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EcoWatt: An Electricity Management App to Illuminate Community-Driven Sustainability in Student Accommodations

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EcoWatt: An Electricity Management App to Illuminate Community-Driven Sustainability in Student Accommodations

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ABSTRACT

This project addresses the rising issue of excessive energy consumption in student accommodations across the UK which has shown a 20% increase from 2022 to 2023. Student accommodations provide a unique context due to the communal proximity of its inhabitants and students who are not directly responsible for a separate utility bill. Through a mixed-method user research process, 28 questionnaires and 7 interviews revealed two key insights - a lack of awareness and motivation for sustainable behavioural change. The project solution, EcoWatt, is an interactive mobile app complemented by a community dashboard, to bridge the gap between awareness and action. Leveraging elements of anthropomorphism and gamification, EcoWatt delivers real-time data visualisations and educational content, empowering users to explore and better manage their energy consumption. Its scope can be broadened to other energy sources and settings, fostering sustainability in various sectors.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; **Interaction design**.

KEYWORDS

behavioural change, electricity, energy conservation, student accommodation, sustainability

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1 INTRODUCTION

The problem of excessive energy consumption across the UK contributes heavily to the inflation of energy bills and environmental concerns[22]. Electricity generation remains a major player in global greenhouse gas emissions[7] and contributes around 30% of total CO_2 emissions in the UK alone [1], all of which detracts from the decreasing energy consumption trend over the past 10 years[8]. Addressing this issue in student accommodations allows for the opportunity to create organisational change in a collective yet complex system [19]. The prevalence of increased energy demand in student accommodations is a subset of the broader problem of energy inefficiency and wastage in urban environments[13]. Based on a UK-based student accommodation ESG report[20], there has been a 20% increase in total energy usage from 2022 to 2023. Based on this user group, the project goal aims to encourage energy-saving practices in student accommodations and instil sustainable attitudes in the younger generation providing long-term benefits for urban environmental conservation.

Key user research insights revealed a lack of awareness in students of the scale of their energy consumption and a lack of motivation to adjust their behaviours accordingly, despite a willingness to do so. The project's solution, EcoWatt, is an 'energy management' mobile app complimented by a community dashboard, both of which consist of an array of data visualisation and gamification techniques to inform, educate, and influence the user's energy usage in their student accommodation. The purpose is to empower users to reflect and make informed decisions about how they manage their daily energy consumption. Overall, EcoWatt aims to contribute towards the Sustainable Development Goals (SDGs) of building sustainable cities and communities (Goal 11) and fostering climate action (Goal 13). By directly addressing the challenges of urban energy wastage and its impact on the environment, EcoWatt aligns with broader efforts to create a more sustainable and energy-efficient future, as well as contributing to the field of Sustainable Human-Computer Interaction (SHCI).

2 BACKGROUND

2.1 Prior Works

The exploration of energy-saving behaviour in student accommodations revealed a research gap in comprehensive technological

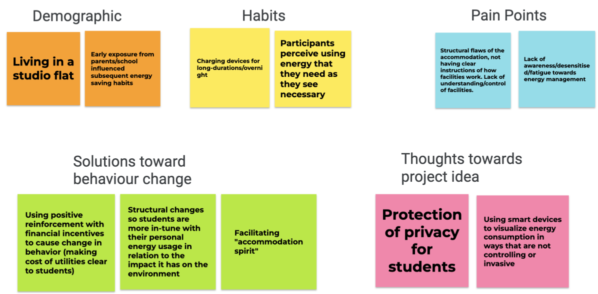

Figure 1: Affinity diagram of primary user research findings.

solutions. Vadodaria et al. [22] emphasised the UK's limited understanding of student housing energy performance, stressing the need for comprehensive energy usage data. Carter et al. [5] found student housing accounts for a significant portion of university electricity use, indicating potential for efficiency improvements. Bull et al.'s[3] SAVES project and Wisecup et al.[24] demonstrated the effectiveness of real-time challenges and tailored interventions in reducing energy use. In contrast, Posner and Stuart[19] and Owens and Halfacre-Hitchcock[17] provided a systemic campus-wide approach to sustainability, advocating for comprehensive strategies instead of isolated initiatives. Petersen et al.[18] found that real-time feedback systems in dormitories greatly lower energy use than less frequent monitoring, indicating a need for more efficient technologies. Additionally, studies by Watson et al.[23], Bekker et al.[2], and Ntouros et al.[15] emphasise student engagement through competitions, feedback, and campaigns. Hermann[11] and Chiang et al.[6] also suggest that disaggregated data and simple visual displays significantly influence energy-saving behaviour. Therefore, this project aims to address these gaps by understanding student behaviours and attitudes and developing technology-driven solutions for energy-saving behaviour. The report evaluates research on energy consumption habits in accommodations, showing a lack of awareness and motivation as key issues. Consequently, EcoWatt was created, featuring an app and dashboard that leverage data visualisation to promote sustainable behaviour. User testing has suggested areas for future scalability research.

2.2 Primary User Research

To gain an initial understanding of participants' attitudes, habits, and motivations related to their energy consumption and environmental perspectives, a mixed-methods questionnaire of 28 responses was utilised. Building on insights from the questionnaire, an anonymous, semi-structured interview was designed using a top-down approach. The research cohort consisted of 7 participants who had previously completed the questionnaire using convenience sampling. A bottom-up thematic analysis was then conducted, organised into an affinity diagram (see Fig. 1). The outcome of the research led to the discovery of two key insights and personas.

A lack of awareness was identified to be a multifaceted problem. Despite the presence of existing energy-saving measures in the accommodations, a significant portion of participants remains uninformed about such facilities. Furthermore, when it came to awareness of energy bills, participants displayed a varied understanding,

Figure 2: User persona of the energy waster.

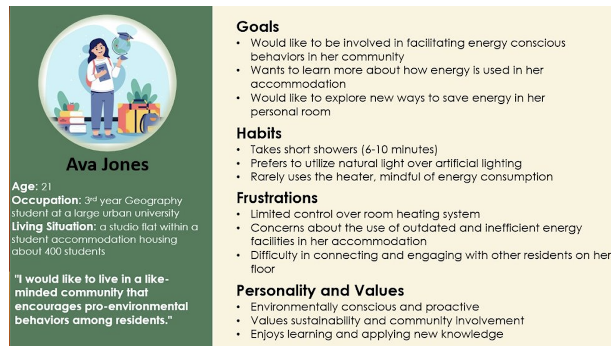

Figure 3: User persona of the energy saver.

with 33% underestimating and 11% overestimating when compared to the average UK household. In the broader context, there was a widespread lack of awareness among participants concerning the financial and environmental implications of excessive energy usage. The lack of motivation revolves around a gap found between the willingness among students to adopt energy-saving habits and the reality of not committing to them. Financial incentives were found to be more motivating for behaviour change than environmental concerns, and suggestions for enhancing energy efficiency favoured structural change and tangible solutions. Participants felt that while they were open to changing their behaviours, their habits were too deeply rooted to be altered by current educational and motivational campaigns. An absence of direct consequences was ultimately highlighted as contributing to unchecked energy spending behaviours.

Following the identification of key themes and pain points, two *personas* were created to encapsulate the diverse user group EcoWatt aims to address. The personas represent the 'Energy Waster' (see Fig. 2) and the 'Energy Saver' (see Fig. 3).

3 DESIGN PROCESS

3.1 Initial Ideation

Design ideation began with '*Crazy 8*' sketches (see Fig. 4), leading to three potential solutions. The first concept was a dashboard and mobile app in student accommodations, educating users on energy usage through creative visualisations and incorporating community

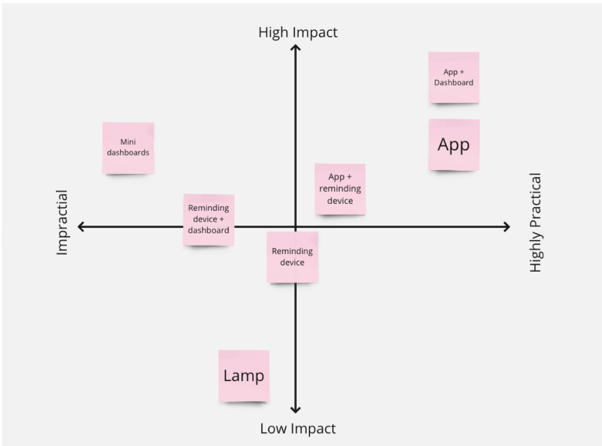

Figure 4: 2x2 evaluation matrix of product ideations.

and competition. The second solution was a smart lamp that auto-adjusts brightness based on ambient light. The third idea involved attachments to outlets and taps, signalling excessive energy use through visual and audio cues. Subsequently, a *2x2 evaluation matrix* was employed to rank all ideas based on their practicality and level of impact.

3.2 First Prototype

As a result, an 'energy management' mobile application paired with a dashboard interface in the lobby of the student accommodation emerged as the best solution. To address users' awareness and motivation, a key function of the app was to give users the capability to track and manage their energy consumption at both individual and floor levels. To enhance user engagement, an anthropomorphic character, named 'Wattson', was created. Wattson offers emotional feedback on the user's energy usage pace through three different facial expressions - energised, neutral, and exhausted (see Fig. 5). By embodying energy usage through different emotions, Wattson transforms abstract energy data into relatable emotional feedback and makes energy consumption data more accessible and understandable. This approach leverages the psychological principle of embodied cognition[21], where human emotions and experiences are used to understand and interact with data more intuitively. Complementing the app was a digital dashboard in the accommodation foyer, displaying an accommodation-wide energy-saving target to build a community in the student accommodation through collective motivation. The app was designed to help 'Energy Savers' align their lifestyles more closely with their sustainability goals, and to motivate 'Energy Wasters' to be more conscious and educated regarding their energy usage.

The low-fidelity prototype was then evaluated using a SWOT analysis (see Fig. 6) and the COM-B model. The COM-B model[14], identifies capability, opportunity, and motivation as the three key factors required to engage in a specific behaviour. To address psychological capability, the design incorporated relatable data visualisations in layman analogies, making users aware of their energy usage and savings. Information on the app that explained how

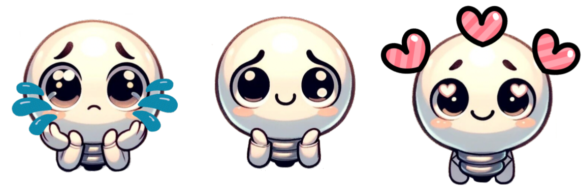

Figure 5: Three emotional states of Wattson, exhausted (left), neutral (middle), energised (right).

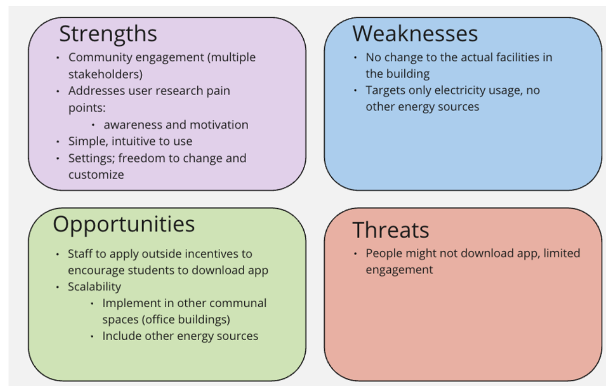

Figure 6: SWOT analysis of first prototype.

the facilities work in their accommodation also guided users toward more efficient energy-spending methods. Integrating staff involvement by setting energy-saving targets for the accommodation fostered reflective motivation. Data visualisations on a personal, floor, and accommodation level facilitated social opportunities for engagement among students.

For user testing, the low-fidelity prototype was created and evaluated by 7 students. Techniques such as *think-aloud* and *wizard-of-oz*, revealed positive reactions towards Wattson and the energy usage data visualisations. Users also appreciated the accessibility option to understand their data in financial terms, which was perceived as more relatable. However, feedback also highlighted concerns about content organisation, where a desire was shown for clearer feature labelling and dynamic interactive elements. An attempt was made to contact accommodation staff but due to availability constraints, this could not be achieved. The evaluation methods guided the following design reiteration, resulting in the development of the high-fidelity prototype.

3.3 Second prototype

The high-fidelity prototype was designed with colour and interactions used to conduct *expert reviews* with a senior researcher from the UCL Behavioural Innovations Society and HCI professors with backgrounds in interaction design and data visualisation. This was done after the user testing to garner professional feedback using a higher-functioning prototype. These reviews identified a notable disconnect between the data visualisations presented and the emotions conveyed by Wattson. Moreover, a critical observation highlighted the lack of active data interactivity for users, risking

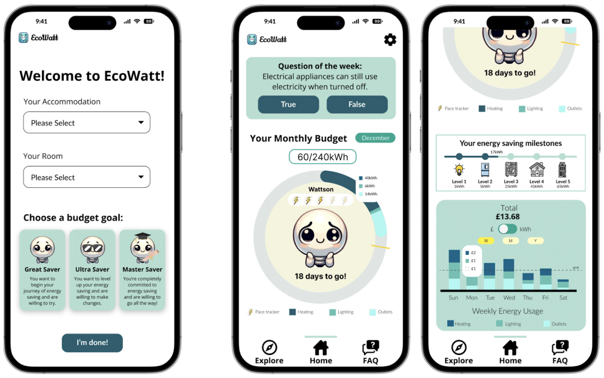

Figure 7: EcoWatt's final prototype showing onboarding (left), Home page (right).

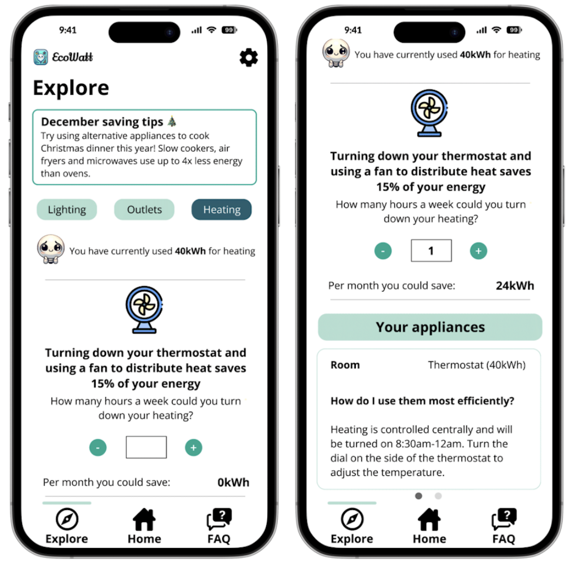

Figure 8: EcoWatt's final prototype showing Explore page.

diminishing the frequency of app usage. To address this, Wattson's emotions became more visibly linked with tracking progress on the energy budget. The education section was enhanced, allowing users to discover how much energy could be saved by altering behaviour in different ways. Considering the feedback, a final high-fidelity was established.

4 FINAL DESIGN

4.1 Product Overview

4.1.1 App. The final prototype features an onboarding page (see Fig. 7) where first-time users choose an energy-saving goal (great, ultra, or master saver) enabling their commitment to save energy as a personal goal. Users then receive a corresponding energy budget to guide electricity usage for each month determined by the accommodation staff, involving multiple stakeholders in the process. Users receive notifications for hitting milestones, or if they become the 'top saver' of the month, winning a financial reward.

The app contains 4 pages: Home, Explore, FAQs, and Settings. The Home page (see Fig. 7) shows personal usage data to increase users' awareness, with features like 'Question of the week' for engagement and education, with an energy budget breakdown (lighting, heating, outlets) throughout the month. Introducing anthropomorphic elements to boost motivation, 'Wattson' at the centre of the screen reacts directly to the user's pace of energy usage by displaying different expressions ranging from energetic to fatigued. An energy bar further illustrates Wattson's emotional state depending on whether the user is consuming relatively low, moderate, or high levels of energy at a given time. Underneath, users conceptualise their energy saving through quantified analogies represented as 'milestones'. Saving more energy every month results in unlocking new milestones, and motivating users to continuously progress with their goals. Past electricity usage is displayed graphically in kWh or cost, highlighting the importance placed on financial understanding by interviewees. These data visualisations help tackle awareness and motivation by allowing users to see where their energy expenditure is occurring and emphasise the goal they are working towards.

In the Explore page (see Fig. 8), content focuses on educating users and providing advice on how to reduce electricity usage. Derived from expert reviews, monthly tips are displayed and a data manipulation tool is also included to show less energy-intensive behaviour alternatives sourced from the UK government on how to save energy and lower bills[9]. Users could visualise how much electricity they can save based on how many hours per week of the alternative they can implement. Lastly, information about how to most efficiently use facilities in the accommodation is included to tackle a lack of understanding revealed in user research. The Explore page aims to address the users' lack of awareness of how to change their energy-wasting habits by giving them reasonable alternatives.

4.1.2 Dashboard. A large dashboard is designed to be displayed in a public space to depict accommodation-wide participation and progress towards the yearly energy-saving goal (see Fig. 9). The inclusion of a leaderboard was left out to avoid unhealthy and comparative competition. The dashboard is dynamic, with three alternating pages depicting goal progress, sustainability facts, and the percentage of students in the accommodation participating with the app. This will help involve more students and nudge them to download the app. Monthly energy reports are recorded by accommodation staff to better track energy usage patterns and to determine the building's 'top saver'. Based on the prior implementation of sustainability programs in student accommodations containing financial rewards, we can assume that this can also be distributed on the same scale to serve as positive reinforcement from a monetary perspective.

4.2 User journey

The user journey illustrates EcoWatt's simple interactions with a user who makes changes in their lifestyle to reduce their energy consumption due to the awareness and motivation that the app

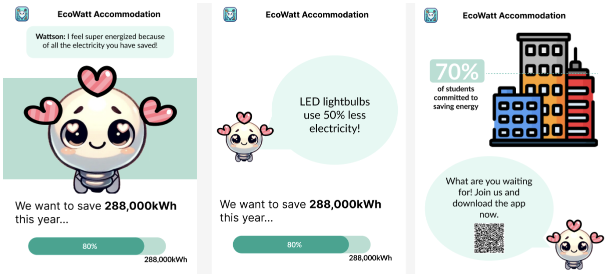

Figure 9: EcoWatt's community dashboard showing 3 pages containing awareness and motivation elements.

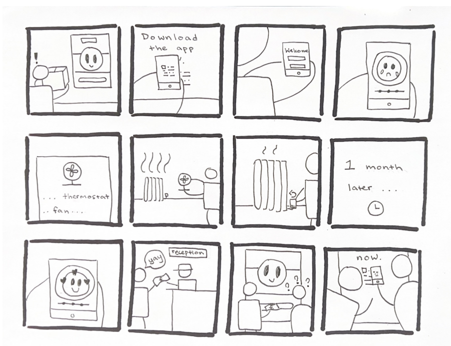

Figure 10: User journey of EcoWatt's interactions with students and staff.

provides them (see Fig. 10). One user's positive impact thus creates a ripple effect cascading to other students in the accommodations.

5 DISCUSSION AND NEXT STEPS

EcoWatt not only gives students access to personalised education and awareness about their electricity usage but also encourages a transition towards pro-environmental behaviours. By incorporating data visualisations, users can fully understand their energy usage regardless of technological literacy. Users also gain the knowledge to make real-life behaviour changes with limited disruption to their current lifestyle.

Previous research has debated whether eco-feedback through smart technologies makes an impact on users' behaviour, as individuals often do not reflect on their data usage to make changes[10]. Using disaggregated data could aid in the future of smart technologies within energy preservation[4], which has produced positive effects in reducing users' energy usage[11]. It was also important to address the issue of data accessibility to a general audience as well, as previous research has found that despite awareness of the amount of energy individuals were using, a lack of understanding of the data diminished the effects of decreasing energy usage[12]. To address this, a variety of data visualisations were implemented to aid in increasing users' awareness and motivation to produce behavioural change. Past interventions have also presented siloed solutions which prevented the creation of systemic and organisational change (e.g.[19]). Utilising the dashboard to remind students of their community and their collective energy-saving goals prevents this while emphasising 'community spirit'.

Limitations of this study can be found in our research sample, as most of our participants lived in studio flats, unlike most students in the UK. Bias in sampling is a potential limitation as well due to a bulk of user research being conducted with students in London specifically. Furthermore, the current design assumes a certain level of predictability in user behaviour, which may not always be deemed true. Users' energy consumption patterns can be influenced by various unpredictable factors like weather conditions, personal schedules, or lifestyle changes. These limitations could be addressed by diversifying the sample to better understand different energy usage patterns and behaviours. Longitudinal studies are also essential to assess whether the environmentally friendly behaviours encouraged by our design are sustained over time. Such studies would track long-term changes in energy usage and attitudes towards sustainability. We would also focus future research on designing an interface for accommodation staff to be used to set electricity-saving goals and better track the progress of overall electricity saving, to further involve all stakeholders. Further research could also focus on the potential utilisation of generative AI to evolve Wattson's role in our product. Implementing this feature could allow users to ask Wattson questions regarding the environment and sustainability practices in their accommodation, and could increase user understanding and interactivity.

The product involves multiple stakeholders and in using this interface, accommodations across the UK could witness a shift towards lower electricity costs, as well as the birth of a sustainable community. Saving on energy bills allows accommodations to reap financial benefits, offering a compelling incentive for widespread adoption. Furthermore, the scalability of our product opens avenues for application in diverse settings, such as office areas or other residential buildings. It could be expanded to track data from other energy sources, such as gas and water. This dual advantage of cost reduction and environmental responsibility makes our product an attractive proposition for a variety of settings, underscoring its significant commercial potential.

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