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Assessing Awareness of Energy Consumption Among University Students: A Comparative Study Using Visual Interfaces

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ABSTRACT:
This study evaluated the effectiveness of an interactive energy dashboard in enhancing energy awareness and promoting sustainable behaviours among university students. The dashboard visualized campus energy consumption, estimated CO2 emissions, and offset metrics through intuitive displays, enabling users to engage with real-world sustainability data. Two groups were studied—Sustainability Students and General Students—using pre- and post-surveys to assess knowledge and behavioural change. Both groups showed statistically significant improvements in knowledge scores, with the Sustainability Students Group ($p = 0.0027$, $d = 0.275$) and the General Students Group ($p = 0.0291$, $d = 0.256$) benefiting similarly from the intervention. Most participants, including ninety-eight percent of Sustainability Students and eighty-six percent of General Students, reported increased awareness, and over eighty percent of students expressed willingness to engage in future energy-saving initiatives. While the dashboard effectively raised awareness of campus energy use, gaps in personal energy knowledge remained, highlighting the need for future enhancements. These findings underscore the dashboard's potential as a scalable educational tool for fostering energy literacy and sustainable behaviour in higher education.

Keywords: Sustainability, Energy Awareness, Data Visualization, Ecological Engagement

1. Introduction and Literature Review

Energy consumption in Higher Education Institutions (HEIs) has become a critical concern due to its environmental and economic impacts. As microcosms of society, universities play a key role in modelling sustainable energy practices and preparing students to adopt energy-conscious behaviours (Quevedo et al., 2024). The diversity of campus infrastructure—including classrooms, laboratories, residence halls, and recreational facilities—makes energy use in HEIs particularly complex (Alnahhal et al., 2024), highlighting the need for systematic approaches to monitor, analyse, and reduce consumption.

To promote energy literacy among students and stakeholders, various tools have been developed. Interactive visualization platforms have shown promise in enhancing

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users' understanding of consumption patterns by presenting data in accessible, intuitive formats (Munaro & John, 2024). These platforms allow users to engage with real-time or historical data, offering metrics such as energy usage intensity (EUI), CO2 emissions, and offset equivalents—critical components in fostering energy-aware behaviour (Laporte & Cansino, 2024). When integrated into educational settings, such dashboards support experiential learning and a deeper comprehension of energy systems and their broader implications (Hu & Yang, 2024).

Promoting energy awareness in HEIs aligns with global sustainability goals, notably the United Nations Sustainable Development Goals (SDGs). SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities) emphasize energy efficiency and behaviour-driven conservation strategies (United Nations, 2015). Universities, therefore, have a dual mandate: to reduce their institutional energy footprint and to cultivate sustainable practices among students that can extend to society at large.

Despite growing interest in campus sustainability, few studies have examined the role of interactive platforms in improving energy awareness among students (Quevedo et al., 2024). Traditional approaches such as energy audits or surveys focus on quantifying energy usage rather than engaging students in understanding behavioural impacts (Chung & Rhee, 2014). While methods like Building Energy Simulation (BES) and utility bill analyses are common, they often overlook non-expert stakeholders who are critical to energy-saving initiatives (Oyedepo et al., 2021).

An important gap remains in comparing energy literacy between students with and without formal sustainability education. Research shows that students enrolled in sustainability courses tend to be more proactive in energy conservation (Li et al., 2024), but the degree to which such coursework improves their ability to interpret and use energy data remains underexplored (Mokhtari & Jahangir, 2021). Investigating how dashboards function as educational tools across different student groups is essential.

There is also limited research on the use of interactive dashboards to analyse historical energy consumption in HEIs. Existing studies stress the importance of understanding trends like peak usage and high-demand buildings to guide conservation strategies (Torres-Navarro et al., 2022), yet few platforms visualize such data intuitively or include metrics like CO2 emissions and offset requirements (Ohalete et al., 2023). Addressing these gaps can support the development of tools that bridge the divide between awareness and action.

This study aims to evaluate the impact of an interactive energy visualization dashboard in enhancing student awareness of campus energy consumption. The research is guided by the following objectives:

- Assess changes in energy literacy after students engage with a custom dashboard featuring historical energy use, CO2 emissions, and ecological impact
- Compare the platform's effectiveness between students with and without current sustainability coursework
- Identify dashboard features (e.g., building-level comparisons, emissions metrics) that contribute to improved energy understanding and engagement

Through these objectives, the study contributes to understanding how interactive platforms can drive energy literacy and behavioural change within HEIs, while also supporting institutional efforts toward energy efficiency and sustainability.

2. Methodology

This study used a mixed methods approach to assess the impact of an interactive energy dashboard on student awareness. Quantitative and qualitative data was collected through pre- and post-surveys, along with user interaction metrics from the dashboard. A comparative design was used to examine changes in energy awareness between two groups: students enrolled in a sustainability course and those not enrolled. Usability feedback was also collected to evaluate the role of the dashboard as a learning tool. This comprehensive design supported a well-rounded analysis of gains in energy literacy and user engagement.

2.1 Study Design

A two-group comparative study was conducted with participants drawn from class sections of the university. The groups included:

- Sustainability Students Group: This group consisted of students who were currently enrolled in a sustainability course. These students were expected to have a foundational understanding of sustainability concepts, which could influence their baseline knowledge and engagement with the dashboard.
- General Students Group: This group included students who were not currently enrolled in any sustainability course. These students were considered to represent the general campus population with varying levels of energy awareness.

All participants completed a pre-survey to assess baseline knowledge of energy use, sustainability attitudes, and household energy practices. They were then given access to a custom-built energy dashboard for one week, which visualized campus energy usage, estimated CO2 emissions, and equivalent tree offsets. Dashboard features included:

- Campus-wide and building-specific energy data
- Top 5 energy-consuming buildings
- Comparative metrics between buildings
- A user interface to submit energy-saving tips

After the dashboard interaction, participants completed a post-survey with similar core questions to enable direct comparisons, along with additional feedback on dashboard usability and impact. This setup enabled analysis of within-group knowledge changes and between-group differences in response to the dashboard. Participation was voluntary and anonymous.

2.2 Pre- and Post-Survey Construction

The surveys evaluated energy awareness and behavioural intent before and after dashboard use. The pre-survey included:

- General Awareness (e.g., knowledge of monthly energy bills and high-consumption appliances)
- Self-Rated Knowledge (scale of 1 to 5)
- Behavioural Context (current habits and interest in sustainability)

The post-survey captured:

- Knowledge Gains (e.g., identifying high-energy buildings on campus)
- Dashboard Feedback (e.g., usefulness in raising awareness)
- Behavioural Intentions (likelihood of adopting sustainable habits)

Consistent questions across both surveys allowed for measurable comparisons. Open-ended questions provided qualitative feedback, including suggestions for additional features and energy-saving tips.

2.3 Dashboard Development

The interactive dashboard built using the open-source Python library 'Streamlit' (Streamlit, 2025), served as the intervention tool. It displayed 10 years of university energy data and derived environmental metrics based on the assumption of fossil-fuel-based energy. Screenshots of the dashboard can be found in Fig. 1.

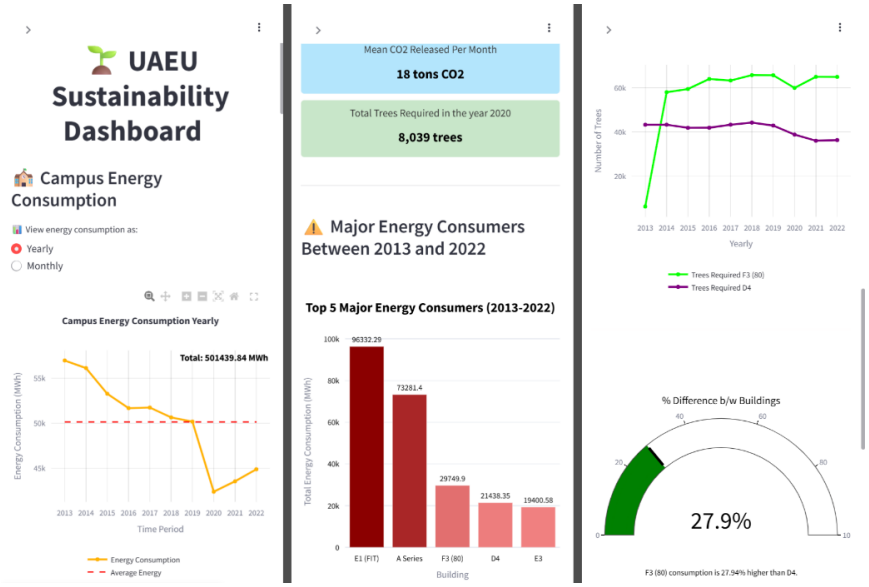

Fig. 1. Screenshots of the various views offered by the dashboard

2.4 Data Analysis

Pre- and post-survey data were analysed to evaluate knowledge changes, dashboard impact, and behavioural intent. Comparisons were drawn both within groups (pre-post differences) and between groups (sustainability vs. general students). Quantitative analysis included self-rated knowledge, awareness of energy metrics, and identification of high-consuming buildings. Statistical tests such as the Kruskal-Wallis test (Kruskal & Wallis, 1952) and Cohen's *d* (Cohen, 1988) measured significance and effect size. Qualitative responses underwent thematic analysis to extract recurring feedback on dashboard usability and feature suggestions. This enriched the quantitative findings and highlighted learning experiences. Given the ordinal nature and mild non-normality of the self-rated knowledge scores, we employed the Kruskal–Wallis test as a non-parametric alternative to one-way ANOVA. This choice, combined with the relatively large group sizes, supports the robustness of the statistical inferences despite the brief intervention period.

Key metrics evaluated included:

- Knowledge Gains
- Behavioural Intentions
- Impact of Sustainability Education

Statistical significance was set at $p < 0.05$, with robustness checks confirming reliability. This ensured credible conclusions on the dashboard's role in promoting energy literacy.

3. Results

This section presents the impact of the interactive energy dashboard on participants' awareness of energy consumption and sustainability. Analysis of pre- and post-survey data assessed changes in knowledge, perceptions, and behavioural intentions across two groups: students enrolled in a sustainability course and those who were not. The results highlight baseline awareness differences, dashboard engagement patterns, and the effectiveness of the intervention in improving energy literacy. Key outcome metrics—including knowledge gains, behavioural intent, and qualitative feedback—are used to evaluate the dashboard's role as an educational tool with potential for broader sustainability engagement.

3.1 Survey Participation

In total, 267 Sustainability Students completed the pre-survey, and 228 completed the post-survey (85% retention). The General Students Group saw 152 pre-survey responses and 125 post-survey responses (83% retention). Participation fluctuations could

potentially be attributed to absences and voluntary opt-out during lecture sessions. The larger sample size for Sustainability Students resulted from larger class sections. While the groups were imbalanced, this was a logistical constraint, not a reflection of engagement differences. Given these conditions, results are analysed on an aggregate level to provide reliable comparisons.

3.2 Pre- and Post-Survey Findings

Self-rated knowledge scores showed improvement across both student groups following interaction with the energy dashboard. Table 1 summarizes the pre- and post-survey statistics. The Sustainability Students Group increased from a mean score of 3.57 (SD = 0.83) to 3.81 (SD = 0.90), while the General Students Group improved from 3.44 (SD = 0.90) to 3.68 (SD = 0.98). Both groups shared a median score of 4.0 post-survey.

Table 1: Summary Statistics for Survey Knowledge Scores

Survey	Group	Mean	Median	Standard Deviation
Pre-Survey	Sustainability Students	3.57	4.0	0.83
	General Students	3.44	3.0	0.90
Post-Survey	Sustainability Students	3.81	4.0	0.90
	General Students	3.68	4.0	0.98

The combined boxplot (Fig. 2) illustrates the distribution of scores across both groups and timepoints. While score distributions shifted upward for both groups, Sustainability Students showed slightly greater variability post-survey, whereas General Students exhibited more consistent mid-range responses. Statistical analysis using the Kruskal-Wallis test confirmed significant within-group improvements: p = 0.0027 for Sustainability Students and p = 0.0291 for General Students. However, between-group comparisons were not statistically significant pre-survey (p = 0.130) or post-survey (p = 0.268), suggesting both groups benefited similarly from the intervention.

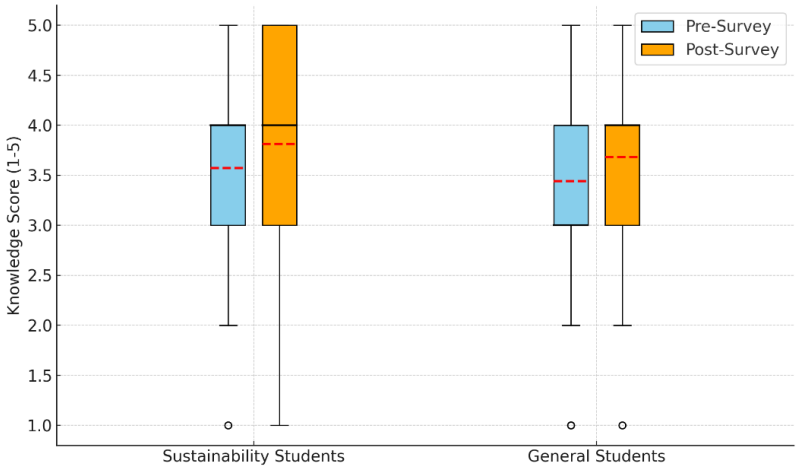

Fig. 2. Distribution of pre- and post-survey knowledge scores for both groups

Beyond knowledge scores, survey responses provided additional insights. In both groups, misconceptions were evident—only 3–8% correctly identified the kettle as the highest energy-consuming appliance, which consumes 1,200–3,000 watts when in use, compared to the constant 100–250 watts of the refrigerator, the 1,000–1,500 watts of the clothes iron, and the 80–400 watts of a TV (Durand et al., 2022). Most participants incorrectly selected the refrigerator. Similarly, only 48% of Sustainability Students and 50% of General Students correctly identified the highest energy-consuming campus building. Post-survey results showed that correct identification rose significantly to 77% among Sustainability Students and 51% among General Students, reflecting improved engagement with the dashboard data.

Behavioural attitudes also shifted. Willingness to engage in future energy-saving initiatives increased to 88% among Sustainability Students and 76% among General Students. However, awareness of personal household energy usage remained limited. In the post-survey, 31% of Sustainability Students and 54% of General Students reported not knowing their monthly electricity bill—up from 25% and 35%, respectively—suggesting a continued gap in personal energy literacy.

3.3 Comparative Analysis

Pre- and post-survey comparisons confirmed significant improvements in knowledge for both groups. For Sustainability Students, the Kruskal-Wallis test yielded $p = 0.0027$, and for General Students, $p = 0.0291$, both below the 0.05 threshold. Cohen's d indicated small-to-moderate effects: 0.275 (Sustainability) and 0.256 (General), aligning with the statistical significance. These small-to-moderate effect sizes are consistent with the magnitude of change that can reasonably be expected from a short, one-week intervention.

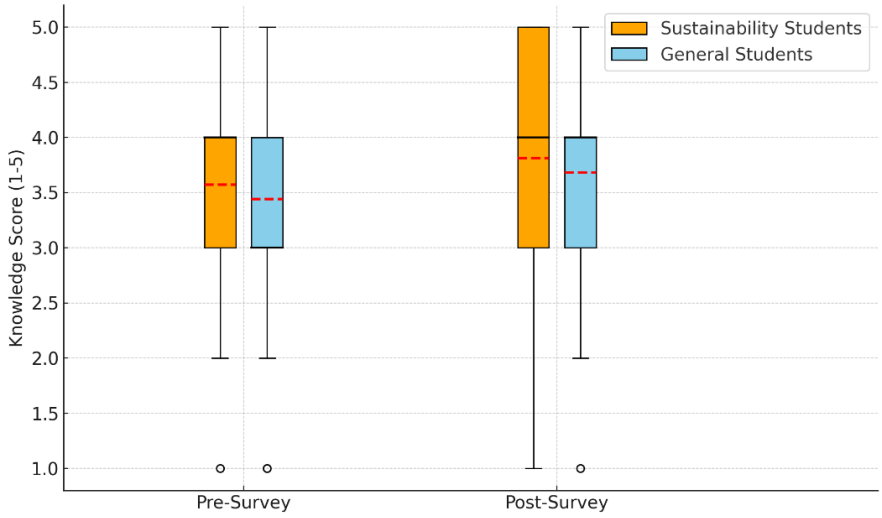

Fig. 3. Pre- and Post-Survey Knowledge Scores for both groups

Fig. 3 further supported these gains. The median score increased in both groups, with Sustainability Students showing greater spread and more high scores, while General Students displayed moderate but consistent improvement. The dashboard proved effective for both groups, though Sustainability Students benefited slightly more, likely due to existing familiarity with sustainability topics.

3.4 Qualitative Dashboard Feedback

Feedback indicated strong approval of the dashboard. A total of 98% of Sustainability Students and 86% of General Students reported increased awareness of campus energy use. Most students (177 Sustainability, 87 General) said the dashboard provided 'just about enough information', with few reporting too much or too little content. Suggestions for improvement were minimal. Most students, especially from the Sustainability group, expressed satisfaction without proposing major changes. Some General Students requested clearer explanations for energy patterns. Energy-saving tips varied. While many left the section blank, common suggestions included switching off unused appliances, using LED lights or inverter AC units, and reducing standby power consumption. These insights reflect emerging awareness of practical behaviours, particularly among students who engaged more deeply.

4. Discussion

This section interprets the study's findings on the effectiveness of the interactive energy dashboard in promoting energy awareness and behavioural intent. Results from quantitative and qualitative analysis are discussed to evaluate group-wise differences, behavioural impacts, and future implications for sustainability education.

4.1 Dashboard Impact

The dashboard effectively increased knowledge and awareness across both groups, with statistically significant post-survey score improvements. Its interactive features helped students connect theoretical sustainability concepts with real-world campus data, enhancing learning and engagement. High satisfaction rates—98% of Sustainability Students and 86% of General Students—affirmed the dashboard's usefulness. Additionally, 88% and 76% of students in the respective groups expressed interest in future energy-saving initiatives, demonstrating the dashboard's motivational impact.

While both groups benefited, Sustainability Students showed slightly greater gains, likely due to prior exposure. General Students also improved, though the dashboard may be more effective for them with added context or introductory guidance. The increase in students unable to estimate home energy bills post-survey suggests a need to expand the dashboard's scope to include personal energy practices.

From a methodological perspective, these findings should be interpreted as evidence of short-term knowledge gains rather than lasting behavioural change. The one-

week exposure window provided students with an initial opportunity to explore the dashboard, but it also raises the possibility that part of the observed engagement and self-reported intent reflects novelty effects. Future longitudinal research with repeated exposure to similar dashboards would be valuable to determine whether the improvements we observed persist once novelty has diminished and how they translate into sustained behavioural outcomes.

4.2 Group-Wise Comparison

Both groups showed comparable improvements, with small-to-moderate effect sizes (Cohen's *d* of 0.275 and 0.256). Visual analyses supported this, showing upward shifts in medians and higher post-survey score concentrations for both groups. Sustainability Students exhibited more variability and a stronger shift toward higher scores. These results indicate that while prior sustainability education helps, there is a need to tailor educational tools to the specific needs and knowledge levels of different groups to ensure equitable learning outcomes.

4.3 Behavioural and Qualitative Insights

Most students found the dashboard's content appropriately balanced. Only a small portion felt it had too much or too little information, suggesting it largely met users' expectations. Open-ended feedback confirmed satisfaction, with minimal suggestions for improvement. A few General Students recommended adding explanations for energy trends. Shared energy-saving tips included common practical actions like turning off unused devices and using efficient appliances, reflecting increased awareness of everyday sustainable practices.

At the same time, the increase in students who reported not knowing their monthly electricity bill suggests a divergence between campus-level awareness and confidence in managing household energy use. We interpret this as an indication that future dashboards should more explicitly bridge institutional and personal contexts; for instance, by allowing students to log or simulate their household energy consumption and compare it with campus benchmarks through simple, gamified visualisations.

4.4 Limitations and Future Directions

A key limitation of this study is the short exposure period. While this timeframe was sufficient to capture immediate knowledge gains and shifts in intention, it limits the ability to draw conclusions about long-term behavioural change or retention. A second limitation is the dashboard's exclusive focus on campus-level data, which may have limited connections to students' personal energy practices, as reflected in the increased uncertainty about household electricity bills.

Future research should embed similar dashboards into longer interventions and combine campus data with optional personal or household profiles, adaptive feedback, and gamified challenges. With appropriate infrastructure, integrating real-time data and simple AI-driven analytics (e.g., personalised recommendations and predictive alerts

around peak demand) could transform such dashboards from informational tools into decision-support systems that more directly foster sustained engagement and behavioural transformation.

4.5 Broader Implications

The dashboard's success in raising awareness, especially among General Students, supports its value as a scalable educational tool. For Sustainability Students, it reinforced existing knowledge and encouraged proactive behaviour. Its integration into academic courses or campus-wide initiatives could foster a culture of sustainability. By aligning educational tools with practical insights, institutions can promote both individual responsibility and broader environmental goals, contributing meaningfully to campus sustainability efforts.

5. Conclusion

This study evaluated the effectiveness of an interactive energy dashboard in improving energy awareness and promoting sustainable behaviours among university students. The dashboard, which integrated campus energy data, environmental metrics, and user-friendly visualization tools, significantly improved knowledge and behavioural engagement among both groups of students.

Key findings demonstrated that both the Sustainability Students Group and the General Students Group experienced statistically significant improvements in their knowledge scores ($p = 0.0027$, $d = 0.275$ and $p = 0.0291$, $d = 0.256$, respectively). Both groups showed similar statistical significance and effect sizes, indicating that their knowledge improved to a similar extent. This suggests the dashboard was broadly effective, regardless of students' prior exposure to sustainability education. Moreover, these results are consistent with previous work showing that experiential, visual approaches to energy education can enhance students' engagement and understanding of sustainability concepts (Li et al., 2024; Hu & Yang, 2024).

Behavioural feedback revealed that most participants found the dashboard information accessible and engaging, with 98% of Sustainability Students and 86% of General Students reporting that it improved their awareness. Qualitative responses highlighted high levels of satisfaction with the dashboard, with only minimal suggestions for improvement, such as adding actionable solutions or explanations for energy consumption trends. However, a notable gap appeared in participants' familiarity with personal energy practices, as indicated by the increase in those unable to estimate their household electricity bills in the post-survey.

Despite its successes, the study faced a key limitation, mainly the short duration of the dashboard interaction and the lack of personal energy behaviour data. Future interventions could address this gap by extending the exposure period and expanding the scope of the dashboard to include personal energy management tools.

In conclusion, the energy dashboard has proven to be a powerful educational tool to foster energy awareness and motivate sustainable behaviour. By integrating such tools into curriculum design, campus-wide initiatives, and institutional sustainability governance

frameworks (Laporte & Cansino, 2024; Munaro & John, 2024), educational institutions can promote a culture of sustainability and help bridge the gap between knowledge and action.

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