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EDITED BY
Omaima Hassan,
Robert Gordon University, United Kingdom

REVIEWED BY
Teresa Nogueiro,
University of Evora, Portugal
Professor Adel Ahmed,
Amity University Dubai, United Arab Emirates

*CORRESPONDENCE
Wint Mon Swe
✉ wmswe@ualg.pt

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Ecodesign and environmental assessment: a synergy for higher education institutions

Wint Mon Swe[1]*, Margarida Ribau Teixeira[2], Laura Smuleac[3] and Luís M. Nunes[1]

[1]Civil Engineering Research and Innovation for Sustainability Center, Universidade do Algarve, Faro, Portugal, [2]CENSE, Center for Environmental and Sustainability Research & CHANGE, Global Change and Sustainability Institute, Universidade do Algarve, Faro, Portugal, [3]University of Life Sciences "King Mihai I", Timisoara, Romania

This article explores how ecodesign can help enhance environmental assessment methods (EAMs) employed by Higher Education Institutions (HEIs). Current EAMs primarily offer resource management evaluations or sustainability rankings but lack holistic and actionable solutions for institutional improvements. The proposed method integrates ecodesign tools, such as Life Cycle Assessments (LCA), environmental benchmarking, and parametric design tools, with existing EAM frameworks. This synergy allows HEIs to quantitatively assess their environmental and social impacts while identifying targeted strategies for improvement. By embedding ecodesign into institutional practices the approach provides a structured pathway to align HEIs with global sustainability goals, fostering innovation and continuous improvement. The paper emphasizes a multi-tool integration strategy, offering a cohesive solution to advance sustainability comprehensively within HEIs.

KEYWORDS

higher education institutions, ecodesign for services, environmental assessment methods, multi-tool integration strategy, sustainability in HEIs

1 Introduction

The Brundtland Report defines sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." It is a holistic concept built on three main pillars: economic, social, and environmental (Brundtland, 1987). Therefore, sustainability must define economic and social development goals, involving a progressive transformation of the economy and society, without overexploiting resources and endangering the natural life systems (Brundtland, 1987). Sustainability requires equitable access to constrained resources and reorienting technological efforts to relieve the presume (Brundtland, 1987). Therefore, sustainability was highlighted as a complex model impacting various areas and activities (Berzosa et al., 2017). Ecodesign, under sustainable development, focuses on creating environmentally friendly products and methods to minimize harm, conserve resources, and promote sustainability. It incorporates environmental considerations into the design process, accounting for impacts throughout a product's lifecycle to reduce resource use, energy consumption, waste, and pollution (Bovea and Perez-Belis, 2012; Ahmad et al., 2018; Schäfer and Löwer, 2021). The concept has expanded beyond products to include applications in organizations and services (McAloone and Pigosso, 2017). Many similar concepts exist in the same realm as ecodesign, such as Design for Environment (Kapur and Graedel, 2004), Life Cycle Engineering (Alting, 1995; Hauschild et al., 2017), and Sustainable Product Design (Ahmad et al., 2018), which all share similar objectives: to design products and services with the goal of reducing negative environmental impacts throughout their

lifecycle (Pardo et al., 2011; Schäfer and Löwer, 2021). The Ecodesign Directive (Directive 2009/125/EC) (European Parliament, Council of the European Union, 2009) sets a framework for the setting of ecodesign requirements for energy-related products (Bovea and Perez-Belis, 2012). However, the term is not limited to energy-related products. It can be widely applied to other products and systems such as consumer goods, industrial equipment, transportation, food and agriculture, and services.

Ecodesign tool's main function is to reduce the environmental impacts of a product or service, and they are available in different levels of complexity and input requirements (Lofthouse, 2006; Ahmad et al., 2018). Numerous tools are available on the market, so it is a challenge for engineers and designers to select a tool that best fits their needs (Pardo et al., 2011). Many of the ecodesign tools are mainly associated with production industries, such as manufacturing and product design, consumer electronics, automotive, and textile and fashion to name a few (European Commission, 2024). However, these tools are insufficient when it comes to an area such as Higher Education Institutions (HEIs). Managers of such institutions frequently face difficulties analyzing their organization's capability for innovation and mapping viable ecodesign techniques due to the lack of specific tools and internal competencies.

HEIs have a moral responsibility to promote the knowledge, skills, and values needed for a sustainable future (Gomez et al., 2012). HEIs play a crucial role in integrating sustainability into education, research, and operations (Mapar et al., 2022). They also help equip students with the tools to build a sustainable society (Alonso-Almeida et al., 2015). At the 2012 UN conference, HEIs committed to sustainable development through action, not just policies or statements (United Nations, 2024). Adopting sustainability initiatives and ecodesign is key to addressing environmental impacts. However, scientific experiments are designed to reduce bias and ensure consistent conditions, which makes them resource intensive. This often requires constant energy supply for temperature control and reliance on disposable items like gloves, plastic tubes, and pipette tips (LABMATE, 2019). Laboratory waste, especially biohazardous materials like blood, cells, or pathogens, poses risks to humans and the environment and must be carefully handled (Dolski, 2022; Manufacturing Chemist, 2022). Biohazard waste incineration at 1,200°C (Webber, 2024) leaves a significant environmental footprint. The extensive use of disposable plastics is a major issue in research. For instance, a McGill University study found that 16 of their labs produced over 100 tons of plastic and 275 tons of glass waste in one year (Akbari et al., 2015). Globally, academic labs generate about 5.5 million tons of plastic waste annually, despite scientists representing only 0.1% of the population (Urbina et al., 2015; Manufacturing Chemist, 2022). Plastic waste harms marine life and persists in the environment. In ecology studies, only 11–18% achieve full informative value (Purgar et al., 2022), meaning many environmental costs are not justified by the benefits. Therefore, both individuals and institutions must take steps to reduce scientific waste, and many HEIs use tools to assess advancement toward sustainability.

This brief aims to explore links between ecodesign and sustainability assessment tools (SATs), highlighting how specific ecodesign methods can support SATs. The paper summarizes common objectives, tools, and evaluation factors using select methodologies to illustrate its focus.

2 Overview of current widely used environmental assessment methods in HEIs

Environmental assessment tools are designed to evaluate sustainability in HEIs, but many focus on resource management rather than enabling campus-to-campus comparisons (Gomez et al., 2012). Some tools offer certification to highlight an institution's sustainability efforts, while others provide ranking systems for comparison. Table 1 presents the widely applied sustainable assessment tools in HEIs; considering the variation in types, tools' evaluation factors, and whether ecodesign tools exist that evaluate these factors. Commonly used tools include Sustainability Tracking, Assessment & Rating System (STARS), Leadership in Energy and Environmental Design (LEED), Green Lab Certification, and Times Higher Education rankings (THE). These tools were derived from the Google Scholar using the keywords "campus sustainability," "HEI sustainability assessments," and "sustainability assessment tools for HEIs" to identify and apply commonly discussed tools in higher education institutions.

Many environmental assessment tools, mainly ranking tools, utilized by HEIs allow for qualitative data analysis in their methodologies. Ranking tools provide an overview of the status of the participating university but do not provide, nor address overall sustainability aspects particularly Education for Sustainable Development (ESD) indicators (Veidemane, 2022), nor do they provide the path for improvement. Table 1 highlights that not all key factors of HEI sustainability have corresponding ecodesign concepts, making it easy to identify gaps and guide future studies to address them.

3 How Ecodesign can complement HEI environmental assessment methods

Ecodesign tools can be complementary to HEIs' environmental assessment methods by providing academic and operational approaches with sustainable practices (Vallet et al., 2013). Moreover, ecodesign not only streamlines the environmental performance but also other sustainability aspects like social and economic performances that apply to institutes like HEIs. Ecodesign principles can add value to these assessments by integrating sustainable practices into both institutional infrastructure and educational programs.

Ecodesign tools can be summarized as Table 2:

- *BIM (Building Information Modeling):* For energy efficiency of the buildings, which helps design energy-efficient buildings with 3D representation that simulates geometric and energy use and optimizing designs for natural light and heat management (Lamé et al., 2017; Paolini et al., 2019);
- *Checklists:* A qualitative tool that allows a quick and easy evaluation of environmental impacts over the life cycle of a product or service (Ali et al., 2012);
- *Environmental Benchmarking:* Using environmental benchmarking parameters such as Key Environmental Indicators to compare the quality and meet the benchmarking target (Yim and Lee, 2002);
- *LCAs (Life Cycle Assessments):* Life Cycle Assessments are popular ecodesign methods for evaluating the environmental impacts of a product's stages of life, through its entire life cycle. S-LCA (Social

TABLE 1 Some of the widely applied sustainable assessment tools in HEIs.

Tools	Description	Type	Evaluation factors of the tools	Ecodesign tool availability	Source
Building research establishment environmental assessment methodology (BREEAM)	BREEAM is a building assessment and rating system that evaluates sustainability in areas like energy, water, materials, waste, pollution, transport, and ecology. Based on a scoring system, buildings receive a rating from "Pass" to "Outstanding" depending on their performance in these areas.	Building sustainability assessment	Energy	Yes	Abdul-Azeez (2018) and Ferreira et al. (2023)
			Health and Wellbeing	No	
			Innovation	Yes	
			Land use	Yes	
			Materials	Yes	
			Management	No	
			Pollution	Yes	
			Transport	Yes	
			Waste	Yes	
			Water	Yes	
Carbon footprint analysis	Carbon footprint measures greenhouse gas emissions in carbon dioxide equivalents. It quantifies the total emissions released into the atmosphere due to the activities of that product, service, or organization.	Assessment	Carbon emissions	Yes	Valls-Val and Bovea (2021) and Ridhousari and Rahman (2020)
Ecological footprint analysis	The ecological footprint measures the amount of land and water needed to supply the resources people use and to absorb their waste. This analysis helps assess the sustainability of human activities and highlights where changes might reduce environmental impact.	Assessment	Area of land and water	Yes	Conway et al. (2008), Nunes et al. (2013), Lambrechts and van Liedekerke (2014), Liu et al. (2017)
Green lab certification	"My Green Lab" is a program that helps laboratories improve sustainability and reduce environmental impact by assessing practices in energy, water, waste, procurement, transportation, and community engagement. It offers various certification programs tailored to different needs.	Certification program	Community	No	My Green Lab (2025), Wenzel (2021), and The Anlalytical Science (2023)
			Recycling and waste reduction	Yes	
			Resource management	Yes	
			Purchasing	No	
			Green chemistry and green biologics	Yes	
			Water	Yes	
			plug load	Yes	
			Fume hoods	Yes	
			Cold storage	Yes	
			Large equipment	Yes	
			Infrastructure energy	Yes	
			Field work	Yes	
			Animal research	Yes	
			Travel	Yes	
Leadership in energy and environmental design (LEED)	LEED is a rating system that evaluates building environmental performance, focusing on energy efficiency, water conservation, indoor air quality, and sustainable site development. Buildings earn points in each category, with the total points determining their LEED certification level.	Building sustainability assessment	Sustainable sites	Yes	Chester County Planning (2025) and Ferreira et al. (2023)
			Water efficiency	Yes	
			Energy and atmosphere	Yes	
			Materials and resources	Yes	
			Indoor environmental quality	Yes	
			Locations and linkages	Yes	
			Awareness and education	Yes, in part	
			Innovation in design	Yes	
			Regional priority	Yes	

(Continued)

TABLE 1 (Continued)

Tools	Description	Type	Evaluation factors of the tools	Ecodesign tool availability	Source
Sustainability reporting using global reporting initiative (GRI)	GRI offers a framework for sustainability reporting, allowing companies to measure and disclose their economic, environmental, and social impacts, including governance and supply chain practices. Widely used across sectors, the GRI Standards provide a common language for transparency and accountability in sustainability performance reporting.	Assessment	Economy	Yes, in part.	Alonso-Almeida et al. (2015)
			Environment	Yes	
			People	Yes	
Sustainability assessment for higher technological education (SAHTE) model	This model was developed to assess the adoption of sustainable practices from existing frameworks in higher education technological institution services in Brazil.	Assessment	Governance/Policies	Yes	Drahein et al. (2019)
			People	Yes	
			Food	Yes	
			Energy/Water	Yes	
			Waste/Environment	Yes	
The sustainability tracking, assessment and rating system (STARS)	STARS is a voluntary, self-reporting framework for higher education institutions to measure sustainability performance. It tracks progress in areas like emissions, energy, water, waste, transportation, education, diversity, and affordability, with ratings from Bronze to Platinum based on performance.	Framework	Academic	No	Association for the Advancement of Sustainability in Higher Education, (2024) and Zhu and Dewancker (2021)
			Engagement	No	
			GHG emissions	Yes	
			Energy consumption	Yes	
			Food and beverage purchasing inventory	No	
Times higher education impact ranking (THE)	The THE is the only global performance tables that assess universities against the United Nations' Sustainable Development Goals (SDGs).	Ranking	SDGs	Yes	THE Reporters (2024)
Triple bottom line	Triple bottom line accounting is a framework that measures an organization's impact across three areas: social, environmental, and financial. It emphasizes that companies should consider not only financial results but also their effects on people and the planet.	Framework	Social wellbeing	Yes	Slaper and Hall (2011), Saeudy (2014), and Ibrahim et al. (2022)
			Environmental health	Yes	
			Economy	Yes, in part, ecodesign tools do not measure the quality of the economic performances.	
UI GreenMetric ranking	UI GreenMetric is a global ranking system that evaluates universities on their sustainability efforts in areas like energy, waste, water, transportation, green spaces, and education.	Ranking	Setting and infrastructure	Yes	Atici et al. (2021)
			Energy and climate change	Yes	
			Waste	Yes	
			Water	Yes	
			Transportation	Yes	
			Education and research	Yes, in part (with S-LCA)	

Life Cycle Assessment) evaluates the socio and economic impacts while O-LCA (Organization Life Cycle Assessment) evaluates the environmental impacts of the entire organization instead of focusing on a single product (UNEP, 2015; UNEP, 2020);

- *Matrix-based tools:* Structured tools that use grids and matrices to compare and analyze the relationship between different criteria. They are used in ecodesign methodologies where they are applied for decision-making, process improvement and problem-solving (Ali et al., 2012; Russo et al., 2014; Alemam and Li, 2016);
- *MFA (Material Flow Analysis):* Material Flow Analysis (MFA) tracks material use and waste generation, helping design processes that minimize waste and maximize recycling and reuse. It can be integrated as an ecodesign strategy part of design reconstruction to meet sustainability targets (Barkhausen et al., 2023);
- *Parametric Tools:* The tools are parameter-driven models that use parameters to simulate design models by automatically updating related components when one parameter is changed. This allows designers to explore environmentally friendly configurations

TABLE 2 Relationship between sustainability assessment tools and ecodesign tools.

Evaluation factors	Ecodesign tools						
	BIM	Checklists	Environmental benchmarking	LCAs (S-LCA & O-LCA)	Matrix-based	MFA	Parametric tools
Academic and research							
Economy					x	x	x
Energy performance	x	x	x	x	x	x	x
Environmental health		x	x	x	x	x	x
Ethics				x	x		
Facilities and campus operations	x						
Governance and policies		x	x	x			
Human resources management				x			
Mobility and transportation				x			
Settings and infrastructure	x	x				x	x
Waste management		x	x	x	x	x	x
Water management		x		x		x	x

(Ostad-Ahmad-Ghorabi et al., 2008; Kamalakkannan and Kulatunga, 2021; Campos-Carriedo et al., 2024).

Table 2 shows where the different ecodesign tools can contribute to improving environmental performance of the environmental factors summarized from sustainability assessment tools listed in Table 1.

Most ecodesign tools focus on the environmental aspects of tangible products, with very few focusing on social aspects (Table 2). This is because ecodesign tools were initially intended to focus on product specific environmental impacts and have never been utilized on an institutional level that provides multiple service streams. Hence, the integration of such tools and their application to multilevel institutions can be another mean to address sustainability issues in a more streamlined and quantitative approach.

4 Integration of assessment tools and ecodesign solutions

Ecodesign tools that overall assist and evaluate the integrity of many different sustainability indicators do not exist. Implementing such an approach to multifunctional institutions like higher education and research institutes requires thorough steps in design development and implementation. The aim is to integrate essential aspects of characterization tools, e.g., S-LCA and O-LCA, university sustainability ranking tools and ecodesign tools in a methodology that provides an allrounder evaluation so that HEIs can benefit from such integration.

The integrated tool is inclusive in assessing both *environmental and social concerns*, *quantitative* by assessment, and allows for *comparison* and guides *solutions* for improvements, being the latter imported from ecodesign. Figure 1 illustrates the simplified concept of integration of ecodesign strategies to HEI assessment tools. The very first step is to assess the state-of-the-art sustainability status of the HEI; assessment tools and ranking tools such as THE Impact Ranking or GreenMetric provide the means of understanding sustainability using graphs or final ranks (Caeiro et al., 2020). For more comprehensive and quantitative assessment, variations of LCA tools are recommended, i.e., S-LCA, O-LCA, or Social Organizational LCA (Martínez-Blanco et al., 2015; Martínez-Blanco and Finkbeiner, 2017; Cimprich, 2022). For instance, O-LCA can be applied to an institution on an organizational level to evaluate the environmental impacts associated with the organization's operations (UNEP, 2015). However, these assessments do not provide solutions for improvement, *per se*. Some guidance is needed to choose the optimal path to more sustainable management of HEI. This would be where the integration of ecodesign tools comes into play (Zhu and Liu, 2010). A step forward would be building quantitative checklists and solutions tools, which provide an assessment of material and energy inputs/outputs, and impacts (e.g., using LCA, or the Material Input per Unit of Service approach; Ritthoff et al., 2002), and also guide the user to optimal management solutions; examples include eco-design checklists, of which the Ecodesign Pilot[1] is developed for products and services. The key evaluation factors in HEI have already been identified (see Table 1), being necessary only to identify which ecodesign tool is best adapted given the available data. In complement, linkage with the databases built for measuring environmental performance of HEI would further improve the integrability of tools [data collection and storage (database), performance assessment, and ecodesign target solutions]. Veidemane (2022) has thoroughly explained the lack of validity in international HEI rankings and the need for the development of indicators that are internationally comparable, i.e., pointing out the need for benchmarking, a common ecodesign tool for product and service improvement.

The final step needed is combining the individual tools into a unified, cohesive solution.

5 Conclusion

Like in the industry, by adopting ecodesign principles (Rodrigues et al., 2017), HEI institutions can innovate with sustainability in mind from the outset, leading to products and processes that are inherently more efficient and less harmful to the environment. Ecodesign

1 http://pilot.ecodesign.at/

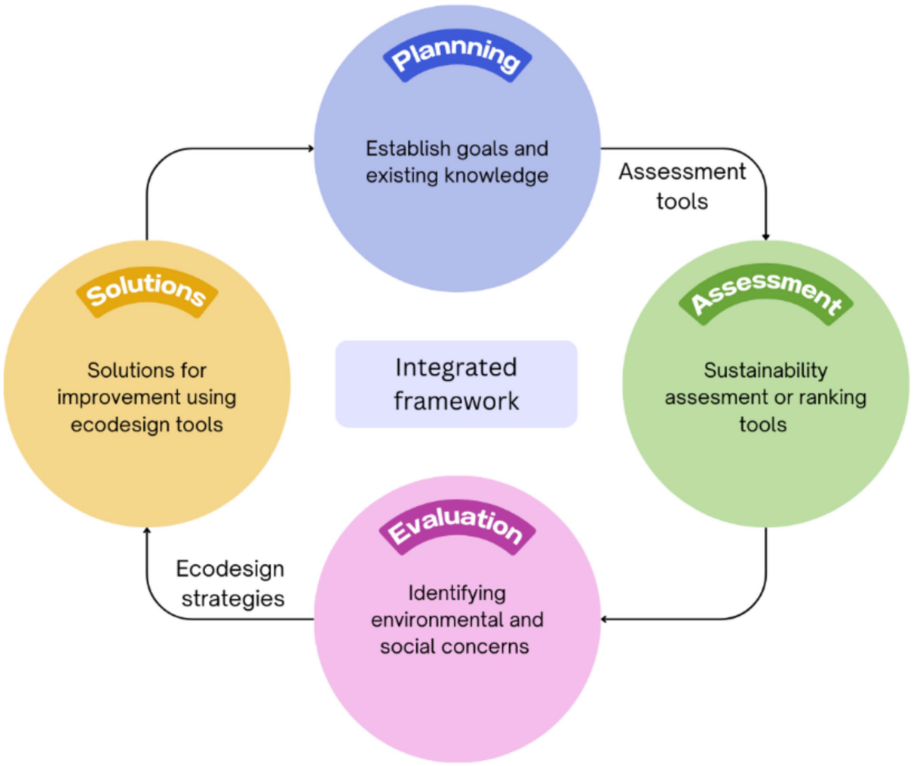

FIGURE 1
Proposed framework for integration of assessment tools and ecodesign strategies.

encourages the use of sustainable resources, efficient processes, and the use of better conceptual designs toward more sustainable products. The tools are solution-oriented, thus helping in finding the way. When combined with environmental assessment tools, which many institutions already use, ecodesign may enable the institutions to not only mitigate existing environmental impacts but also prevent future ones by proactively integrating sustainability into their core operations, including in teaching (Thürer et al., 2018). This synergy may help foster a culture of continuous improvement and innovation, contributing to the long-term sustainability of the institution.

By aligning with global sustainability initiatives and adopting proactive strategies, higher education institutions can act as pioneers in addressing climate and societal challenges, and adopting ecodesign offers a clear, actionable pathway to sustainability goals. This brief reflects the authors perspective on the needs and importance of HEIs to adopt ecodesign measures and not only rely on the assessment tools that give the simple rankings.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

WS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. MR: Supervision, Validation, Writing – review & editing. LS: Validation, Writing – review & editing. LN: Conceptualization, Formal analysis, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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