Mapping sustainability in higher education institutions: co-creating a spatial dashboard for monitoring and engaged action

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Abstract

Purpose – Several certified frameworks exist for ranking sustainability credentials of higher education institutions (HEIs), but few institutions regularly register efforts in a geographically-specific way. Mapping sustainable infrastructure, services and activities within HEIs can improve both awareness and decision-making, enhancing the evidence-base for informed action. This paper aims to present and discuss the co-creation of a novel online mapping dashboard that captures sustainability efforts in University College Dublin, Ireland.

Design/methodology/approach – Systematic review of sustainability policies and resources, and a campus-wide student, faculty and staff survey helped identify ongoing activities, information needs and availability. Through a systematic data gathering process and consultation with key stakeholders, sustainability-driven initiatives were compiled, and a comprehensive set of spatial data for each sustainable development goal (SDG) was created. These were subsequently integrated into a bespoke interactive dashboard.

Findings – The dashboard establishes a baseline of sustainability efforts across the university, provides a teaching and learning tool and gives the academic community the opportunity to identify areas for research and targeted action. The data collection and dashboard creation process revealed SDG priorities and data limitations to be addressed for strengthening sustainability implementation and reporting mechanisms.

Originality/value – The dashboard was co-created by students, faculty and staff. To the best of the authors' knowledge, it provides the first transferable template to support geographically-specific SDG monitoring within HEIs and, therefore, can be of value to other institutions. This paper contributes to debates on the need for spatial reporting of actions towards sustainability, to meaningfully recognise local SDG implementation progress.

Keywords Universities, Sustainable development goals, Ranking frameworks, Collaborative action, Spatial data

Paper type Research paper

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1. Introduction

Higher education institutions (HEIs) play a crucial role in embedding sustainability into teaching, learning, research, governance and operations, thereby reducing their environmental footprint as well as nurturing sustainable values and capacitating their community and the broader society in eco-conscious practices (Price *et al.*, 2021; Ralph and Stubbs, 2014). Building upon the influential role of universities in sustainability, Turriziani (2021, p.11) underscores their ability "to shape future generations, creating future world leaders by promoting positive attitudes and introducing the correct approach towards achieving sustainability". This capacity to impart the appropriate knowledge and skills is critical for instilling a system of sustainable values across all societal sectors (Sady *et al.*, 2019; Žalėnienė and Pereira, 2021). By developing sustainability-focused programmes and embedding sustainable elements into all curricula, universities can ensure that positive impacts made today resonate with future generations. Fehlner (2019) also acknowledges that the relationship between HEIs and sustainability is pivotal for helping graduates secure well-paying jobs and contribute to the creation of stable and prosperous societies. Similarly, several authors have underlined the environmental and community benefits of integrating sustainability in campus operations (e.g. Argento *et al.*, 2020; Blasco *et al.*, 2021; Žalėnienė and Pereira, 2021).

Various frameworks have emerged to measure and provide HEIs with certified rankings of their contribution towards sustainability (Table 1). These frameworks use various metrics such as education for sustainability, publications related to the sustainable development goals (SDGs) (UN, 2015), gender balance in student/faculty/staff (faculty and staff referred to as staff from here on for simplicity), energy consumption, water use and commuting patterns. Such university ranking frameworks play a critical role in promoting sustainable practices by creating competitive pressures and incentives for improvement (Alghamdi *et al.*, 2017; Wright, 2002). By publicly showcasing results, ranking frameworks not only encourage universities to adopt sustainable practices, but also provide them with a platform to demonstrate to stakeholders, including external partners, their commitment to sustainability and the SDGs (Alghamdi *et al.*, 2017; Waas *et al.*, 2014).

Measuring universities' commitments and actions is crucial for tracking their progress towards achieving the SDGs. Using robust frameworks allows HEIs to be able to see where they lie on a global scale and, thus, benchmark their progress against other institutions and, more importantly, identify practices that may require further improvements – thus, helping formulate sustainability strategies. However, concerns have been raised about the uniform approach of these rankings, ignoring evident differences among universities, such as their geographical locations or other typological characteristics (Aguillo *et al.*, 2010; Lauder *et al.*, 2015), that can lead to unintended biases towards certain countries. The inclusion of indicators that are more applicable to larger universities and limitations in data monitoring frameworks have also been noted to influence rankings (Marginson and Wende, 2007; Usher, 2009). These issues present a significant oversight, as sustainability challenges and solutions are deeply influenced by specific geographic and cultural contexts. For instance, water usage indicators need to be linked to water scarcity issues as certain regions might necessitate more stringent conservation strategies, yet current frameworks may not fully address these nuances (Alghamdi *et al.*, 2017). Similarly, each university is faced with different challenges and, thus, may prioritise different sustainability goals. It has been, therefore, argued that it is important for HEIs to develop their own assessment and monitoring tools, to address the challenges of adopting the conventional "one-size-fits-all" approach of mainstream assessment tools (Alghamdi *et al.*, 2017).

Table 1. Outline of key certified ranking frameworks for sustainability in higher education institutions (HEIs)

Scope	Limitations	References
QS world university rankings: Sustainability www.topuniversities.com/sustainability-rankings		
Globally influential, the sustainability raking was only recently launched (2022). Monitored closely by university administrators, industrial leaders, politicians and ministry officials. It applies 52 indicators across the three key sustainability aspects: environmental impact, social impact and governance	Most indicators have a percentage weight between 1 and 3%, with important exceptions such as academic reputation (10%) and research impact on SDGs (9%), potentially biasing rankings towards larger and more established institutions	Aguillo *et al.*, 2010; Hazelkorn, 2015; Marginson, 2014; Marginson and van der Wende, 2007
Sustainability tracking, assessment and rating system (STARS) Stars.aashe.org/		
Globally recognised. Measures sustainability across 186 indicators through a point scoring system for the following aspects: academics, engagement, operations, planning and administration and innovation and leadership. It was launched in 2010	Requires a vast amount of data collection to provide high ratings. This can put smaller universities at a disadvantage as they might not have the resources to achieve their desired rating	AASHE, 2024; Alghamdi *et al.*, 2017
Times higher education (the) impact rankings www.timeshighereducation.com/		
Globally influential, but the sustainability element was only launched in 2019. Monitored closely by university administrators, industrial leaders, politicians and ministry officials. It measures global universities' success in delivering the SDGs, against 247 indicators aligned with the SDGs around the following aspects: research, stewardship, outreach and teaching	The total score is calculated by combining the SDG 17 score (which includes 27 indicators and accounts for 22% of the total score) with its best three results on the remaining 16 SDGs (each accounting for 26%; number of indicators varies from 4–19 depending on the SDG). Thus, universities are scored based on a different set of SDGs, depending on their focus	Marginson and van der Wende, 2007; Hazelkorn, 2015
Universitas Indonesia GreenMetric (GM) greenmetric.ui.ac.id/		
Mostly applied in Asia but also in Europe and the United States. Measures campus sustainability efforts using an online survey with 39 indicators that capture 6 criteria: setting and infrastructure; energy and climate change; waste; water; transportation; and education and research. It was launched in 2010	A point system is applied to indicators and a weighting to the criteria. The data are submitted to the organisation who then establish the ranking. Uncertainties on the evaluation process of applications and the precise effects of individual categories on the overall results, especially the geographical aspects	Lauder *et al.*, 2015; UI GreenMetric, 2023

Source(s): Authors' own work

In addition to the above contextual disparities and challenges, the indicators that make up a ranking pertain to any given university as a whole. The indicators do not differentiate areas within a campus, or academic colleges/departments – particularly significant where a HEI has multiple campuses across a number of provinces/regions. Arguably, a more geographically-explicit approach to measuring sustainability indicators can provide a more detailed understanding of a university's progress, as well as the identification of areas within a campus that require targeted action. This would involve not only the adaptation of current ranking frameworks to include geographically-specific (i.e. spatial) criteria and indicators, but also a broader institutional shift towards integrating spatial data in sustainability reporting and decision-making processes (Moldan *et al.*, 2012). Spatial approaches have been long recognised as central to evidence-based decision-making (e.g. González, 2012; Li, 2008; Smith, 2016). Moreover, participatory approaches to spatial data identification, creation and centralisation in online interfaces, support transparent assessments and accountable actions (e.g. Drummond and French, 2008; González *et al.*, 2019; González *et al.*, 2023; Smith, 2016). In this context, and in light of the need to adopt more localised approaches to measuring and promoting sustainability in HEIs, using Geographic Information Systems (GIS) in sustainability assessments could help in visualising and analysing the geographic distribution of indicator metrics, and the specifics of SDG implementation progress (Avtar *et al.*, 2020). Such a shift would ensure that the unique challenges and opportunities of each university's locale are acknowledged and addressed in their sustainability strategies and, thus, enhance both the accuracy and impact of sustainability initiatives and their reporting.

Digital campus sustainability maps have emerged as tools for visualising and communicating these efforts (Stanton *et al.*, 2021). While there is no centralised inventory of such campus maps, an online search [1] reveals a number of these, and suggests that these are most common in the USA (e.g. Universities of Auburn, [2] Cornell, [3] Danforth, [4] Mason, [5] Iowa, [6] Maryland [7] and Washington [8]), Canada (e.g. New Brunswick [9] and Waterloo [10]) and England (e.g. Birmingham City, [11] Northumbria, [12] and Plymouth [13]). However, some of these digital campus maps are no longer operational (e.g. data are not displayed or the URL does not works). And, for the most part, they are not structured around the SDGs: they commonly provide spatial representations of key sustainability features (e.g. recycling stations, energy-efficient buildings, transport hubs and biodiversity conservation areas), but only in one occasion (i.e. Auburn University), these are directly linked to the SDGs. This non-exhaustive review also reveals inconsistency of information; some themes appear repeatedly across the reviewed digital maps (e.g. buildings, transport), while others very occasionally (e.g. gardening, stormwater, waste). Similarly, data sets (or data layers) are not curated to provide attributes of relevance: in some cases, a description and purpose of a feature is provided but in most cases, the attribute pop-ups only provide location information. In any case, contemporary campus sustainability maps leverage GIS, Web-based interactive interfaces and mobile-friendly applications to provide seamless access to sustainability resources. Some universities even provide real-time feedback on electricity, water and waste generation patterns (e.g. University of Western Australia [14]). Empirical studies suggest that digital sustainability maps enhance environmental awareness and encourage sustainable behaviours, such as increased use of refill stations and participation in campus waste diversion programs (Mosca *et al.*, 2024; Stanton *et al.*, 2021; Wu *et al.*, 2024).

In light of the above, and in an attempt to enhance local reporting of efforts towards sustainability, this paper presents the steps undertaken for the co-creation of a novel SDG dashboard (cms.ucd.ie/sustainability/resources/) that provides a policy and resource register together with a geographically-specific inventory of sustainable infrastructure, activities and services, associated with each SDG, within University College Dublin (UCD), Republic of Ireland. In doing so, it discusses the challenges of aligning this pragmatic spatial approach with existing ranking frameworks, and indeed, the SDG indicators. The paper concludes by reflecting on the opportunities unveiled by mapping resources within campus specifically around the SDGs, and the potential for such spatial reporting to enhance sustainability awareness, engagement and action. Thereby, the paper contributes to advancing debates around scalability of SDG indicators, and the value and challenges of concerted local data-gathering efforts in effectively understanding shifts towards sustainability.

2. Methods

The methodological approach for the co-creation of a geographically-specific inventory of sustainable infrastructure, activities and services within UCD was grounded in a student-staff collaboration. It included a series of systematic, interconnected and tiered steps, detailed in Figure 1 and described below. These led to improvements in both content and interface design, and contributed to ensuring the dashboard was designed according to user needs.

2.1 Report review

The first step in understanding the scope and extent of sustainability information at UCD was to examine the two sustainability reports produced by the university (UCD, 2020, 2021) and the environmental baseline review (UCD, 2019). The aim was to identify the information already gathered and accessible for evaluating the university's contribution to sustainability, and inform further data collection needs. This was undertaken by a small group of students who systematically extracted infrastructure, activities and services on campus, and created a database of records against each SDG.

2.2 Campus-wide consultation

A survey was designed to examine the perceptions of UCD students and staff regarding the university's efforts towards sustainability initiatives and communication on such initiatives. In addition, it evaluated the respondents' interest in using an online map with information on sustainable resources across campus. The anonymous survey categorised respondent by role (as students/faculty/staff) and by college affiliation and included the following eight questions:

(1) prior interest on sustainability;

(2) level of availability of sustainability information in UCD;

(3) usefulness of a sustainability map;

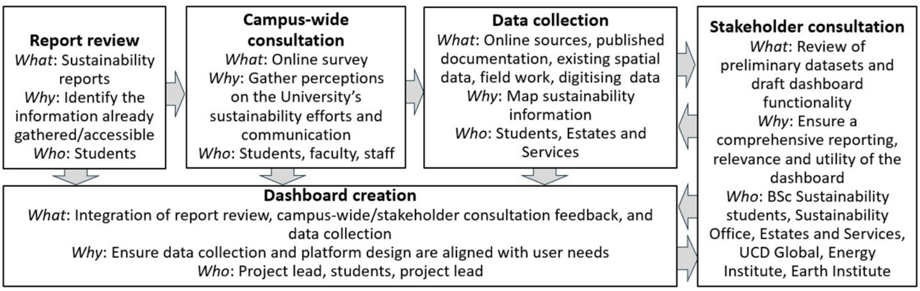

Figure 1. Methodological steps for the co-creation of the sustainability dashboard at University College Dublin

Source(s): Authors' own work

(4) likelihood of using such map;
(5) its applicability – i.e. to learn where infrastructure/activities/services are, what they involve or how to access these;
(6) main two SDGs of interest;
(7) relevant information to be mapped for the selected SDGs; and
(8) suggestions on online map content and functionality.

It incorporated drop-down menus for standardised responses (e.g. main SDGs of interest) and open-ended questions (e.g. content and functionality suggestions), allowing for both quantitative and qualitative data collection.

The survey was conducted online over a three-week period, between January and February 2024. To optimise dissemination and response rates (Tuten *et al.*, 2002), two promotional campaigns were launched. The first used university e-news and social media communication channels, while the second involved large posters placed around campus, advertising the survey QR code on digital screens, and flyers distributed in classrooms. These different means of dissemination were intended to ensure that the whole UCD community was made aware of and encouraged to participated in the survey. As the purpose of the survey, in the context of the dashboard co-creation, was to canvas opinion on the main SDGs, related information to be mapped, and interface functionality, basic descriptive statistics were applied when analysing survey results (e.g. response counts and percentage values).

2.3 Data collection

The survey and stakeholder consultation feedback enabled creating a "wish list" of information/data to be included in the dashboard. A pragmatic approach was adopted for data collection, including:

- retrieving available information from online sources and published documentation;
- using available data from Estates and Services (entailing comprehensive and verified records for infrastructure in particular – e.g. buildings, roads, energy and water services and networks);
- completing the information (where relevant features and/or attribute details were not complete or compiled for a given data set);
- digitising or digitally drawing these data (where PDF maps where provided);
- identifying the geographical location of data (geolocating) as appropriate (for most data sets, coordinates or location maps were not available); and
- collating new information and creating associated spatial data sets where these were not readily available.

The latter was achieved by either using satellite imagery to identify and digitise features, or by walking/cycling around the campus to gather data. Field data collection was mainly undertaken by students, who used ArcGIS Survey123 to record pre-defined specific attributes and, thus, ensure uniformity and accuracy of data. Moreover, the geographically bounded area of UCD, and the fact that the students engaged in data collection were very familiar with campus facilities, contributed to ensure comprehensive data records. The inclusion of the collected data sets into the dashboard also helped with quality control, as these were scrutinised by the consulted stakeholders as detailed below.

2.4 Stakeholder consultation

Multiple stakeholders were engaged through the co-creation process to ensure alignment of data collection and interface design with user needs and, thus, support dashboard adoption and use. Stakeholders included academics, undergraduate and postgraduate student representatives from the BSc Sustainability programme, the Sustainability Unit, Estates and Services (who have a central role in campus operations), UCD Global (leading on partnership and engagement) and the Energy Institute and Earth Institute (two key institutes driving sustainability research and education at UCD). They were consulted ongoingly through the data collection process to verify data completeness, and identify and source additional data. This helped ensure comprehensive reporting of all relevant and available information across the range of SDGs. Three distinct input windows were provided: the preliminary compilation of data and functionality, from the report review and survey, was circulated to the stakeholders for review and comment, with the aim to expand information and data knowledge; and two pilot versions of the user interface were circulated for review to further enhance data comprehensiveness, and dashboard layout and functionality.

2.5 Dashboard creation

The survey and consultation findings informed, in particular, the content and functionality of the dashboard, created using Experience Builder in ArcGIS Online. The adoption of commercial software (versus open-source GIS alternatives) was based on its versatility for creating interactive user interfaces, but also on the fact that this is the most widely used software for research and teaching purposes in UCD. The need to include both non-spatial (e.g. PDF documents) and spatial (e.g. building-specific characteristics) information was key for a comprehensive dashboard, as well as the requirement to clearly present a range of data sets pertaining each of the 17 SDGs. The dashboard was co-created between students and staff to integrate multiple user requirements, and ensure an easy to access and use interface. This was supported by internal iterative testing of pilot dashboard versions, as well as by the stakeholder consultation feedback.

3. Results

3.1 Report review

The reports unveiled relevant sustainability policies, strategies, initiatives, working groups, supports and infrastructure. The review also helped establish links between each of these efforts and the relevant SDG(s) (see supplementary material). The following SDGs were most covered by the information/data in these reports: SDG4 (quality education), SDG7 (affordable/clean energy), SDG11 (sustainable cities/communities), SDG12 (responsible consumption/production) and SDG17 (partnerships for the goals). The review also pointed to limited reporting on SDG1 (no poverty), SDG2 (zero hunger), SDG8 (decent work and economic growth), SDG13 (climate action) and SDG14 (life below water). These findings guided data collation efforts, with particular focus on SDGs with limited reporting to fill in the identified data and knowledge gaps and provide a more comprehensive range of information to the UCD community. In addition, the review revealed that many relevant sustainability-driven initiatives (e.g. policies, standards and awards) are applicable campus-wide (i.e. have no specific implementation locations) and, therefore, cannot be spatially mapped. This influenced the dashboard design, leading to the creation of a complementary webpage compiling and presenting (non-spatial) aspects applicable to the campus as a whole.

3.2 Survey results

The survey garnered 1,369 responses, of which 59.5% were students and 37.8% faculty/staff with representation from all the colleges in the university (UCD, 2024). Interestingly, less than half (43.8%) of respondents have searched for information on UCD sustainability in the past. Of these, a significant minority (31.8%) rated the provision of such information as poor/very poor, and 21.7% deemed it to be good/very good. The majority (76.2%) considered that an online sustainability map would be useful, and 75.6% confirmed they would likely use such resource.

When asked to select the two main SDGs of interest, both students and staff consistently identified SDGs 11 (sustainable cities), 13 (climate change) and 12 (consumption and production), with 14.5%, 14.1% and 13.9% responses, respectively (Figure 2). Differences were observed between colleges in this prioritisation with, for example, the College of Science favouring SDG13, and the College of Business SDG12. In contrast, the Colleges of Health and Agricultural Sciences and of Social Sciences and Law prioritised SDG3 (health and wellbeing), which featured strongly as the second most important SDG for students and staff. When combined with the respondents' second choice, the importance of SDGs 11 and 12 was reiterated, but SDG4 (quality education) emphasised, with both SDG3 and SDG4 gaining prominence over SDG13 (Table 2). Overall, the survey findings suggest shared SDG priorities, and broadly similar information interests among the UCD community as further illustrated below.

When asked about specific data and/or information needs, the responses reveal a wide variety of priorities across campus (Table 2). Not all survey participants answered this question, but the findings suggest the following aspects as most important (linked to the prioritisation of two main SDGs of interests): climate adaptation and mitigation initiatives/plans, and greenhouse gas emissions (SDG13); essential health services, student wellbeing infrastructure and healthy living initiatives and events (SDG3); academic support services

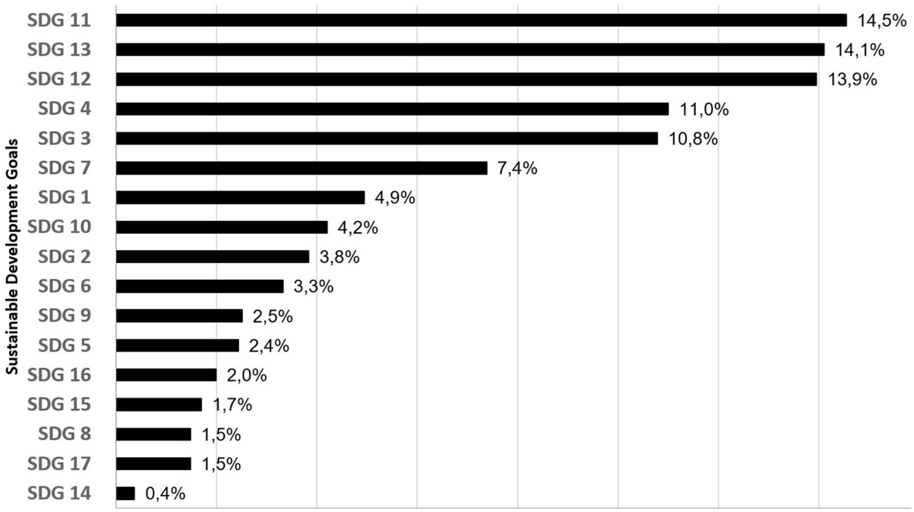

Figure 2. SDGs selected by survey respondents as their first main interest for mapping sustainability at UCD ($n = 1{,}355$)
Source(s): Authors' own work

Table 2. Sustainability SDGs of most interest and associated data/information needs prioritised by survey respondents

Data/information needs	Selection counts	% of total
Sustainable cities and communities (SDG 11)	*n* = 1,755	
Affordable housing options	204	11.6
Air quality (particular matter)	177	10.1
Building retrofitting plans/initiatives	177	10.1
Cultural and natural heritage	158	9.0
Open spaces	220	12.5
Participation in campus development plans	161	9.2
Research centres on sustainable communities/cities	153	8.7
Solid waste collection and disposal	197	11.2
Sustainable transport modes and routes	292	16.6
Other (e.g. bike infrastructure, energy efficiency)	16	0.9
Responsible consumption and production (SDG 12)	*n* = 1,638	
Drinking water fountains	256	15.6
Recycling facilities (e.g. segregation bins)	291	17.8
Research centres on sustainable consumption	133	8.1
Reuse and repurpose activities	285	17.4
Sustainable consumption reports	170	10.4
Sustainable consumption workshops/events	183	11.2
Waste reduction measures	297	18.1
Other (e.g. second-hand sales, circular economy procurement)	23	1.4
Good health and wellbeing (SDG 3)	*n* = 1,152	
Essential health services	229	19.8
Healthy living initiatives and events	216	18.8
Mental health support	232	20.1
Research centres on health and well-being	132	11.5
Student wellbeing infrastructure and centres	211	18.3
Student wellbeing perceptions	108	9.4
Other (e.g. access to affordable food, subsidised canteens)	24	2.1
Quality education (SDG 4)	*n* = 1,015	
Academic support services	203	20.0
ICT related courses/programmes	122	12.0
Scholarship opportunities	193	19.0
Student statistics (diversity, success, etc.)	142	14.0
Sustainability related programmes/courses	162	16.0
Sustainable development initiatives	173	17.0
Other (e.g. education culture, facilitated career change)	20	2
Climate action (SDG 13)	*n* = 1,050	
Climate adaptation initiatives/plans	248	23.6
Climate education programs/modules	189	18.0
Climate mitigation initiatives/plans	222	21.1
Greenhouse gas emissions	221	21.0
Research centres on climate change	160	15.3
Other (e.g. climate education, meat-free campus)	10	1.0

Source(s): Authors' own work

and scholarship opportunities (SDG4); recycling facilities (SDG12); and sustainable transport (SDG11).

With regards to the user interface, many respondents (41.4%) highlighted the importance of ensuring user-friendly design and access. Yet, there was a relative split in opinion between three key practical aspects: the inclusion of interactive features (25%), ensuring accessibility (23%) and providing regular updates (21%). Interactive features repeatedly referred to included data querying and layering, while accessibility features comprised large fonts, distinct colour schemes and easy to navigate layouts across various devices. Some respondents (11.4%) observed that the provision of regular updates could be supported by enabling user input and feedback. This was considered essential to "continually refine and adapt the map to actual user experiences and needs". Integration of the online map in existing platforms (e.g. UCD website and social media) was also considered important by respondents (11.4%). Overall, survey responses highlighted the need for a simple and clear design that does not require significant mapping skills and facilitates an effective use of the resource.

3.3 Spatial data

The first step to respond to the information/data needs identified by survey respondents was to compile data from existing sources (e.g. Estates and Services, Energy Institute). Such data mainly consisted of inventories without location details; where location references were provided (e.g. address), no geographic coordinates (X,Y) were available. Some information was available in PDF drawings or sketch format (e.g. electric vehicle EV-charging points, walking trails); no GIS-compatible files were available in UCD at the start of this project. The available data sets were often outdated (e.g. newly installed bicycle parking racks had not been recorded). To link such information to specific locations throughout campus and complete the information, additional field work and digital mapping were, therefore, required. Similarly, key data sets were not readily available, particularly for initiatives not centralised at Estates and Services, and for those informally/irregularly reported by colleges/departments. These had to be compiled by accessing multiple websites and reports (e.g. university policies supporting sustainability), collected locally (e.g. walking/cycling around the campus to identify and map segregation bins, disabled access points or biodiversity enhancement features) or created using satellite imagery (e.g. vegetative land cover, solar panels). Of the identified 156 data sets, 107 data sets were eventually completed and included in the dashboard (see supplementary material). It was not possible to complete or update a number of data sets due to lack of available resources. These included: ecosystem services (this has not been undertaken for the campus and requires dedicated resources); water filtration/run-off (linking to Sustainable Urban Drainage System measures would have been relevant but this information is currently not available); light-emitting diode (LED) lighting (while Estates and Services confirmed that outdoor lighting has been upgraded and all new buildings include LED lighting, it was not possible to inventory older buildings for a comprehensive understanding of areas/rooms that require upgrading); and accessible signage (dedicated time and resources are required to compile and map this complex information).

The data compilation process revealed that there are more extensive sets of data readily available for some of the SDGs. For example, SDGs 3, 10 and 15 include a wide variety of data sets given the range of health services, mobility infrastructure and green spaces on campus. In contrast, limited data were available for SDGs 4, 6, 13 and 14, for example, with research institutes and student societies presenting the primary sources of information in such cases. The availability of infrastructure data is particularly good given the role of Estates and Services in monitoring these, but information on activities was not centrally available and had to be compiled from various sources. Existing data gaps and difficulties compiling certain data sets, thus, influenced the comprehensiveness of information across the SDGs, with some goals being better represented and reported on than others.

New additions to the compiled data sets (such as new bus stops on campus, and segregation bins in some buildings) prompted the adoption of a more fluid data collection strategy, with information added on an ongoing basis as the project developed and stakeholders were consulted. Similarly, it became apparent that some data sets (e.g. building energy ratings) are updated on an annual basis. This highlighted the need for continuous updates to ensure that information does not rapidly become obsolete. Similarly, potential data accuracy and completeness issues are anticipated. While efforts were made to ensure standardised data collection approaches and a comprehensive coverage of the campus grounds, no resources were available for systematic validation and quality checks.

3.4 Consultation

Stakeholder consultation resulted in the identification of 90 additional data sets (see supplementary material), which enabled expansion of SDGs 6, 8, 15 and 16 in particular. Stakeholders placed emphasis on ensuring that GIS skill requirements to use the dashboard are minimised, and the interface is compatible across devices. Overall, the consultation process contributed to sourcing some data sets and to including new ones, while also influencing the dashboard layout and functionality.

During the consultative process, the Vice-President for sustainability noted that the dashboard is:

> […] a game changing asset for the university, providing a real level of detail about the sustainability initiatives that are going on around the campus and enabling a higher level of engagement by staff and students and also the wider community.

A professor in Geography who has used it for teaching observed that:

> The dashboard provides a comprehensive source for information on the campus environment that is linked to the Sustainable Development Goals and visible actions. Critically, it provides a means for student citizens to become involved in campus sustainability issues and take these ideas outside the university.

Similarly, a campus assistant indicated that "when asked by students about sustainability policy, about how they can get involved, where things are on campus, using the dashboard as a resource has been really helpful." Estates and Services have also indicated that the dashboard has significantly contributed to data enhancement and management by, for example, digitising, centralising and making publicly available relevant information pertaining to campus operations (e.g. bicycle parking, EV charging points, green roofs, etc.).

3.5 Dashboard design and creation

The development of the dashboard followed an iterative process of design, consultation and feedback integration by adjusting, expanding and improving both the user interface and the content. The report review and campus-wide survey findings were the basis for the creation of the first version. This considered, among other things, the need to ensure that the dashboard included and presented in a clear way both non-spatial and spatial information for each of the 17 SDGs. This was achieved by developing a main page with 17 dynamic cards, each including a comprehensive inventory of links to UCD policies, strategies, standards and supports that have a remit for a given SDG (Figure 3).

Each of these cards link to its associated Web map (i.e. a map that is interactive and accessible online), depicting geographically-specific data and information on sustainable infrastructure, activities and services (Figure 4). The data sets included in each Web map are directly informed by the survey and consultation feedback, and influenced by data availability (see supplementary material). By querying these data sets, users can easily find relevant information about, for example, where water fountains are, how much energy is consumed in each building or what mental health supports are available. The attribute information for each feature on the map varies according to the nature of the data set. For example, student societies and research institutes data sets include information on their mission and contact details; drinking water fountains, public microwaves and segregation bins contain location details and pictures for ease of identification; bicycle racks and EV charging points indicate number of spaces available; wheelchair access specifies whether an automated power button is available; biodiversity records detail the species common name and taxon; and the building energy rating data set includes building type, heating fuel, energy use, CO_2 emissions, etc. Nevertheless, common attributes were also created in each data set to consistently denote the "main SDG" the data relate to, and the "related SDGs" to capture their interconnectedness and the fact that certain data sets are cross-cutting. Similarly, each data layer's source and creation year were consistently recorded; while these fields are not visible on the dashboard query pop-ups, they provide relevant information for future data updates.

The dashboard's functionality was kept simple to ensure technical barriers (e.g. need for GIS skills) were minimised and user-friendliness optimised. Interactive functionality for data visualisation and querying includes the option to reorganise layers, turn on/off layers, query the attribute information associated to each mapped feature, change the basemap to a simpler background and print the map(s). The SDGs colour scheme was adopted both in the main page and Web maps to facilitate interpretation. The interface was designed and customised

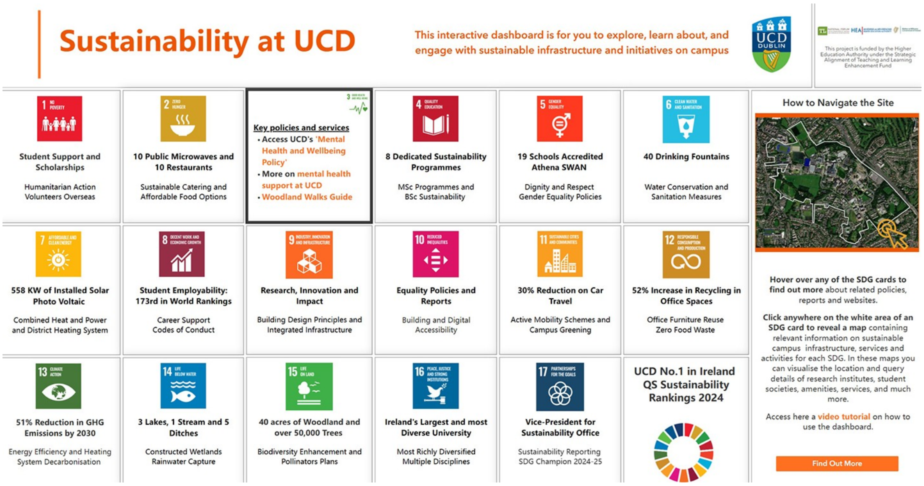

Figure 3. Dashboard home page depicting 17 cards, one per sustainable development goal, that provide links to relevant policies/strategies/resources when hovering over (see highlighted box). The home page also includes "how to navigate" instructions and a link to further information (on the right)
Source(s): Authors' own work

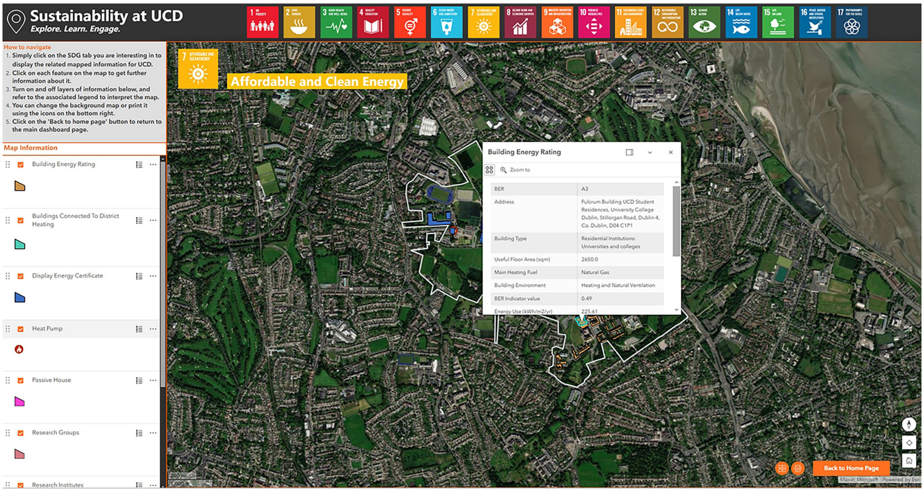

Figure 4. Dashboard Web map for sustainable development goal 7. The remaining 16 SDGs Web maps can be accessed through the top menu bar icons. The data sets or data layers available for a given SDG are presented on the table of contents (left). The query box in the middle provides an example of the information available for a given data set, obtained by clicking on any given feature

Source(s): Authors' own work

(e.g. by adjusting layouts) to ensure effective accessibility, visualisation and readability in PC, tablet and phone devices. Limitations in ArcGIS Experience Builder configurations (e.g. font resizing and grid template visibility) compelled the creation of a version for each device type to, thus, ensure consistent interface formats and streamlined access across all devices.

To further enhance accessibility and implementation, navigation instructions are provided in the main page and in each Web map via step-by-step guidance and a video tutorial. To support ongoing interface maintenance, the "find out more" section in the main page includes a user feedback survey, created using Survey123, that supports a citizen-science initiative for local data collection. This is to enable continuous community-led data gathering efforts for improving and enhancing the information made available in the dashboard. Accessibility and use are promoted by integrating the dashboard in the UCD Sustainability Unit's website, as well as by referring to it in the students' orientation week (first week of the academic year) and annual staff knowledge exchange workshops.

4. Discussion

Measuring sustainability in HEIs has gained significance since the publication of the SDGs (UN, 2015) and the development of certified ranking frameworks (Table 1). However, the quest for a universally applicable framework has raised questions on their relative applicability and effectiveness, particularly given the complexities of governance agendas, cultural contexts and scalability across different HEIs (Alghamdi *et al.*, 2017; Turriziani, 2021). In addition, varying adaptations of SDG-related indicators across frameworks, with different reference values and targets, and the large volume of data required to populate these, not only create comparability and validity issues, but also introduce significant levels of difficulty in cross-departmental data sourcing and management (Ceulemans *et al.*, 2015; Lozano *et al.*, 2014). Perhaps more importantly, existing frameworks capture a university's overall performance for a range of aspects, but the lack of spatial approaches to such assessment and reporting renders outcomes that most often fail to identify specific campus areas/aspects that require targeted action. This paper's premise is that adopting a spatial approach to recording sustainability efforts can significantly enhance the information basis and, thus, existing ranking frameworks. Given the intrinsic geographic nature of planning for and managing university infrastructure and resources, GIS have the potential to augment the quality and quantity of information provided to decision-making (González, 2012; Li, 2008; Smith, 2016). In this way, a spatial approach can enhance existing sustainability assessment frameworks by providing greater level of local detail (i.e. granularity) and specific information (i.e. attribute specifics for each sustainable feature). Spatially-specific information, in turn, can more effectively inform governing bodies and campus operations on policy development, infrastructure planning and financial allocations. In addition, publicly accessible maps showing sustainability initiative locations (e.g. solar panels, reusable cups or wildlife corridors) can increase students/staff awareness and engagement . Such maps can also be used as a teaching tool to illustrate real-world applications of sustainability concepts – as anecdotally illustrated in this paper.

The fact that university online sustainability maps are increasingly available (Stanton *et al.*, 2021), points towards a demand for more visually engaging and effective communication of sustainability efforts. While interactive online maps can facilitate information exchange and foster engagement and participative action (Mosca *et al.*, 2024; Wu *et al.*, 2024), these benefits can only be accrued if they are focused on user needs and applications (Veenendaal *et al.*, 2017). In the context of HEI sustainability monitoring, structuring the information around the SDGs facilitates the identification of links between the data/information visualised and globally recognised sustainability themes/goals. More importantly, curating the information in a way that attributes associated with a mapped feature provide its location, characteristics, purpose and/or how to use/access it, is essential to ensure it informs and engages. A non-exhaustive review of existing digital sustainability maps indicates that the spatial information is rarely consistently organised or curated. Arguably, the SDG framework adopted in the development of the dashboard presented in this paper, and the careful curation of both relevant policy documents and data sets in response to stakeholder needs, significantly enhance and advance existing initiatives by making the information more accessible and relevant.

In the context of HEIs in Ireland, a general absence of acceptable sustainability monitoring standards has been observed, with data either unavailable, inaccessible or uncollected (Shawe *et al.*, 2019). This is also the case in UCD; despite the university being featured in the QS rankings and currently implementing the STARS framework, data availability and access remain challenging. Importantly, spatial detail is rarely available as confirmed at the onset of this research. In this context, the consultation and data gathering outputs of this project provide an important way forward for the UCD's sustainability agenda. The resulting novel SDG dashboard contributes to addressing some of the observed data management issues (e.g. data gaps, systematic updates and validation and lack of centralised access), and sets a baseline and a pathway for regular monitoring of sustainability-related data. The provision of open online access to all aspects sustainable, facilitates knowledge sharing and collaboration within the academic community.

This project's findings identify five SDGs as the most important for sustainability accounting at UCD: SDGs 3 (health and wellbeing), 4 (education), 11 (sustainable cities), 12 (responsible production/consumption) and 13 (climate action). The limited prominence of other relevant SDGs (e.g. 7, 9, 17) is notable, and contrasts with the emphasis on infrastructure, innovation and governance in existing frameworks (Alghamdi *et al.*, 2017). Yet, the consistent prioritisation of SDG11, and the identified associated data/information needs, perhaps suggests this to be perceived as an all-encompassing SDG that embeds critical infrastructure and innovation aspects with regards to, for example, energy, transport and water supply. Nevertheless, the general inattention to other SDGs invites awareness raising efforts in other areas such as poverty, gender, innovation, biodiversity and justice within campus.

It is argued that the breadth of sustainability as a concept makes it difficult to ensure consistent high quality data for effective assessments, particularly across different colleges/departments of the same institution (Alghamdi *et al.*, 2017; Wright, 2002). Arguably, this is reflected in the varied data identified as relevant by the UCD community. Nevertheless, data categories in this project resonate with the findings of Alghamdi *et al.* (2017) on common denominators in HEI sustainability frameworks: governance (e.g. policies and strategies towards sustainability); academic (e.g. sustainability-focused courses, modules and research projects); activities (e.g. societies, events); infrastructure (e.g. bicycle racks, disabled toilets, energy-efficient buildings, green spaces); and operations/management (e.g. energy usage, waste volumes, water consumption, commuting patterns). A relevant outlier, when compared to existing frameworks and the international literature, is the prioritisation of SDG3. A review of current frameworks unveils a very limited number of indicators pertaining to this consideration: "health provisions on campus" in the QS framework; "mental health support for students and staff" and "access to university sports facilities" in THE; and "health infrastructure facilities" and "campus facilities for disabled, special needs and/or maternity care" in the GreenMetric are the only partially relevant indicators identified. Its relevance to the academic community suggests that existing ranking frameworks may need to place greater emphasis on measuring health and wellbeing infrastructure and supports. In contrast, very limited spatial data were available for certain SDGs (e.g. 6, 13, 14). The data sets compiled for these SDGs include related research groups/institutes, which suggests resource availability and calls for greater efforts to collate locally relevant data in these areas (e.g. carbon sinks in campus, water supply networks, water-dependant biodiversity) and, thus, provide comprehensive information across the range of SDG.

The co-creation of the dashboard facilitated a dynamic, easily accessible and user-friendly configuration to provide equal access to all. The data collection and creation process, central to its development and applicability, relied on available student-staff skills and limited financial and time resources, constraining effective quality checks for many of the data sets. Acknowledging that heterogeneity of both attribute syntaxes and spatio-temporal representations can present issues for data integration and analysis (Oliveira *et al.*, 2005), it is important to develop standardised data collection methods, including definitions, reporting formats and measurement criteria to improve data consistency and comparability between colleges within UCD, and between different HEIs that may undertake similar processes. This was partially addressed in this project by creating Survey123 forms for student-driven data collection, fostering the systematic and harmonised recording of features (e.g. selecting from a pull-down list the types of waste collection bins). Similarly, stakeholder review of the dashboard data supported informal quality checks (e.g. by identifying missing features in the public microwaves data set and incorrect contact details for a number of research institutes).

Mechanisms need to be put in place for formal data verification and monitoring of changes over time, to ensure data remain updated and the dashboard does not rapidly become obsolete. This could involve regular cross-referencing of data gathered from multiple sources/colleges, as well as field checks to confirm the accuracy of infrastructural and operational data. It would seem most obvious for Estates and Services to take on such data management and monitoring responsibilities, as most Irish universities seem to rely on this department and Green-Campus Committees, where established, to act as implementation structures for sustainability (Shawe *et al.*, 2019). Implementing a citizen-science approach for data collection/updates, integrated into specific curricular activities, presents a plausible approach to maintaining and improving information availability in the dashboard. This has already been implemented in UCD: the integration of a practical GIS-based data collection exercise in an undergraduate module has enabled updating biodiversity data across campus (i.e. a Bioblitz was undertaken in autumn 2024, updating the sparse and obsolete Bioblitz 2016 data set). As part of this module, new data collection and data updates are scheduled for subsequent academic years.

The need for sustained data and service maintenance mechanisms, to ensure long-term applicability of data-driven decision support tools beyond project end-dates, has been repeatedly called for in the literature (e.g. Bagstad *et al.*, 2013; González *et al.*, 2019; González *et al.*, 2023; Roth, 2013). This entails ongoing financial support (e.g. to incentivise data collection or cover server maintenance costs), as well as technical expertise for data gathering, validation, curation and integration and their seamless deployment (e.g. fixing bugs, server glitches) (González *et al.*, 2019, 2023). In the context of the UCD sustainability dashboard, these financial and technical supports are partially secured by the commitment of the university's Sustainability Unit to use it as a monitoring, reporting and communication resource.

The dashboard data directly respond to academic community requests for information, thus, fostering the development of a bespoke tool that supports local priorities and addresses local challenges. Yet, importantly, the available data can feed into specific indicators from existing frameworks. For example, GreenMetric's "campus facilities for disabled, special needs and/or maternity care" can be easily populated by counting such features on the map; THE's "free drinking water for students, staff and visitors" can be directly informed by the location and quality of mapped drinking water fountains; and some of the information to support the energy consumption per square metre and greenhouse gas emissions indicators for STARS is readily available under the building energy rating data set in the dashboard. In this way, it is considered that the dashboard adds value to local efforts towards sustainability but also facilitates the work of the UCD's Sustainability Unit in implementing mainstream assessment tools.

The campus-wide survey feedback suggests a strong desire for the dashboard to not only inform but also involve the UCD community in sustainable activities. This is supported by a recent study that highlights the urgent need to enhance awareness and engagement towards sustainability at UCD (Russell, 2023). As discussed by Godfrey and Feng (2017), existing habits can influence individual decisions regardless of the presented information. It is, therefore, important ensuring management and leadership support to integrate sustainability measures into campus life, curriculums and institutional strategies, applying the dashboard as a dynamic tool for environmental stewardship and community involvement. Measuring engagement of dashboard users with different SDGs and associated data sets, delivering capacity building workshops for the effective use of the dashboard and for encouraging engagement with relevant infrastructure/activities/services, as well as incentives could steer and guide action across the range of SDGs. Future initiatives could also leverage the development of sustainability literacy programmes and community service tracking mechanisms which are pivotal in forming future sustainability leaders and fostering societal shifts towards a sustainable future (Vaughter *et al.*, 2013).

Although the dashboard was only recently launched (on 15 October 2024), it has been accessed by more users than the sustainability website itself (i.e. Google metrics indicate 163 dashboard users versus 115 for the website). More importantly, it has already influenced student and staff awareness about sustainability within UCD. Anecdotally, five unsolicited students have contacted project team members indicating that the dashboard has prompted engagement with certain infrastructure and initiatives (e.g. water fountains and societies) and inspired research ideas (e.g. on waste management policies and existing segregation bins). Estates and Services have also indicated that it has enhanced data visualisation, centralisation and management, and enabled public access to information on campus operations. Two module coordinators have applied the dashboard in the classroom to support teaching and have reported it to be of benefit by showcasing types of sustainability efforts within the university, and by illustrating pragmatic approaches to online mapping and public engagement. Other anticipated impacts include enhanced teaching and learning through user-friendly, real-life and meaningful data and tools, and improved understanding of and wider engagement with sustainable infrastructure, activities and services towards more sustainable behaviours within campus and beyond. The dashboard can also help identify infrastructure gaps to inform Estates and Services' prioritisation of investment and action, as well as highlight what SDGs may receive less attention and target efforts towards their enhancement.

5. Conclusion

The project was driven by the need to enhance education for sustainable development, gain a better understanding of what universities are currently doing locally to promote sustainability and identify areas requiring more targeted efforts. The power of GIS to spatially gather and visualise data as well as to develop interactive online maps was embraced to ultimately develop an interactive online dashboard that brings together information on available campus infrastructure, activities and services, thus, providing curricular innovation for sustainability and informed citizenship.

To the best of the authors' knowledge, this is the first sustainability dashboard of its kind in Ireland. Its integration in campus governance and operations has been supported by the UCD Sustainability Unit. Furthermore, it enhances and advances existing sustainability mapping initiatives (and existing sustainability assessment frameworks) by structuring the non-spatial and spatial information around the SDGs, and providing local detail and feature-specific information, thus, making information more accessible and providing a structured basis for monitoring. The dashboard co-creation process (i.e. direct student and staff involvement in its development) and its template (e.g. structuring policy documents and mapped features around the SDGs) are transferable and can be of value to other HEIs. While it is acknowledged that different student/staff skills, budgetary resources and software infrastructure are available in HEIs (e.g. Guillén-Gámez *et al.*, 2020; Shirazi and Hajli, 2021), the imperative global drive towards sustainability provides the foundation to voluntarily pursue similar initiatives in HEIs around the world. This is exemplified by the digital sustainability mapping tools and dashboards available in a range of universities. The described co-creation process is adaptable to different academic contexts, as it can be implemented through the application of different student/staff engagement methods. The only requisite is a transparent approach that acknowledges and prioritises an institution's information needs and sustainability goals. Where data are limited, data collection efforts can be integrated into research and student learning (e.g. campus surveys, field work using mobile phone devices). Data validation can be undertaken by engaging different groups of students or stakeholders in data review. Following from this, the creation of a centralised, easily accessible one-stop-shop database within the university can be based on existing local technological resources. ArcGIS Experience Builder was adopted in this case, a widely applied commercial software package, but alternative online mapping tools (e.g. Google Maps, QGIS Cloud) could be similarly used to visualise and share sustainability information. Moreover, data can be incorporated in existing HEIs' sustainability tools, such as SET4HEI (set4hei.org/), UniSAF (www.greenofficemovement.org/sustainability-assessment/) and Graphical Assessment of Sustainability in Universities (Lozano, 2006). It can also complement, and enhance, existing and widely used university ranking frameworks (e.g. QS, THE, STARS). Adopting a GIS-based approach to reporting on sustainable infrastructure and initiatives within HEIs can arguably raise awareness of local efforts and improve the evidence-base for informed action. Similarly, ongoing data updates and iterative user engagement can contribute to influencing a university's governance towards positive sustainability outcomes. However, for a dashboard/GIS-tool to be effective over time, data and interface maintenance commitments need to be established and sustained.

The dashboard presents an educational resource for faculty and has the potential to support teaching and learning across a wide range of disciplines (e.g. sustainability, energy, waste, social and environmental sciences, geography). Its interactive and user-friendly interface facilitates student engagement with course content through technology. More importantly, the extensive information provided within it supports a living-lab approach to teaching, experiential learning and research. Arguably, this improved access to information through the dashboard and the subsequent enhanced visibility of sustainability efforts can, in turn, augment engagement and foster societal change within the campus community. Further studies are, however, required to establish the extent to which the availability and use of this dashboard impacts student and staff behaviour, involvement and/or research, and to explore whether it triggers targeted measures to address existing gaps in sustainable infrastructure/services. In all cases, more effective local understanding of where a HEI focuses sustainability efforts and where inadequacies remain is not merely a beneficial enhancement but a fundamental necessity.

Notes

[1.] Using the string ("digital" OR "online") AND ("campus" OR "university") AND "sustainability" AND ("map" OR "dashboard").

[2.] www.google.com/maps/d/u/0/viewer?mid=1VFsyIyhpbzqFrq1k93mGTIblmNzeAKmZ&ll=32.59728984734623%2C-85.47415944710468&z=15

[3.] www.google.com/maps/d/viewer?mid=1ZG5ElBMeQ_JLWFmxBPglkrcWHPQ&ll=42.4487471229243%2C-76.47950182392316&z=15

[4.] https://wustladm.maps.arcgis.com/apps/webappviewer/index.html?id=b36853dded3d48308efc642ff5bac4e2

[5.] www.arcgis.com/apps/webappviewer/index.html?id=09fa43a9873448b18f4fe8a0ba27e75f&extent=-8606299.374%2C4696848.9958%2C-8605152.8186%2C4697384.6521%2C102100

[6.] www.arcgis.com/home/webmap/viewer.html?webmap0fa8984fafa418b921da4af933&extent=5582,41.6538,-91.5265,41.6684

[7.] https://umbaltimore.maps.arcgis.com/apps/webappviewer/index.html?idfe6a7565d6d47a49aecd51c859de638

[8.] https://sustainability.uw.edu/maps/sustainability

[9.] www.unb.ca/initiatives/sustainability/campus-sustainability-maps.html

[10.] https://uwaterloo.ca/sustainability/operations/campus-sustainability-map

[11.] www.bcu.ac.uk/about-us/corporate-information/environment-sustainability/map

[12.] www.northumbria.ac.uk/about-us/environmental-sustainability/sustainable-campus-map/

[13.] www.google.com/maps/d/u/0/viewer?mid=1thO1n5BjvXt3x9j7fmsidttPHScwh-ih&ll=50.39070403868811%2C-4.127898049999983&z=13

[14.] www.uwa.edu.au/about/leadership-and-governance/strategy-and-values/sustainability/sustainability-campus-dashboard

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Supplementary material

The supplementary material for this article can be found online.

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