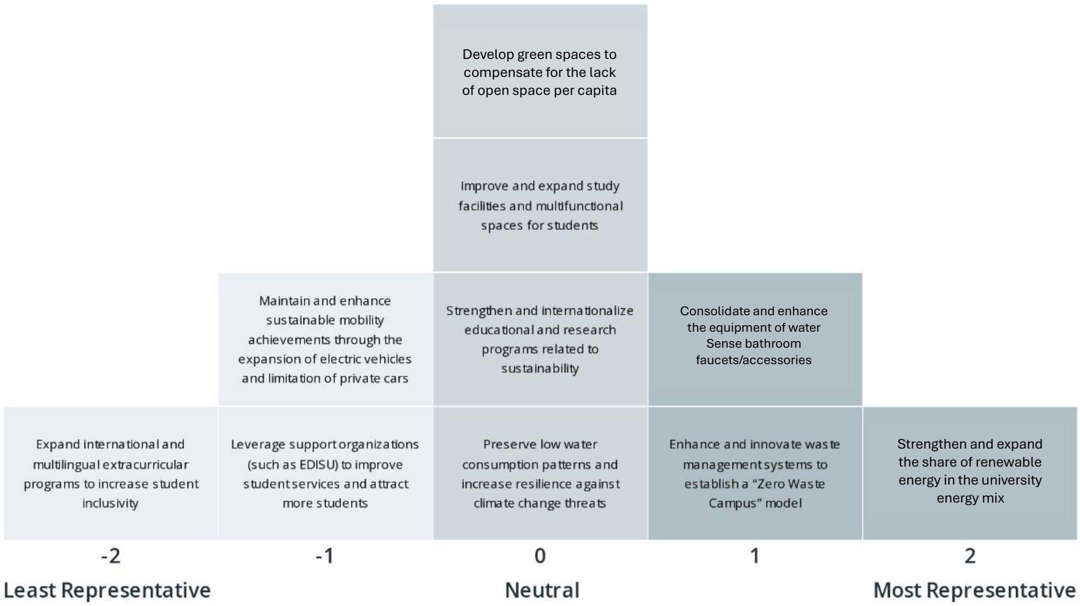


Figure A 8. Q-sort pyramid - university administration

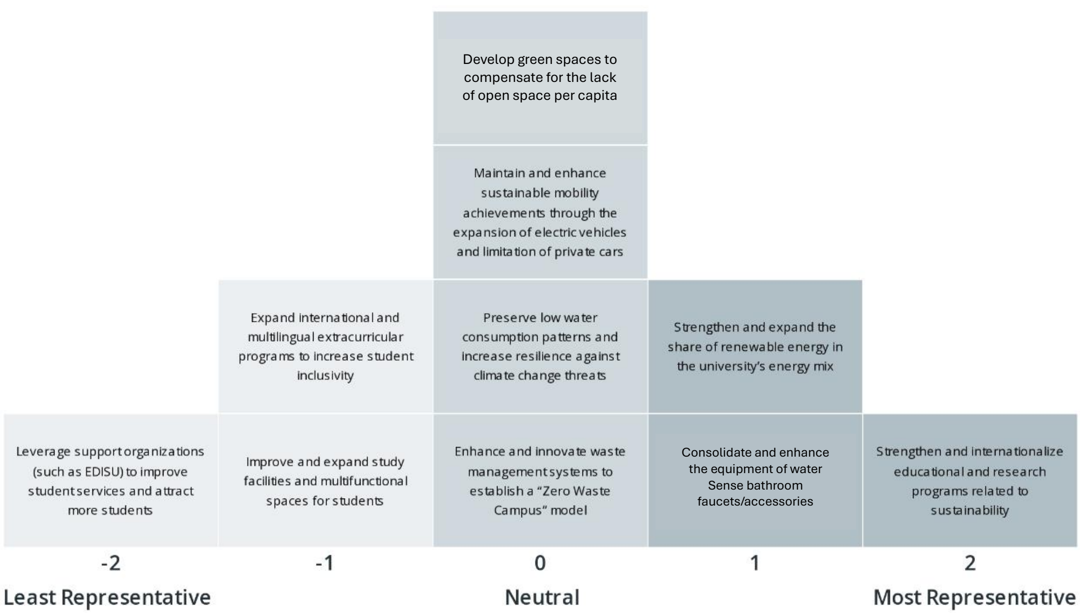


Figure A 9. Q-sort pyramid - Professors and academic staff

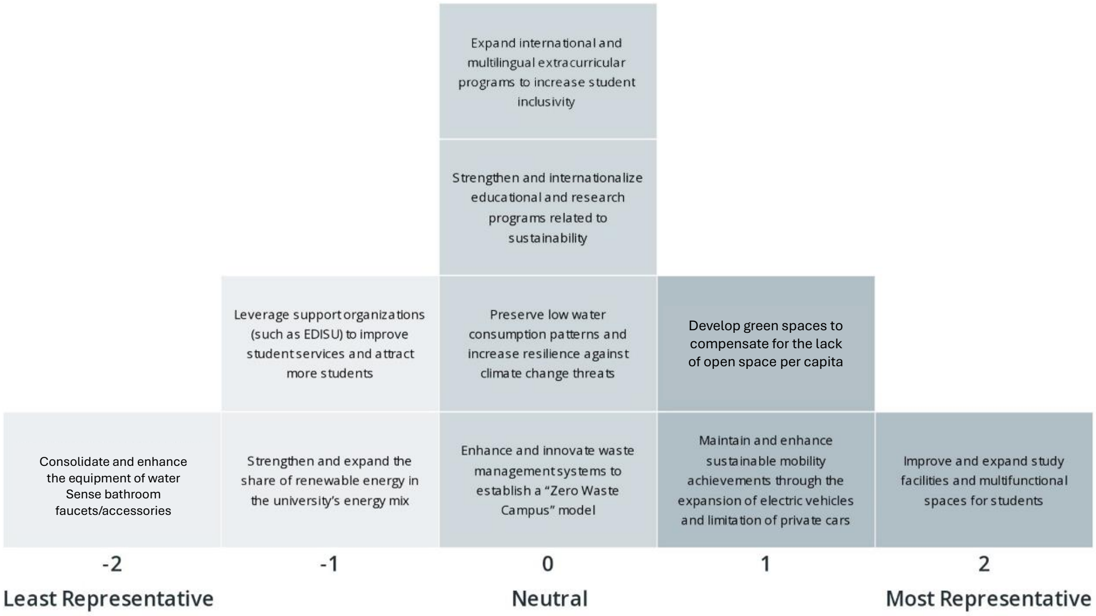


Figure A 10. Q-sort pyramid - student unions

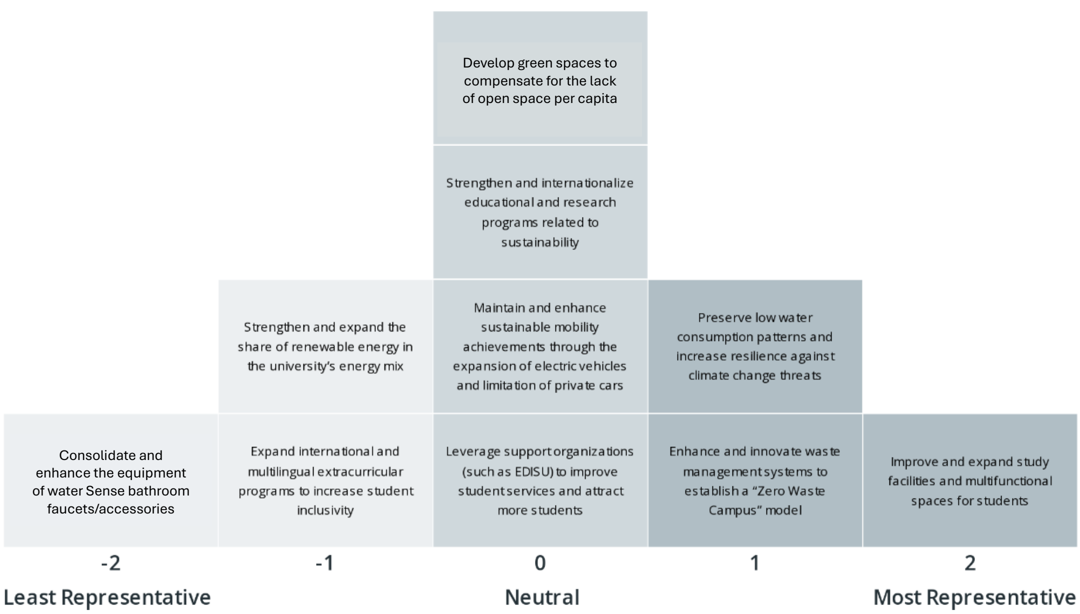


Figure A 11. Q-sort pyramid - technical and support staff

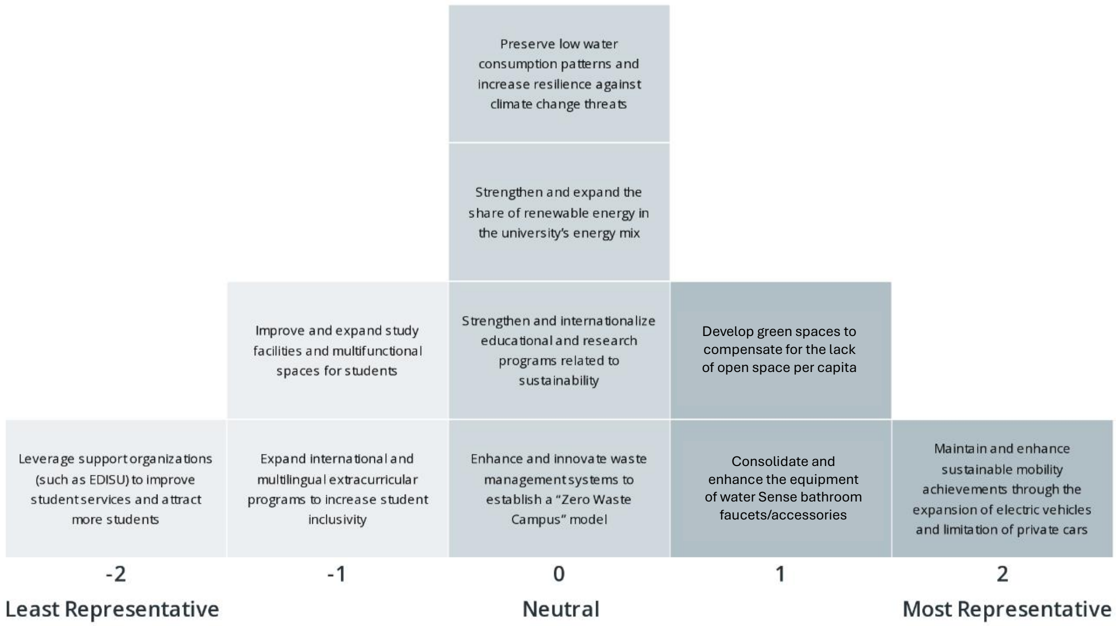


Figure A 12. Q-sort pyramid - local government and authorities

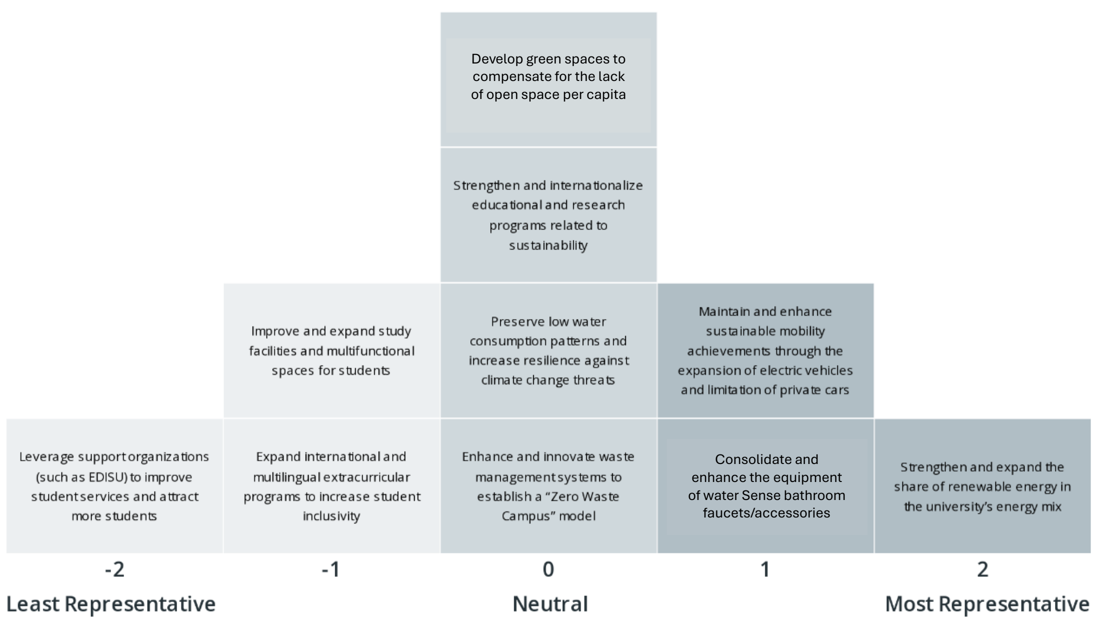


Figure A 13. Q-sort pyramid - private sectors and technology providers

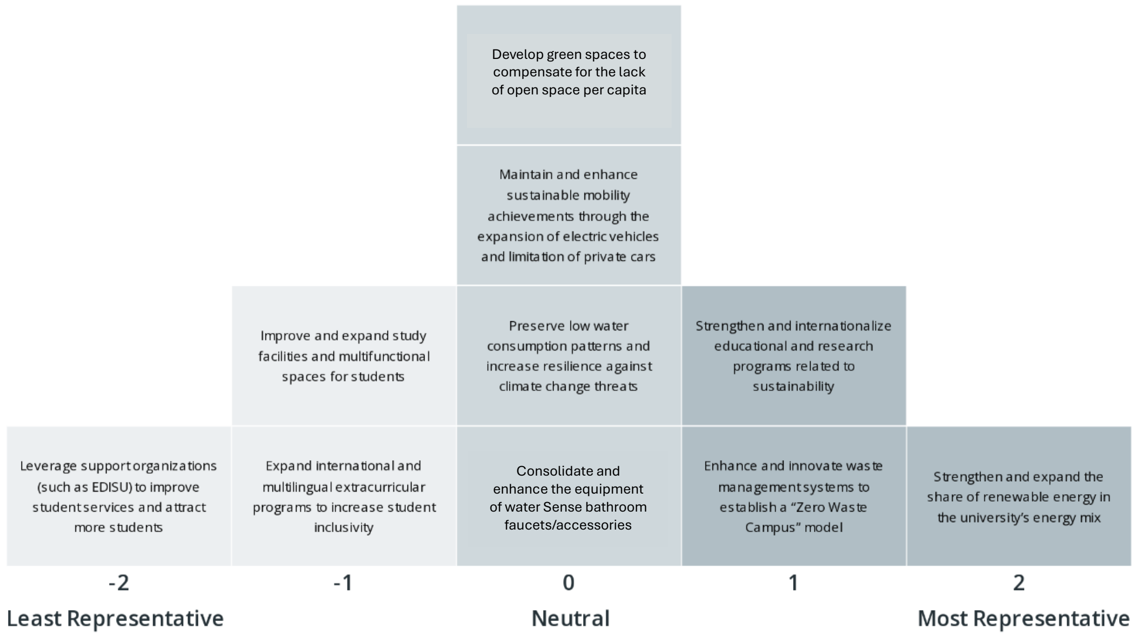


Figure A 14. Q-sort pyramid - funding agencies

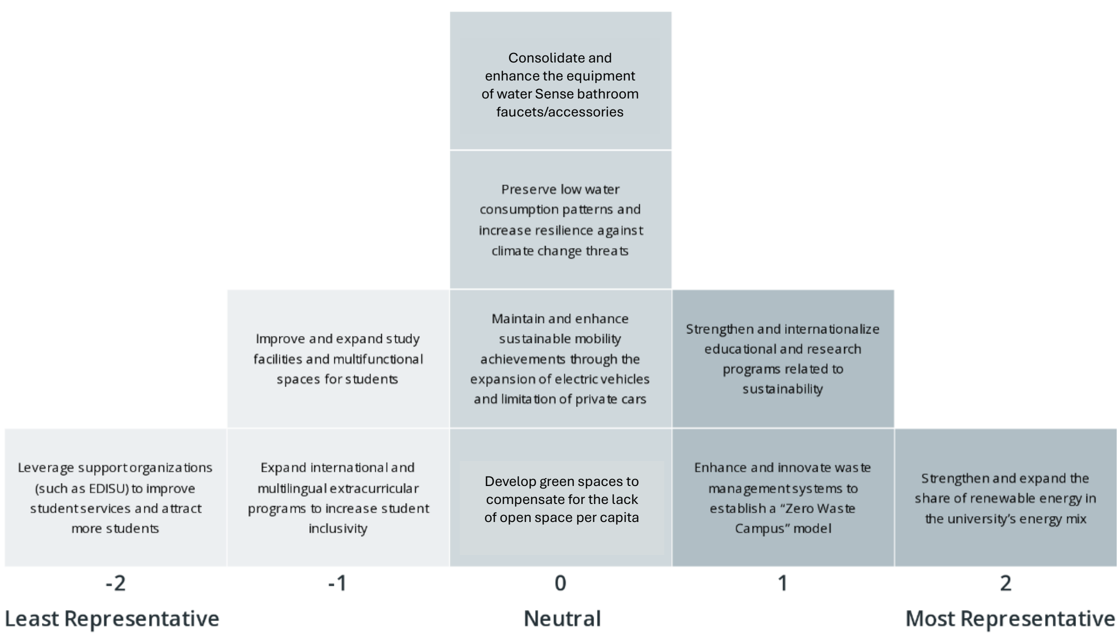


Figure A 15. Q-sort pyramid - organizations setting standards

5.7 Appendix 5

Action/indicator Assessment

Action 1 on Renewable Electricity

Increase the renewable electricity to twice (from 6.15% to 12.30%)

Methodology

Roofs occupied by PV panels = 18,090 m2

Free roofs = 65,092 m2

Total roof area = 83182.8 m^2

Current area used by PV Panels on roofs = 18,090 m2
Green Team of POLITO

Usable Roof Area Factor (for campus building stock, moderately) = 0.6
https://docs.nrel.gov/docs/fy16osti/65298.pdf

Usable Roof Area = 0.6*65,092 = 39,055.2 m^2

Area to reach the goal of a 100% increase = 2 * 18,090 = 36,180 m^2

36,180 m2 < 39,055 m2 → Goal Attainable ✓

Action 1 on Energy Consumption

Annual electricity consumption /m^2 : 6.63 % Decrease

Methodology

Annual Electricity Purchased (kWh)

Campus	january	february	march	april	may	june	july	august	september	october	november	december	overall
Sede centrale	588,335	549,538	582,523	511,861	555,527	629,418	761,231	582,857	668,203	639,803	609,317	583,552	7,262,163
Cittadella	526,558	491,835	521,356	458,114	497,195	563,328	681,300	521,656	598,040	572,622	545,337	522,277	6,499,620
Castello del Valentino	75,229	68,651	70,840	52,360	52,261	59,246	73,777	60,203	56,012	61,468	63,668	61,655	755,370
Lingotto	60,341	54,193	57,821	47,720	50,132	50,470	57,383	51,340	53,016	60,616	68,897	62,281	674,210
Mirafiori	75,628	67,333	74,463	60,934	66,086	72,121	70,128	59,059	64,066	69,714	69,579	75,175	824,286
Architettura Morgari	9,338	8,353	9,586	6,263	9,402	10,280	9,526	8,666	8,871	9,642	8,861	8,665	107,453
Energy Center	42,426	32,081	33,045	26,719	30,998	42,099	54,145	45,172	49,287	48,163	47,947	31,617	483,699
	1,377,855	1,271,984	1,349,634	1,163,971	1,261,601	1,426,962	1,707,490	1,328,953	1,497,495	1,462,028	1,413,606	1,345,222	16,606,801

Since the action doubles the share of on-site PV generation, we assume the additional PV output directly offsets electricity purchased from the grid.

on-site PV generation in a year = 1,021,455.7 kWh
Electricity purchased from the grid = 16,606,801 – 1,021,455 = 15,585,346 kWh

$$\frac{\text{Annual (Grid) Electricity Consumption}}{\text{Total Area}} = \frac{15{,}585{,}346}{286{,}941} = 54.3 \text{ kWh/m}^2$$

$$\text{Before the Action } \frac{16{,}606{,}801}{286{,}941} = 57.9 \text{ kWh/m}^2$$

PV Production (kWh)

Month	PV production	Unit
January	41330.931	kWh
February	64910.741	kWh
March	101135.248	kWh
April	100366.525	kWh
May	99523.99	kWh
June	96695.828	kWh
July	109583.204	kWh
August	126596.139	kWh
September	103945.72	kWh
October	72541.57547	kWh
November	61309.83182	kWh
December	43515.92615	kWh
	1021455.659	

Action 1 on GHG Production

Annual greenhouse gas emissions from electricity per m^2 : 8.7 % decrease

Methodology

Based on **ISPRA** (the Italian Institute for Environmental Protection and Research), which publishes official data like Italy's grid electricity CO_2 emission factors, **1 kWh PV ≈ 0.199 kg CO_2 avoided** (operational, Italy context)
https://emissioni.sina.isprambiente.it/wp-content/uploads/2025/05/Le-emissioni-di-CO2-nel-settore-elettrico_r413-2025_def.pdf

Month	PV production	Unit
January	41330.931	kWh
February	64910.741	kWh
March	101135.248	kWh
April	100366.525	kWh
May	99523.99	kWh
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August	126596.139	kWh
September	103945.72	kWh
October	72541.57547	kWh
November	61309.83182	kWh
December	43515.92615	kWh
	1021455.659	

Net avoided emissions (including PV life-cycle): $EF_{grid} - EF_{PV,LCA}$

PV life-cycle emission factor ~ 0.010 – 0.036 $kgCO_2e/kWh$ → 0.023 $kgCO_2e/kWh$ (average)
https://docs.nrel.gov/docs/fy24osti/87372.pdf?utm

Net avoided ≈ 0.199 − 0.023 = **0.175** kg CO_2e per kWh

Estimated on-site PV generation in a year = 1,021,455.7 kWh (currently)*(Green Team)** 2(goal of action) = **2,042,911.3** kWh

Annual GHG Reduction from on-site PV generation= 2,042,911.3 * 0.175 = 357,509.5 kg CO_2e = **357.5 tCO_2e**

Final Annual GHG Production from Electricity= 4,099.73 tCO_2e (current production from electricity) - 357.5 = 3,742.23 tco_2e

Final GHG per m^2 = $\frac{3,742.23*1000}{286941}$ = 13.04 kg/m^2

Primary GHG per m^2 = $\frac{4,099.73*1000}{286941}$ =14.3 kg/m^2

Percentage of Reduction = **8.7 %**

Scope	Quantity	Unit	Related CO_2 emissions	Unit
1 - mobile combustion >> PoliTO cars using PETROL------ scope1	538.67	l of fuel	1.47	tCO_2
1 - mobile combustion >> PoliTO cars using DIESEL------- scope1	13,646.72	l of fuel	36.63	tCO_2
2 - electrical energy consumption-------scope2	17,595,388	kWh	4,099.73	tCO_2
2 - thermal energy consumption--------scope2	14,790,501	kWh	2,987.68	tCO_2

Action 1 on GHG Production

Annual scope 1 & 2 greenhouse gas emissions from building operations / person : 5.6 % decrease

Methodology

Total Scope 1+2 GHG per person decreases by **less than 8.7%**, because only the electricity slice shrinks.
The exact total reduction is:

$$\%\Delta G_{total} = 8.7\% \times \frac{G_{electricity}}{G_{total}} = 8.7\% * \frac{4,099.23}{7,150.71} = 4.9\% \text{ decrease}$$

Total Scope 1+2 GHG per person = (1 - 0.049) * 0.18 (current) = **0.17 kg / person**

Total Scope before the Action = ($\frac{7,150.71*1000}{39,414}$ = 0.18 kg/person**)**

Scope	Quantity	Unit	Related CO_2 emissions	Unit
1 - mobile combustion >> PoliTO cars using PETROL------ scope1	538.67	l of fuel	1.47	tCO_2
1 - mobile combustion >> PoliTO cars using DIESEL------- scope1	13,646.72	l of fuel	36.63	tCO_2
2 - electrical energy consumption-------scope2	17,595,388	kWh	4,099.73	tCO_2
2 - thermal energy consumption--------scope2	14,790,501	kWh	2,987.68	tCO_2
3 - waste generated operations ---- Scope 1	auto-calculated		25.20	tCO_2
			7,150.71	

Action 2 on Share of Sustainability Courses

26% Increase (from 54% to 80%)

Methodology

Share of Sustainability Courses= $\frac{1187}{2172} = 54\%$

Education and Research

Question		Answer
6.1()	Number of courses/subjects related to sustainability offered	1187
6.2()	Total number of courses/subjects offered	2172
6.3(ED.1)	The ratio of sustainability courses to total courses/subjects	[5] **> 20%**

(Green Team)

The indicator *"share of sustainability courses / total courses," which is basically obtained from **UIGM**,* reaches the **maximum score** once an institution passes a relatively low threshold (e.g., **>20%**), meaning the **benchmark scale is not sensitive** to high-performing universities such as POLITO. Therefore, a **campus-adjusted benchmark**— is defined based on best-commitment / universal education:

Some leading universities publicly commit to embedding sustainability across the curriculum (i.e., approaching **full coverage**).
https://www.lunduniversity.lu.se/about-university/university-glance/mission-vision-and-values/sustainability?utm

Major international policy frameworks (e.g., UNESCO's *ESD for 2030* and EU recommendations on learning for the green transition) emphasize that **all learners should acquire sustainability competencies by 2030**.
https://unesdoc.unesco.org/ark%3A/48223/pf0000374802?utm
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=oj%3AJOC_2022_243_R_0001&utm

High benchmark (frontier) can be justified as **~100% curriculum integration** (best practice / universal sustainability education).
Target = 80% by 2030 becomes a defensible **milestone** toward that referenced frontier.

Action 3 on Share of Waste Treatment

No effect!

Methodology

3.3()	Total volume organic waste produced (ton)	2.04
3.4()	Total volume organic waste treated (tons)	2.04
3.5(WS.3)	Organic waste treatment	[5] **Extensive (> 85% treated)**
3.6()	Total volume inorganic waste produced (tons)	194.3
3.7()	Total volume inorganic waste treated (tons)	194.3
3.8(WS.4)	Inorganic waste treatment	[5] **Extensive (> 85% treated)**

(Green Team)

The indicator "share of waste treated", has a limited discriminating power: according to the available documentation, practically 100% of both organic and inorganic waste is already "treated" by authorised municipal operators. As a result, the standard "waste treated" indicator overestimates performance and does not fully capture circularity, because **it mainly reflects the existence of a formal waste management service, but tells very little about how much waste is actually separately collected and recycled or composted**.

There is no publicly reported waste-separation statistics for PoliTO itself. The university's sustainability website describes *what* is collected (e.g. there are "isole ecologiche" with bins for plastic, glass/metal, paper, organics and residual waste), but it does not give quantities or rates. polito.it

By contrast, official data for the City of Turin's waste services show that separate collection is around **57–60%**. For example, Amiat's 2024 data report a total of **248,093.24 tonnes** of recyclables collected versus **184,369.54 tonnes** of residual (non-recyclable) waste in the city of Turin. amiat.it

A logical workaround is to use City of Turin (AMIAT) waste-management statistics as a proxy baseline, since PoliTO's waste enters the municipal system; yet this immediately introduces partial dependency on city performance, because improvements in final recovery rates by any action are influenced by municipal operations. If we instead restrict actions to what is clearly under PoliTO's control (upstream measures such as improved on-campus separation, reduced contamination, or cafeteria organic capture), we face the same limitation: without measured campus data, we can only state aspirational claims without verifying feasibility or quantifying expected impact.

Action 3 on Containers for Sorted Waste

100% increase

Methodology

Since using the word "treated" in the two previous indicators makes the assessment, to some extent, misleading. The thesis uses an additional indicator, although it is not as widespread as others (only used in one article), it is spatially explicit enough to increase the precision. It is focused on **access to separate collection points**, rather than on downstream treatment.

A sorted-waste collection point is defined as one location providing a complete set of clearly labelled containers for the main waste fractions (at least: residual, organic, paper, plastic/metal, glass). The indicator is then expressed as:
Number of sorted-waste collection points per 1,000 m^2 of campus area

To set reasonable benchmarks for this indicator, the thesis assumes that **no user should have to walk more than about 20–30 m to reach a sorted-waste collection point** in main circulation and common areas, which is aligned with existing **building and waste-planning guidance** that limits the acceptable walking distance to bin stores to not more than 30m horizontal distance. https://assets.publishing.service.gov.uk/media/5a7e24d9e5274a2e87dafd5b/140910_HSR_Supporting_Doc5_H6_Waste.pdf?utm_

The thesis **transfers this logic to the campus context**: if a collection point can reasonably serve an area whose dimension is on the order of 20–30 m, then having roughly one collection point per ~1,000 m^2 (a 30 m × 30 m block ≈ 900 m^2) is consistent with the idea.

On this basis, the highest benchmark (score 5) is considered the maximum walking distance of roughly 20–30 m, or approximately **1** collection point per 1,000 m^2.

*To allow for some design tolerance, we set it at ≥**0.8** complete sets per 1,000 m^2, corresponding to about 80% of this ideal density. The interval between 0 and 0.8 was then divided into four equal bands of width 0.2 (0–0.2, 0.2–0.4, 0.4–0.6, 0.6–0.8) to obtain a simple, quasi-linear mapping onto the 0–5 scoring scale, with score 0 reserved for situations with virtually no organised sorted-waste sets.*

Score	Benchmark for "number of sorted-waste collection points per 1,000 m^2 of campus area"
0	Practically no organised sorted-waste collection sets;
1	≤ 0.2 complete sets / 1,000 m^2
2	0.2 – 0.4 complete sets / 1,000 m^2
3	0.4 – 0.6 complete sets / 1,000 m^2
4	0.6 – 0.8 complete sets / 1,000 m^2
5	≥ 0.8 complete sets / 1,000 m^2

Action 3 on Containers for Sorted Waste

100% increase

Methodology

1.5()	Total campus area (m^2)	169695
1.6()	Total campus ground floor area of buildings (m^2)	81936
1.7()	Total campus buildings area (m^2)	291602

UIGM questionnaire 2024)

Site	Indoor bins		Outdoor bins	
	Type	Number	Type	Number
Sede centrale	complete	42	complete	5
Cittadella	complete	43	complete	9
Energy Center	complete	10	complete	1
Mirafiori	complete	6	complete	5
Castello del Valentino	complete	15	complete	3
Sum		116		23

$$\textbf{Number of bins / 1000 m}^2 = \frac{116+23}{(169695+291602)/1000} = 0.3$$

Feasibility Study:

The target "0.3 → 0.6 by 2030" is **realistically feasible:**

In a report from the RUS network (Rete delle Università per lo Sviluppo Sostenibile)_ an Italian initiative connecting over 80 universities committed to integrating sustainability into their core activities, it is stated that the University of **Padua** implemented a project to install around 1,000 waste collection points (with about 5,000 separate containers), eliminating individual desk bins and replacing them with multi-stream collection stations. This shows that in Italian universities, an increase even more ambitious than merely "doubling" the number of collection points is achievable within a few years. *https://www.campus-sostenibile.polimi.it/wp-content/uploads/2025/10/251015_Sardinia_RW_WG_PoliMI_Perotto_def_compressed.pdf*

According to the Polito 2022 sustainability report, the university has already launched a project to redesign its waste collection areas: existing bins have been mapped, re-organised, and re-coloured using a unified code, and for the first time, organic waste has been integrated into these collection points. The report explicitly states that this system was first implemented at the headquarters campus and will then be progressively extended to all PoliTO sites. *https://www.polito.it/sites/default/files/2024-05/GT_Report%20Polito%20Sostenibile%202022_EN.pdf*
In other words, a broad process of upgrading the waste-collection infrastructure is already underway, and adding new multi-stream collection points over the next four years (up to 2030) is fully consistent with this ongoing trajectory.

Action 3 on Publicly Shared Facilities

63.2 % increase

Methodology

A) Politecnico di Torino does have on-site spaces that can be used for **meetings/events:**

- Aula Magna (Corso Duca degli Abruzzi) – 450 seats, €2,350
- Aula Magna Lingotto – 128 seats
- Salone d'Onore (Castello del Valentino) – 100 seats, €2,350

Is it Free? Usually **no,** for external/community use, PoliTO spaces are **typically fee-based**, and the published tariffs are **not "low-cost".**

B) Facilities PoliTO has on-site are mostly restricted to the university community (students/staff and closely related users):

C) POLITO has **on-site cultural facilities** publicly accessible, mainly via free guided visits/reservations:

- GeMM (Geo-Mineralogical Museum); an on-campus permanent museum hosted at DIATI, Corso Duca degli Abruzzi 24.
- Castello del Valentino; PoliTO open to the public on Saturday mornings with free guided tours.

Type of on-site facility		Points	Source
A. Publicly accessible space for public **meetings or events**	Yes	0.25	https://www.polito.it/ateneo/chi-siamo/concessione-temporanea-spazi-per-eventi
Free or low cost access to the meeting or event space	No	_	
B. Publicly accessible facility that helps people meet their **basic needs**. For example, a community garden, food bank, child care center, or health clinic	No	_	https://www.polito.it/ateneo/parita-welfare-e-inclusione/benessere-della-persona
Free or low cost access to the basic needs facilities	_	_	
C. Publicly accessible facility that provides **cultural services**. For example, a library, computer lab, resource center, museum, or gallery.	Yes	0.25	https://www.polito.it/en/social-impact/culture/gemm-geo-mineralogical-museum/visit-gemm
Free or low cost access to the cultural service facilities	Yes	0.25	
D. Publicly accessible facility that provides **recreational services**. For example, a gym, athletic field, fitness trail, or playground	No	_	https://www.polito.it/didattica/servizi-e-vita-al-politecnico/vivere-il-politecnico/sport/calendario-eventi-sportivi/news?idn=26808
Free or low cost access to the recreational service facilities	_	_	
		0.75 / 2	
	Normal	**1.9** / 5	

D) POLITO does have on-campus recreational spaces, but the on-site facilities are intended for the university community (students, faculty, staff) rather than the general public. For example, the new multi-sport field in the central courtyard.

Action 3 on Publicly Shared Facilities

63.2% increase

Methodology

Feasibility Study:

Considering the **Torino Esposizioni project,** these additional spaces are predictable:

Type of on-site facility		Points	Source
A. Publicly accessible space for public **meetings or events**	Yes	0.25	will increase strongly because **Teatro Nuovo** is a public venue (a metropolitan cultural hub with spaces not only for performances, but also rehearsal/ lab rooms, coworking areas), and the library system can rent some spaces under municipal tariffs. *(rehearsal/didactic/coworking)3Bhttps://www.polito.it/ateneo/chi-siamo/concessione-temporanea-spazi-per-eventi*
Free or low cost access	No	_	Not free / generally not low-cost *https://www.polito.it/sites/default/files/2023-01/Allegato%20A%20-%20Tariffario.pdf?utm_source=chatgpt.com*
B. Publicly accessible facility that helps people meet their **basic needs**. For example, a community garden, food bank, child care center, or health clinic	No	_	No confirmed additions in accessible public descriptions *https://www.torinoclick.it/cultura/nuova-biblioteca-centrale-di-torino-presentato-il-progetto-di-fattibilita-tecnico-economica/*
Free or low cost access	_	_	
C. Publicly accessible facility that provides **cultural services**. For example, a library, computer lab, resource center, museum, or gallery.	Yes	0.25	will increase substantially due to the new **Biblioteca Civica Centrale** (reported ~19,380 m^2 open to public, 700+ seats) and the renewed **Teatro Nuovo** (~8,398 m^2, ~1,800 seats) *https://www.masterplan.polito.it/en/progettualita/campus_architettura_torino_esposizioni*
Free or low cost access	Yes	0.25	The City states: "L'accesso alla biblioteca è libero e gratuito."
D. Publicly accessible facility that provides **recreational services**. For example, a gym, athletic field, fitness trail, or playground	Yes	0.25	Torino Esposizioni campus becomes **embedded in a renewed public park** that adds/strengthens outdoor recreational opportunities at the site scale. *https://www.scr.piemonte.it/it/opere-pubbliche/progetto-torino-il-suo-parco-il-suo-fiume-memoria-e-futuro-riqualificazione-e-recupero-delle-aree*
Free or low cost access	Yes	0.25	
		1.25	Normalized: **3.1** / 5

Action 2 on Planted Vegetation

100 % increase

Methodology

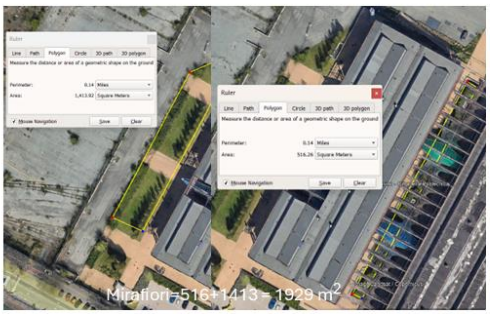
Share of current greenery

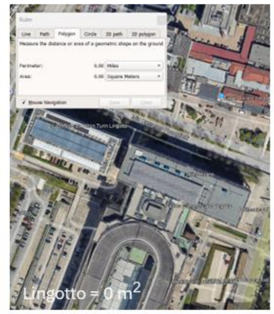
1.8(SI.1)	The ratio of open space to total area.	[2] > 1 - 80%
1.9(SI.2)	Total area on campus covered in forest vegetation (please provide total area in square meters)	[1] <= 2%
1.10(SI.3)	Total area on campus covered in planted vegetation (please provide total area in square meters)	[1] <= 10%: 7 m2

Calculating the green space area using Google Earth confirms the Green Metric figure.

Main Campus $= 17{,}442\ \text{m}^2$
Castello del Valentino $= 388\ \text{m}^2$
Lingotto $= 0\ \text{m}^2$
Mirafiori $= 1929\ \text{m}^2$

$$\textbf{Ratio of green area} = \frac{17{,}442+388+0+1929}{202{,}124+4{,}515+21{,}951+15{,}462} = \frac{19{,}759}{244{,}016} = 0.08\ ✓$$





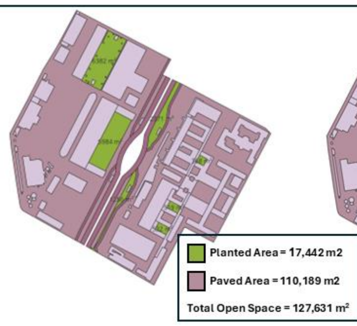
Action 2 on Planted Vegetation

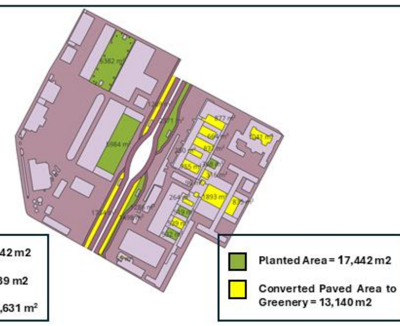
100 % increase

Methodology

Only Castello, with its 4,542 m^2 internal courtyard, can meet the requirement for doubling the green space.

The total green space required to double the share of Castello and Mirafiori = 388 + 1929 = 2,317 < 4,542





$$\textbf{Share of current greenery} = \frac{17{,}442}{127{,}631} = 0.14\ \%$$

To reach the goal for the main campus; We need to convert 17,442 m^2 of paved area to greenery.

To a conservative assumption, we can take the yellow areas corresponding to small, enclosed inner courtyards and that don't interrupt primary circulation, fire-engine access, or other essential services. Their total area is about **13,140 m²**, which is roughly **three-quarters of the additional 17,442 m²** required to double the current green ratio. This shows that a large part of the target can be achieved through these low-risk spaces.

Share of Greenery by Courtyards $= \frac{13{,}140+17{,}442}{127{,}631} = 0.24\ \%$
Share of Greenery by Main Open Space = 17,442 – 13,140 = 4,302 m^2. Which is only **4%** of it.
So, we can be sure that we meet the target without compromising mandatory uses.

Action 2 on Users using more sustainable commuting options
7.7 % increase, by reducing private car trips to 0

Methodology

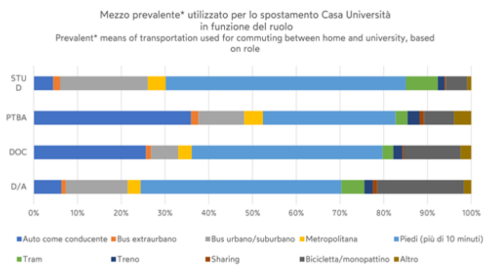
According to STARS, the available points for each group (students vs. employees) are allocated in proportion to that group's share of the total campus population. (total points available = 6)

A) Points available
B) Students factor = 32257 / 36241 = 0.89 →
C) Students **points available** = 6 × 0.89 = 5.34
D) Employees factor = 3984 / 36241 = 0.11→
E) Employees points available = 6 × 0.11 = 0.66

Ruolo *Role*	Popolazione PoliTO *Community PoliTO* 11/2023	Rispondenti al questionario *Respondents to the questionnaire*	Incidenza % risposta *Response rate %*
D/A	1770	494	27,91%
STUD	32257	4968	15,40%
DOC	1209	604	49,96%
PTAB	1005	588	58,51%
Totale	36241	6654	18,36%

STUD: Componente studentesca/ *Students*
PTAB: Personale tecnico amministrativo/ *Admin. staff*
DOC: Personale docente e ricercatore / *Academic staff*
D/A: Dottorandi e assegnisti di ricerca/ *Ph.D. st. and contract researchers*

User	D/A	STUD	DOC	PTAB
Percentage of using sustainable commuting	92	94.7	72.1	60.3
Population	1770	32257	1209	1005



B) Points earned
Students points earned = 5.34 × (94.7/100) = 5.06
Employees **points earned** = 0.66 × (77.96/100) = 0.51
✅ Total points = 5.3606 + 0.2554 = 5.57 / 6
Normalized = 4.64 / 5

https://www.polito.it/sites/default/files/2024-03/Poster%20dati%20questionario%20mobilit%C3%A0%20PoliTO.pdf

Action 2 on Bicycle Parking Spaces per Capita
50 % increase

Methodology

According to the London Plan cycle parking, the minimum parking space for universities and colleges is:

Benchark = $\frac{STUD/20+EMP/4}{STUD+EMP} = \frac{(32257/20)+(\frac{3984}{4})}{32257+3984} = \frac{1612.85+996}{36241} = \mathbf{0.072}$

https://www.london.gov.uk/programmes-strategies/planning/london-plan/past-versions-and-alterations-london-plan/london-plan-2016/london-plan-chapter-six-londons-transport-2?utm_

According to POLITO 2024 survey on daily commuting:

All the campuses of the Polytechnic University of Turin are reachable by bicycle and provide bicycle and scooter racks within their premises. From 2012 to date, the number of spots has increased from 200 to 1,200. The university periodically conducts surveys on the use of the racks to check for any critical situations or underutilization.

POLITO = $\frac{1200}{36241} = \mathbf{0.033}$ → Normalized = 2.3

https://www.polito.it/sites/default/files/2024-03/Poster%20dati%20questionario%20mobilit%C3%A0%20Po

After applying the action which is aligned with Torino Esposizioni project, we expect to have 1.5 times more bicycle slots around the campus, which increases POLITO's score to :

https://www.masterplan.polito.it/en/progettualita/campus_architettura_torino_esposizioni

$\frac{1200*1.5}{36241} = \mathbf{0.049}$ → Normalized = 3.4

Action 2 on Water use per Capita
6 % Decrease

Methodology

Annual water consumption per capita$= \frac{216,833}{37,051}$ = **5.853** m^3/people * **1000 = 5853** l/people **/365 = 16.04** l per person per day

Trimester	Overall PoliTO water supply	Unit
First	49,463.00	m^3
Second	40,932.00	m^3
Third	89,384.00	m^3
Fourth	37,104.00	m^3
	216,883.00	

According to the report of the Green Team given to the UIGM, **80%** of conventional appliances have already replaced with water-efficient ones.

Water		
Question		Answer
4.1(WR.1)	Water conservation program and implementation	[3] **1 - 25% water conserved**
4.2(WR.2)	Water recycling program implementation	[5] **> 50% water recycled**
4.3(WR.3)	Water efficient appliance usage	[5] **> 80% of water efficient appliances installed**
4.4(WR.4)	Consumption of treated water	[5] **> 75% treated water consumed**
4.5(WR.5)	Water pollution control in campus area	[5] **Policy and programs for water pollution control are fully implemented and monitored regularly**
4.6()	Planning, implementation, monitoring and/or evaluation of all programs related to Water Management through the utilization of Information and Communication Technology (ICT)	[4] **Program has been implemented and evaluated**

Feasibility Study:

EPA (the USA Environmental Protection Agency) notes Water Sense bathroom faucets/accessories can reduce flow by **~30%** or more.
https://www.epa.gov/watersense/bathroom-faucets?utm

So, basically, 20% of the capacity remains unretrofitted. Reduction = 0.2 * 0.3 = 0.06 = **6%**
Annual water consumption per capita = (1-0.06)* 16.04 **= 15.07** l per person per day

5.8 Appendix 6

UIGM Questionnaire 2024

Questionnaire Data

University Profile

Username : polito.it
University Name : Politecnico di Torino
University Leader : Rector: Stefano Corgnati

PIC Profile

PIC Name : Valentina Colaleo
PIC Position : Sustainability Division
Email : valentina.colaleo@polito.it

Setting and Infrastructure

Question		Answer
1.1()	Type of higher education institution	[2] **Specialized higher education institution**
1.2()	Climate	[5] **Mediterranean**
1.3()	Number of campus site	4
1.4()	Campus setting	[3] **Urban**
1.5()	Total campus area (m^2)	169695
1.6()	Total campus ground floor area of buildings (m^2)	81936
1.7()	Total campus buildings area (m^2)	291602
1.8(SI.1)	The ratio of open space to total area.	[2] **> 1 - 80%**
1.9(SI.2)	Total area on campus covered in forest vegetation (please provide total area in square meters)	[1] **<= 2%**
1.10(SI.3)	Total area on campus covered in planted vegetation (please provide total area in square meters)	[1] **<= 10%**: **7 m2**
1.11(SI.4)	Total area on campus for water absorption besided forest and planted vegetation (please provide total area in square meters)	[2] **> 2 - 10%**: **5 m2**
1.12()	Total number of regular students (part time and full time)	38013
1.13()	Total number of online students (part time and full time)	0
1.14()	Total number of academic and administrative staff	2611
1.15(SI.5)	The total open space area divided by total campus population.	[1] **<= 10 m2 / person**
1.16()	Total university's budget (in US Dollars)	375029455
1.17()	University's budget for sustainability effort (in US Dollars)	116260891
1.18(SI.6)	Percentage of University's budget for sustainability effort	[5] **> 15%**
1.19(SI.7)	Percentage of operation and maintenance activities of building in one year period	[5] **100%**
1.20(SI.8)	Campus facilities for disable and maternity care	[5] **Facilities exist in all buildings and are fully operated**
1.21(SI.9)	Security and safety facilites	[5] **Security infrastructure is available and fully functions and security responding time for accidents, crime, fire, and natural disasters is less than 10 minutes**

1.22(SI.10)	Health infrastructure facilities for students and academic and administrative staff wellbeing	[3] **Health infrastructure (first aid, emergency room, clinic and certified personel) available**
1.23(SI.11)	Conservation: plant (flora), animal (fauna), and wildlife, genetic resources for food and agriculture secured in either medium or long-term conservation facilities	[4] **Conservation program > 50-75% implemented**
1.24()	Planning, implementation, monitoring and/or evaluation of all programs related to Setting and Infrastructure through the utilization of Information and Communication Technology (ICT)	[5] **Program has been implemented, evaluated, and is currently revised**

Energy and Climate Change

Question		Answer
2.1(EC.1)	Energy efficient appliances usage	[5] **> 75%**
2.2()	Total campus smart building area (m^2)	283779
2.3(EC.2)	Smart Building implementation (percentage of the total floor area of smart building to the total all floors building area (smart and non-smart buildings area).	[5] **> 75%**
2.4(EC.3)	Number of renewable energy sources in campus (solar power, bio diesel, wind power, etc)	[4] **3 sources**
2.5()	Renewable energy sources and their amount of the energy produced (in kilowatt-hour)	[4] **Solar Power** [6] **Geothermal** [8] **Combine Heat and Power**
2.6()	Electricity usage per year (in kilo watt hour)	16606801
2.7(EC.4)	The total electricity usage divided by total campus population (kWh per person).	[4] **279 - 633 kWh**
2.8(EC.5)	The ratio of renewable energy production divided by total energy usage per year	[4] **> 2 - 25%**
2.9(EC.6)	Elements of green building implementation as reflected in all construction and renovation policies	[5] **> 3 elements**
2.10(EC.7)	Greenhouse gas emission reduction program	[5] **Program(s) aims to reduce all three scopes emissions (Scope 1, 2 and 3)**
2.11()	Please provide the total carbon footprint (CO_2 emission in the last 12 months, in metric tons)	3913
2.12(EC.8)	The total carbon footprint divided by total campus population (metric tons per person).	[5] **< 0.10 metric tons**
2.13(EC.9)	The number of innovative program(s) in Energy and Climate Change	[5] **More than 3 programs**
2.14(EC.10)	Impactful university program(s) on climate change	[5] **Provide training, educational materials, seminars/conferences, and activities which are implemented by communities at the international level**
2.15()	Planning, implementation, monitoring and/or evaluation of all programs related to Energy and Climate Change through the utilization of Information and Communication Technology (ICT)	[5] **Program has been implemented, evaluated, and is currently revised**

Waste

Question		Answer
3.1(WS.1)	3R (Reduce, Reuse, Recycle) program for university's waste	[5] **3R program > 75% implemented**
3.2(WS.2)	Program to reduce the use of paper and plastic on campus	[5] **More than 10 programs**

3.3()	Total volume organic waste produced (ton)	2.04
3.4()	Total volume organic waste treated (tons)	2.04
3.5(WS.3)	Organic waste treatment	[5] **Extensive (> 85% treated)**
3.6()	Total volume inorganic waste produced (tons)	194.3
3.7()	Total volume inorganic waste treated (tons)	194.3
3.8(WS.4)	Inorganic waste treatment	[5] **Extensive (> 85% treated)**
3.9()	Total volume toxic waste produced (tons)	2.75
3.10()	Total volume toxic waste treated (tons)	2.75
3.11(WS.5)	Toxic waste treatment	[5] **Extensive (> 85% treated) or campus produces a minimum amount of toxic waste**
3.12(WS.6)	Sewage disposal	[5] **Treated with tertiary treatment**
3.13()	Planning, implementation, monitoring and/or evaluation of all programs related to Waste Management through the utilization of Information and Communication Technology (ICT)	[2] **The program is currently in the planning stage**

Water

Question		Answer
4.1(WR.1)	Water conservation program and implementation	[3] **1 - 25% water conserved**
4.2(WR.2)	Water recycling program implementation	[5] **> 50% water recycled**
4.3(WR.3)	Water efficient appliance usage	[5] **> 80% of water efficient appliances installed**
4.4(WR.4)	Consumption of treated water	[5] **> 75% treated water consumed**
4.5(WR.5)	Water pollution control in campus area	[5] **Policy and programs for water pollution control are fully implemented and monitored regularly**
4.6()	Planning, implementation, monitoring and/or evaluation of all programs related to Water Management through the utilization of Information and Communication Technology (ICT)	[4] **Program has been implemented and evaluated**

Transportation

Question		Answer
5.1()	Number of cars actively used and managed by University	25
5.2()	Number of cars entering the university daily	479
5.3()	Number of motorcycles entering the university daily	30
5.4(TR.1)	The total number of vehicles (cars and motorcycles) divided by total campus population.	[5] **< 0.045**
5.5(TR.2)	Shuttle service	[5] **Shuttle service is provided by university, regular, and environment friendly. Or shuttle use is not possible (not applicable)**
5.6()	Number of shuttles operated in your university	0
5.7()	Average number of passengers of each shuttle	0
5.8()	Total trips of shuttle services each day	0
5.9(TR.3)	Zero Emission Vehicles (ZEV) policy on campus	[3] **Zero Emission Vehicles are available, but not provided by university**
5.10()	Average number of Zero Emission Vehicles (e.g. bicycles, cano, snowboard, electric car, etc.) on campus per day	1200
5.11(TR.4)	The total number of Zero Emission Vehicles (ZEV) divided by total campus population.	[5] **> 0.02**
5.12()	Total ground parking area (m^2)	5987
5.13(TR.5)	Ratio of parking area to total campus area.	[4] **> 1 - 4%**
5.14(TR.6)	Transportation program designed to limit or decrease the parking area on campus for the last 3 years (from 2021 to 2023)	[5] **Program resulting in more than 30% decrease in parking area or parking area reduction has reaches its limit.**
5.15(TR.7)	Number of initiatives to decrease private vehicles on campus	[5] **> 3 initiatives, or initiative no longer required**
5.16(TR.8)	Pedestrian path on campus	[5] **Pedestrian paths are available, designed for safety, convenience, and in some parts provided with disabled-friendly features**
5.17()	Approximate daily travel distance of a vehicle inside campus only (in Kilometers)	0
5.18()	Planning, implementation, monitoring and/or evaluation of all programs related to Transportation through the utilization of Information and Communication Technology (ICT)	[2] **The program is currently in the planning stage**

Education and Research

Question		Answer
6.1()	Number of courses/subjects related to sustainability offered	1187
6.2()	Total number of courses/subjects offered	2172
6.3(ED.1)	The ratio of sustainability courses to total courses/subjects	[5] **> 20%**
6.4()	Total research funds dedicated to sustainability research (in US Dollars) (average per annum over the last 3 years).	68490091
6.5()	Total research funds (in US Dollars) (average per annum over the last 3 years).	72496810
6.6(ED.2)	The ratio of sustainability research funding to total research funding	[5] **> 40%**
6.7(ED.3)	Number of scholarly publications on sustainability published. (average annualy for the past 3 years)	[5] **> 300**
6.8(ED.4)	Number of events related to sustainability. (average annualy for the past 3 years)	[5] **> 50**
6.9(ED.5)	Number of activities organized by student organizations related to sustainability per year	[5] **> 20**
6.10(ED.6)	University-run sustainability website	[5] **Website is available, accessible, and updated regularly**
6.11()	Sustainability website address (URL) if available	https://www.polito.it/ateneo/campus-sostenibile
6.12(ED.7)	Sustainability report	[5] **Sustainability report is accessible and published annually**
6.13()	Sustainability report link address (URL) if available	https://www.polito.it/ateneo/campus-sostenibile/report-e-documenti
6.14(ED.8)	Number of cultural activities on campus	[5] **More than 10 events per year**
6.15(ED.9)	Number of university program(s) with international collaborations	[5] **More than 10 programs per year**
6.16(ED.10)	Number of community services related to sustainability organized by university and involving students	[5] **More than 10 projects per year**
6.17(ED.11)	Number of sustainability-related startups	[5] **> 15 startups**
6.18()	Total number of graduates with green jobs (for the last 3 years)	1066
6.19()	Availability of units or offices that coordinate or are related to sustainability	[5] **Unit(s) or office(s) with university leader decree of establishment, structure and duties has been operational and lead the university implementation of sustainability**

Reference

Accardo, D., Meschini, S., Gasbarri, P., Tagliabue, L. C., & Giuda, G. M. Di. (2023). Smart digital campus UniTO: data gathering and visualisation to support sustainability and indoor comfort. *Journal of Physics: Conference Series*, *2600*(8). https://doi.org/10.1088/1742-6596/2600/8/082033

Alghamdi, N., den Heijer, A., & de Jonge, H. (2017). Assessment tools' indicators for sustainability in universities: an analytical overview. *International Journal of Sustainability in Higher Education*, *18*(1), 84–115. https://doi.org/10.1108/IJSHE-04-2015-0071

Alshubiri, F. N. (2021). Analysis of financial sustainability indicators of higher education institutions on foreign direct investment Empirical evidence in OECD countries. *International Journal of Sustainability in Higher Education*, *22*(1), 77–99.

Amaral, A. R., Rodrigues, E., Gaspar, A. R., & Gomes, Á. (2020). A review of empirical data of sustainability initiatives in university campus operations. In *Journal of Cleaner Production* (Vol. 250). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2019.119558

Ameen, R. F. M., Mourshed, M., & Li, H. (2015). A critical review of environmental assessment tools for sustainable urban design. *Environmental Impact Assessment Review*, *55*, 110–125. https://doi.org/10.1016/j.eiar.2015.07.006

Anderson, K. (2024). *The Sustainability Accounting Standards Board (SASB)*. Greenly.

Berzosa, A., Bernaldo, M. O., & Fernández-Sanchez, G. (2017). Sustainability assessment tools for higher education: An empirical comparative analysis. *Journal of Cleaner Production*, *161*, 812–820. https://doi.org/10.1016/j.jclepro.2017.05.194

Blasco, N., Brusca, I., & Labrador, M. (2019). Assessing Sustainability and Its Performance Implications: An Empirical Analysis in Spanish Public Universities. *Sustainability*, *11*(19), 5302. https://doi.org/10.3390/su11195302

Bond, A., Morrison-Saunders, A., & Pope, J. (2012). Sustainability assessment: the state of the art. *Impact Assessment and Project Appraisal*, *30*(1), 53–62. https://doi.org/10.1080/14615517.2012.661974

BREEAM. (2024a). BREEAM Communities. In *BREEAM*.

BREEAM. (2024b). *BREEAM Communities*. BREEAM.

Casado-Aranda, L. A., Caeiro, S. S., Trindade, J., Paço, A., Casas, D. L., & Landeta, A. (2020). Are distance higher education institutions sustainable enough? – A comparison between two distance learning universities. *International Journal of Sustainability in Higher Education*, *22*(4), 709–730. https://doi.org/10.1108/IJSHE-07-2020-0260

CASBEE. (2024a). *CASBEE*. CASBEE. https://www.ibecs.or.jp/CASBEE/english/

CASBEE. (2024b). *CASBEE for Urban Development*.

Castanheira, G., & Bragança, L. (2014a). The Evolution of the Sustainability Assessment Tool <math id="M1"> <mrow> <msup> <mrow> <mtext>SBTool</mtext> </mrow> <mrow> <mtext>PT</mtext> </mrow> </msup> </mrow> </math> : From Buildings to the Built Environment. *The Scientific World Journal*, *2014*, 1–10. https://doi.org/10.1155/2014/491791

Castanheira, G., & Bragança, L. (2014b). The Evolution of the Sustainability Assessment Tool SBTool PT From Buildings to the Built Environment. *The Scientific World Journal*, *2014*, 1–10. https://doi.org/10.1155/2014/491791

Cernostana, Z. (2018, May 23). *Measuring financial sustainability of private higher education institutions*. https://doi.org/10.22616/ERDev2018.17.N343

Crotti, D., Grechi, D., & Maggi, E. (2022). Reducing the carbon footprint in college mobility: The car commuters' perspective in an Italian case study. *Environmental Impact Assessment Review*, *92*. https://doi.org/10.1016/j.eiar.2021.106702

Dawodu, A., Cheshmehzangi, A., Sharifi, A., & Oladejo, J. (2022). Neighborhood sustainability assessment tools: Research trends and forecast for the built environment. *Sustainable Futures*, *4*, 100064. https://doi.org/10.1016/j.sftr.2022.100064

Dawodu, A., Dai, H., Zou, T., Zhou, H., Lian, W., Oladejo, J., & Osebor, F. (2022). Campus sustainability research: indicators and dimensions to consider for the design and assessment of a sustainable campus. In *Heliyon* (Vol. 8, Issue 12). Elsevier Ltd. https://doi.org/10.1016/j.heliyon.2022.e11864

DGNB. (2023). *DGNB*. DGNB. https://www.dgnb.de/en

Du, Y., Ye, Q., Liu, H., Wu, Y., & Wang, F. (2023a). Sustainable Assessment Tools for Higher Education Institutions: Developing Two-Hierarchy Tools for China. *Sustainability*, *15*(15), 11551. https://doi.org/10.3390/su151511551

Du, Y., Ye, Q., Liu, H., Wu, Y., & Wang, F. (2023b). Sustainable Assessment Tools for Higher Education Institutions: Developing Two-Hierarchy Tools for China. *Sustainability*, *15*(15), 11551. https://doi.org/10.3390/su151511551

EDGE. (2021). *EDGE - Excellence in Design for Greater Efficiencies*. EDGE. https://edgebuildings.com/edge-excellence-in-design-for-greater-efficiencies/

Engel-Yan, J., Kennedy, C., Saiz, S., & Pressnail, K. (2005). Toward sustainable neighbourhoods: the need to consider infrastructure interactions. *Canadian Journal of Civil Engineering*, *32*(1), 45–57. https://doi.org/10.1139/l04-116

Findler, F., Schönherr, N., Lozano, R., & Stacherl, B. (2019). Assessing the impacts of higher education institutions on sustainable development-an analysis of tools and indicators. *Sustainability (Switzerland)*, *11*(1). https://doi.org/10.3390/su11010059

Freidenfelds, D., Kalnins, S. N., & Gusca, J. (2018). What does environmentally sustainable higher education institution mean? *Energy Procedia*, *147*, 42–47. https://doi.org/10.1016/j.egypro.2018.07.031

Genta, C., Favaro, S., Sonetti, G., Barioglio, C., & Lombardi, P. (2019). Envisioning green solutions for reducing the ecological footprint of a university campus. *International Journal of Sustainability in Higher Education*, *20*(3), 423–440. https://doi.org/10.1108/IJSHE-01-2019-0039

González-Torre, P. L., & Suárez-Serrano, E. (2022). A framework for implementing and reporting United Nations sustainable development goals in Spanish higher education institutions. *International Journal of Sustainability in Higher Education*, *23*(6), 1349–1365. https://doi.org/10.1108/IJSHE-03-2021-0118

Green Globes. (2024). *Green Globes*. Green Building Initiative. https://thegbi.org/greenglobes/

Green star. (n.d.). *Green star*. 2024. Retrieved September 22, 2024, from https://new.gbca.org.au/green-star/exploring-green-star/

GRI. (2023). *GRI*. GRI. https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/

Gu, Y., Wang, H., Xu, J., Wang, Y., Wang, X., Robinson, Z. P., Li, F., Wu, J., Tan, J., & Zhi, X. (2019). Quantification of interlinked environmental footprints on a sustainable university campus: A nexus analysis perspective. *Applied Energy*, *246*, 65–76. https://doi.org/10.1016/j.apenergy.2019.04.015

Hanga-Fărcaş, I. F. P., Bungău, C. C., Scurt, A. A., Cristea, M., & Prada, M. F. (2023). The Building Certification System - A Tool of Sustainable Development of University Campuses. *Journal of Applied Engineering Sciences*, *13*(1), 105–112. https://doi.org/10.2478/jaes-2023-0014

Herzner, A., & Hommerová, D. (2022). Multi-Dimensional Assessment of a Bavarian and Czech University: A Case Study of Sustainability Implementation. *European Journal of Sustainable Development*, *11*(2), 93. https://doi.org/10.14207/ejsd.2022.v11n2p93

Horan, W., & O'regan, B. (2021). Developing a practical framework of sustainability indicators relevant to all higher education institutions to enable meaningful international rankings. *Sustainability (Switzerland)*, *13*(2), 1–15. https://doi.org/10.3390/su13020629

HQE-GBC. (2023). *HQE-GBC*. HQE-GBC. https://www.hqegbc.org/

iiSBE Italia. (2023). *SNTool MED Sustainable Neighborhood Tool*.

Jakimiuk, A., Matsui, Y., Podlasek, A., Koda, E., Goli, V. S. N. S., Voběrková, S., Singh, D. N., & Vaverková, M. D. (2023). Closing the loop: A case study on pathways for promoting sustainable waste management on university campuses. *Science of the Total Environment*, *892*. https://doi.org/10.1016/j.scitotenv.2023.164349

Jiang, Q., & Kurnitski, J. (2023). Performance based core sustainability metrics for university campuses developing towards climate neutrality: A robust PICSOU framework. *Sustainable Cities and Society*, *97*. https://doi.org/10.1016/j.scs.2023.104723

Juncker, J.-C. (2018). *Environmental Reporting*.

Jürgens, M., Hartmann, K., Endres, H. J., & Spierling, S. (2023). Life cycle assessment of higher education institutions – method and case study. *Journal of Cleaner Production*, *430*. https://doi.org/10.1016/j.jclepro.2023.139649

Kifor, C. V., Olteanu, A., & Zerbes, M. (2023). Key Performance Indicators for Smart Energy Systems in Sustainable Universities. In *Energies* (Vol. 16, Issue 3). MDPI. https://doi.org/10.3390/en16031246

Kirrane, M. J., Pelton, C., Mehigan, P., Poland, M., Mullally, G., & O'Halloran, J. (2020). *"Reaching for the STARS": A Collaborative Approach to Transparent Sustainability Reporting in Higher Education, the Experience of a European University in Achieving STARS Gold* (pp. 991–1008). https://doi.org/10.1007/978-3-030-26759-9_58

KılkıŞ, Ş. (2017). Comparative analyses of sustainable campuses as living laboratories for managing environmental quality. *Management of Environmental Quality: An International Journal*, *28*(5), 681–702. https://doi.org/10.1108/MEQ-06-2015-0107

LEED. (2020a). *LEED Reference Guide for Neighborhood Development*.

LEED. (2020b). *LEED Reference Guide for Neighborhood Development v4*.

Lima, R. G. De, Lins, H. N., Pfitscher, E. D., Garcia, J., Suni, A., Guerra, J. B. S. O. D. A., & Delle, F. C. R. (2016). A sustainability evaluation framework for Science and Technology Institutes: An international comparative analysis. *Journal of Cleaner Production*, *125*, 145–158. https://doi.org/10.1016/j.jclepro.2016.03.028

Living Future Institute. (2024). *Living Building Challenge*. Living Future Institute. https://living-future.org/lbc/

Ma, B., Bashir, M. F., Peng, X., Strielkowski, W., & Kirikkaleli, D. (2023). Analyzing research trends of universities' carbon footprint: An integrated review. *Gondwana Research*, *121*, 259–275. https://doi.org/10.1016/j.gr.2023.05.008

Mapar, M., Bacelar-Nicolau, P., & Caeiro, S. (2022). 8 Sustainability Assessment Tools in Higher Education Institutions: Comprehensive Analysis of the Indicators and Outlook. In *The Wiley Handbook of Sustainability in Higher Education Learning and Teaching* (pp. 153–186). https://onlinelibrary.wiley.com/48aefdf2-2d1d-4439-92fd-c2fa2...

Marrone, P., Orsini, F., Asdrubali, F., & Guattari, C. (2018). Environmental performance of universities: Proposal for implementing campus urban morphology as an evaluation parameter in Green Metric. *Sustainable Cities and Society*, *42*, 226–239. https://doi.org/10.1016/j.scs.2018.07.012

Mendoza-Cavazos, Y. (2016). Sustainable evaluation systems in higher education institutions. *CienciaUAT*, *11*(1), 65–78.

Montrone, S., Perchinunno, P., & Cazzolle, M. (2020). *The Classification of the University for Type of Campus Setting in a World Sustainability Ranking*. 899–912. https://doi.org/10.1007/978-3-030-58808-3_64

Niedlich, S., Bauer, M., Doneliene, M., Jaeger, L., Rieckmann, M., & Bormann, I. (2020). Assessment of sustainability governance in higher education institutions—a systemic tool using a governance equalizer. *Sustainability (Switzerland)*, *12*(5), 1–17. https://doi.org/10.3390/su12051816

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Pappi, I. N., Paterakis, N. G., Catalao, J. P. S., Panapakidis, I., & Papagiannis, G. (2015). Analysis of the energy usage in university buildings: The case of aristotle university campus. *2015 Australasian Universities Power Engineering Conference (AUPEC)*, 1–5. https://doi.org/10.1109/AUPEC.2015.7324856

Parolin, G., McAloone, T. C., & Pigosso, D. C. A. (2024). How can technology assessment tools support sustainable innovation? A systematic literature review and synthesis. *Technovation*, *129*, 102881. https://doi.org/10.1016/j.technovation.2023.102881

Perchinunno, P., & Cazzolle, M. (2020). A clustering approach for classifying universities in a world sustainability ranking. *Environmental Impact Assessment Review*, *85*, 106471. https://doi.org/10.1016/j.eiar.2020.106471

Ramírez, O., Hernández-Cuellar, B., & de la Rosa, J. D. (2023). Air quality monitoring on university campuses as a crucial component to move toward sustainable campuses: An overview. In *Urban Climate* (Vol. 52). Elsevier B.V. https://doi.org/10.1016/j.uclim.2023.101694

Ramos, T. B., Montaño, M., Melo, J. J. De, Souza, M. P., Lemos, C. C. De, Domingues, A. R., & Polido, A. (2015). Strategic Environmental Assessment in higher education: Portuguese and Brazilian cases. *Journal of Cleaner Production*, *106*, 222–228. https://doi.org/10.1016/j.jclepro.2014.12.088

Ribeiro, P., Fonseca, F., & Meireles, T. (2020). Sustainable mobility patterns to university campuses: Evaluation and constraints. *Case Studies on Transport Policy*, *8*(2), 639–647. https://doi.org/10.1016/j.cstp.2020.02.005

Salati, M., Bragança, L., & Mateus, R. (2022). Sustainability Assessment on an Urban Scale: Context, Challenges, and Most Relevant Indicators. *Applied System Innovation*, *5*(2), 41. https://doi.org/10.3390/asi5020041

Singh, A. B., Meena, H. K., Khandelwal, C., & Dangayach, G. S. (2023). Sustainability Assessment of Higher Education Institutions: A Systematic Literature Review. *ECP 2023*, 23. https://doi.org/10.3390/ECP2023-14728

Sonetti, G., Lombardi, P., & Chelleri, L. (2016). True Green and Sustainable University Campuses? Toward a Clusters Approach. *Sustainability*, *8*(1), 83. https://doi.org/10.3390/su8010083

STARS. (2019). *STARS AASHE*. STARS. https://stars.aashe.org/

Sustainable Development Solutions Network. (2022). *NET ZERO ON CAMPUS // 1 unsdsn.org/net-zero-on-campus NET ZERO ON CAMPUS*. https://www.unsdsn.org/net-zero-on-

Tichomirova, E., & Sukhinina, E. (2021). Justification of educational institutions environmental reconstruction in accordance with the UI green metric rating and environmental standards. *Urbanism. Arhitectură. Construcţii*, *2*, 133–144.

TUV. (2015). *Guidebook_ISO_14001_GB*.

UI Green CityMetric. (2022). *UI Green Metric*. IREG Observatory. https://greenmetric.ui.ac.id/about/criteria-indicator

UIGreenMetric. (2023). *UI Green Metric*. UI Green Metric. https://greenmetric.ui.ac.id/

Valls-Val, K., & Bovea, M. D. (2021). Carbon footprint in Higher Education Institutions: a literature review and prospects for future research. In *Clean Technologies and Environmental Policy* (Vol. 23, Issue 9, pp. 2523–2542). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s10098-021-02180-2

Valls-Val, K., Ibáñez-Forés, V., Lo-Iacono-Ferreira, V. G., Capuz-Rizo, S. F., & Bovea, M. D. (2023). Adequacy of existing circular economy assessment tools for higher education institutions. *Sustainable Production and Consumption*, *39*, 399–413. https://doi.org/10.1016/j.spc.2023.05.011

Velazquez, L., Munguia, N., Platt, A., & Taddei, J. (2006). Sustainable university: what can be the matter? *Journal of Cleaner Production*, *14*(9–11), 810–819. https://doi.org/10.1016/j.jclepro.2005.12.008

Violano, A., & Cannaviello, M. (2023). *Imagining a Carbon Neutral University* (pp. 449–460). https://doi.org/10.1007/978-3-031-29515-7_41

Wellcertified. (2020). *WELL v2*. WELLcertified. https://v2.wellcertified.com/en/wellv2/concepts

Zaballos, A., Briones, A., Massa, A., Centelles, P., & Caballero, V. (2020). A smart campus' digital twin for sustainable comfort monitoring. *Sustainability (Switzerland)*, *12*(21), 1–33. https://doi.org/10.3390/su12219196

Zhu, B., Liu, G., & Feng, J. (2022). A comparison on the evaluation standards of sustainable campus between China and America. *International Journal of Sustainability in Higher Education*, *23*(6), 1294–1314. https://doi.org/10.1108/IJSHE-03-2021-0095

Ziemba, P. (2022). Application Framework of Multi-Criteria Methods in Sustainability Assessment. *Energies*, *15*(23), 9201. https://doi.org/10.3390/en15239201