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Original research article

User perceptions on the adoption of smart energy management systems in the workplace: Design and policy implications

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ABSTRACT

Smart energy management systems equipped with advanced sensing and Internet of Things technologies allow users to monitor and manage their energy consumption through different control and automation features. While the success of existing systems has led to significant energy savings in the residential context (i.e., smart homes), recent field implementations of such technologies in the workplace continue to experience significant challenges in gaining user acceptance, resulting in limited success. Our study attempts to gain a more holistic understanding of users' perceptions on adopting smart energy management systems in the workplace through a mixed-methods approach consisting of a series of focus group discussions, online surveys, and laboratory studies. Through a comprehensive analysis of the responses obtained, the findings are grouped into seven high-level categories: External and Internal Influence, User Appeal, User Control, Reliability, Ease of Use, Personalised and Contextualised Information, and Data Privacy. Based on these findings, we proposed several design implications and organisation-level policies to help guide the design of future systems in the workplace and ensure a successful company-wide technology roll-out. These policies include adjusting existing workflows to encourage collective technology adoption in the company, educating employees on system features, and assuring users of the usage of their private data.

1. Introduction

Plug loads are defined as electrical devices that draw power from the building's electrical sockets and exclude other building systems such as conventional cooling, heating and lighting loads in the building [1]. While the growth in plug load usage in the workplace (i.e., desktops, laptops, and monitors) has contributed to increased worker productivity over the past 20 years [2], the energy contribution of these plug loads has been steadily rising over recent years, accounting up to 33% of the overall energy use in commercial buildings [3]. Aside from the growth in plug load usage, the survey findings released by the Alliance to Save Energy (ASE) coalition found that a significant portion of office users currently do not adopt any positive energy management habits in their workplace. More specifically, over half of the desktop users at work reportedly do not switch off their devices when they leave the office, resulting in an annual energy cost of $2.8 billion in the United States alone [4].

A recent review of different workplace intervention strategies found that the implementation of smart energy management systems (SEMS) in the office could result in energy reductions between 20%–38% [5]. These systems consist of advanced sensing and IoT technologies that track the office's energy usage and allow building managers to reduce the building's energy consumption through centralised controls. SEMS for plug loads, in particular, involves the use of smart power plugs to monitor the energy consumption of individual plug loads at different temporal resolutions and empower office users to manage their energy consumption through the use of different control and automation features [6]. Past studies have attempted to enhance the effectiveness of such systems by combining them with different intervention strategies to promote behaviour change and encourage the adoption of positive energy management habits. These behavioural interventions include integrating eco-feedback systems to inform users on their energy usage [7]; introducing different forms of incentives to motivate the adoption of positive energy management habits [8], and using of interactive games to increase user awareness of different energy-saving strategies [9].

However, despite the potential benefits of implementing SEMS for plug loads in the workplace, several studies have reported significant challenges in gaining user acceptance and adoption of the technology, thereby limiting the solution's effectiveness and viability during real-world implementations. A recent National Renewable Energy Laboratory (NREL) field study reported limited success during a field

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deployment of a SEMS for plug loads where users were not adopting the system as initially expected [10]. On top of not using the system's energy dashboard to monitor their plug load consumption, some users were even observed to unplug the sensors connected to their plug loads, thereby crippling the system's effectiveness in reducing their energy consumption during the study period. Similar challenges and resistance were also faced during a nation-wide rollout of a smart meter program in the United Kingdom, which aims to install a smart gas and electricity meter along with an in-home display in every household by the year 2020 [11]. Given the relationship between the acceptance of the technology and its ability to effectively achieve long-term energy reduction, developers of such systems must recognise these social challenges and account for them during the product design phase to maximise its intended impact. These issues are even more pronounced in the context of office workplaces where users are not responsible for their energy consumption cost, thereby posing a significant hurdle in motivating user acceptance and adoption of the technology in the workplace [5].

The objective of this study is to gain a thorough understanding of users' perceptions and motivations on the adoption of SEMS in the workplace. This is achieved by using a mixed-methods approach and combining the qualitative and quantitative data obtained through a series of focus group discussions, online surveys, and laboratory studies. Through a comprehensive analysis of the participants' responses, we investigated various topics related to their willingness to adopt the technology, their preferences for different design features in an ideal SEMS, as well as their views and concerns about automating their plug loads through a SEMS in the workplace context. As a result, we have identified several findings that align with existing studies in the residential context and discovered several new findings unique to the workplace context. Apart from these new findings, we have also highlighted several notable differences in perceptions and motivations between participants from different age groups, industry sectors and prior knowledge of SEMS. Based on these findings, we proposed seven design implications that would help guide the future design of SEMS for plug loads in the workplace. We also discussed the policy implications of these findings and how they can be introduced at the organisation level to ensure the successful adoption of the technology in the long run.

2. Related work

2.1. Adoption of SEMS in residential homes

As the world's population continues to grow and migrate towards urban areas searching for new settlements, this demographic shift has had negative consequences on the environment [12], with energy contributions from residential buildings on the rise. With SEMS in residential homes (or smart home systems) being touted as a promising solution to this worrying trend, different theoretical models have been proposed in past studies to identify significant factors influencing the adoption of such technologies. An example is the Technology Acceptance Model (TAM) [13] which extends upon Ajzen and Fishbein's theory of reasoned action [14] by considering different factors that influence a user's decision during technology adoption. These factors include the belief that the technology is useful in achieving a specific purpose (i.e., perceived usefulness) and the belief that it is easy to use (i.e., perceived ease-of-use). Based on this behavioural framework, [15] concluded that attitude, perceived usefulness, and trust are positive influences in users' intention to adopt smart home systems while lack of awareness and perceived risk discourage technology adoption. Furthermore, [16] proposed a modified framework based on TAM by considering, image, perceived voluntariness, subjective norms, environmental worldview, and goal internalisation to capture users' intention to adopt smart home systems within their homes.

Besides using theoretical models, a study conducted by [17] adopted concepts from behaviour decision research to gain insights into customer perceptions of deploying smart power meters in residential homes. While most participants indicated a desire of having smart meters in their homes, they were also concerned about having less control over their electrical usage, potential privacy violations, and increased cost. These results align with the findings by [18], which found that homeowners were generally optimistic about the technology improving their quality of life while expressing concerns about losing control of their appliances, losing their privacy, issues with the technology's reliability, and intrusion upon their daily routines. A study conducted in Singapore [19] also found that while most households were willing to invest in a smart home system to improve their comfort and save energy in their homes, it is unlikely that they would actively adjust their behaviours after adopting these technologies to reduce their consumption.

Given these findings, several studies have adopted a user-driven approach during the development phase of such systems to align more closely with users' requirements and encourage technology adoption. Through a series of semi-structured interviews and design workshops to gather user requirements for a smart home interface, [20] proposed a flexible interface that allows users to customise their dashboards based on their unique needs.

This approach of personalising smart home technologies can also help to reduce the users' perception of alienation and security concerns surrounding the technology, as highlighted by [21].

2.2. Adoption of SEMS in commercial workplaces

Despite the differences in user motivation between residential homes and commercial workplaces, a study conducted in the United Kingdom found that the study participants were more likely to support the adoption of smart energy technologies in the workplace as compared to the residential context [22]. Despite this surprising finding, relatively few studies have attempted to investigate the adoption of SEMS for plug loads in the workplace. Within the context of smart campuses, [23] examined the adoption of SEMS for plug loads in university offices and found that while the users are generally optimistic about the technology, they were also concerned about the possibility of system misuse, such as for surveillance or for assessing job performance. A review conducted by [24] highlighted that while such systems can provide office users with the assurance that environmental conditions can be adaptable to their comfort requirements, there are still many hurdles to smart technology adoption. These hurdles include low labour force skills, limited monetary budget, lacking compatibility with existing technological infrastructure, and organisational distrust. Despite these hurdles, some studies have attempted to evaluate the impact of introducing these technologies in the workplace. [25] investigated the effect of eco-feedback on office users' energy consumption by monitoring and providing individualised feedback to 83 participants in a university office. While the authors reported significant energy reductions by the end of the study period, the participants' engagement diminished over time as they lacked the motivation to reduce their energy consumption actively. Another study conducted by [26] invited 31 office users to participate in an energy competition where they were given a mobile application to control their devices in the workplace. By the end of the study period, there was a 32% reduction in energy consumption, demonstrating the energy-saving potential of these technologies in the workplace.

Due to the relationship between the users' engagement with the technology and its effectiveness in reducing energy consumption in the workplace, researchers have begun adopting user-driven development approaches to retain long-term engagement with its users [27]. One relevant example is a study by [28] who was interested in understanding users' perceptions of energy use in the workplace. During the study, a series of workshops were conducted with a group of building managers where they were tasked to complete a survey evaluating different eco-feedback visualisations and to design a 1-year energy intervention plan to be implemented within their buildings. Through an analysis of the participants' responses using Grounded Theory [29], several design implications were derived for future smart technologies in the workplace.

However, many of the prior studies are limited as they rely solely on the use of surveys or semi-structured interviews to study the complex topic of new technology adoption [30]. The complexity of the problem is further compounded given the workplace context, as the users' perception and motivation towards the adoption of SEMS could potentially be influenced by other factors such as their current use cases for different plug load types as well as external influences from the organisation and other colleagues. Given the topic's complexity, the over-reliance on any single type of data collection approach may lead to the collection of inadequate feedback, especially if the participants lack sufficient prior knowledge of the technology introduced. Therefore, in this study, we attempted to minimise this limitation by combining different data collection strategies (e.g., focus group discussions, online surveys, and laboratory studies) to capture a comprehensive and holistic view of the barriers impeding the adoption of SEMS for plug loads in the workplace, as well as user perceptions of the technology. The inclusion of a laboratory study is particularly beneficial in this scenario as it also provides users with the rare opportunity to interact with a mock system to extract more realistic and detailed feedback on the use of such systems in the workplace.

3. Methodology

3.1. Study design and data collection

In this study, we adopted a mixed-methods approach involving a series of focus group discussions, online surveys, and laboratory studies to gain a comprehensive understanding of user perceptions and motivations when adopting SEMS for plug loads and plug load automation in the workplace, as illustrated in Fig. 1. The study was conducted in Singapore and involved office workers between the ages of 21 to 60 from different industry sectors, genders, nationalities, prior knowledge of SEMS, as well as representing both local and multinational companies. A detailed breakdown of the study participants' demographic information has been provided in Table 2. Participants were invited to take part in the study using a snowball sampling method, and informed consent is obtained in line with our Institutional Review Board (IRB) approved protocol.

We have also introduced several measures throughout the study to ensure that the questions posed are valid and account for common-method and social desirability biases. Firstly, all questions posed in the focus group discussion, online survey and laboratory study are first tested internally among other members in our research group who are not involved in the questionnaire design to ensure that they are unambiguous. Secondly, at the start of the focus group discussion and laboratory study, the facilitators spent the first five minutes explaining the study context and educating the participants on any technical terms they might encounter during the conduct of the study. Furthermore, at any point in time, participants were strongly encouraged to provide their honest opinions and raise any questions they might have to ensure that they can fully understand the question posed. Lastly, the study participants who took part in the online survey were also not required to provide any personally identifiable information to protect their anonymity and encourage honest feedback.

3.1.1. Stage 1: Focus group discussions

The first stage of the data collection effort involved conducting multiple focus group discussions with different office users to learn more about their current energy management habits, general perceptions of SEMS for plug loads and identify any concerns related to plug load automation. The reason for beginning the study with a focus group discussion was to provide an open platform for participants to express their opinions about the relevant discussion items without being limited by the predefined options listed in study questionnaires [31] and to facilitate an active exchange of viewpoints between different participants. A total of 15 participants took part in this stage of the study, where they were divided into three groups, with each group consisting of five participants each. Each focus group discussion took around one and a half hours and was audio-recorded, transcribed, and documented to prepare the data for post-evaluation. A researcher was also assigned to take notes during the session if the participants do not want to be audio recorded, as per IRB guidelines.

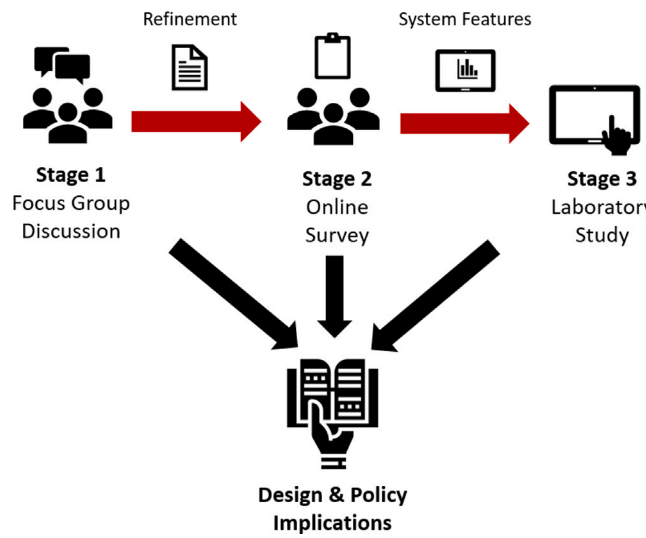

Fig. 1. Our proposed methodology follows a mixed-methods approach.

The first section of the focus group discussion began by understanding the users' energy management habits, where they were asked about their current switch off habits and their motivations in reducing energy waste in the workplace. Following this, the second section aimed to learn more about the participants' general perceptions of SEMS for plug loads by asking them to list their desired attributes for an ideal system and highlight any possible reasons for not adopting the technology. In the second half of the focus group discussion (i.e., third and fourth sections), participants were asked to generate design ideas for a system user interface by suggesting different eco-feedback information to increase the users' energy awareness and express their thoughts on different control features. Some of these control features included remote control, schedule-based control, and presence-based control. The remote control feature allowed users to switch their plug loads ON/OFF remotely by sending wireless signals over the Internet to control the smart power plugs attached to these plug loads. Schedule-based control enabled users to set predefined schedules for their plug loads by automatically switching them ON and OFF based on each schedule. Lastly, presence-based control allowed users to automatically switch their plug loads ON/OFF based on their presence information, which can be detected using traditional infrared sensors or more advanced indoor localisation techniques that use WIFI [32], Bluetooth [33] or GPS technology [34].

3.1.2. Stage 2: Online surveys

Based on the responses obtained during the focus group discussions, the questions used in the previous stage were refined and structured based on the format of an online questionnaire to reach out to a larger group of participants. To ensure that each question in the questionnaire was clearly understood, detailed explanations and informative visualisations have been included to address any queries that might arise. The questionnaire was shared through different channels and resulted in a total of 86 responses.

The online questionnaire followed a similar structure to the focus group discussion by having four main sections. The first section asked about the respondent's demographic information, plug load switch off habits, and motivations to reduce energy wastage in the workplace. The next section then proceeded to ask about the respondent's general perceptions of SEMS for plug loads by asking them to rate, between the scale of 1 to 5, the importance of different attributes in an ideal system, and different reasons for adopting SEMS for plug loads in the workplace. In the third section of the survey, respondents were asked to help design a system user interface by rating different types of information that should be reflected in the interface and how it should be presented. Finally, in the last section, the respondents were asked to rate their likelihood of using each control feature (i.e., remote control, schedule-based control, and presence-based control) to manage or automate their plug loads and express any concerns if they are asked to do so. The options provided in each question were extracted based on the common responses obtained during the focus group discussions, but the participants were also free to suggest other responses if necessary.

3.1.3. Stage 3: Laboratory study

After the focus group discussions and online survey, the next stage of the study involved conducting a laboratory study where study participants were given an opportunity to interact with a prototype user interface. The purpose of this part of the study was to allow the participants to familiarise themselves with the features and capabilities of a mock SEMS so that they have a more realistic view of the system and allowed us to obtain a more informative and reliable portrayal of their perceptions. Furthermore, this process could also help to clarify any misconceptions that the users might have had before using such systems in the past, which may influence their decision to adopt the technology. By allowing the study participants to interact with a prototype user interface, we were also interested in identifying any discrepancies or new findings that could be useful in guiding the design of future SEMS for plug loads, apart from those highlighted in the focus group discussions and online survey.

Based on the responses gathered during the focus group discussions and online surveys, we identified a set of core features that should be included within our prototype user interface, which comes in the form of an energy dashboard and a control interface. The energy dashboard presented different information about the users' plug load usage, such as their real-time power consumption, historical energy consumption, general educational tips on reducing energy wastage, accumulative cost savings, as well as personal goals and progress. On top of that, the control interface presented the users with three different control features, including remote control, schedule-based control, and presence-based controls. The interface was developed using the ReactJS library (refer to Fig. 2) to allow the study participants to interact with the components on the interface during the laboratory study.

The laboratory study was conducted with 33 office users, for approximately 1.5 h, where participants were asked to perform a set of tasks that required them to interact with the interface. Each task was designed to allow the participants to interact with the core features included within the user interface. An example of one of the assigned tasks is provided in Fig. 3 where participants were asked to find out the largest energy consumer among their plug loads for a particular week by interacting with the energy dashboard. During the conduct of the laboratory study, participants were also encouraged to share their thoughts and suggestions on how to improve the system features.

Finally, after all tasks have been completed, the participants were asked a series of open-ended questions to identify different ways of improving their engagement with the system, their current plug load management habits, their views about automating their plug loads through a SEMS for plug loads, and the level of control they would prefer to have in an automated system.

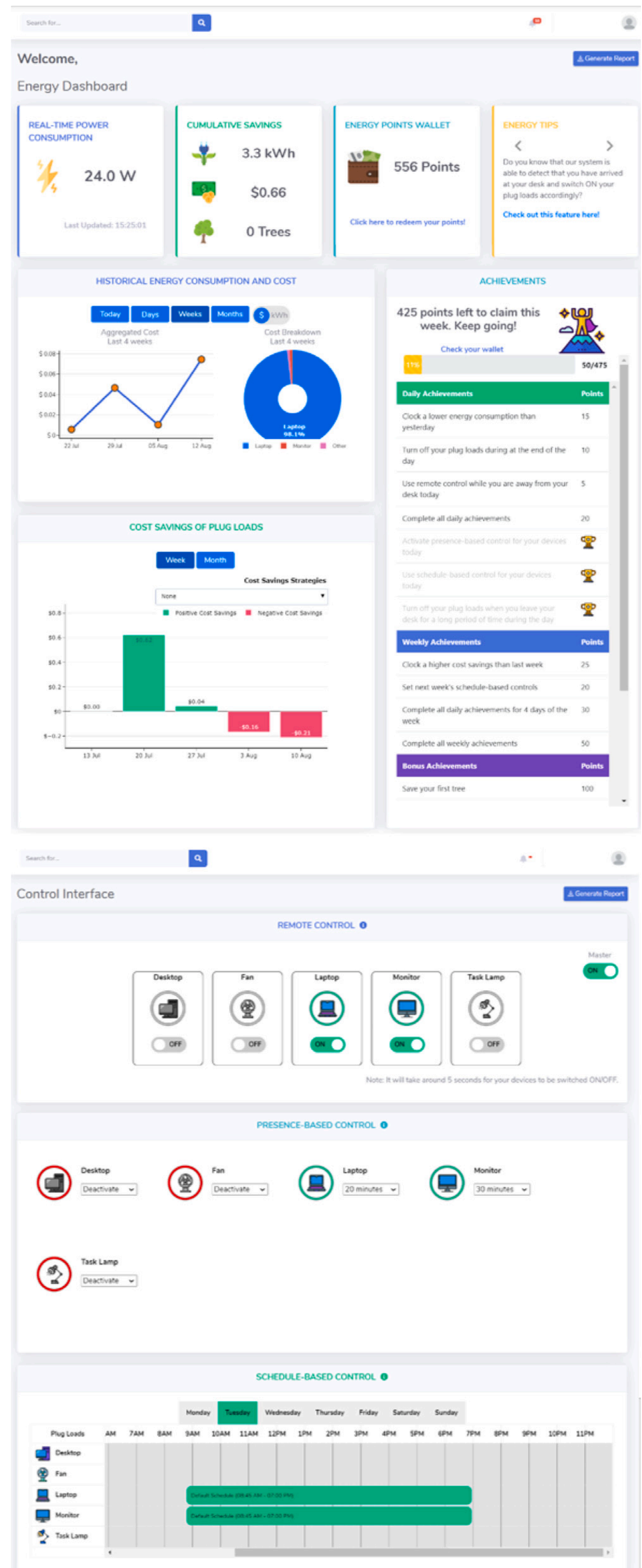

Fig. 2. User interface used in this study. Energy Dashboard (top) and Control Interface (bottom).

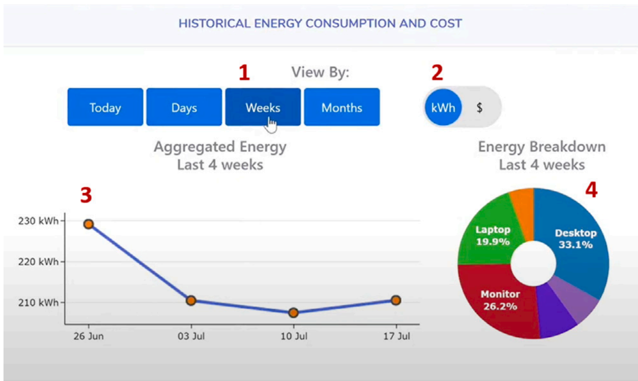

Fig. 3. An example of an interaction task: Can you find out what is the largest energy contributor among your devices for the week of 26th June? Possible steps the participants can take to answer the question: 1. Click on the "Weeks" button at the top to change to a weekly view, 2. Click on the toggle to represent the energy consumption information in terms of kWh, 3. Click on the data point on the line graph representing 26th June, 4. Refer to the pie chart on the right for a breakdown of each plug load's consumption to identify the largest energy contributor.

Table 1
Overview of the 34 low-level codes and their corresponding high-level categories identified during the open coding process.

High-level categories	Low-level codes
External and Internal Influence	Competition, Peer Comparison, Self-comparison, Organisational Influence
User Control Situational	Ability to Override, Customisation,
Ease of Use	Well-designed, Intuitive, Simple, Convenience, Clean, Clarity, Not Time Consuming, Non-intrusive, Familiarity
Personalised and Contextualised Information	Detailed, Informative, Actionable, Increase, Awareness, Useful, Relatable, Misinterpretation, Uniform, Relevancy High-level Overview, Personalisation of Information
Reliability User Confirmation	System Reliability, Accuracy,
User Appeal	Incentivisation, Fun, Engaging
Privacy	Privacy

3.2. Data processing

The qualitative data and responses obtained during the focus group discussions and laboratory studies were processed by segmenting each users' response into individual sentences and filtering out irrelevant sentences from subsequent analysis. Some examples of such sentences include passing comments by the study participants that were irrelevant to the study or responses that did not answer the question posed. The remaining sentences were also manually labelled to indicate a positive, negative, or neutral sentiment. In the end, this resulted in over 1,400 individual responses that were suitable for subsequent analysis. The quantitative responses were also checked for common method bias by performing Harman's single factor test. Given that none of the extracted components from each data collection approach (i.e., focus group discussions, online surveys, laboratory study) single-handed accounted for more than half of the total covariance (i.e., 37.5% to 39.2%), we can conclude that common method bias is not significant in the data collected [35].

3.3. Thematic analysis

Thematic analysis was adopted in this study to process the qualitative data provided by the study participants as it helps to provide a valuable summary of the data and categorise it into high-level features for interpretation. Through the identification of these high-level features, this allowed us to develop general design and policy guidelines that are applicable to a wide range of system use cases. Furthermore, an additional advantage of using thematic analysis was that it also allowed us to generate unanticipated insights, as highlighted by Braun, Virginia, and Clarke [36], as we are not restricted by our preconceived notions and assumptions when proposing an initial set of hypothesis as is required in other methodologies such as Grounded Theory.

The processed qualitative data were analysed following a two-phase approach: open coding and thematic coding.

The first phase involved open coding, where the research team manually trawled through each response and extracted a set of low-level codes that captured the common themes raised by the study participants. After identifying these low-level codes, they were refined and amalgamated to form seven high-level categories, as reflected in Table 1, which formed a standard code book for the second phase of the analysis.

The second phase involved thematic coding where three independent researchers not involved in the open coding phase were asked to evaluate the same set of responses and assign one or more categories to each response based on the code book obtained in the first phase [36]. In the end, we evaluated the reliability of agreement between the three researchers by computing their inter-rater reliability score using the Fleiss Kappa statistic and obtained a high agreement score of 0.796. The codes assigned by each researcher were subsequently merged following a majority voting approach to obtain the final encoded dataset.

4. Descriptive statistics

This section provides the descriptive statistics of the study participants' demographic information for all three data collection stages (i.e., focus group discussion, online survey, and laboratory study) and current energy management habits in the workplace.

A total of 134 individuals have participated in this study, with the majority of the participants involved in the online survey (64.2%), followed by the laboratory study (24.6%), and finally, the focus group discussion (11.2%). A detailed breakdown of the study participants' demographic information, grouped based on age, gender, industry sector and prior knowledge of SEMS, has been provided in Table 2, categorised based on the three data collection stages.

When the study participants were asked to rate their current energy management habits based on four different categories (i.e., inactive, mildly active, active, and very active), it is observed from Fig. 4 that almost 40% indicated that they are either active or very active in adopting positive energy management habits in the workplace. In this case, participants who indicated that they are inactive do not attempt to manage their energy consumption. Mild participants only manage their energy consumption whenever it is convenient or when they happen to remember. Active participants take personal responsibility in managing their energy consumption and go out of their way to reduce it, while very active participants take it a step further to invite others in reducing their energy consumption. Among this group of participants, most of them (76%) also indicated having prior knowledge of SEMS before the study. On the other hand, 67.3% of the participants who reported being mildly active or inactive in reducing their workplace energy consumption do not have any prior knowledge of SEMS. More details about the study participants' energy management habits are provided in Appendix for the interested reader.

Table 2
Detailed breakdown of the study participants' demographic information based on age, gender, industry sector, and prior knowledge of SEMS, categorised based on the three data collection stages.

	Focus group discussion	Online survey	Laboratory study
Age	40.0% 21–29 yrs 20.0% 30–39 yrs 20.0% 40–49 yrs 20.0% 50–65 yrs	45.6% 21–29 yrs 29.8% 30–39 yrs 12.4% 40–49 yrs 12.2% 50–65 yrs	60.4% 21–29 yrs 14.7% 30–39 yrs 19.3% 40–49 yrs 5.6% 50–65 yrs
Gender	60.0% Male 40.0% Female	55.8% Male 44.2% Female	42.4% Male 57.6% Female
Industry Sector	13.3% Manufacture 6.7% Construction 6.7% Business 20.0% Info Comms 13.3% Finance 13.3% Academia 6.7% Healthcare 13.3% Service 6.7% Others	7.0% Manufacture 5.8% Construction 9.3% Business 11.7% Info Comms 8.2% Finance 25.5% Academia 7.0% Healthcare 10.4% Service 15.1% Others	3.1% Manufacture 3.1% Construction 6.2% Business 9.3% Info Comms 6.2% Finance 50.7% Academia 3.1% Healthcare 6.2% Service 12.1% Others
Knowledge on SEMS	46.7% Yes 53.3% No	52.4% Yes 57.6% No	65.7% Yes 34.3% No
Total	**15**	**86**	**33**

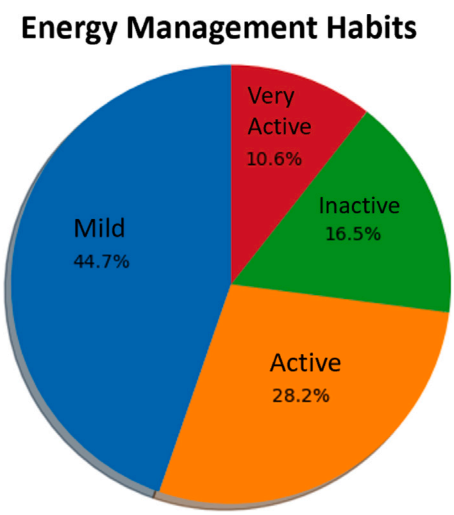

Fig. 4. Breakdown of the study participants' energy management habits in the workplace from all three data collection stages (i.e., focus group discussion, online survey, laboratory study) (n = 134).

5. Findings and discussion

This section provides a detailed analysis of the qualitative and quantitative responses obtained during the three data collection stages to gain useful insights into the study participants' perception and motivations when adopting SEMS for plug loads in the workplace. We also attempted to highlight the differences in perceptions between study participants of different age groups and those who have prior knowledge of SEMS. The section is divided based on the seven high-level categories depicted in Table 1. When quoting the participants' responses raised during the focus group discussions and laboratory studies, each response is tagged based on its source and unique ID. For instance, FG-101 refers to a response raised during the focus group discussion and has a unique ID of 101. LS, on the other hand, refers to responses that were brought up during the laboratory study.

5.1. External and internal influence

External influence refers to extrinsic factors that are not within the user's control but have a discernible impact on his decision to adopt the technology, such as influence from the organisation or other peer groups. On the other hand, internal influence refers to intrinsic factors that originate within the user and drives his decision to adopt the technology, such as self-motivation, prior knowledge, and attitudes towards energy management.

To investigate the impact of different strategies in motivating the study participants to reduce their energy consumption through the adoption of SEMS, participants are asked to rate the effectiveness of each strategy based on a scale from 1 to 5, where 1 indicates that it is not effective and 5 indicates that it is very effective (refer to Fig. 5). When it comes to external influences from the company, many participants agree that the introduction of complementary policies would be effective (3.95) in motivating them to use the SEMS to reduce their energy consumption in the workplace. This result is further supported by the qualitative responses obtained during focus group discussions and laboratory studies where 77% of the participants indicated that they would adopt the technology at their workplace if the initiative was also encouraged by their supervisors and their colleagues were also seen adopting the system. This finding is supported by Dearing et al. [37] and Venkatesh et al. [38] which recognised the positive influences from organisational leaders, who are crucial in ensuring the successful adoption of sustainable initiatives [39].

FG-218: "One way to do this would be through a collective effort, where we can come up with an initiative together to remind each other to use the system and conserve electricity.", **S-221:** "I think collective effort can help push this initiative forward, as a team or as a company as a whole." and **LS-929:** "...if the company or my boss enforces it, I will carry it out."

We can further segment the results reflected in Fig. 5 based on the study participants' age group where participants between the ages of 21 to 39 years old are categorised under one group while participants between the ages 40 to 59 years old are categorised under another group. We observed that the older group of participants considered Company Policy as the most effective motivational strategy (4.30), while the younger group only considered Company Policy as the third most effective approach (3.90). This result is interesting as it seems to show that the older generation is more compliant towards authority figures in the company and is therefore more likely to embrace the policies implemented by the company.

Another motivational strategy commonly raised during the focus group discussions and laboratory studies is to conduct competitions or games between different office users or different departments to motivate more users to reduce their energy consumption in the workplace. This finding is supported by [28] which highlighted the effectiveness of using gamification approaches to encourage technology adoption. However, other study participants (32%) disagreed by raising that

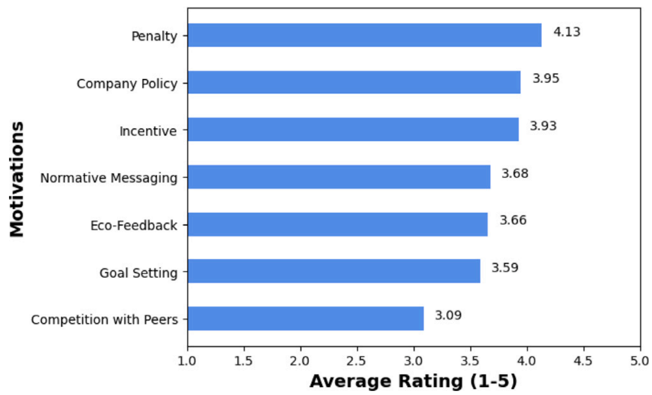

Fig. 5. Average ratings that describe the effectiveness of different motivational strategies to adopt SEMS for plug loads in the workplace to reduce energy consumption (1 = Least Effective and 5 = Most Effective).

while this approach might reduce energy consumption in the short run, they are concerned that it will have an adverse impact in the long run when users become demoralised or disinterested when the competition becomes too intense or toxic. There were also concerns regarding the fairness of such competitions as some departments may consume more energy than others due to the nature of their operations. The results in Fig. 5 support this view as the conduct of competition within the company was the least popular approach (3.09) to motivate users to reduce their energy consumption in the workplace.

FG-64: "…some sort of gamification of the system can encourage users to compare their progress with others in the office.", **LS-225**: "…you can get departments to compete against each other to see who can save more electricity. I think that can help to save more electricity in the short term. However, I think that this would not be very effective in the long term….", **FG-130:** "…not everyone cares about recognition, so this might demoralise people when the competition becomes toxic." and **FG-113:** "…comparing between departments with the company's overall usage might not be fair as different departments require different electrical usage."

Therefore, instead of hosting competitions between different users or departments, participants prefer to be internally motivated or influenced by benchmarking their current energy consumption against their historical consumption to track their performance. This benchmark can be calculated based on a moving average of their daily or monthly consumption, and users will be informed when they have exceeded a certain threshold. A small group of participants (10%) have also highlighted during the focus group discussions and laboratory studies that it would be useful if the system could suggest a recommended level of consumption based on their usage patterns.

FG-78: "…a moving average based on my daily or monthly consumption would be useful to help benchmark my performance and check my progress." and **FG-109:** "I would like to see a specification of an ideal consumption compared to actual consumption, and warning me when I exceed the average usage…"

5.2. User appeal

User appeal relates to the technology's ability to attract user interest and maintain long-term engagement and acceptance from its users.

By referring back to the results reflected in Fig. 5, it was observed that the inclusion of a penalty system (4.13) and an incentivisation system (3.93) are both highly effective strategies for motivating users to reduce their energy consumption through the SEMS. These two approaches are particularly effective among younger participants between the ages of 21 to 39. When the survey participants are asked to rate the different types of incentives that would motivate their behaviours, most respondents preferred financial incentives (76%) over other incentives such as self-accomplishment (6%) and social recognition (18%). This preference is echoed during the focus group discussions and laboratory studies, where a significant portion of the responses are related to providing financial incentives to users and rewarding them based on the amount of energy savings they achieved. The financial incentives can come in the form of annual bonuses or redeemable perks and vouchers for different food and beverage establishments. However, a small group of study participants (6%) have questioned the long-term effectiveness of monetary incentives, especially if the amount awarded is too minuscule. Apart from introducing financial incentives to encourage energy reduction, the introduction of penalties could also bridge the difference in user motivation at home and in the workplace as the office users are now directly and financially responsible for their energy consumption in both scenarios. However, this approach's effectiveness is not well evaluated in real-office settings, as it will likely be highly unpopular among office users who have to abide by it.

FG-10: "…office users could be given bonuses depending on the amount of energy saved.", **FG-42:** "I need a reward system that gives me vouchers. It serves as a nice bonus for most office workers.", **FG-60:** "…some sort of reward system that could be redeemable for perks at work such as free snacks or coffee.", **FG-93:** "If there were vouchers or partnerships with different shops, that would encourage me too.", **FG-107:** "I think a reward system would work as well, but I think that is a short term approach…" and **FG-11-12:** "You can also use penalties rather than rewards. One example would be to get the office occupants to pay the electricity bills."

While participants from the focus group discussions raised that rewards could be a motivating factor, some of them (38%) also highlighted their doubts about the effectiveness of using financial incentives to encourage long-term user engagement. On the other hand, most participants (84%) were highly receptive when they were introduced to an achievement system as a feature in the system during the laboratory study stage. The achievement system combines several well-known concepts related to incentivisation, goal setting, and gamification by awarding energy points to users after completing a specific achievement or goal defined by the system. Users can subsequently use the points earned to redeem for different perks in the future. By describing various daily and weekly achievements to be completed, many participants indicated that this would motivate them to use the system regularly to check on their progress and complete all of their achievements, thereby ensuring long-term engagement with the system.

LS-1016: "This type of reward system would motivate me to save energy. I would want to complete all of my daily achievements and weekly achievements.", **LS-344:** "…maybe if you can hit a certain energy-saving goal, then the company can award points that you can exchange for vouchers.", **LS-1065:** "…there are achievements to do every day, and that makes it more engaging." and **LS-1356:** "The achievements section is something I will visit the user interface daily for."

5.3. User control

User control relates to the amount of control that a user would prefer to have when using a SEMS to manage his energy consumption.

One of the key advantages of adopting SEMS for plug loads is using different control and automation features to help office users conveniently and effortlessly manage their energy consumption in the workplace. When the study participants are asked to rate a list of attributes that should be included in an ideal SEMS based on a scale from 1 to 5, the second most important attribute (4.12) was that the system should allow users to control their plug loads easily (refer to Fig. 6). Moreover, while the study participants were generally receptive to adopting the technology in the workplace, most of them (71%) preferred to have a semi-automated system that allows them to provide their preferred control settings to adjust the system's behaviour based

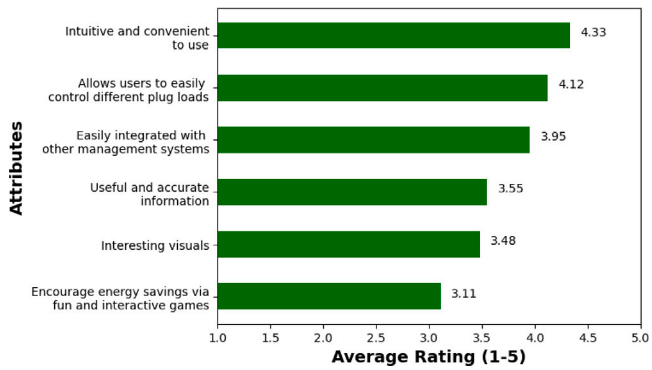

Fig. 6. Attributes of an ideal SEMS, arranged in descending order based on the level of importance (1 = Least Important and 5 = Most Important).

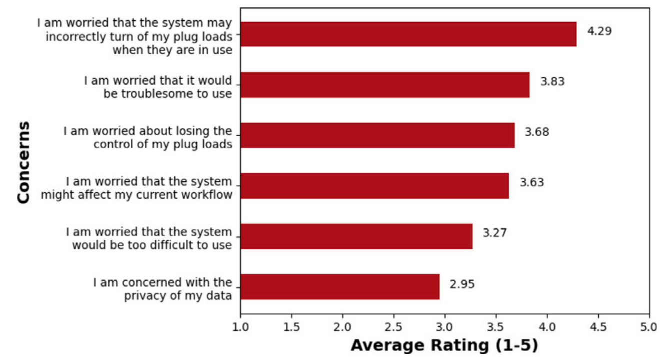

Fig. 7. Top concerns when using an automated system (1 = Not Concerned and 5 = Very Concerned).

on their preferences. This observation is particularly valid for the participants in the academic sector as they are occasionally required to run their simulations or models overnight and would like to prevent their workstations from being switched off by the SEMS during those use cases. Only 25% of the participants indicated that they were comfortable with a fully automated system, while the remainder of the participants indicated that they were not comfortable with an automated system.

Moreover, when it comes to the desired level of control that the participants would prefer to have, many participants from the focus group discussions and laboratory studies (68%) mentioned that the ideal level of control would depend heavily on the specific plug load. For instance, some participants (31%) indicated that they would prefer to maintain more control over plug loads that they deemed more critical such as their laptops and desktops, as they are concerned about losing their work if their plug loads are switched off accidentally by the system. On the other hand, they were willing to give up more control over auxiliary devices such as task lamps and desk fans since the latter can be easily switched back on without much disruption.

LS-337-338: "For auxiliary items like the table lamp, I would let the system take over control because accidentally turning off that appliance would not affect me much since I can just turn it back on. But for my laptop and desktop, I would rather have more control over them because there might be unfinished work on these devices." and **LS-417:** "We are using the desktop and monitor as our main working devices at the office, so the fan and lamp accidentally shutting down are less inconvenient than the desktop or monitor shutting down."

When the participants are asked to rate their willingness to use each control feature based on a scale from 1 to 5, we observed that remote control was the most preferred control feature with an average rating of 4.58, followed by occupancy-based control with an average rating of 4.02, and lastly schedule-based control with an average rating of 3.63. When we investigated the relationship between the participants' preference for using each control feature and their prior knowledge of SEMS, we found that participants with prior knowledge of the technology are, on average, more likely to use all three types of control features than their peers who do not have prior knowledge. More specifically, participants with prior knowledge of SEMS gave an average rating of 4.92 for remote control, 4.64 for occupancy-based control, and 4.47 for schedule-based controls, while participants without prior knowledge gave an average rating of 4.68 for remote control, 3.81 for occupancy-based control, and 3.52 for schedule-based controls. A notable outlier from the above results shows that although some participants might not have any prior knowledge of SEMS, they still indicated that they are very likely to use the remote control feature. This result could be due to their familiarity with the control feature based on their previous experiences with other commonly used devices, such as televisions, that mainly rely on the same remote control technology. While the participants from the focus group discussions and laboratory studies have a positive attitude towards adopting SEMS for plug loads in the workplace, most of them (86%) still preferred to have the flexibility to adjust the control settings of each control feature based on their preferences. They also preferred to have the option of overriding the system manually and deactivating certain features as a fail-safe mechanism.

FG-88: "If the occupancy or scheduling-based controls were in place, I would want a system where you can overwrite your existing control settings.", **FG-125:** "...there should be an option to manually overwrite everything if needed." and **LS-1084:** "I think it is a good idea to give users this autonomy to control when these devices are switched ON or switched OFF."

5.4. Reliability

System reliability refers to the system's ability to operate stably and predictably, which instills trust from its users.

When the study participants are asked to rate a list of possible concerns when using an automated system based on a scale from 1 to 5, it is observed from Fig. 7 that the participants' top concern is related to the system's reliability (4.29) as they are worried about the system incorrectly switching off their plug loads while they are still in use. These views are also echoed during the focus group discussions and laboratory studies as many study participants (92%) expressed strong concerns that the system's automated features would malfunction and unexpectedly switch off their plug loads, thereby negatively impacting their work productivity. This concern is particularly valid for study participants from the finance and info-communication sectors as they indicated that an unreliable system would result in a very significant and costly impact on their companies' operations. While it is less highlighted, it would also be undesirable if the system fails to switch off a plug load when it is supposed to do so as this inevitably contributes to energy wastage and jeopardises the system's effectiveness in reducing energy consumption in the workplace.

FG-49: "I am concerned that my devices may get switched off even when I do not want them to be switched off.", **LS-1400:** "I am afraid that the system will turn off my devices when I still intend to use them.", **LS-497:** "...there would be no point using it if it is unreliable." and **LS-1741:** "I don't have much concerns about using the system but I am concerned that my desktop might be switched off in the middle of my work."

In addition to concerns about system reliability, while the participants are interacting with the system interface during the laboratory study, some were observed to be worried about switching off their plug loads unintentionally due to human error while using the system. Therefore, participants have suggested to include fail-safe mechanisms such as requiring the user to perform a confirmation step or include a user prompt before switching off critical plug loads such as desktops and laptops to serve as a precautionary measure.

LS-138: "I am concerned that I would accidentally click this button when I actually need to use the device and switch the device off.", **LS-303:** "You should include a confirmation message like, "You are currently switching off this device. Please confirm.", **LS-1143-1144:** "The system should prompt whether or not you want to switch off everything. I think that is important because it ensures that you do not accidentally turn off devices that you do not want to turn off." and **LS-302:** "This reduces the convenience because there is an additional step that needs to be performed, but a confirmation tab should be implemented just as a safeguard."

5.5. Ease of use

Ease of use refers to how easily users can learn to use the SEMS to manage their plug load energy consumption and adopt it in the workplace with minimal disruption to their current workflow.

Based on the survey results reflected in Fig. 6, the study participants indicated that the most important attribute of an ideal SEMS is that it is intuitive and convenient to use (4.33). The first factor on intuitiveness aligns with the qualitative responses collected during the focus group discussions and laboratory studies as the majority of the participants (91%) indicated that the general design of the system should be natural and straightforward to use so that it can be adopted with minimal guidance, aligning with the findings from Venkatesh et al. [38]. We also found that study participants are more receptive and comfortable when encountering familiar designs during the laboratory study stage due to their ability to leverage past experiences. It was also suggested that system users should be provided with adequate guidance via various means such as information guides or video tutorials to ensure that the system's features are well understood and fully utilised.

LS-233: "If the UI is made simple, even if the system is multi-featured, I think that is the best benefit that you can bring about to entice users to use this system.", **LS-1114:** "If you were to think from the perspective of a typical worker, if you want them to adopt this system, it should not be complicated.", **LS-618:** "The design is very intuitive because it is a common thing to see in games or other software.", **LS-620:** "The Apple watch's fitness rings is a gamified version of a progress bar too, perhaps we can learn a thing or two from there." and **LS-804-807:** "...maybe include a section to teach the user what to do as it is not easy to understand without video guidance. I would like a notification or general instructions on how to switch ON and OFF a device."

On the topic of convenience, 83% of the participants in the focus group discussions and laboratory studies agreed that this is a major contributing factor to system adoption. This preference also aligns with the results from Fig. 7, where the study participants' second top-most concern is that the system would be too troublesome or inconvenient to use (3.83). Given that the office user's main priority is to complete their assigned work within a stipulated time, they would prefer not to spend a significant amount of time using the system to actively manage their energy consumption. Therefore, the concept of an automated system was well-received, with study participants giving schedule-based controls and occupancy-based controls an average rating of 3.63 and 4.02, respectively, as mentioned in the previous section. Furthermore, some participants (37%) have also suggested that since they are already adopting positive energy management habits in the workplace, such as switching off their plug loads at the end of the day, they would prefer to use a system that would make it more convenient for them to continue doing so.

FG-66: "I think convenience and accessibility of the energy management system are the most important factors for me.", **FG-108:** "I will not use the system if it takes up too much time, too technical, not easy to read, or is not convenient to use.", **LS-748:** "I do not need incentives, but would prefer convenience over saving energy actively.", **LS-402:** "If it is all in one app, it is more convenient than manually turning it on or off on each device.", **FG-114:** "It will be cool if I can automatically switch my plug load ON/OFF depending on my presence...convenient for those who want to avoid the act of switching ON/OFF their plug loads as they find it a hassle." and **LS-685:** "The automation and level of control is the main game changer - you don't have to cultivate any habits and yet reduce energy."

5.6. Personalised and contextualise information

Personalised and contextualised information refers to displaying customised information based on the users' plug load usage patterns to increase awareness and influence behaviour change.

When the participants are asked to rate the importance of several potential attributes in an ideal SEMS (refer to Fig. 6), the fourth-highest rated attribute is the provision of useful and accurate information (e.g., reminders, alerts, and historical energy trends) to help increase the awareness and encourage the adoption of positive energy management habits. Many participants in the focus group discussions and laboratory studies (52%) indicated that the information provided in the system should increase their awareness of the negative impacts of their current behaviours and propose actionable and practical changes that can be exercised to reduce energy consumption. Moreover, another group of participants (17%) also indicated that it would be helpful if the system can specify the benefits of adopting certain behaviours to encourage users to do so.

FG-56-58: "Other than turning off my appliances, I do not know how much more I could do to reduce energy usage without compromising on productivity. I would like to receive practical tips on how to reduce my energy consumption.", **LS-216:** "If people are more consciously aware of the amount of money they can save just from doing basic things like turning their devices off when they are not at their table or turning off their lights when they leave the room, I think that would encourage them to put in more emphasis and effort to reduce their electricity consumption.", **LS-324:** "...it would motivate me more if the benefits are made known, and I am made aware of it." and **FG-76:** "I think the information presented should be contextualised."

Furthermore, for the information to be considered useful, many study participants (46%) further specified during the laboratory study that the information presented on the user interface should be personalised and relatable. One example is displaying personalised tips based on the users' current plug load usage habits. Moreover, when the survey respondents are asked about the most relatable way to represent their plug load energy consumption, the top three representation methods ordered in terms of preference include (1) displaying it in terms of dollars and cents, (2) representing it using a traffic light system where red indicates excessive use, and (3) kilowatt per hour (kWh). The qualitative responses obtained during the laboratory studies agree with the survey results, where the largest proportion of study participants (22%) preferred the use of dollars instead of kWh to represent their energy consumption.

LS-789: "If the tips are not personalised based on my usage, I will find it not useful.", **LS-1070:** "If you are able to know what the user uses predominantly, then you can tweak the tips according to that device.", **LS-562:** "It would be more relatable if you use something related to energy or power to represent the energy consumption information, for example, an electrical extension socket.", **LS-149:** "...I don't really understand what 30 kWh means, but I can understand what $5 means." and **LS-883:** "I am not sure if everyone will know what does kWh represent, but I...prefer dollars instead of kWh."

A significant portion of the study participants (65%) in the laboratory studies also indicated that it is more informative if their energy consumption information is represented in terms of days, weeks, or months instead of every minute or second, as they are uninterested in tracking their consumption at such high resolutions. An additional benefit for aggregating the consumption information is to display a higher overall cost to the users as some participants (14%) suggested that if the cost represented on the interface is too minuscule, it might have an opposite effect of discouraging the users from adopting the technology since it would not be worth the effort.

LS-249-250: "If it is cost, I would prefer that it gets shown as a collective whole, something like how much I spend per day. This would also be more realistic because I do not want to spend the time and effort to check the amount of money I spent every hour due to my usage.", **LS-368:** "...I do not think that you need to track your consumption every minute.", **LS-555:** "Display the total savings for that week first, and if the user wants to see more details, then they can maybe click a drop-down button to show the breakdown." and **LS-614-616:** "...if I turn off my laptop, and I learn that it only saves me $1, it would discourage me from saving. On the flip side, if I learn that it makes me save a lot, I would be encouraged to save more."

5.7. Data privacy

Data privacy refers to the users' right to control how their personal information will be used and who will have access to it.

Based on the results reflected in Fig. 7, it is observed that the issue of data privacy is of low concern (2.95) to the study participants compared to the other concerns listed. By segmenting the study participants based on their age groups where participants between the ages of 21 to 39 are categorised under one group while the rest are categorised under another, we noticed that both groups disagree on the importance of data privacy with the older participants having more significant concerns about their data privacy (4.42) compared to their younger peers (2.83). Furthermore, by dividing the participants based on their prior knowledge of SEMS, we noticed that participants that do not have prior knowledge of SEMS are, on average, more concerned about their data privacy (3.08) compared to their more knowledgeable peers (1.75). This finding contributes upon the findings of [15,28], which simply highlighted the importance of maintaining user privacy.

Among the study participants in the focus group discussions and laboratory studies who are concerned about their data privacy, they were especially worried about the misuse of their data and whether it would be misinterpreted. One of the most common examples raised by the study participants was the constant fear of being monitored by their supervisors and mistaken as not working just because they are not at their desks. Other participants were also concerned that their energy consumption levels would be used as an evaluation metric for their job performance, causing them to be passed over for a raise or promotion when they do not conserve enough energy for the company.

FG-47: "I am concerned that my supervisor would be able to find out that I am not at my desk when I am supposed to be.", **LS-1291-1292:** "I am concerned that my boss can check whether I am at my desk or not. They might interpret that since I am not at my desk, then I am not doing any work.", **FG-126:** "I do not want to be constantly monitored, misunderstood, and ostracized when energy usage was taken as an indicator of work performance." and **LS-1478:** "...my energy consumption might become part of the reason why I feel like I did not get a raise."

6. Design implications

The design implications highlighted in this section are divided based on the seven high-level categories depicted in Table 1 and aims to address the current challenges of increasing SEMS adoption in the workplace.

External and Internal Influence: When designing the user interface, developers should focus on features that allow users to monitor their current energy consumption and benchmark it against their historical consumption to track their performance. This design approach focuses on allowing users to be internally motivated and push themselves to reduce their energy consumption in the workplace.

User Appeal: The second design implication is related to maintaining long-term user engagement with the technology by introducing an achievement system as a feature in the SEMS. This feature combines several well-known concepts from incentivisation, goal setting, and gamification, where users will be rewarded with points for completing specific predefined goals or daily tasks associated with positive energy management habits, and these points can be subsequently used to redeem for different rewards or perks in the future.

User Control: While SEMS for plug loads are designed to help office users manage their energy consumption through different automation features, the system must continue to allow users to maintain control over their plug loads by enabling users to customise each plug load's control settings based on their desired preferences. This design feature is especially crucial for critical plug loads such as laptops and desktops as the repercussions of losing control of these plug loads will be highly detrimental to the users' willingness to adopt the technology. The system should also include a fail-safe mechanism where users can override the system if necessary and regain full control of their plug loads in a controlled manner. Lastly, the heterogeneity of devices and their use patterns indicate the need for developers of SEMS to develop and integrate additional software into different computing platforms to ensure safe staging of power shutoff sequences without losing the users' data.

Reliability: System reliability is deemed as one of the most critical attributes of a SEMS as an unreliable system would not only limit its ability to reduce energy wastage in the office, but it would also result in user frustration when their plug loads are unexpectedly switched off while in use. These flaws will lead to a loss of trust in the system's reliability and ultimately resulting in technology abandonment. Therefore, the fourth design implication involves recommending developers of future systems to prioritise the development of features that would ensure the reliable system operation. In the case of a system malfunction, the SEMS should notify the users and recover gracefully before returning full control to the users by default. Lastly, the SEMS for plug loads should also be error-proofed and include fail-safe mechanisms to avoid unintentional user errors, especially when dealing with critical devices such as desktops and laptops.

Ease of Use: The fifth design implication is to ensure that the interface is intuitive and convenient to use by adopting familiar design elements and providing information guides to flatten the users' learning curve and lower the adoption barrier. This design approach would allow users to quickly pick up the technology with minimal guidance and fully utilise the system features to maximise its impact. The system should also be convenient to use and does not intrude upon or significantly affect the users' daily routine so that the technology can be easily introduced into their current workflow. As a result, developers of SEMS for plug loads should strive to include automation features within the system.

Personalised and Contextualised Information: The sixth design implication involves displaying information to the user that increases their awareness and encourages positive energy management habits. This information includes informing the user of the negative impacts of their current behaviours or the benefits of desirable behaviours so that users can make actionable and practical changes to their daily habits. Personalised information should also be presented so that it is highly relevant to each user's individual use case. Lastly, it is also recommended to represent the information in the appropriate units and resolution to ensure that it is relatable to the users.

Data Privacy: Finally, the last design implication involves ensuring proper management of users' personal data (i.e., energy consumption and presence information) by anonymising any sensitive information and storing it in secure servers that can only be accessed by authorised personnel. The users should also have full control over their private data and are informed of any parties that will have access to it.

7. Conclusion and policy implications

In this study, we provided a better understanding of user perception and motivations when adopting SEMS for plug loads in the workplace by applying a mixed-methods approach consisting of focus group discussions, online surveys, and laboratory studies. Through a comprehensive analysis of the qualitative and quantitative data obtained through these data collection approaches, we grouped our findings using thematic analysis to obtain seven high-level categories related to the system design. These categories include External and Internal Influence, User Appeal, User Control, Reliability, Ease of Use, Personalised and Contextualised Information, and Data Privacy. Based on these findings, we proposed seven design implications that would guide the design of future SEMS for plug loads in the workplace.

While several of our findings aligned with previous studies conducted within the residential context, we were able to identify several new findings, and in some cases contradictory findings, that are unique to the workplace context. One of these new findings includes the user's preference for benchmarking their energy performance based on their historical consumption over competing with other colleagues in the organisation. The introduction of penalties was also found to be a particularly effective, albeit unpopular, strategy in encouraging participants to adopt SEMS to reduce their energy consumption. However, this finding will need to be field-tested to accurately evaluate its effectiveness and impact on the users' acceptance of the system. Thirdly, a significant portion of the participants indicated a strong preference for a semi-automated SEMS that allowed them to easily adjust the control settings for different plug loads to better fit their unique use cases. The participants also expressed strong concerns regarding the system's reliability due to its potential impact on the participants' work efficiency, especially when their plug loads are accidentally switched off due to system errors. Last but not least, concerns were also raised regarding data privacy as participants were worried about the misuse of their energy consumption data to monitor their movement patterns or treated as an evaluation metric for their job performance. Apart from these new findings, we have also identified several notable differences in the perceptions and motivations between participants from different age groups, industry sectors and prior knowledge of SEMS.

Besides considering the design implications when developing SEMS for plug loads in the workplace, it is also crucial to strengthen these efforts by introducing the appropriate policies at the organisation level to ensure the successful adoption of the technology in the long run.

It was highlighted in the previous section (i.e., External and Internal Influence) that study participants would be more likely to adopt SEMS in the workplace if the initiative was encouraged by their supervisors and similarly adopted by their colleagues. Therefore, the organisation should supplement the technology's roll-out with the appropriate company policies and workflows that encourage office users to adopt the technology collectively to sustain the initiative and empower their supervisors to enforce the policies implemented. The importance of gaining management support when adopting sustainable practices in the workplace also aligns with findings from similar studies [39].

On top of introducing company policies to encourage technology adoption, the organisation should also educate and train its employees on various aspects of the SEMS. It is an important factor to consider as the responses collected from the study participants show that those that do not have any prior knowledge of the technology are generally more concerned about their data privacy (1.75 versus 3.08), the system's usability (2.25 versus 3.70), and losing control of their plug loads (2.75 versus 3.79) compared to their more knowledgeable peers. Furthermore, it was highlighted in the previous section that participants with prior knowledge of SEMS are also, on average, more likely to use control features such as remote control, occupancy-based control, and schedule-based control to manage their plug load energy consumption in the workplace. Therefore, there is value in educating the employees of the capabilities of the SEMS as it not only ensures that the system' features are well understood and fully utilised to maximise any energy savings, it also serves to address any unfounded concerns and erroneous assumptions that would otherwise reduce the users' trust in adopting the technology.

Lastly, the organisation should also provide full disclosure to its employees on who will have access to their data, how their data will be used, and assuring them that their data will not be used as part of their performance evaluation.

Based on the insights gained through this study, we identified several future directions that could be explored as part of future works.

Firstly, while the use of a mix-method approach was useful in obtaining a better understanding of the users' perception and motivations when adopting SEMS in the workplace, a longitudinal field study is necessary to truly assess the users' long-term adoption and engagement of such systems in the long run. For instance, a proof-of-concept system can be developed based on the seven design implications identified in this study before evaluating the long-term energy impacts of the system. The introduction of advanced system features based on various machine learning approaches [40] can also be integrated to provide users with more control over their plug loads. This suggestion aligns with the design implication on "User Control."

While the study was conducted in Singapore, we have taken several steps to increase the generalisability of our findings beyond the study area by recruiting participants of diverse nationalities and those working in multinational firms as they might be influenced by organisational policies, which are enforced throughout the organisation. However, to ensure that the findings are truly generalisable between different cultural and geographical contexts, a large-scale study could be conducted in multiple countries before comparing the findings to identify overlaps in the participants' perceptions and motivations. It would also be interesting to investigate the rationale behind the differences between different contexts and propose field-tested solutions to resolve these disparities.

Lastly, given that the findings presented in this paper are obtained predominantly based on the office workers' point of view, it would be appropriate to expand the scope of the study to cover the organisational perspective or to other non-residential contexts (e.g., retail stores, hotels and industrial sites) to increase the applicability of the work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

A.1. Energy management habits

To gain a deeper understanding of the study participants' energy management habits in the workplace, each participant was also asked to share their plug load switch off behaviours during short-term and long-term absence events for different plug loads types commonly found in the workplace. These plug loads include monitors, laptops, desktops, task lamps, desk fans, and other miscellaneous devices (e.g., coffee machines, chargers, and humidifiers). In this study, we refer to a short-term absence event as when the office occupant leaves his desk during the day but returns after some time within the same day, while a long-term absence event involves the office occupant leaving his desk at the end of the day and only returning in the next work day. Based on the participants' responses depicted in Fig. 8, it is observed that the participants' plug load switch off habits is significantly different between these two events, whereby they are less likely to switch off their plug loads during a short-term absence event compared to a long-term absence event. The results showed that only

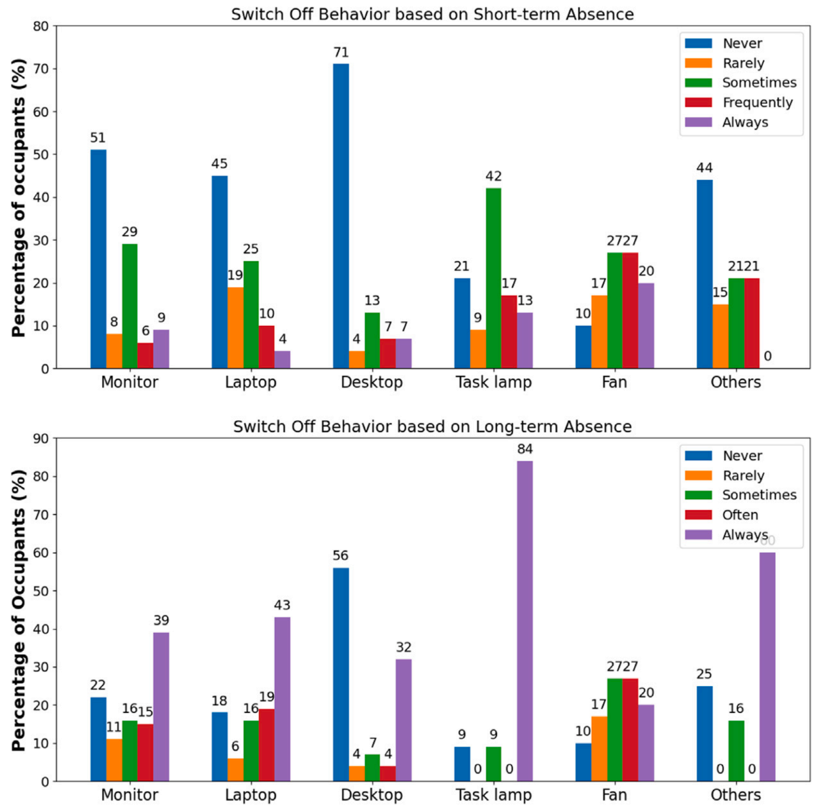

Fig. 8. Frequency of switch off behaviours during short-term (Top) and long-term (Bottom) absence events represented based on the participants' ownership of each plug load. $n_{monitor} = 103$, $n_{laptop} = 142$, $n_{desktop} = 51$, $n_{tasklamp} = 43$, $n_{fan} = 48$, $n_{others} = 69$).

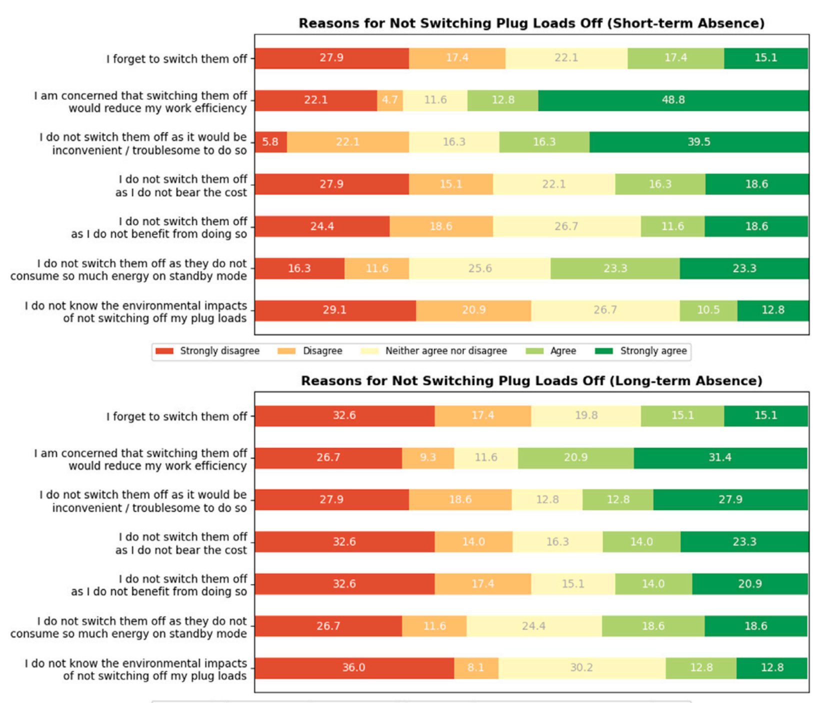

Fig. 9. Different reasons explaining the participants' plug load switch off behaviours during short-term (Top) and long-term absence events (Bottom) obtained from the survey responses ($n = 86$).

27% of the participants mentioned that they will always or frequently switch off their plug loads during a short-term absence event compared to 57% during a long-term absence event.

The participants' switch off behaviours also differs between different plug load types during a short-term absence event as they are more likely to never or rarely switch off their desktops (75%), laptops (64%),

Fig. 10. Heat map showing the number of responses that have been categorised under any two categories..

monitors (59%), and other miscellaneous devices (59%) compared to their task lamps (29.2%) and desk fans (26.7%). When the participants are asked about the rationale behind their switch off behaviour, most of them agreed that it was too inconvenient or troublesome to do so (60.5%) since they will have to switch it back on when they return, as reflected in Fig. 9.

On the other hand, when it comes to long-term absence events, the participants are not only more likely to switch off their plug loads compared to short-term absence events, but their behaviours are also more consistent between different plug load types. More specifically, 84% of the participants mentioned that they would frequently or always switch off their task lamps, 62% mentioned they would do so for their laptops, 60% for other miscellaneous devices, 54% for monitors, 47% for their desk fans, and lastly 36% for their desktops. The most prevalent reasoning behind the participants' switch off behaviours during long-term absence events is to avoid disruptions to their work efficiency especially when they have uncompleted work which they intend to resume the next day (refer to Fig. 9).

A.2. Response statistics

The qualitative responses collected from the focus group discussions and laboratory studies are combined, segmented, and cleaned of any uninformative comments to result in over 1400 individual responses. Through an analysis of the combined codes assigned by the three independent researchers, the number of responses assigned to each hierarchical category can be sorted in descending order starting with Ease of Use (753), Personalised and Contextualised Information (364), User Appeal (156), User Control (151), Reliability (84), External and Internal Influence (40), and Data Privacy (28). Since each response can be assigned to more than one hierarchical category, Fig. 10 provides a visualisation of the number of responses that have been categorised under any two categories. With the vast majority of the responses assigned under one category with minimal amount of overlap between any two categories, this result provides strong evidence that the hierarchical categories are well-defined, unambiguous, and mutually exclusive.

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