Energy Saving Behaviours of Occupants in a Multi-Tenant Zero-Carbon Office Building: The Integration of Social Influence Theory and the Energy Cultures Framework

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

Energy sustainability in the building industry has received increased attention as building technologies become more energy efficient and the building codes become more stringent. However, the role of occupants in energy conservation of commercial buildings has not been studied as often. This study documents changes and the impact of occupant behaviour on energy usage in a net-positive, zero-carbon office building in Ontario, Canada. The integration of social influence theory and the energy cultures framework sheds light on the interactions between human and physical factors which influence the energy sustainability of buildings. This study examined stairs usage, as well as electricity usage for lighting and plug loads in order to document and gain insights into occupant behaviour. The effects of multiple interventions, such as structural interventions, information provision, and the COVID-19 pandemic, were investigated to see changes in occupant behaviour and its impact on electricity usage in the building. This study also explored how social influence related to occupant energy saving behaviour in the zero-carbon building, which would reveal the influence of socio-psychological factors on occupant behaviour. The results of this study demonstrate the importance of occupant behaviour for energy sustainability of buildings, and illustrates that the role of occupants in energy saving becomes more important when building technologies become more energy efficient. From the perspective of the energy cultures framework, material culture, such as the building design, the presence of a central staircase, devices, and appliances, was found to have a strong impact on both stairs usage and electricity usage of occupants in the building. However, the results also indicate that material culture alone may not promote energy saving behaviour among occupants over the long run, and further stimulation on cognitive norms and energy practices is necessary to maintain energy saving behaviour by occupants. Furthermore, the predicted impact of social influence was not observed

on energy saving behaviour of occupants in the building. Nevertheless, the results also implied that electricity usage for plug loads may be more subject to social influence since individual occupants had more control over plug loads than lighting. Hence, this study contributes to the understanding of the relationships between human and physical factors, as well as the role of occupants in the zero-carbon building by developing a holistic approach to energy sustainability.

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1. Introduction

Achieving a low carbon future is important for climate change mitigation and a sustainable future. While the buildings and construction sectors are accounted for 40% of carbon emissions, decarbonization in these industries is crucial to accomplish sustainable goals set for the Paris Agreement (United Nations Environment Programme, 2019). However, research often focuses on the technical solutions without recognizing the equal importance of socio-psychological approaches toward low carbon targets and energy sustainability. As a result, the relevance of human behaviour is overlooked in many energy studies (Sovacool et al., 2015). The building industry illustrates this challenge as human decisions greatly influence the energy and carbon performance of the building. This research will document the effectiveness of various interventions designed to encourage occupants to reduce energy consumption and to achieve zero carbon design goals of an office building.

1.1 Emergence of zero-carbon and zero-energy buildings

New buildings are becoming more sustainable and energy efficient due to the increasing concern about climate change, and more strict building codes are increasingly designed to reduce the environmental impact of buildings. The construction of sustainable and energy efficient buildings, such as zero-carbon buildings, is expanding because of increasing demand for energy efficiency and durability of buildings (Day, 2014). According to Canada Green Building Council (2017), the definition of a zero-carbon building is “one that is highly energy-efficient and produces onsite, or produces, carbon-free renewable energy in an amount sufficient to offset the annual carbon emissions associated with operations” (p.4). A zero-energy or net-zero energy building is another similarly used term for a green building, and it refers to a building which generates the equal amount of energy it consumes on site in a year (Hui, 2010; Pan, 2014). Zero-carbon buildings are targeted as a key criterion for future buildings in the international context as the United Nations proclaimed the necessity of governmental and local actions to reduce carbon emissions of buildings in the next few decades (International Institute for Sustainable Development, 2019; United Nations Environment Programme, 2019). In order to respond to this international call for building sustainability, Canada also aims to have building codes require net zero-energy buildings by 2030 (Government of Canada, 2018). Although governments and building developers are paying more attention to green buildings, the energy performance of green buildings in the post-occupancy period has been studied much less, especially in Canada (Ouf, Issa, & Polyzois, 2013). Thus, the management of green buildings, including zero-carbon and zero-energy buildings, requires more research exploration.

1.2 Behaviour and Energy Performance of Buildings

Predicting a building's energy performance is not an easy task due to various physical and social factors affecting energy demand in the building. Researchers argue that the performance gap of a building, that is the discrepancy between the estimated and actual energy consumption of the building, is attributed to the structure, facility management, institutional measures, as well as occupant behaviour (Abrahamse, Steg, Vlek, & Rothengatter, 2005; Barthelmes, Becchio, & Corgnati, 2016; Fedoruk, Cole, Robinson & Cayuela, 2015). Past studies also demonstrate that the energy demand of buildings is largely subject to individuals' energy consumption behaviour. In the residential sector, Gill, Tierney, Pegg, & Allan (2010) found that individual users influence the demand for heat by 51%, electricity by 37%, and water by 11% in British houses. Even in energy efficient houses, the energy demand of the house can be 76% higher with energy-intensive users and 83% lower with less energy-intensive users, compared to the baseline (Barthelmes et al., 2016). Moreover, Parker , Mills, Rainer, Bourassa, and Homan, (2012) studied energy consumption of

428 houses in Florida, the US, which had the same building characteristics. The houses were built in the same year by the same builder, and had the same windows, as well as the same heating and cooling systems. The authors revealed that the total electricity consumption varied by a factor of three, while the houses with the highest electricity consumption and the lowest consumption were the same size with the same number of bedrooms (Parker et al., 2012). Other researchers similarly observed considerable differences in the total energy demand among similar buildings (Firth, Lomas, Wright, & Wall, 2008; Gram-Hanssen, 2013). The use of appliances, lighting, and water greatly affects energy consumption of households, which suggests that the lifestyle of the occupants is the major source of discrepancy in energy usage of residential buildings (Barthelmes et al., 2016). Thus, energy demand of residential buildings varies according to energy usage of households.

In the commercial sector, the impact of occupant behaviour on the energy consumption in the building is also significant. Hong & Lin (2013) indicate that private offices with energy-intensive work culture can increase 89% of energy consumption, while offices with energy-saving work culture can reduce 50% of energy consumption compared to the standard energy usage. The authors also argue that the thermal setting of office buildings can significantly change the total energy demand of workplaces. Moreover, van Dronkelaar, Dowson, Burman, Spataru, and Mumovic (2016) found that offices had a larger performance gap than other types of buildings. The actual energy consumption was 22 % higher in average than the predicted energy consumption in UK, and occupant behaviours, including lighting, adjusting blinds, temperature setting, the use of office equipment, and the rate of occupancy, are some of the major sources of such discrepancy (van Dronkelaar et al., 2016). This demonstrates that occupant behaviour is also influential to energy demand of office buildings, and organizational culture is relevant to energy conservation in the workplace. Ultimately, past studies strongly support the idea that individuals' behaviour greatly contributes to variances of energy demand in both residential and commercial buildings; therefore, high energy consumption of buildings can be attributed to individuals' energy decisions. Indeed, occupants play an increasingly important role in determining the energy consumption of buildings as technological advancements make heating systems and envelopes more energy efficient (Carpino, Mora, Arcuri, & De Simone, 2017; Owens & Driffill, 2008; P. Zhu, Gilbride, Yan, Sun, & Meek, 2017). As a result, the discretionary decisions of occupants become influential in relative terms.

What is more, energy usage of occupants in green buildings can be more intense than conventional buildings. This phenomenon is called *rebound effect* which is increased energy consumption due to the implementation of energy efficient technology (Herring & Sorrell, 2009). When occupants feel positive about their buildings due to its sustainability and energy efficiency, they may offset the savings by consuming more energy (Guerra Santin, 2013; Midden, Meter, Weenig, & Zieverink, 1983). For instance, researchers found that people adjusted the thermal setting higher after renovating their houses (Calì, Osterhage, Streblow, & Müller, 2016; Guerra Santin, 2013; Hong, Gilbertson, Oreszczyn, Green, & Ridley, 2009). This illustrates that technological advances do not always solve the issue of energy usage due to conflicting behaviours by people. Pan (2014) also argues zero-carbon buildings are "complex socio-technical systems" (p.434). Thus, being certified as 'green buildings' does not necessarily prove sustainability in the real performance of the buildings. This shows that understanding occupant behaviours is relevant to reducing the discrepancy in energy consumption as well as carbon emissions of buildings, even in green buildings. Therefore, factors which motivate sustainable energy consumption of individuals need to be investigated.

1.3 Research Objectives & Questions

This study examines the energy saving behaviors of occupants in a zero-carbon office building in Ontario. The purpose of this study was to investigate how socio-psychological factors and material factors interact with each other and encourage individuals to consume energy in a sustainable way. This study also aims to show the impact of occupant behaviour specifically on electricity usage for lighting and plug loads in the zero-carbon building. From the perspectives of social influence theory and the energy cultures framework, the following research questions were addressed in this study:

(a) How does energy saving behaviour of occupants change and relate to social norms when structural and informational interventions are introduced?

(b) How do social identities of the occupants, the group norm regarding pro-environmental behaviour, and the amount of electricity usage relate with one another?

(c) How do occupants make an impact on electricity usage of a zero-carbon building?

Understanding the effect of social influence on an individual's energy saving behaviour is crucial to facilitate the reduction of energy demand as well as carbon emissions of buildings. The energy cultures framework is also applied to explain how social influence can affect other physical and human aspects of buildings, which potentially triggers behavioural change in the green office building. This study offers insights into the following aspects: the impact of social influence in the workplace, energy saving behaviours of occupants in zero-carbon buildings, and the interactions between physical and human factors that potentially affect energy usage of occupants.

1.4 Conceptual Framework

This study applies social influence theory and the energy cultures framework to develop the understanding of the relationship between occupant behaviour and energy consumption of a zero-carbon office building. Social influence theory is used to examine aspects of behavioural changes in energy conservation through lenses of social-psychology. Therefore, this study focuses on the perspective of social influence theory to address the aforementioned research questions, and to investigate the impact of social influence on energy usage of occupants in a green office building. At the same time, the energy cultures framework is employed to study behavioural changes of the occupants in the building from a broader perspective. Since this study is based on the world view that energy usage is the result of interactions between human and material factors, the energy cultures framework helps the author conceptualize how the building and occupants are integrated to shape energy behaviour in a zero-carbon office building. This ultimately leads the reader to the broader picture of how social influence fits in the energy cultures framework to promote sustainable energy consumption in a zero-carbon office building. The following sections will explore the literature related to these key concepts.

2 Literature Review

2.1 Occupants' engagement in energy conservation

Past researchers have demonstrated that engaging occupants in energy conservation is essential to change their behaviour. Different types of interventions have been employed to study energy saving behaviour of occupants. One of the prevalent interventions is to provide information about environmental issues or particular information to solve existing problems, such as energy saving tips to reduce wasteful consumption of electricity (Abrahamse et al., 2005; Judd, Sanquist, Zalesny, & Fernandez, 2013). When people receive such information, they will be conscious about environmental problems and they will gain understanding of how to mitigate the impact of their actions (Abrahamse et al., 2005; Judd et al., 2013). As Scott, Amel, Koger, and Manning (2016) note "[b]ehavior can't change without some knowledge" (p.172), information provision plays an important role in encouraging people to initiate behavioural changes by offering instructions on what they need to do.

Asensio and Delmas (2015) revealed the effectiveness of health and the environment related information on energy conservation in households. The authors divided 118 households into two groups; one group received information about electricity costs of their home, and another group received information about health and environmental consequences, such as cancer and air pollution, which can potentially be caused by electricity consumption. The participants were provided with either type of information, and they were also able to check real-time energy consumption of their home (Asensio & Delmas, 2015). The results show that those who received health and environmental information reduced their energy usage by 8.2% while those who received cost-related information did not lower their energy consumption (Asensio & Delmas, 2015). The authors suggest that people were motivated to conserve energy because reducing health and environmental impact was considered beneficial for themselves. In addition, households with children reduced their energy usage further by 19.1%, and the authors note that tailored information which is targeted at specific people is more effective to change energy saving behaviours. Thus, information provision can potentially encourage people to save energy, and past experimental studies (Asensio & Delmas, 2015; Delmas, Fischlein, & Asensio, 2013) also illustrate the effectiveness of information provision on energy conservation.

On the other hand, some researchers argue that information provision is not a sufficient trigger for behavioural changes. This is suggested by Geller (1981) who revealed that there were no significant differences between energy saving behaviours of workshop participants and those of non-attendees who did not attend workshops about energy saving in households. Although the author notes that workshop participants' concern for energy issues increased, post-workshop surveys found that there were only a few differences in energy saving practices between workshop participants and non-attendees, which were not statistically significant. Other researchers also state that information does not necessarily convince people to take certain actions but it increases the likelihood of behavioural changes when information is offered with other types of interventions (Abrahamse et al., 2005; Lokhorst, van Dijk, Staats, van Dijk, & de Snoo, 2010). As a result, information provision is commonly used with other interventions, such as feedback, to create stronger stimulation for pro-environmental behaviour.

Staats, van Leeuwen, and Wit (2000) combined different types of interventions, including information provision, to study employees' behaviour to improve the efficiency of heating systems in an office building. The authors examined changes in their behavior for 11 weeks by using information provision in combination with different interventions. Brochures were provided to each employee in the building with the message telling them to make space near the openings of ducts and to change the setting of the room temperature for energy saving (Staats et al., 2000). In the initial stage of the experiment, posters were also displayed in offices to help people remember the energy saving actions (Staats et al., 2000). Moreover, the authors described the percentage of departments which followed the guideline for energy conservation on the posters in the hallways, which can be regarded as a type of group feedback. The results showed that nearly 40% of offices in the building kept the space open near ducts and changed the temperature settings according to the information provided. The authors found that the employees continued these behaviours recommended by the interventions even after 2 years, and the amount of natural gas was estimated to be 6% lower, which was equivalent to $6,000 over 2 years. Thus, multiple interventions, including information provision, can be combined to encourage energy saving behavior of occupants, and their effect can last in the long run as the study showed.

Approaches to occupants' engagement in energy conservation may differ depending on the situation, and the organization setting can be more difficult to engage occupants in energy saving practices than the household setting. Researchers argue that employees in the workplace may not be as enthusiastic as households about their energy conservation since they are not responsible for electricity costs; in addition, other employees also affect the organization's energy usage that cannot be managed by individuals (Carrico & Riemer, 2011; Siero, Bakker, Dekker, & Van Den Burg, 1996). This suggests that energy saving in the workplace can be perceived as an organization's responsibility by occupants rather than their own responsibility, which may diminish occupants' motivation for energy saving. Therefore, energy conservation in the organizational setting requires different approaches from the private setting.

Dixon, Deline, McComas, Chambliss, & Hoffmann (2015) argue that socio-psychological factors affect decision making of occupants on energy saving in the workplace. The authors examined the relationship between occupants' perception on social norms – that is how they think other people would response to energy saving – and their intention to reduce energy usage in the workplace. The research found out that the perception of social norms had a positive relationship with occupants' intention to save energy (Dixon et al., 2015). This means that when people believe other people would be supportive about energy saving, they would also choose to reduce their energy consumption in the workplace. Furthermore, the authors investigated whether the sense of community is relevant to energy conservation in the organizational setting. They revealed that sense of community positively correlated with behavioural intentions to save energy, as well as with self-reported energy saving behavior. This finding also corresponds with the argument of Carrico and Riemer (2011) that occupants in the workplace may be more subject to normative influence, which can potentially encourage them to save energy due to peer pressure.

Likewise, other studies demonstrate that socio-psychological factors, such as normative influence, can stimulate energy saving behaviors of occupants in the workplace by introducing interventions (Shippee & Gregory, 1982; Siero et al., 1996). Nevertheless, the research on the subject has not been adequately explored in the organizational setting since most research focuses on the private setting (Abrahamse, Steg, Vlek, & Rothengatter, 2007; Grønhøj & Thøgersen, 2011; Midden et al., 1983; Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008; Pallak & Cummings, 1976; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007; M. G. Scott, McCarthy, Ford, Stephenson, & Gorrie, 2016; Stahl & Love, 1985). What is more, it is uncertain how occupants' perception of norms relates with their energy saving behaviours, which is a key aspect of energy conservation in the organizational setting. Hence, understanding of occupants' energy saving behaviours in the workplace needs to be developed further.

2.2 Social Influence Theory

Social influence is one of the approaches to understand the mechanism of how people are convinced to change their behaviour and actions. The theory considers that human behaviour and attitudes are shaped by an individual's perception of other people, and it regards pro-environmental behaviour, including energy saving, as susceptible to the social settings and other people's behaviour (Abrahamse & Steg, 2013; Allcott, 2011; Lede & Meleady, 2018; Salazar, Oerlemans, & Van Stroe-Biezen, 2013). Thus, examining an individual's energy saving behaviour from the perspective of social influence theory presents the socio-psychological aspects of sustainable energy consumption at the individual level, which has not been adequately understood.

Social influence is "the process whereby people directly or indirectly influence the thoughts, feelings, and actions of others" (J. C. Turner, 1991, p.1). The fundamental concept of social influence is that people normally consider behaving like other people to be a correct choice (Cialdini, 2007). As a result, the perception of other people becomes a cue to take particular actions, which is naturally programmed in humans (Cialdini, 2007). This is illustrated by fake laughter in television programs that attracts audiences to watch, as well as by fake tips in bartenders' jars that persuade customers to offer tips (Cialdini, 2007). As these examples demonstrate, social influence is prevalent in the everyday life of an individual, and it can be in the forms of "conformity, socialization, peer pressure, obedience, leadership, persuasion, minority influence and social change" (Smith, Louis, & Schultz, 2011, p. 599). In addition, social influence can also be incorporated in advertisements, sales messages, political propaganda, and publications (B. A. Scott et al., 2016). People are, therefore, exposed to social influence all the time, and they may not be conscious of such influence since social influence can be concealed in information or attitudes of others.

Social norms play an important role in social influence as they can strongly restrain people's actions. A social norm refers to "a generally accepted way of thinking, feeling or behaving that it is endorsed and expected because it is perceived as the right and proper thing to do" (J. C. Turner, 1991, p. 3). Social norms emerge from communications and membership among people in a particular social group (J. C. Turner, 1991, p. 2). If individuals act against social norms, they can be labelled as strangers who do not belong to particular groups or regarded as "a potential threat" by others (B. A. Scott et al., 2016, p. 129). Since humans have evolved in a way that they build and comply with social norms (Goldsmith & Goldsmith, 2011; B. A. Scott et al., 2016), it is the nature of humans to be sensitive to other people's actions and opinions, and adapt themselves to behaviours of others. For this reason, people are likely to be constantly conscious of social norms, that is what other people do and think. Consequently, they tend to be hesitant about behaving against social norms because they do not want to be alienated from a particular group.

Social norms can be divided into two major forms: *descriptive norms* and *injunctive norms*. Descriptive norms express what people normally do, and they are changeable depending on the situation (Farrow, Grolleau, & Ibanez, 2017; B. A. Scott et al., 2016). Descriptive norms include what people generally wear, how people talk to each other, or how people behave in a particular setting, such as in a library or public transportation. In contrast, injunctive norms refer to what people should do, and they influence people's actions by suggesting proper or socially approved behaviour (Farrow et al., 2017; B. A. Scott et al., 2016). Injunctive norms can be illustrated by situations in which people need to behave quietly in the library, or people should offer seats to seniors on public transportation. While norms are considered to be more indirect and complicated than rules and regulations, people can sense the force of norms which urge them to comply with the social settings (B. A. Scott et al., 2016). Therefore, attitudes and behaviour of individuals are often subject to social influence, and this means that people are psychologically pressured by social norms.

Moreover, social influence theory considers group norms and identities to be key determinants of an individual's behaviour in a group, rather than attitudes. Past research has found that attitudes on their own are not a strong predictor of behaviour (Owens & Driffill, 2008; Wicker, 1969), and likewise some researchers argue that pro-environmental behaviour does not always have consistent relationships with the environmental attitudes of people (Gatersleben, Steg, & Vlek, 2002; Owens & Driffill, 2008). For instance, residents who are more concerned about environmental issues consumed more energy because their high living standards corresponded to their heavy energy consumption (Gatersleben et al., 2002). This demonstrates that attitudes are not reliable to predict an individual's behaviour, and that changing attitudes does not necessarily translate into changing behaviour.

Smith and Louis (2009) argue that group norms can be an intermediate between attitudes and behaviour, and they also regard people's identities as the likely driver of behavioral changes. When people believe that they are part of a particular group and this membership is crucial to them, they tend to comply with the perceived group norms more (Goldstein & Cialdini, 2007; Smith & Louis, 2009). This is consistent with the basic assumption of social influence theory that people transform their actions according to other people due to their willingness to remain in a group. J. C. Turner (1991) also notes that the likelihood of complying with a particular group norm depends on the magnitude of group unity because people desire to be accepted by the members of the group which is appealing to them. Theoretically, people follow group norms in three steps: (1) they determine their group to define their social identity; (2) they establish or find particular group norms accepted by other members; and (3) they adapt to the group norms, which enhances their sense of belonging to the group (Hogg & Abrams, 1998). Thus, group norms are an essential criterion to determine the actions and attitudes of individuals, and identities help them build the foundation of the course of actions.

Terry, Hogg, and White (1999) examined the role of group norms and identities in recycling among households. Residents self-reported their recycling practices for two weeks, and the authors inspected the recycling rate in comparison with the following two factors: their perceived group norm on how important recycling is to their group, and the strength of their identities associated with the group. The results of the study showed that people committed to recycling more when they believed recycling was a group norm plus when they felt they strongly belonged to the group (Terry et al., 1999). This experimental study demonstrates that perceived group norms and the sense of identities to particular groups significantly affect an individual's decision making on exercising pro-environmental behaviour.

2.3 Energy Cultures Framework: Multifactorial Aspects of Energy Conservation

Energy conservation requires understanding of energy usage as a complex system where technical and human factors are intertwined. Researchers argue that technological advancement cannot solely solve the issue of energy conservation because behavioural aspects are equally important to promote sustainable energy usage (Barthelmes et al., 2016; Gram-Hanssen, 2013; Lopes, Antunes, & Martins, 2012; Siero et al., 1996). The energy cultures framework illustrates how energy saving behaviour is influenced by multiple factors, and it offers a broader framework to view energy conservation in buildings.

The energy cultures framework considers behaviour to be shaped by "the interactions between cognitive norms, energy practices and material culture" (Stephenson et al., 2010, p. 6127). Cognitive norms in this framework refer to "people's expectations and aspirations about their practices and material culture" (Stephenson et al., 2015, p. 119). This includes how people consider their energy consumption should be (e.g. the room temperature they expect and types of devices they expect to use), as well as what they hope for their energy consumption (e.g. whether they desire to use energy efficient technologies and types of technologies they hope to use) (Stephenson, Barton, et al., 2015). Energy practices in this framework cover from "everyday habitual activities to the less frequent process of choosing and acquiring material objects" (Stephenson et al., 2015, p. 119). The term encompasses all actions taken by people for energy usage, and this is distinguished from 'practices' used in practice theory that focus more on routines (Stephenson, 2018; Stephenson, Barton, et al., 2015). Thus, energy practices here consider how people consume energy both in everyday life (e.g. the way people normally use energy in the workplace), as well as in irregular situations (e.g. purchase of new appliances). Finally, material culture in this framework includes what is used for energy consumption, such as devices, buildings, and other resources (Stephenson, Barton, et al., 2015). The term contains physical objects which directly and indirectly contribute to energy usage (e.g. appliances, electricity meters, and insulation) (Stephenson, Barton, et al., 2015). As it is shown, these three key components of this framework extend to a wide range of physical and nonphysical factors affecting energy consumption. Consequently, they are illustrated as key components of people's energy saving behaviour.

In the energy cultures framework, cognitive norms, energy practices and material culture are considered to interchangeably affect each other. Cognitive norms have an effect on what technologies are used by people and how people consume energy (Stephenson et al., 2010). On the other hand, existence or lack of particular objects may shape cognitive norms of people, and may predetermine people's actions when energy is used (Stephenson et al., 2010). Similarly, energy practices can equivalently persuade people to choose particular types of technologies, and develop people's perceptions of energy usage (Stephenson et al., 2010). As a result of interactions among the three components, energy saving behaviour is formed and this can be difficult to alter (Stephenson, Hopkins, & Doering, 2015). For example, the type of equipment, such as heat pumps in the household, is regarded as material culture, and how heat pumps are used for shower or heating systems represents energy practices while the temperature that the household is willing to set is determined by cognitive norms (Stephenson, 2018). Thus, the choice of technologies, the way they are used, and users' perceptions of their energy usage are greatly influenced by each of the three components; consequently, their interactive relationships establish people's energy behaviour in a particular context (Figure 1).

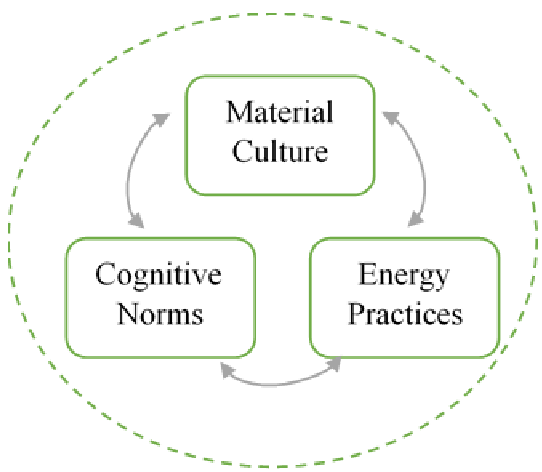

Figure 1 The energy cultures framework (adapted from Stephenson et al., 2010; Stephenson, Lawson, Carrington, Barton, & Thorsnes, 2011)

The framework emphasizes the importance of both technical and behavioural aspects of energy conservation. Gram-Hanssen (2013) argues that technological and behavioural aspects of energy saving need to be integrated in order to address energy conservation of a building with the focus on occupants. People interact with building systems to consume energy, such as by turning on lights and changing temperature setting of air conditioners; thus, the interactions between people and buildings significantly contribute to the increase in energy demand of the building (Hong, Taylor-Lange, D'Oca, Yan, & Corgnati, 2016; Morris, Hong, Chiu, & Liu, 2015). This means that sustainable energy usage in buildings cannot be solved without understanding relationships between physical and human factors, and a holistic view on energy saving behaviour is necessary to develop effective strategies for energy conservation. The energy cultures framework is also formed based on the idea that energy usage is part of "cultural processes" where material factors, knowledge, values, and actions are intertwined (Stephenson, 2018). This suggests that energy consumption comprises multiple components, including both physical and human factors. Therefore, a systematic view may offer an insight into energy saving behaviour in a green office building which has a unique setting.

Although the energy cultures framework was initially employed to understand energy saving behaviours in households (Stephenson, Barton, et al., 2015; Stephenson et al., 2010), Walton, Zhang, and O'Kane (2019) propose its application to energy conservation in organizations, and the framework potentially helps researchers understand effective approaches to energy sustainability of organizations. The authors found three major pattens in which corporations can shift their business procedures toward energy sustainability in workplaces through the interaction of material culture, energy practices, and cognitive norms. In the first pattern, organizations encounter changes in material culture, such as installing new heating systems. The changes in material culture may not cause any changes in the business process; however, it is possible that cognitive norms within the organization are affected by such physical changes (Walton et al., 2019). As the energy cultures framework describes with double arrows, material culture and cognitive norms are interrelated. Consequently, the installation of new technologies may affect the way people perceive energy equipment they use, which may enhance energy efficiency of business operations (Walton et al., 2019). In this way, organizations can change their business cultures toward energy conservation with the use of physical objects.

In the second pattern, organizations change their energy practices in order to gain economic benefit. For example, organizations may decide to operate heating systems more efficiently because they want to reduce the cost of electricity bills (Walton et al., 2019). If the organizations consider that existing operation is not appropriate for energy conservation after inspecting current energy management practices, it is possible that they decide to purchase new energy efficient products. Thus, energy practices in organizations also have a potential to affect material culture. Moreover, the connection between energy practices and norms is crucial to improve the organizations' capacity to develop energy cultures (Walton et al., 2019). The organization can offer employees guidelines or information to educate them on energy efficient actions, which enables the employees to understand the importance of new energy practices. Thus, successful promotion of energy practices requires alignment with cognitive norms so that employees will be motivated to act on new customs.

In the third pattern, cognitive norms stimulate energy saving actions of organizations by affecting material culture and energy practices. Environmental values can be emphasized in the workplace as well as business schemes when the executives are strongly driven by environmental concerns (Walton et al., 2019). In such a situation, material cultures are established in a way that they align with the organization's environmental values (Walton et al., 2019), such as the use of energy efficient equipment. Energy practices inside the corporation can also be shaped by the notion of eco-conscious business (Walton et al., 2019), which may lead to energy efficient operation of the buildings and energy saving actions of employees. Hence, three components of the energy cultures framework – material culture, energy practices, and cognitive norms – can trigger sustainable energy behaviour. When the impact of these three components is strong, they can influence one another to enhance energy saving behaviours within the organization.

2.4 The Integration of the Energy Cultures Framework and Social Influence Theory

Since the energy cultures framework is a relatively new concept developed in 2009 (Stephenson, Barton, et al., 2015), there have not been any studies which report the application of the framework to green office buildings yet. As past studies show that people do not necessarily practice energy saving behaviour in highly energy efficient buildings, it is considered that material culture, such as advanced building technology, alone may not promote energy saving behaviour among occupants in green office buildings. In order to promote energy saving behaviour of occupants in green office buildings, external influences may play a role in affecting the three factors in the energy cultures framework. The framework views that material culture, energy practices, and cognitive norms can be pressured by external factors which can cause behavioural change (Stephenson, Barton, et al., 2015). The examples of external influences include social norms, and such influence can reach out to more than one component of the energy cultures framework at the same time (Stephenson, Barton, et al., 2015). This suggests that social influence may play a role as an external factor in affecting material culture, energy practices, and cognitive norms of people in a green office building. Consequently, this may result in behavioural changes to promote energy conservation in the building. For instance, social norms which suggest that people turn off lights in unoccupied rooms may influence cognitive norms and energy practices in the energy cultures framework. People may start thinking that turning off lights is appropriate and they may be encouraged to do so whenever they leave unused rooms. Therefore, social norms can play a role in energy conservation of office buildings by influencing cognitive norms and energy practices of occupants.

It should be also noted that cognitive norms in the energy cultures framework and social norms in social influence theory are two different concepts. The term ‘cognitive norms’ in the energy cultures framework was not developed from the psychological field, and this is the original concept established for the framework (Stephenson, Barton, et al., 2015). In the energy cultures framework, the authors use cognitive norms as “norms that are reflected in a subject’s current practices and material culture;” norms desired by the subject are referred to as ‘expectations’ and norms which have not been achieved are referred to as ‘aspirations’ (Stephenson, Barton, et al., 2015). On the other hand, social norms in social influence theory derive from the psychological field, and the term is used as implicitly indicated and expected ways of behaviour and actions within groups (Scott, et al., 2016). Social norms function as implied disciplines within groups to shape behaviour of individuals for a group order (Scott, et al., 2016). Based on the literature, cognitive norms in the energy cultures framework are subjective perspectives of an individual on how he/she should or hopes to use energy. In contrast, social norms in social influence theory are how an individual feels he/she has to behave in a group due to the individual’s perception of other people. Therefore, the two terms have different meanings and should be distinguished.

While it is a new approach to apply both social influence theory and the energy cultures framework, this may offer new insights into the interactions between physical and human factors for energy conservation in a zero-carbon building. Previously published studies on social influence have not dealt with pro-environmental behaviour in green office buildings despite the projection of industry growth for zero-carbon and net zero-energy buildings. Since behaviours of occupants tend to have more influence on energy performance of green buildings due to the development of energy efficient technologies, (Brown, Dowlatabadi, & Cole, 2009), energy saving behaviour of individuals is an increasingly important aspect for energy sustainability of buildings. Hence, academic understanding about the effect of social influence on occupants' energy consumption needs to be developed particularly in the field of green buildings to mitigate the impact of human factors on energy usage.

At the same time, the application of the energy cultures framework will offer the multifaced view of energy saving behaviour by revealing how material culture, energy practices, and cognitive norms interact with each other. In this framework, social influence can affect occupants' cognitive norms and energy practices as an external stimulus, which may ultimately promote energy saving behaviours in a green office building. Material culture, such as physical features of the zero-carbon building, may equally affect other factors within the framework to encourage energy saving behaviours of the occupants. This study also may contribute to the advancement of the energy cultures framework since not much research has applied the framework to zero-carbon buildings. Ultimately, social influence theory helps researchers examine socio-psychological factors of energy saving behaviour, while the energy cultures framework offers a broader scope of the mechanism for energy conservation. As a result, applying both social influence theory and the energy cultures framework may provide a more comprehensive perspective on how people response to social influence, as well as how physical and human aspects of the building are intertwined to establish sustainable energy usage (Figure 2).

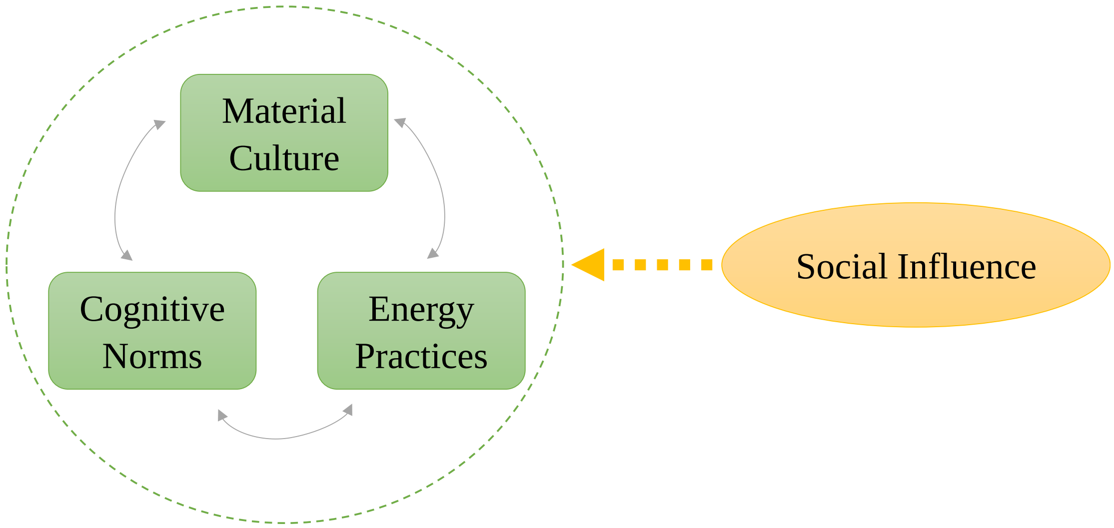

Figure 2 The integration of the energy cultures framework and social influence theory

3 Methods

3.1 Research Approach

This study is part of a five-year research project which studies the Culture of Sustainability (COS) and its development in a green office building (Dreyer et al., in press). The research project addresses sustainability of the building by taking a bottom-up approach which engages occupants and their organizations in sustainability initiatives (Dreyer et al., in press). In particular, this study focuses on energy saving behaviour of occupants in the green office building to contribute to the understanding of how people interact with the building environment for sustainability.

This study employs the mixed method with the explanatory sequential design in order to understand how structural and socio-psychological factors change energy practices of occupants in the zero-carbon building. The mixed method is appropriate for this study because statistical analyses on occupant behaviour and energy consumption data would suggest changes in occupant's energy usage but limit the understanding of the behavioural mechanism. Since this study seeks to understand how the occupants can be motivated to change their energy usage for sustainability, additional information from the literature and feedback sessions will be used to interpret potential causes of and approaches to energy saving behaviours. According to Creswell and Creswell (2018), the explanatory sequential mixed method begins with the quantitative approach for data collection and analyses followed by the qualitative approach. Data acquired from qualitative methods "help to provide more depth, more insight into the qualitative results" (Creswell & Creswell, 2018, Explanatory Sequential Mixed Methods Design section). Mixed methods allow researchers to further inspect research questions by using both qualitative and quantitative approaches, which cannot be accomplished by a single type of methods (Creswell & Creswell, 2018; O'Leary, 2010). This suggests that the use of mixed methods will not only reveal potential effects of physical and human factors on occupants' behavioural changes but also will provide an insight into how these factors may work on energy usage of people. Therefore, by using the mixed method, the study explored theoretical and empirical implications for the underlying causes and the process of energy saving behaviours in the green office building.

Moreover, this study conducted a case study which focused on occupants of the zero-carbon building to understand energy saving behaviour in a green office workplace. According to Yin (1981), a case study inspects "(a) a contemporary phenomenon in its real-life context, especially when (b) the boundaries between phenomenon and context are not clearly evident" (p.59). Since energy consumption is part of everyday activities that is hidden in daily routines of people (Lutzenhiser, 1993; Wilhite, Shove, Lutzenhiser, & Kempton, 2006), the context where energy usage takes place is relevant to understanding of how energy saving can be encouraged. In fact, researchers state that energy saving behaviour is highly dependent on the circumstances, such as the type of buildings, organizations and occupants' routines (Carpino et al., 2017; Hong et al., 2016). Thus, understanding the research context is crucial to study energy saving behaviour, and case studies allow researchers to connect energy usage of occupants to the unique setting of the building, which reveals the mechanism of energy practices. In fact, Hong et al. (2016) argue that behaviour varies across buildings due to differences in activities of occupants, individual obligation to pay for electricity bills, and interactions among people. This suggests that the context and energy usage are closely tied together; therefore, a case study helps the researcher investigate how energy saving behaviour of occupants can be promoted in the existing green office building.

3.2 Research Site

The focus of this research is a net-positive, zero-carbon office building located in Southern Ontario (Canada Green Building Council, 2020). The building has three storeys where universities, corporations, and an environmental non-profit organization have their office space. The size of the zero-carbon building is approximately 110,000 square foot (10,000 m^2), and it has LEED Platinum Certification (Canada Green Building Council, 2020). The construction of the building was completed in 2018 (Canada Green Building Council, 2020).

The building is highly energy efficient because it was designed to minimize energy usage by installing highly efficient building envelope, triple-glazed windows, and a solar wall for building ventilation (Canada Green Building Council, 2020). A central staircase with glass railings is located at the center of the atrium, and two elevators can be found beside the staircase. In addition, there are two side stairs at the east and west ends of the zero-carbon building. Moreover, the building also has solar panels on the roof and in the carport as well as a geothermal system that collects renewable energy on site. Sensors and meters were installed in the building to monitor electricity usage and room temperature (Canada Green Building Council, 2020). Thus, the zero-carbon building is a showcase for building sustainability in Canada, and it offers an opportunity to examine energy behaviour of occupants in a green building.

3.3 Tenant Areas and Electricity Meters

This study focuses on tenant areas in order to investigate electricity usage of occupants in the case study building. Here, tenant areas refer to areas in the building where organizations have tenancy; consequently, common places, such as corridors, the atrium, and washrooms, were excluded from tenant areas. In order to examine electricity usage in tenant areas, four tenants in the building were studied and labelled as Tenant A, Tenant B, Tenant C, and Tenant D. The tenant areas were divided according to the tenancy. One small tenant in the building, which occupies approximately 4% of floor area in the building, was excluded from the analysis of tenant areas because some of their electricity data were missing due to technical errors in two electricity meters.

Tenant A is a multi-party innovation hub. There were two electricity meters measuring electricity consumption of Tenant A; one meter collected plug loads data and another meter collected lighting data. Tenant A space includes a shared kitchen used by Tenant A and Tenant B, and electricity data of the shared kitchen space was merged with electricity data of the office area.

Tenant B is a university group, and it has both office areas for researchers and a classroom for teaching and group events hosted by Tenant A or Tenant B. Electricity data for the combined office areas and classroom were measured by two electricity meters. One electricity meter collected plug loads data, and another electricity meter collected lighting data.

Tenant C is a private corporation, and its tenant areas are divided into a non-office area and an office area. Electricity meters collected plug loads and lighting data of both non-office and office areas of Tenant C. Two electricity meters were used to collect plug loads and lighting data of the non-office area, and two other meters collected plug loads and lighting data of the office area of Tenant C. In addition, Tenant C has a cafeteria and shared bar space within the office area.

Tenant D is also a private corporation, and there were four meters used to measure its electricity usage. Tenant areas of Tenant D are divided into three different parts: a server room, an office area on the east side, and an office area on the west side. There are three electricity meters which separately collected plug loads data of the server room, the office space on the east side, and the office space on the west side. Another electricity meter collected lighting data of all these areas.

Overall, there are twelve electricity meters measuring the electricity use of Tenant A, Tenant B, Tenant C, and Tenant D (Table 1).

Table 1 Electricity meters used for data collection in tenant areas

Meter	Tenant	Type of Usage	Energy Type
1	Tenant A	Office area and shared kitchen	Plug loads
2		Office area and shared kitchen	Lighting
3	Tenant B	Office area and classroom	Plug loads
4		Office area and classroom	Lighting
5	Tenant C	Non-office area	Plug loads
6		Non-office area	Lighting
7		Office area	Plug loads
8		Office area	Lighting
9	Tenant D	Office area on the east side	Plug loads
10		Office area on the west side	Plug loads
11		Server room	Plug loads
12		Office areas and server room	Lighting

3.4 Baselines of Occupants' Electricity Usage

Patterns of electricity usage were analyzed to develop a baseline profile of electricity usage and to understand the energy behaviour of occupants in the case study building.

3.4.1 Sample

This study focuses on electricity data from plug loads and lighting in tenant areas in order to model the baselines of occupants' electricity usage. Occupants in Tenant A, Tenant B, Tenant C, and Tenant D included adult researchers, students, volunteers and employees. Although the population in the case study building may vary, the total number of workday occupants was estimated to be 288 in 2019 according to a previous study in the building (Z. Zhu, 2020) and email survey.

In this section, electricity usage data from January 2019 to February 2020 was employed to build the baselines. As Tenant A, Tenant B, Tenant C, and Tenant D moved into the building by November 2018, the electricity data may reveal general trends of occupants' electricity usage and their routines in the building.

3.4.2 Data Collection

An electricity submetering system and electricity meters were installed by the building owner to collect electricity data throughout the case study building. Plug loads and lighting data in tenant areas were measured by twelve electricity meters in the submetering system. The meters then transferred the data via the wireless connection to the online CircuitMeter platform (CircuitMeter Inc., n.d.) (Figure 3). The electricity data was then saved in the online platform and became available to the researcher.

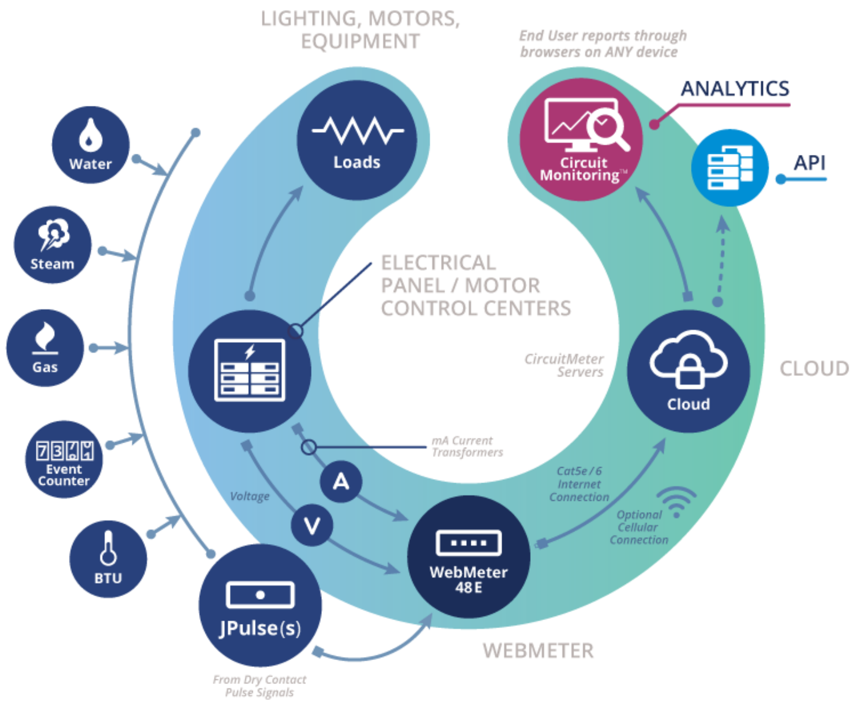

Figure 3 Simplified image of the energy monitoring system, CircuitMeter (CircuitMeter Inc., n.d.)

Electricity data from common areas, such as corridors and washrooms, were excluded from the analyses on the baseline of occupants' electricity usage. This is because tenants did not have control over electricity usage in the common areas as people who were not occupants, such as visitors, may have affected electricity usage in these areas. Consequently, only electricity usage for plug loads and lighting from tenant areas was examined to model the baselines of occupants' electricity usage in the building.

3.4.3 Data Analysis

Firstly, the total building electricity usage and the percentage of electricity usage in tenant areas relative to the total building electricity usage were calculated. The electricity usage of the entire building and tenant areas were compared to examine the relative importance and potential impact of occupant behavior. Electricity data from January 2019 to February 2020 were used for the analysis, and the electricity data of the entire building included electricity usage from corridors, the entrance hall, washrooms, HVAC equipment, and variable refrigerant flow (VRF) systems in the building. The electricity data of the tenant areas included plug loads and lighting measured by the twelve electricity meters. For each month from January 2019 to February 2020, the percentage of electricity usage in tenant areas was calculated as follow:

$$\%\ of\ electricity\ usage\ in\ tenant\ areas\ = \frac{Total\ electricity\ usage\ in\ tenant\ areas\ (kWh)}{Total\ electricity\ usage\ of\ the\ entire\ building\ (kWh)}$$

In addition, energy usage intensity (EUI) was calculated in order to compare energy efficiency of the building with typical office buildings in Canada. EUI refers to energy usage of a building relative to its size and building features (U.S. Environmental Protection Agency & U.S. Department of Energy, n.d.). EUI was calculated as follow:

$$EUI\ of\ evolv1\ (GJ/m^2)$$
$$=\ Total\ electricity\ usage\ of\ the\ building\ in\ 2019\ (kWh)/278\ (GJ/kWh)/total\ floor\ area\ (m^2)$$

Secondly, the average electricity usage by hour was computed both for lighting and plug loads. For the hourly average electricity usage, the patterns of electricity usage on weekdays and weekends were shown on an hourly basis from 0:00 a.m. until 23:59 p.m. Electricity data from January 2019 to December 2019 was used for the hourly average data to build the annual model of energy behaviour on weekdays and weekends. Electricity data on holidays were excluded from the analysis on lighting and plug loads of tenant areas because the patterns of electricity usage were inconsistent on holidays (Appendix A). Since the electricity meters recorded electricity usage in kWh every fifteen minutes, the total electricity usage per hour was aggregated for each day. Then, the average electricity usage by hour was calculated for weekdays and weekends as follow:

$$\textit{Hourly average electricity usage} = \frac{\textit{Total electricity usage by hour}}{\textit{Number of days in a year}}$$

3.5 Stairs usage

This study investigated changes in stairs usage after a series of interventions to examine interactions among structural factors of the building, information provision, and energy behaviors of occupants. Stairs usage is one of the observable behaviours, which can contribute to a reduction of electricity usage in a building (Ruff et al., 2014; Tukia et al., 2016). While multiple factors, including structural and human factors, affect stairs usage of people (Ruff et al., 2014; Tukia et al., 2016), social influence can also be an influential factor for the decision to take stairs or elevators since observable behaviour can be more subject to social influence (Abrahamse & Steg, 2013). The examination of stairs usage addresses research question (a), which sheds light on the relationship between energy saving behaviour, in the form of stairs usage, and social norms of occupants when structural and informational interventions were introduced.

The structural factors here refer to physical components of buildings, such as sustainable building design, central staircases, side stairs, elevators, and floor levels. On the other hand, the information provision refers to newsletter interventions which provide occupants with information about energy conservation and health benefits associated with stairs usage. This study aims to investigate changes in energy practices, in the form of stairs usage, and their relationships with social norms of occupants while structural and informational interventions are introduced. Based on the energy cultures framework, information provision is considered as an external influence that may stimulate cognitive norms which are occupants' concern and aspiration for health benefits and energy conservation resulting from stairs usage. After cognitive norms are affected by the external influence, it is expected to further stimulate energy practices of occupants, which would promote behavioural changes (Figure 4). Consequently, analyses on changes in stairs usage would potentially reveal interactions between social influence and the three factors within the energy cultures framework.

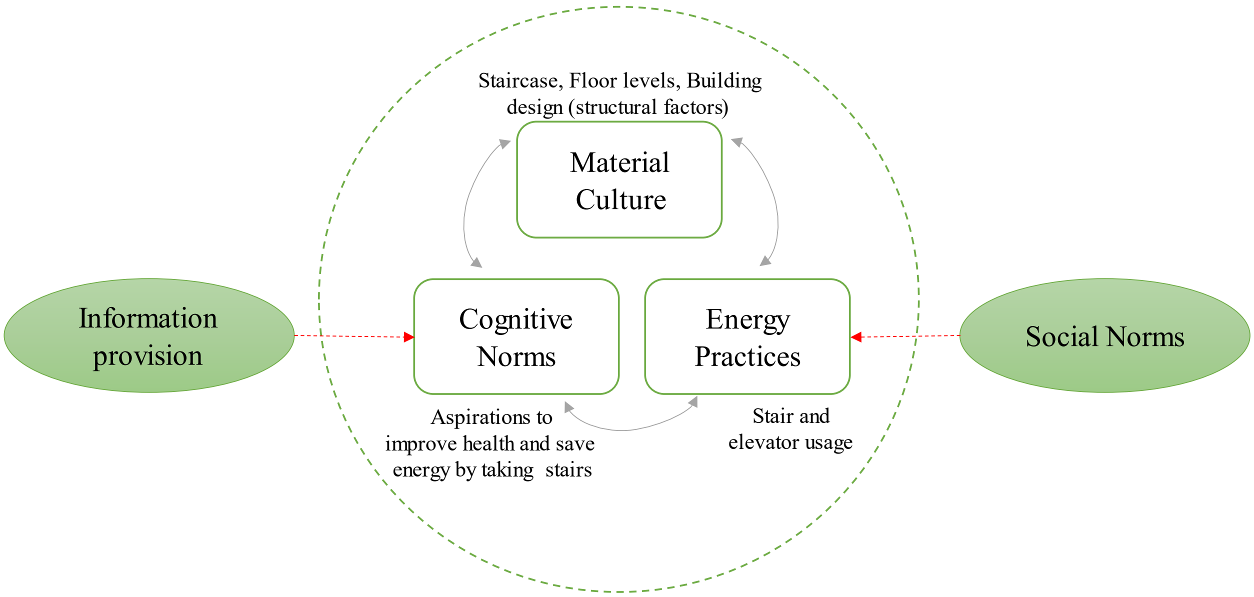

Figure 4 The energy cultures framework applied to the research question (a)

3.5.1 Sample

The sample for the analyses on stairs usage consists of occupants on the second and third floors both in pre-occupancy buildings and the zero-carbon building. The pre-occupancy data were collected from three buildings where three different tenants previously had their office space. The pre-occupancy buildings are referred to as Building 1, Building 2, and Building 3. In the pre-occupancy period, structural designs and the types of occupants varied among Building 1, Building 2, and Building 3. Building 1 was a three-storey office building where Tenant C had their office space. The building was not a green building, it lacked a central staircase, and it was primarily used by office workers.

On the other hand, Building 2 and Building 3 were campus buildings and had classrooms for university students as well as office space for faculty members. In Building 2, Tenant B had classrooms and the office space for researchers. At the same time, Building 2 had similar structural features as the case study building; it was a four-storey green building and had a central staircase in front of the elevators in the entrance hall with additional side stairs. In Building 3, a group of occupants from Tenant A had classrooms and office space for researchers. The building was a three-storey building with two central staircases in the entrance hall and additional side stairs. Building 3 was not a green building and elevators were not located beside the central staircases, which is different from the case study building. In addition, only a small proportion of occupants in Building 2 and Building 3 moved to the case study building.

During the post-occupancy period, the stairs usage data were collected from the case study building with Tenant C on the second floor and Tenant D on the third floor. Since Tenants C and D were private corporations, occupants were mostly employees above 18 years old working in the area of digital technology and consulting business. Overall, the sample for stairs usage consists primarily of occupants affiliated with the tenants along with any visitors in the pre-occupancy and post-occupancy buildings: students and faculty members in the pre-occupancy buildings, and employees of private corporations both in the pre-occupancy and post-occupancy buildings. Table 2 shows sample groups acquired from observation and survey data for stairs usage.

Table 2 Sample groups acquired from observation and surveys

Tenants	Stairs usage	
	Pre-occupancy	Post-occupancy
Tenant A	✓	
Tenant B	✓	
Tenant C	✓	✓
Tenant D		✓

3.5.2 Data Collection

Observation

The study carried out direct observation to count the number of people taking the central staircases and elevators. The observation method was adapted from past studies in which observers recorded the number of people using stairs in buildings (Bassett, Browning, Conger, Wolff, & Flynn, 2013; Boutelle, Jeffery, Murray, & Schmitz, 2001; Kerr, Eves, & Carroll, 2001; Olander, Eves, & Puig-Ribera, 2008). There were six observation phases of stairs usage, and they were divided into the pre-occupancy and post-occupancy periods. The staircase and elevator usage of occupants was observed from the pre-occupancy period in August 2018 until the post-occupancy period in March 2020. In Phase 1, the observation was conducted for three to four days in each pre-occupancy building.

- Building 1: August 28th, 30th, September 4th, and 6th in 2018
- Building 2: September 19th, 20th, and 26th in 2018
- Building 3: September 24th, 28th, and October 2nd in 2018

Observations were carried out on weekdays. In Building 1, stairs usage for the third floor was acquired since Tenant C had their office space on the third floor. In Building 2, stairs usage both for the second and third floors was observed, while stairs usage for the second floor was observed in Building 3.

The post-occupancy observation was conducted from December 2018 after most tenants moved into the case study building. During the post-occupancy period, observation was conducted in five series until March 2020, and each set lasted for three days. The post-occupancy period was divided into the following five phases:

- Phase 2: December 4th to 6th in 2018
- Phase 3: November 4th, 5th, and 8th in 2019
- Phase 4: January 22nd to 24th in 2020
- Phase 5: January 29th to 31st in 2020
- Phase 6: March 2nd to 4th in 2020

Changes in stairs usage from Phase 1 were examined during Phase 2 and Phase 3 to see how structural factors of the buildings affect occupant behavior. On the other hand, the impact of information provision on stairs usage was examined during Phase 4, Phase 5, and Phase 6. The timeline of observation for stairs usage is illustrated in Appendix B.

University students were recruited as observers to record stairs usage in buildings during the pre-occupancy and the post-occupancy periods. During observation, two observers stayed near staircases to count the number of people using stairs and elevators; one observer watched people arriving at and leaving the second floor, and another observer watched people arriving at and leaving the third floor. Observers sat near staircases in buildings where they were able to view people using stairs and elevators at the same time, and they were asked to remain passive so that their presence would not affect the behaviour of occupants. They also recorded stairs and elevator usage according to the direction of people's movement; when people were going up to the second or third floor, it was recorded as 'ascending,' and it was recorded as 'descending' when people were going down from the second or third floor. In addition, observers recorded people who required elevator usage, such as people carrying large objects or injured individuals. These people were coded as 'elevator required,' and were excluded from the analyses since their decision on stairs vs elevator usage was unlikely to be influenced by interventions.

Sensors

In addition to observation data, sensors were also employed to monitor occupants' stairs usage behaviour. There were no sensors recording stairs usage of people in the pre-occupancy buildings. Sensors were first installed in March 2019. As a result, sensor data were available only from Phase 3 of the post-occupancy period.

The type of sensors installed was a Parametric GmbH model "PCR2" radar sensor, which detects the presence and direction of people passing by (Parametric, 2018). These sensors recorded the number of times movement was detected on stairs and the associated direction in five-minute increments. Figure 5 and Figure 6 show the image of how to set up a radar people counter.

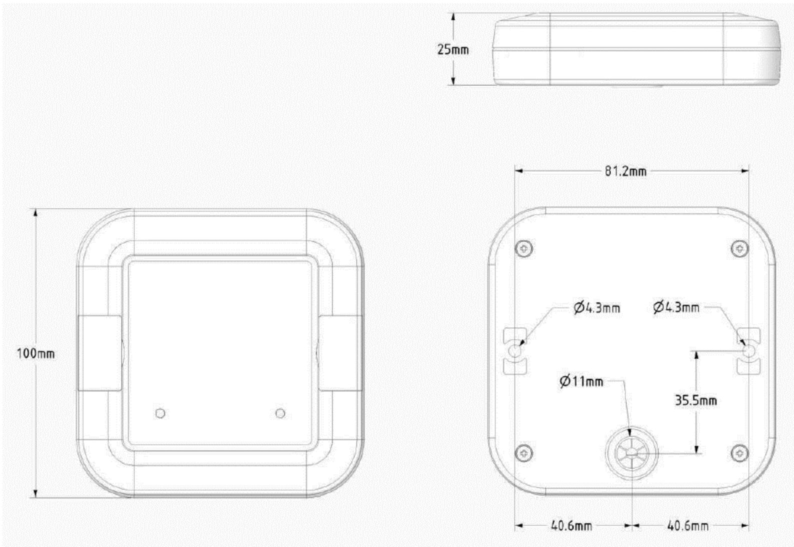

Figure 5 Image of a radar people counter

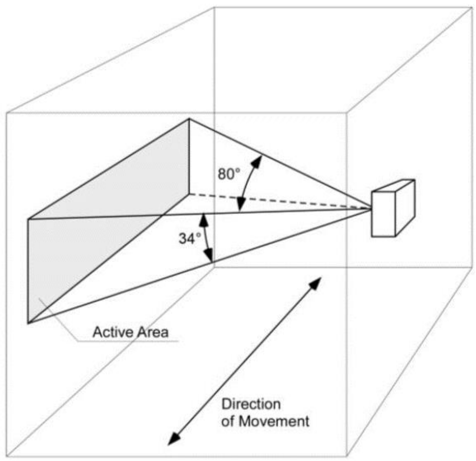

Figure 6 Image of how to set up a radar people counter

One sensor was located on the staircase wall between the ground floor and the second floor, and another sensor was located on the staircase wall of the landing between the second floor and the third floor in the case study building. These sensors were set up in a way that their active area would be facing at people using stairs. The five-minute data of stairs usage were wirelessly transferred to an online platform where data were stored. Although the number of people using stairs for both the second and third floors in the case study building was recorded by the sensors, the sensor stairs usage data for the third floor was excluded from this study due to the significant counting errors on the third floor, compared to observation data. In contrast, sensor data on stairs usage for the second floor were validated by comparison to the observation data.

Information Provision Intervention

Information provision was conducted in January 2020 and March 2020 to study how information about energy conservation and health benefits associated with stairs usage affect the behaviour of occupants. Newsletters were used for this intervention as a method to send information about stairs usage to occupants via email. Newsletters were an established communication mechanism in the case study building and were used to share information about sustainability among occupants on a monthly basis. Newsletters were sent to a key contact in each tenant who then forwarded it to the rest of the occupants. In this study, messages about energy conservation (January) and health benefits (March) associated with stairs usage were added to newsletters. Firstly, the information about electricity saving effect of stairs usage was disseminated on January 28th, 2020. The stairs and elevator usage was observed before (Phase 4) and after sending the newsletter (Phase 5). Figure 7 shows the message about stairs usage and energy conservation disseminated via the January newsletter.

Do you want to save enough electricity to run your laptop for six hours daily?
Yes? Simple. Take the stairs.

Actual measurements in evolv1 found that each time someone uses the elevator, electricity consumption went up by 80 Wh on average, to run the electric motor that lifts the elevator. If you use the elevator when arriving in the morning, when going to and returning from lunch, and when leaving at the end of the day, the four elevator rides would consume approximately 320 Wh of electricity.

A typical laptop computer uses 50 Wh, so you could run the laptop for 6 hours with the amount of electricity that you saved by taking the stairs four times!

Figure 7 The newsletter article about stairs usage and energy conservation

Secondly, the information about health benefits associated with stairs usage was disseminated on March 2nd, 2020. The stairs and elevator usage in the case study building were observed from the same date when the newsletter was sent out (Phase 6). Figure 8 shows the message about stairs usage and health benefits included in the March newsletter.

Want a simple way to reduce your risk of diabetes and cardiovascular disease?
Take the stairs!

Taking the stairs has been shown to decrease body weight, fat mass, waist circumference, diastolic blood pressure, systolic pressure, and LDL cholesterol. By using an average of 20 steps daily for 3 months, workers have also demonstrated improved cardiorespiratory activity. In another study, daily stair usage was a more effective physical activity than running for reducing stroke risk!

Figure 8 The newsletter article about stairs usage and energy conservation

<u>Surveys</u>

Furthermore, this study examined survey data from a larger Culture of Sustainability (COS) research project managed by Viessmann Center for Engagement and Research in Sustainability (VERiS; Principal investigators: Manuel Riemer & Joel Marcus). Survey questions were selected from those designed for the scales developed for the larger research project on COS (Dreyer et al., in press). This study used these secondary data to investigate the level of social norms associated with pro-environmental behaviour among occupants. Survey questions were sent to occupants in the tenants via email, and people were asked to answer questions in two weeks from the date when they received the email. It should be noted that the case study building was also used by university students who were mostly temporary users (such as for classes), but surveys were only sent to research students who worked in the building. As a result, surveys were disseminated only to those who were working at organizations located in the building. The first survey was conducted between May and August 2018 before occupants moved into the case study building, and survey questions were disseminated at different times during this period according to the type of organization. The second and third surveys were conducted in June 2019 and June 2020 after occupants moved into the case study building, and survey questions were disseminated to Tenant A, Tenant B, Tenant C, and Tenant D at the same time.

In order to measure the level of social norms regarding pro-environmental behaviour, participants were asked via surveys to rate the degree to which they agree to an 11-item scale assessing social norms regarding pro-environmental behaviour in their organization (Table 3). These questions were rated from -3 (strongly disagree) to 3 (strongly agree). Although the scale used in the survey questions was not specifically developed to study social norms, but rather for a broader aspect of COS (Dreyer et al., in press), the survey questions are applicable as indicators of social norms. The survey questions were rated from 0 (the question does not describe my organization) to 4 (the question describes my organization very well) by respondents.

Table 3 Survey questions about social norms associated with pro-environmental behaviour

No.	Questions
1	Environmental considerations play a role in day-to-day decision-making.
2	In comparison to other issues, reducing environmental impact is considered a priority.
3	People in management positions lead or support environmental initiatives.
4	Taking care of the environment is central to who we are.
5	There is prominent signage that promotes environmental awareness and practices.
6	There are numerous symbols that reflect environmental engagement (e.g. composting bins, solar panels).
7	People commonly use environmental terminology (e.g. carbon, environmental footprint).
8	There are regular programs and activities focused on environmental impact.
9	People fulfill job tasks in environmentally-friendly ways.
10	Environmental achievements are recognized and celebrated.
11	Environmental objectives and performance are regularly communicated to employees.

After collecting responses from the occupants, responses were reviewed. Survey responses were excluded when the respondent (a) skipped more than 80% of numeric questions, (b) did not complete the question, or (c) spent a very short time to complete the surveys. Consequently, the final data set for the first survey had 227 respondents, and the item completion rate for the eleven questions associated with social norms was 98.3%. In contrast, the number of respondents in the second survey was 119 people, and the item completion rate for the questions associated with social norms was 99.2%. In the third survey, the number of respondents was 114, and the item completion rate for the questions associated with social norms was 97.7%. The timelines of observation, information provision, and surveys are displayed in Figure 9.

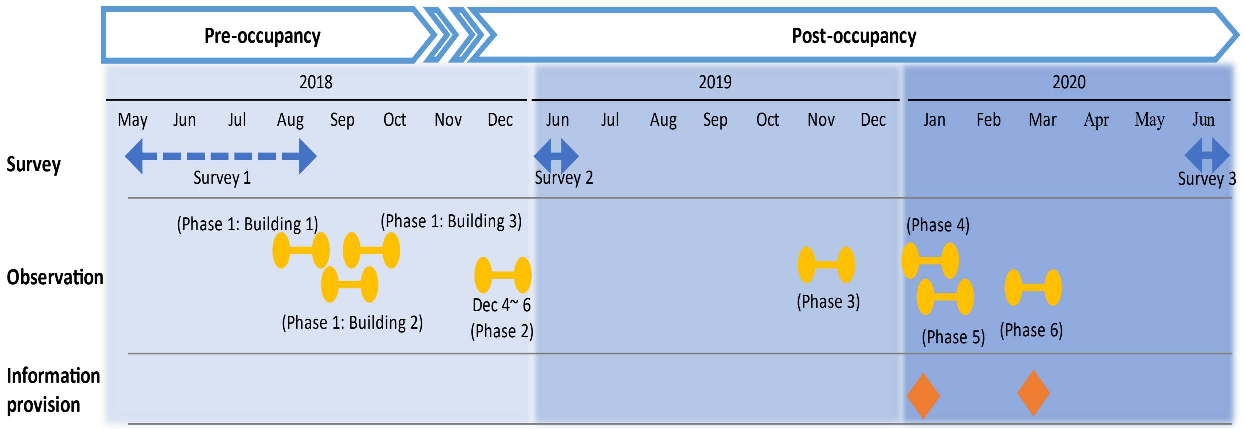

Figure 9 Timelines of observation, information provision, and surveys

3.5.3 Data Analysis

The Statistical Package for the Social Sciences (SPSS) was used for statistical analyses in this research. One factor analysis of variance (one-way ANOVA) was conducted to investigate changes in stairs usage over time. Stairs usage was analyzed according to the direction of movement (descending or ascending), as well as the floor level (the second floor or the third floor). For observation data of stairs usage, the percentages of stairs usage in each phase were calculated as follow:

$$Stairs\ Usage\ (\%) = \frac{Total\ number\ of\ people\ using\ stairs}{Total\ number\ of\ people\ using\ stairs\ and\ elevators}$$

Moreover, sensor data were examined, but the observed numbers of people on the second floor using stairs were used for the analysis. This is because sensors were only found to be accurate for counting stairs usage between the ground and second floor, and the sensor counts differed greatly from the observed number of people on the third floor. For one-way ANOVA, sensor data were adjusted with the counting errors relative to observation data because the total number of people using stairs was different between the observation and sensor data despite the same day and time periods. Consequently, the counting errors were calculated in percentage rates as follow, and then were applied to sensor data in order to generate adjusted estimates of stair users.

$$Counting\ error\ of\ sensor\ data\ (\%)$$
$$= \frac{(Total\ number\ of\ people\ counted\ by\ sensor - Total\ number\ of\ people\ counted\ by\ observer}{Total\ number\ of\ people\ counted\ by\ observer}$$
$$\approx 0.09$$

$$Sensor\ data\ of\ stair\ usage\ (adjusted) = Sensor\ data\ (original) \times 1.09$$

Furthermore, two factor analysis of variance (Two-way ANOVA) was conducted to investigate differences in stairs usage between the second floor and the third floor. Stairs usage on the different floors was compared according to the direction of people's movement from Phase 1 to Phase 6. Since Building 1 of Phase 1 was the only building which did not have a central staircase, the building was excluded from this analysis because the presence of central staircases may have affected people's decision on stairs and elevator usage. Consequently, Buildings 2 and 3 were used to compare stairs usage between the second floor and the third floor during Phase 1. In addition, only observation data was used for the two-way ANOVA since sensor data of the third floor was not available due to significant errors in the data.

Finally, descriptive statistics were employed to investigate if there were any relationships between stairs usage and the level of social norms in the case study building. Descriptive statistics allow researchers to present patterns and characteristics of data by creating images in a concise manner (Nick, 2007; Young & Wessnitzer, 2016). The mean values of social norms were calculated by SPSS for each tenant, and changes in the level of social norms were then examined along with changes in the percentage of stairs usage.

Multilevel modeling is commonly used to analyze relationships of different variables both at the individual level and the organizational level (Heck, Thomas & Tabata, 2014), and this could be applied to study how stairs usage relates to social norms. However, the sample size in this study was too small to use multilevel modeling. As a result, descriptive statistics were selected as the method to explore and interpret relationships between stairs usage and the level of social norms.

3.6 Electricity usage for lighting and plug loads

Electricity usage for lighting and plug loads in tenant areas was examined to analyze its relationships with group norms, as well as to examine the impact of social identities on how social norms affect the electricity usage of occupants. This addresses the research question (b), and electricity usage for lighting and plug loads was used to study energy behaviour of occupants in the green office building. Group norms here refer to subjective norms of occupants about how other people in the same organization perceive pro-environmental behaviour. In addition, social identities refer to affiliation of occupants to their organizations in the case study building.

Based on social influence theory, it is hypothesized that social identities moderate the impact of social norms on electricity usage. As the theory considers that people are likely to comply with social norms of a group which they believe they belong to, it can be argued that occupants would reduce electricity usage if they believe electricity saving is a key pro-environmental behaviour reflecting their group's social norms, and if the membership to the group is important for them. Consequently, it can be considered that an increased level of social identities would make occupants become more conscious of group norms and enhance the perceived significance of group norms. This would potentially reinforce the impact of social norms on electricity usage of occupants, thereby resulting in negative relationships between the level of social norms and electricity usage, as well as positive relationships between the levels of social identities and social norms. The research question (b) therefore focused on the interactions between energy practices, in the form of electricity usage, and social influence as an external influence of the energy cultures framework (Figure 10). While cognitive norms in the framework was not addressed in the analyses on electricity usage, this study also explored how energy practices can be influenced by material cultures, such as types of devices and equipment used by occupants.

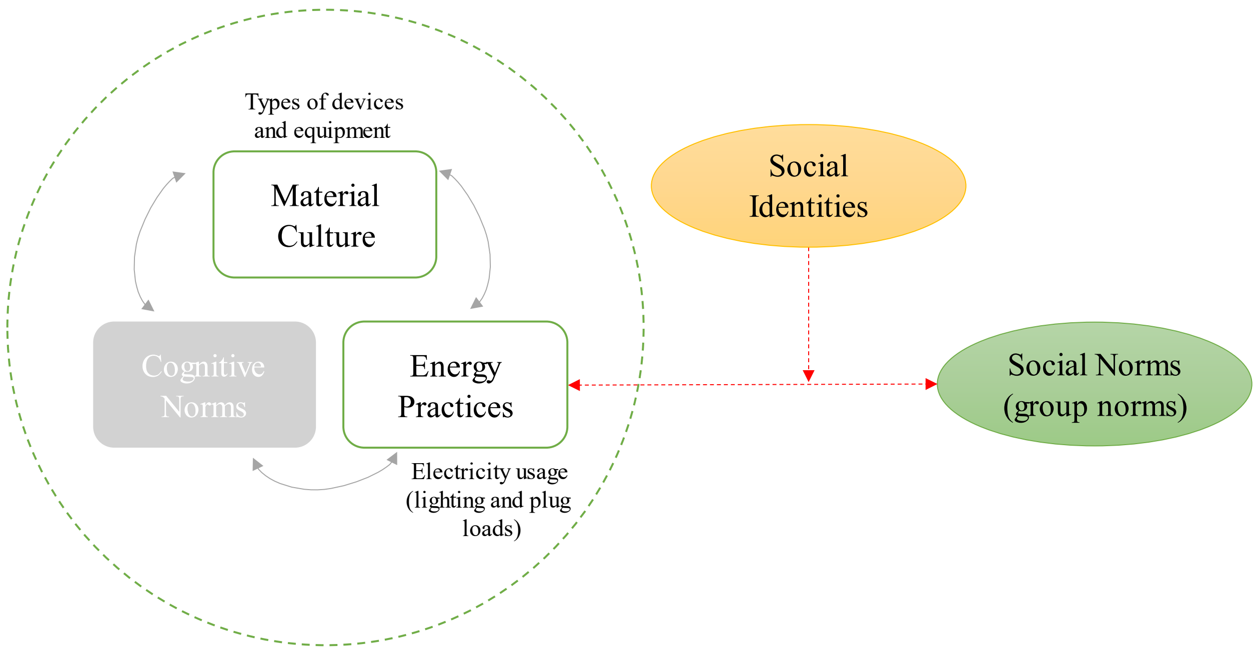

Figure 10 The energy cultures framework applied to the research question (b)

3.6.1. Sample

The sample for the analyses on electricity usage consisted of occupants in Tenant A, Tenant B, Tenant C, and Tenant D. One small tenant was excluded from the sample since some of their electricity data were missing due to technical problems in electricity meters. Plug loads and lighting data from January 2019 to February 2020 in tenant areas were used for the analyses, which is the same as the baseline analyses.

3.6.2. Data Collection

The energy monitoring system of *CircuitMeter* was used to collect electricity data in the case study building as described in the section 3.4.2. Common areas, such as corridors and washrooms, were similarly excluded from this study since non-occupant individuals, including visitors and students, also used these areas.

Surveys were also conducted as stated in the section 3.5.2. The eleven questions from Table 3 were used to study the level of social norms among occupants. Three questions from Table 4 were designed to measure a sense of community, and they were added to study the level of social identities among occupants. Although the concept of social identities was not originally included as a key concept for the larger research project (Dreyer et al., in press), these survey questions were used as a proxy to understand occupants' social identities. For the level of social identities, participants were asked via surveys to rate the degree to which they agree to a 3-item scale assessing their identification to their organization (Table 4). These questions were rated from -3 (strongly disagree) to 3 (strongly agree). Careless responses were excluded from the data as explained in the section 3.5.2.

Table 4 Survey questions about social identities of occupants regarding their organizations

No.	Questions
1	Membership in this organization is meaningful and valuable to me.
2	I feel loyal to the people in this organization.
3	This organization feels like a community.

Furthermore, feedback sessions were conducted to verify and understand how occupants had used electricity in tenant areas. Two key informants from Tenant C and Tenant D were selected for the feedback sessions. Here, an informant from Tenant C is referred to as Informant 1, and an informant from Tenant D is referred to as Informant 2. Since Tenant C and Tenant D were private corporations where access to the tenant areas was limited to employees, feedback sessions with key informants from these tenants would help the researcher understand how occupants had been using electricity for lighting and plug loads in their tenant areas. Graphs showing the average lighting and plug loads on weekdays and weekends were presented to the key informants during the feedback sessions. Based on the graphs, the key informants were asked to offer their insight into what contributed to changes in lighting and plug loads over time in their tenant areas. At the same time, general energy practices of occupants (such as turning lights off/on) and the way occupants used office and non-office areas were discussed. The feedback sessions were conducted through virtual meetings since in-person meetings were restricted due to the COVID-19.

3.6.3. Data Analysis

The average electricity usage for lighting and plug loads on weekdays and weekends was calculated to investigate electricity usage of occupants in the case study building. Lighting and plug loads data of Tenant A, Tenant B, Tenant C, and Tenant D from January 2019 to February 2020 were used for the analyses. Electricity data on holidays were excluded from the analyses since the patterns of electricity usage were inconsistent on holidays, compared to weekdays and weekends. The average electricity usage for lighting plug loads on weekdays was calculated as follow:

$$Average\ weekday\ electricity\ usage\ for\ lighting\ (kWh)$$

$$= \frac{Total\ weekday\ electrcity\ usage\ for\ lighting\ in\ a\ month(kWh)}{Number\ of\ weekdays\ in\ the\ month}$$

$$Average\ weekday\ electricity\ usage\ for\ plug\ loads\ (kWh)$$

$$= \frac{Total\ weekday\ electricity\ usage\ for\ plug\ loads\ in\ a\ month\ (kWh)}{Number\ of\ weekdays\ in\ the\ month}$$

The average electricity usage for lighting and plug loads on weekends was calculated as follow:

$$Average\ weekend\ electricity\ usage\ for\ lighting\ (kWh)$$

$$= \frac{Total\ weekend\ electricity\ usage\ for\ lighting\ in\ a\ month\ (kWh)}{Number\ of\ weekends\ in\ the\ month}$$

$$Average\ weekend\ electricity\ usage\ for\ plug\ loads\ (kWh)$$

$$= \frac{Total\ weeked\ electricity\ usage\ for\ plug\ loads\ in\ a\ month\ (kWh)}{Number\ of\ weekends\ in\ the\ month}$$

Two-way ANOVA was conducted to compare electricity usage for lighting and plug loads among different tenants over time. Since the floor area and the population are different among Tenant A, Tenant B, Tenant C, and Tenant D, electricity usage per m^2 and per person of each organization were used to diminish inconsistency of the data units and compare electricity usage of different tenants. Hochberg's GT2 was also used for the post-hoc comparison of electricity usage among tenants. The rented floor area of the tenants was calculated based on the fit-out layout of the green office building, and the population was estimated from the previous study in the building (Z. Zhu, 2020) as well as email survey.

Table 5 shows the floor area and the population of Tenant A, Tenant B, Tenant C, and Tenant D according to the electricity meters.

Table 5 Floor area and population of Tenants A, B, C, and D

Tenant	Meter No.	Type of Usage	Energy Type	Area size (m^2)	Population
Tenant A	1	Office area and shared kitchen	Plug loads	761	23
	2	Office area and shared kitchen	Lighting	761	23
Tenant B	3	Office area and classroom	Plug loads	530	20
	4	Office area and classroom	Lighting	530	20
Tenant C	5	Non-office area	Plug loads	419	158
	6	Non-office area	Lighting	419	158
	7	Office area	Plug loads	2468	158
	8	Office area	Lighting	2468	158
Tenant D	9	Office area on the east side	Plug loads	847	58
	10	Office area on the west side	Plug loads	544	39
	11	Server room	Plug loads	1391	97
	12	Office areas and server room	Lighting	1391	97

Furthermore, descriptive statistics were selected as a method to inspect relationships among electricity usage, social norms, and social identities of occupants. Since the sample size was too small in this study, the application of multilevel modeling was not feasible for the correlational analyses on these variables. The mean values of social norms and social identities were calculated by using SPSS according to the tenant. Then, changes in the average electricity usage for lighting and plug loads on weekdays were examined along with changes in the levels of social norms over time. For Tenant C, the aggregated electricity usage for lighting and plug loads from the office and non-office areas was analyzed. For Tenant D, plug loads in the server room was distinguished from the aggregated electricity usage for plug loads in the office areas on the east and west sides. Plug loads data of the server room in January 2019 were excluded from the descriptive analyses since plug loads in the month seemed to be an outlier in the overall pattern of plug loads in the server room. At the same time, changes in the level of social identities were compared with changes in the level of social norms to see if they have positive relationships, as well as how their relationships are connected to the relationships between social norms and electricity usage.

After examining each tenant individually, electricity usage, social norms, and social identities of all tenants were compared to examine the overall trends in relationships among these variables. For electricity usage, the average lighting and plug loads on weekdays in Wh/m^2 and Wh/person were compared with the average levels of social norms according to the tenant. The average electricity usage for lighting usage, the average electricity usage for plug loads, and the average levels of social norms were calculated as follow:

$$Average\ weekday\ electricity\ usage\ for\ lighting\ (Wh/m2) =$$

$$\frac{Sum\ of\ weekday\ electricity\ usage\ for\ lighting\ (Wh/m2)\ between\ January\ 2019\ and\ February\ 2020}{Number\ of\ months\ between\ January\ 2019\ and\ February\ 2020}$$

$$Average\ weekday\ electricity\ usage\ for\ lighting\ (Wh/person) =$$

$$\frac{Sum\ of\ weekday\ electricity\ usage\ for\ lighting\ (wh/person)\ between\ January\ 2019\ and\ February\ 2020}{Number\ of\ months\ between\ January\ 2019\ and\ February\ 2020}$$

$$Average\ weekday\ electricity\ usage\ for\ plug\ loads\ (Wh/m2) =$$

$$\frac{Sum\ of\ weekday\ electricity\ usage\ for\ plug\ loads\ (Wh/m2)\ between\ January\ 2019\ and\ February\ 2020}{Number\ of\ months\ between\ January\ 2019\ and\ February\ 2020}$$

$$Average\ weekday\ electricity\ usage\ for\ plug\ loads\ (Wh/person) = \frac{Sum\ of\ weekday\ electricity\ usage\ for\ plug\ loads\ (Wh/person)\ between\ January\ 2019\ and\ February\ 2020}{Number\ of\ months\ between\ January\ 2019\ and\ February\ 2020}$$

$$Average\ level\ of\ social\ norms\ in\ a\ tenant = \frac{Sum\ of\ levels\ of\ social\ nomrs\ in\ a\ tenant\ for\ the\ three\ surveys}{Number\ of\ surveys}$$

In order to investigate whether there was an overall positive relationship between social norms and social identities, the average level of social norms and the average level of social identities were compared according to the tenant. The average level of social identities was calculated as follow:

$$Average\ level\ of\ social\ identities\ \ in\ a\ tenant = \frac{Sum\ of\ levels\ of\ social\ identities\ in\ a\ tenant\ for\ the\ three\ surveys}{Number\ of\ surveys}$$

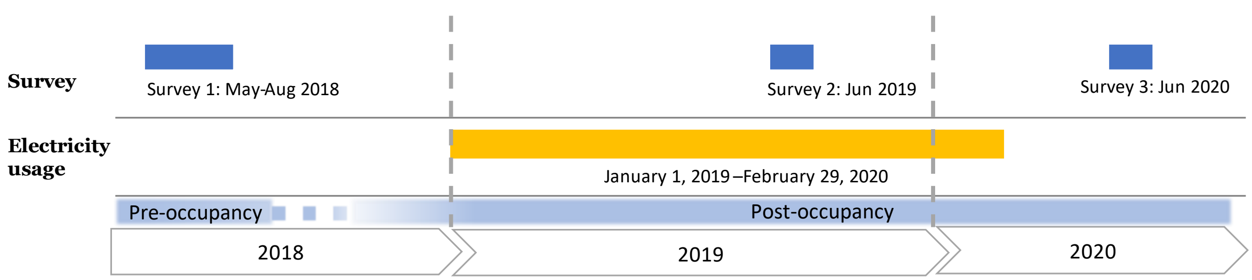

Figure 11 Timelines of surveys and electricity usage used in this study

3.7 Occupants' impact on the building's electricity usage

Finally, this study investigated changes in electricity usage before and after the pandemic happened. Due to the outbreak of COVID-19 in Ontario in Canada, the case study building was closed and all occupants were forced to work from home after mid March 2020. As tenant organizations decided the closure of their office space in the building, there were no occupants and visitors, except cleaners and maintenance workers who occasionally entered the building. As a result, this situation offered a unique setting where the zero-carbon office building was not used by occupants, which allowed the researcher to compare electricity usage in the building during its occupation and after occupants left the building. This consequently offers an insight into the impact of occupant behaviour on electricity usage of tenant areas, as well as the entire green office building.

3.7.1 Sample

Electricity usage for lighting and plug loads in tenant areas was selected to compare occupants' energy behavior in the building before and after the pandemic. The total electricity usage of the building was also used to examine how the total electricity usage of the building changed after occupants were forced to work from home. Unlike plug loads and lighting data in tenant areas, electricity data of the entire building included electricity usage in common areas, such as corridors, the entrance hall, and the HVAC system. For tenant areas, electricity usage in Tenant A, Tenant B, Tenant C, and Tenant D was studied, and there was one tenant excluded from the sample due to technical problems in electricity meters.

3.7.2 Data Collection

Electricity data of both the tenant areas and the entire green office building were collected from January 2019 to November 2020. However, some electricity data of tenant areas in June, July, and August 2020 were missing due to technical problems in electricity meters. In particular, the majority of data in August 2020 was unavailable, and consequently, electricity data of tenant areas from this month were excluded from the analyses. In addition, some electricity data of tenant areas during June and July 2019 were excluded in order to maintain the same sample size with electricity data during June and July 2020 due to missing data.

As Table 6 shows, the levels of occupancy in the building are categorized into four phases. The pre-pandemic phase had the high level of occupancy, and it covers from January 2019 to February 2019. During this phase, occupants came to the building on a regular basis before the COVID 19 outbreak occurred. March 2020 is the transition phase when the number of occupants dropped from the middle of the month because people started working from home, thereby having the middle level of occupancy. The pandemic phase 1 refers to three months from April 2020 to June 2020 when the building was deserted as all occupants worked from home, which resulted in the very low level of occupancy. Finally, the post pandemic phase 2 starts from July 2020 and ends in November 2020. During this time, a few occupants came to the building several times per week for work because the COVID-19 restrictions were temporally eased. Thus, the level of occupancy during this phase was low.

Table 6 shows the level of occupancy in the case study building from the pre-pandemic phase to the pandemic phase 2.

Table 6 Phases of electricity usage

Phase	Time	Level of occupancy
Pre-pandemic	January 2019 ~ February 2020	High
Transition	March 2020	Middle
Pandemic 1	April 2020 ~ June 2020	Very low
Pandemic 2	July 2020 ~ November 2020	Low

Moreover, feedback sessions with the key informants from Tenant C and Tenant D were conducted as stated in the Section 3.5.2. Patterns of electricity usage for lighting and plug loads, as well as the level of occupancy in tenant areas after March 2020 were asked to the key informants from each tenant in order to validate the researcher's interpretation of electricity data.

3.7.3 Data Analysis

Differences in the monthly electricity usage in the green office building were studied, and electricity data were compared between 2019 and 2020 to investigate the impact of occupants' presence on electricity usage. The percentage of the total electricity usage of the building in 2020 was calculated relative to the total electricity usage in 2019. The percentage of the total electricity usage of the building was calculated by month as follow:

$$Electriccity\ usage\ of\ the\ building\ in\ 2020\ relative\ to\ 2019\ (\%) = \frac{Total\ electricity\ usage\ of\ the\ building\ in\ 2020}{Total\ elecctricity\ usage\ of\ the\ building\ in\ 2019}$$

Furthermore, paired samples t-test was conducted by using SPSS to analyze differences in electricity usage of tenant areas before and after the pandemic. Electricity data of tenant areas from April to November was compared between 2019 and 2020, except August. For paired samples t-test, the monthly total, the weekday average, and the weekend average electricity usage in tenant areas were calculated according to the meter. The weekday average and the weekend average electricity usage of twelve meters in tenant areas were calculated as follow.

$$Average\ electricity\ usage\ on\ weekdays\ (kWh) = \frac{Total\ electricity\ usage\ on\ weekdays\ in\ a\ month (kWh)}{Number\ of\ weekdays\ in\ the\ month}$$

$$Average\ electricity\ usage\ on\ weekends\ (kWh) = \frac{Total\ electricity\ usage\ on\ weekends\ in\ a\ month\ (kWh)}{Number\ of\ weekends\ in\ the\ month}$$

Holidays were also excluded from the weekday average and weekend average electricity data because electricity usage on holidays tended to be inconsistent.

4 Results

4.1 Baselines of Occupants' Electricity Usage

The baselines of occupants' electricity usage illustrate the general trend of electricity usage in the building. Figure 12 shows the total electricity usage of by month, as well as the percentage of total electricity usage in tenant areas, relative to the total electricity usage of the building. The mean electricity usage of the building was 74,515 kWh per month (SD = 8,872, COV = 8). The energy usage intensity (EUI) of the building in 2019 was 0.32 GJ/m^2 while the median EUI of office buildings in Canada is 0.99 GJ/m^2 (U.S. Environmental Protection Agency & U.S. Department of Energy, 2018). Therefore, the EUI of the case study building is just one-third that of general office buildings in Canada, which demonstrates the high energy efficiency of the cast study building.

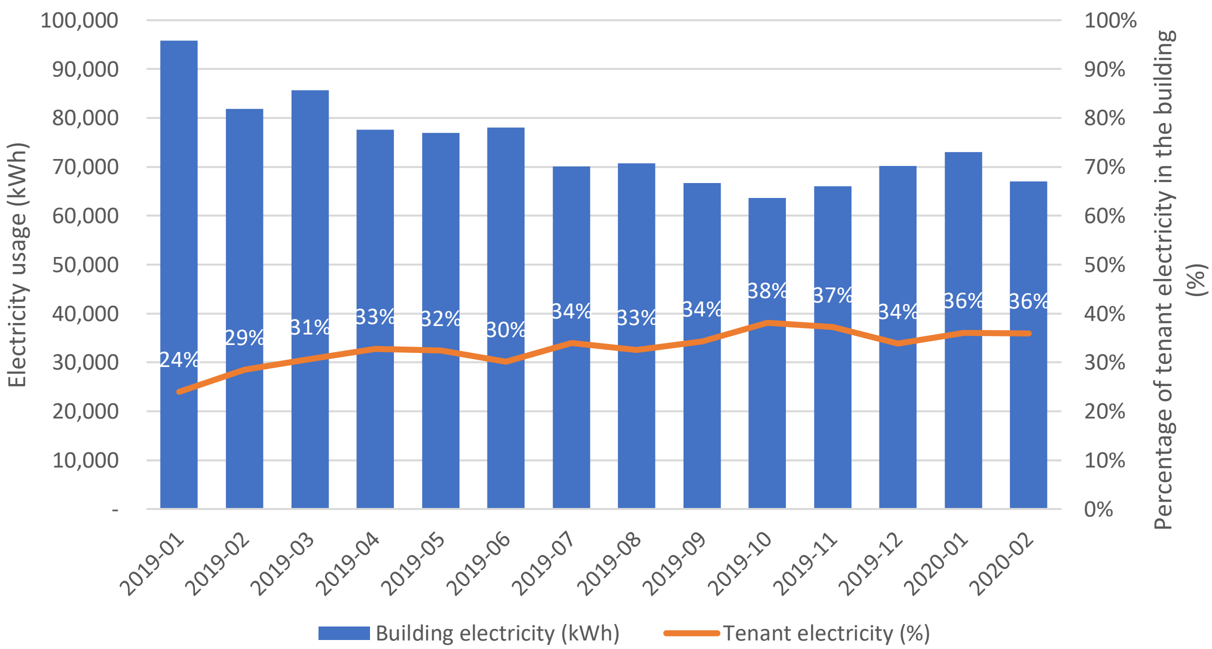

Figure 12 Total electricity usage of the case study building and the percentage of total electricity usage in tenant areas, January 2019 – February 2020

As Figure 12 illustrates, the total electricity usage of the case study building was highest in January 2019 and gradually reduced until February 2020; the total electricity usage in February 2020 was approximately 30% lower than that in January 2021. Meanwhile, the percentage of total electricity usage in tenant areas slightly increased over time. The mean percentage of total electricity usage in tenant areas was 33% (SD = 0.04), and the percentage of total electricity usage in tenant areas increased from 24% in January 2019 to 36% in February 2020.

Electricity usage for lighting in tenant areas represents the amount of electricity used for lighting in Tenant A, Tenant B, Tenant C, and Tenant D. Figure 13 shows the hourly profile of aggregated lighting usage of Tenant A, Tenant B, Tenant C, and Tenant D on weekdays and weekends. The weekday lighting usage of the tenants accelerated from 5 a.m. to 9 a.m. when most people came to their offices in the morning. The highest weekday lighting usage was approximately 17 kW/hr, and the amount of the weekday lighting usage remained high until 5 p.m. when people started leaving for home. On the other hand, the weekend lighting usage was relatively low, rising from 2 kW/hr over night to about 5 kW/hr from 10 a.m. to 5 p.m.

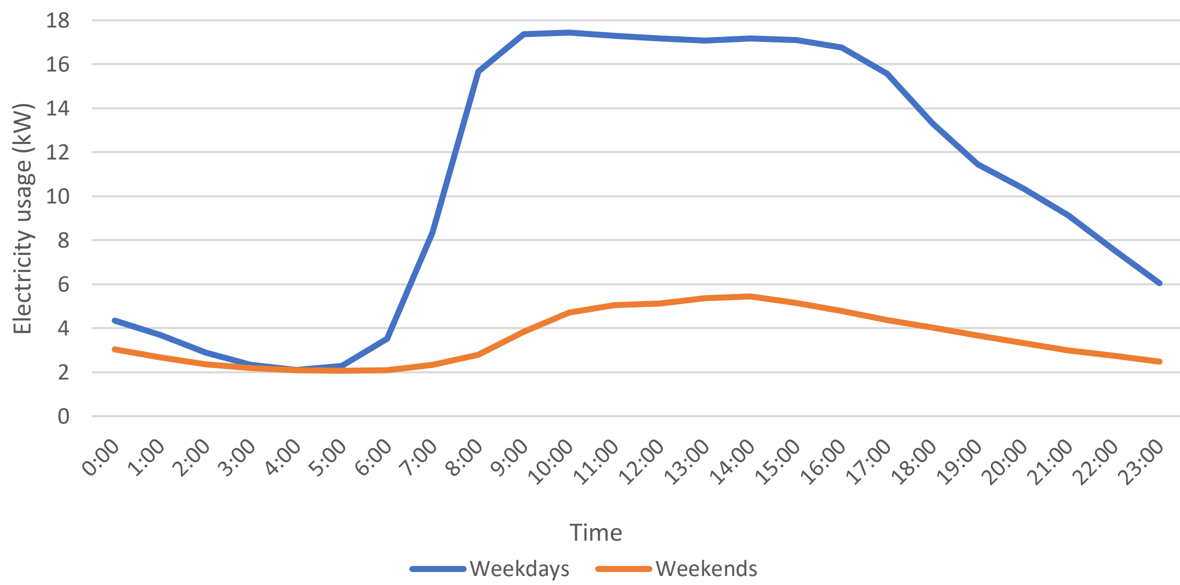

Figure 13 The hourly profile of aggregated electricity usage for lighting of Tenant A, Tenant B, Tenant C, and Tenant D on weekdays and weekends, January – December 2019

Electricity usage for plug loads in tenant areas represents the amount of electricity used for plug loads in Tenant A, Tenant B, Tenant C, and Tenant D. Figure 14 shows the hourly profile of aggregated plug loads of Tenant A, Tenant B, Tenant C, and Tenant D on weekdays and weekends. The weekday plug loads rapidly increased from 7 a.m. to 10 a.m., and it remained around 35 kW/hr until 2 p.m. Compared to the hourly profile of lighting usage, the weekday plug loads increased two hours later in the morning and started reducing three hours earlier in the afternoon. The weekend plug loads were relatively constant about 20 kW/hr, which was more than three times higher than the weekend lighting usage.

Figure 14 The hourly profile of aggregated electricity usage for plug loads of Tenant A, Tenant B, Tenant C, and Tenant D on weekdays and weekends, January – December 2019

4.2 Stairs usage

4.2.1 Changes in stairs usage

This section shows analyses on changes in stairs usage of occupants during the pre-occupancy and the post-occupancy periods. Meanwhile, there was a series of interventions in the case study building during the post-occupancy period, and the analyses also focus on how structural and information interventions affected stairs usage of occupants over time. Cronbach's alphas for stairs usage rates on the second floor and the third floor were 0.79 and 0.65 respectively, which suggests adequate reliability of stairs usage data on the second floor but low reliability of stairs usage data on the third floor.

Figure 15 shows the percentage of stairs usage on the second floor from the pre-occupancy period until the post-occupancy period in March 2020. For stair ascending, the mean percentage of stairs usage in Phase 1 of the Building 2 was 91.1%, and the mean percentage of stairs usage in

Phase 1 of the Building 3 was 87.2%. During the post-occupancy period, the mean percentage of stairs usage in Phase 2, Phase 3, Phase 4, Phase 5, and Phase 6 was 91.0%, 95.6%, 94.3%, 92.2%, and 94.4%. respectively. As these results demonstrate, the percentage rates of stairs usage on the second floor for ascending was very high at over 90%.

For stair descending, the mean percentage rates of stairs usage on the second floor in Phase 1 of the Building 2 was 87.2%, and the mean percentage of stairs usage in Phase 1 of the Building 3 was 89.57%. During the post-occupancy period, the mean percentage rates of stairs usage in Phase 2, Phase 3, Phase 4, Phase 5, and Phase 6 was 95.1%, 98.1%, 94.3 %, 92.2%, and 95.6 % respectively.

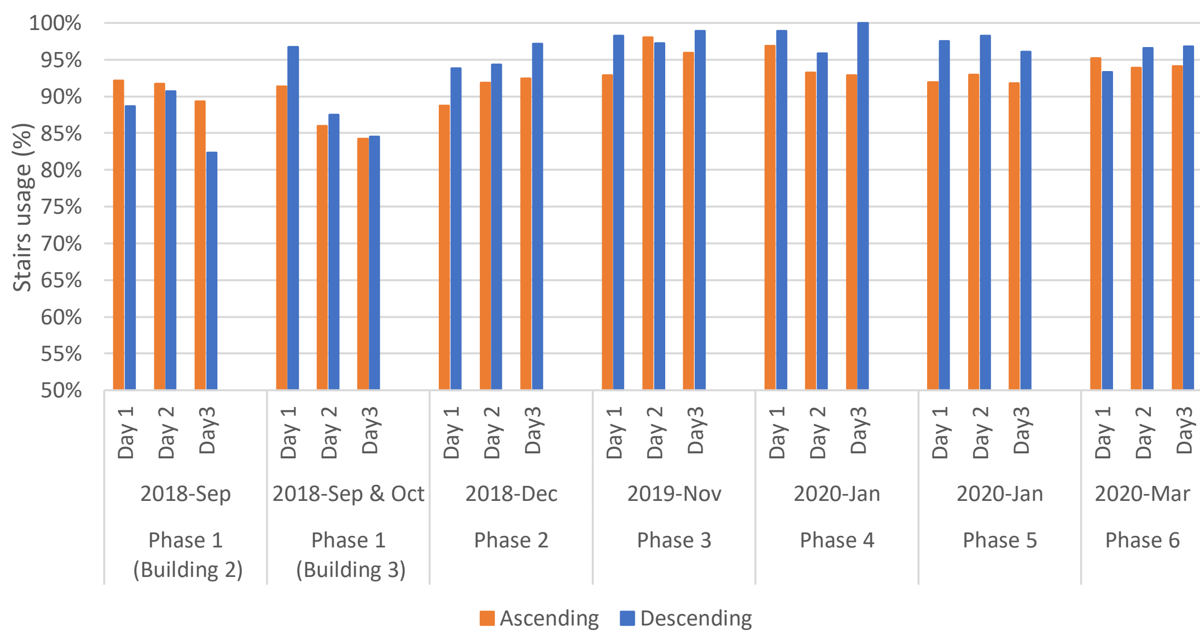

Figure 15 Stairs usage of the second floor, September 2018 – March 2020

In order to test whether significant changes in stairs usage occurred among different phases, one-way ANOVA test was conducted for stairs usage on the second floor. Table 7 shows the results of one-way ANOVA test on stair-ascending data of the second floor. There were significant differences between Phase 1 of the Building 3 and Phase 3 ($p < 0.05$); Phase 1 of Building 3 and

Phase 4 ($p < 0.05$); and Phase 1 of Building 3 and Phase 6 ($p < 0.05$). This indicates that stairs usage for ascending on the second floor increased in Phases 3, 4 and 6 compared to Phase 1 of the Building 3. The higher rate of pre-occupancy ascending stairs usage in Building 2, compared to Building 3, was not statistically different than the post-occupancy levels in the case study building. Both had levels over 90% with little room for further increases. Stairs usage for ascending did not significantly change among Phases 4, 5, and 6, which suggests that newsletter interventions did not significantly affect stairs usage for ascending on the second floor.

Table 7 One-way ANOVA test on stairs usage for ascending to the second floor, September 2018 – March 2020 (observation data)

Phase	**1 (B2)**	**1 (B3)**	**2**	**3**	**4**	**5**	**6**	**M**	**SD**
Phase 1 (Building 2)	-							91.1%	0.02
Phase 1 (Building 3)	0.35	-						87.2%	0.04
Phase 2	1.00	0.36	-					91.0%	0.02
Phase 3	0.20	0.00*	0.19	-				95.6%	0.03
Phase 4	0.54	0.02*	0.52	0.99	-			94.3%	0.02
Phase 5	0.99	0.13	0.99	0.49	0.88	-		92.2%	0.01
Phase 6	0.50	0.01*	0.49	0.99	1.00	0.86	-	94.4%	0.01

*The mean difference is significant at the 0.05 level.

Table 8 shows the results of one-way ANOVA test on stair-descending data of the second floor. There were significant differences between Phase 1 of the Building 2 and Phase 3 ($p < 0.05$); Phase 1 of the Building 2 and Phase 4 ($p < 0.05$); Phase 1 of the Building 2 and Phase 5 ($p < 0.05$). This indicates that stairs usage for descending increased from Phase 1 of the Building 2 to Phases 3, 4, and 5. The higher rate of pre-occupancy descending stairs usage in Building 3, compared to Building 2, was not statistically different than the post-occupancy levels in the case study building.

Both had levels over 87% with little room for further increase. Similar to the stair-ascending data on the second floor, stairs usage for descending on the second floor also did not significantly change between Phases 4 and 6, which indicates that there were no significant changes in stairs usage during the newsletter interventions.

Table 8 One-way ANOVA test on stairs usage for descending from the second floor, September 2018 – March 2020 (observation data)

Phase	1 (B2)	1 (B3)	2	3	4	5	6	M	SD
Phase 1 (Building 2)	-							87.2%	0.04
Phase 1 (Building 3)	0.97	-						89.5%	0.06
Phase 2	0.10	0.40	-					95.1%	0.02
Phase 3	0.01*	0.07	0.91	-				98.1%	0.01
Phase 4	0.01*	0.06	0.89	1.00	-			98.3%	0.02
Phase 5	0.02*	0.12	0.98	1.00	1.00	-		97.3%	0.01
Phase 6	0.08	0.32	1.00	0.95	0.94	0.99	-	95.6%	0.02

*The mean difference is significant at the 0.05 level.

Figure 16 shows the percentage rates of stairs usage on the third floor from the pre-occupancy period until the post-occupancy period in March 2020. For stair ascending, the mean percentage of stairs usage in Phase 1 of Building 1 was 30.6%, and the mean percentage of stairs usage in Phase 1 of Building 2 was 64.3%. During the post-occupancy period, the mean percentage of stairs usage in Phase 2, Phase 3, Phase 4, Phase 5, and Phase 6 was 57.1%, 53.0%, 35.2%, 37.6%, and 36.4% respectively.

For stair descending, the mean percentage of stairs usage in Phase 1 of Building 1 was 47.13%, and the mean percentage of stairs usage in Phase 1 of Building 2 was 81.1%. During the post-occupancy period, the mean percentage of stairs usage in Phase 2, Phase 3, Phase 4, Phase 5, and Phase 6 was 82.1%, 66.8%, 67.9%, 64.1%, and 70.4% respectively.

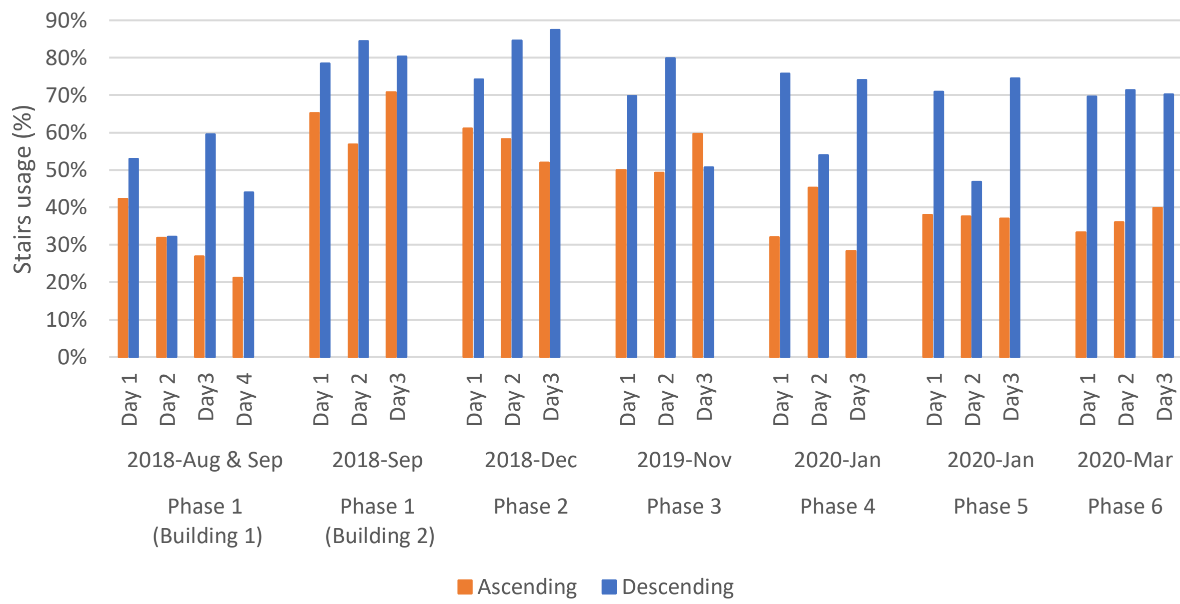

Figure 16 Stairs usage of the third floor, September 2018 – March 2020

Table 9 shows the results of one-way ANOVA test on stair-ascending data of the third floor. There were significant differences between Phase 1 of Building 1 and Phase 1 of Building 2 ($p < 0.05$); Phase 1 of Building 1 and Phase 2 ($p < 0.05$); and Phase 1 of Building 1 and Phase 3 ($p < 0.05$). In addition, there were also significant differences between Phase 1 of Building 2 and Phase 4 ($p < 0.05$); Phase 1 of Building 2 and Phase 5 ($p < 0.05$); Phase 1 of Building 2 and Phase 6 ($p < 0.05$). During the post-occupancy period, there were significant differences between Phase 2 and Phase 4 ($p < 0.05$); Phase 2 and Phase 5 ($p < 0.05$); and Phase 2 and Phase 6 ($p < 0.05$).

The stairs usage for ascending to the third floor was two times higher in Building 2 compared to Building 1 in Phase 1. The importance of the structural configuration of the central staircase in the atrium was noted previously. Stairs usage for ascending in Phase 2 and 3 was similar to that in Building 2 and significantly above Phase 1 in Building 1. On the other hand, stairs usage for ascending reduced significantly during Phase 4 to Phase 6, compared to Phase 2.

Although stairs usage for ascending significantly changed during the post-occupancy period, there were no significant changes during the newsletter intervention periods.

Table 9 One-way ANOVA test on stairs usage for ascending to the third floor, September 2018 – March 2020 (observation data)

Phase	1 (B1)	1 (B2)	2	3	4	5	6	M	SD
Phase 1 (Building 1)	-							30.6%	0.09
Phase 1 (Building 2)	0.00*	-						64.3%	0.07
Phase 2	0.00*	0.82	-					57.1%	0.05
Phase 3	0.01*	0.39	0.99	-				53.0%	0.06
Phase 4	0.96	0.00*	0.01*	0.05	-			35.2%	0.09
Phase 5	0.79	0.00*	0.03*	0.12	1.00	-		37.6%	0.00
Phase 6	0.89	0.00*	0.02*	0.08	1.00	1.00	-	36.4%	0.03

*The mean difference is significant at the 0.05 level.

Table 10 shows the results of one-way ANOVA test on stair-descending data of the third floor. There were significant differences between Phase 1 of Building 1 and Phase 1 of Building 2 ($p < 0.05$); and Phase 1 of Building 1 and Phase 2 ($p < 0.05$). The result shows that stairs usage for descending was almost two times higher in Phase 1 of Building 1, compared to Phase 1 of Building 2 and that the difference was statistically significant. However, there were no significant differences among phases in the post-occupancy period, as well as during the newsletter interventions. This suggests that stairs usage for descending was not affected by newsletters. Although not statistically significant, a pattern similar to the ascending usage can be seen with higher descending usage in Phase 2 and then lower levels thereafter. Figure 16 shows that stairs usage was consistent at 70% for all three days of observation in Phase 6 whereas Phases 3, 4, and 5 had two days at the 70% level and 1 day at the 50% level.

Table 10 One-way ANOVA test on stairs usage for descending from the third floor, September 2018 – March 2020 (observation data)

Phase	1 (B1)	1 (B2)	2	3	4	5	6	M	SD
Phase 1 (Building 1)	-							47.1%	0.12
Phase 1 (Building 2)	0.01*	-						81.1%	0.03
Phase 2	0.01*	1.00	-					82.1%	0.07
Phase 3	0.26	0.67	0.60	-				66.8%	0.15
Phase 4	0.21	0.74	0.67	1.00	-			67.9%	0.12
Phase 5	0.42	0.48	0.42	1.00	1.00	-		64.1%	0.15
Phase 6	0.13	0.88	0.82	1.00	1.00	0.99	-	70.4%	0.01

*The mean difference is significant at the 0.05 level.

In addition to the observation data, sensor data of stairs usage on the second floor was also investigated to see changes in stairs usage during the post-occupancy period. As there were no sensors in the pre-occupancy period, sensor data from Phase 3 to Phase 6 in the post-occupancy period was examined. In addition, sensors recorded the number of people using stairs unlike observation data showing the percentage of stairs usage.

Figure 17 shows the average daily number of people using stairs for ascending and descending on the second floor from Phase 3 to Phase 6. For stair ascending, the mean numbers of people using stairs in Phase 3, Phase 4, Phase 5, and Phase 6 were 116 people, 133 people, 97 people, and 87 people respectively. For stair descending, the mean numbers of people using stairs in Phase 3, Phase 4, Phase 5, and Phase 6 were 111 people, 137 people, 106 people, and 92 people respectively.

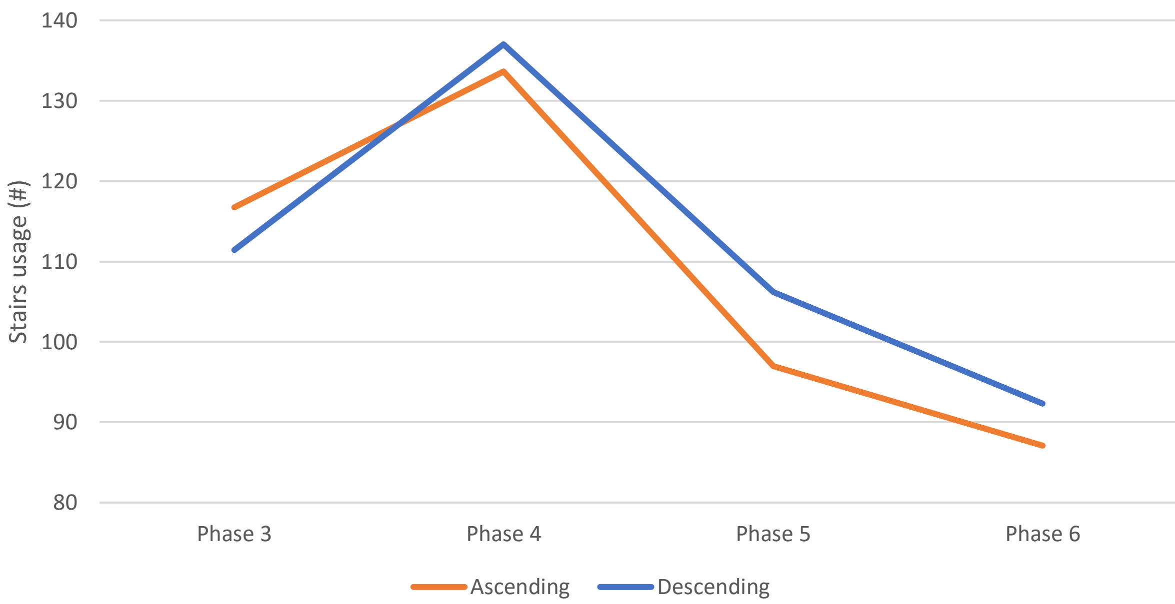

Figure 17 Average daily number of people taking stairs from sensor data for the second floor in the case study building (24 hours data)

One-way ANOVA test was also conducted to examine if there were significant changes in the number of people using stairs on the second floor. Table 11 shows the results of one-way ANOVA test on stair-ascending data of sensor data on the second floor. There were significant differences between Phase 3 and Phase 6 ($p < 0.05$); Phase 4 and Phase 5 ($p < 0.05$); and Phase 4 and Phase 6 ($p < 0.05$). This suggests that the number of people using stairs for ascending significantly reduced from Phase 3 and Phase 4 to Phase 5 and Phase 6. It should be noted that this measure is based on the sensor counts of people while the previous analysis was based on the share of the stairs/elevator total.

Table 11 One-way ANOVA test on the number of stairs usage for ascending to the second floor, October 2019 – March 2020 (sensor data)

Phase	**3**	**4**	**5**	**6**	**M**	**SD**
Phase 3	-				117	17.6
Phase 4	0.22	-			134	14.8
Phase 5	0.12	0.00*	-		97.0	25.7
Phase 6	0.01*	0.00*	0.66	-	87.1	17.0

Table 12 shows the results of one-way ANOVA test on stair-descending data of sensor data on the second floor. There were significant differences between Phase 4 and Phase 5 ($p < 0.05$), and Phase 4 and Phase 6 ($p < 0.05$). As Table 12 shows, the number of people using stairs for descending significantly reduced from Phase 4 to Phase 5, and Phase 4 and Phase 6. These results from the sensor data were different from observation data; sensor data showed significant changes during the newsletter interventions while there were no significant changes in the observation data. Thus, the sensor data showed that there was significant reduction in the number of people using stairs both for ascending and descending during the newsletter interventions.

Table 12 One-way ANOVA test on the number of stairs usage for descending from the second floor, October 2019 - March 2020 (sensor data)

Phase	**3**	**4**	**5**	**6**	**M**	**SD**
Phase 3	-				111	15.8
Phase 4	0.09	-			137	20.5
Phase 5	0.96	0.04*	-		106	36.1
Phase 6	0.28	0.00*	0.56	-	92.3	14.9

4.2.2 Comparison of stairs usage among groups

This section shows analyses on differences in stairs usage between the second floor and the third floor. Comparison of stairs usage between different floors were examined to study how the structural factor affects stairs usage. Figure 18 displays the percentage of stairs usage for ascending to the second and the third floors from the pre-occupancy period until the post-occupancy period in March 2020. In Phase 1, Building 2 and Building 3 were compared since they both had a central staircase, which is the same as the case study building.

T-test and two-way ANOVA test were conducted to see differences in stairs usage between different floors and phases. T-test between the second and third floors for stair ascending showed that there was a significant difference between the second and the third floor from Phase 1 to Phase 6, $t (34 = 14.644, p < 0.05)$. Two-way ANOVA test also showed that the floor, $F (1,24 = 977.320, p < 0.05)$, and Phase, $F (5,24 = 9.051, p < 0.05)$, were significant main effects on stairs usage for ascending. As Figure 18 shows, stairs usage was always higher on the second floor than the third floor in all phases. It also seems that the gap between the second and the third floors became larger from Phase 4.

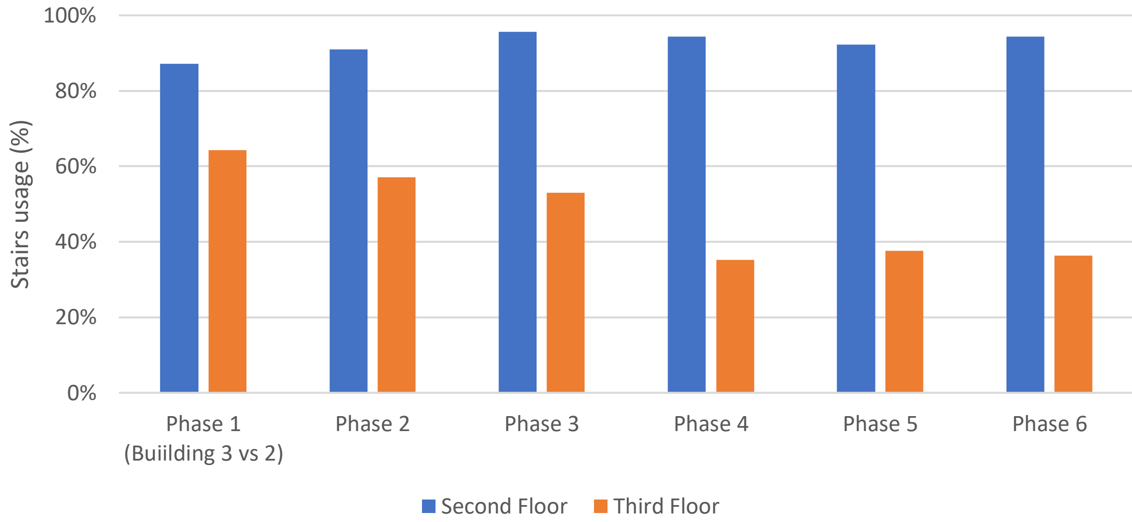

Figure 18 Average stairs usage for ascending to the second and third floors, September 2018 – March 2020

Figure 19 shows the percentage of stairs usage for descending from the second and the third floors from the pre-occupancy period until the post-occupancy period in March 2020. In Phase 1, Building 2 and Building 3 were again compared since they both had a central staircase, which is the same as the case study building. T-test between the second and third floor for stair descending showed that there was a significant difference between the second and the third floor from Phase 1 to Phase 6, t (34 = 8.343, $p < 0.05$). Two-way ANOVA test also showed that the floor was a significant main effect on stairs usage for descending, F (1,24 = 85.357, $p < 0.05$). However, the test shows that Phase was not a significant main effect on stairs usage for descending, F (5,24 = 0.781, $p > 0.05$) unlike stair ascending.

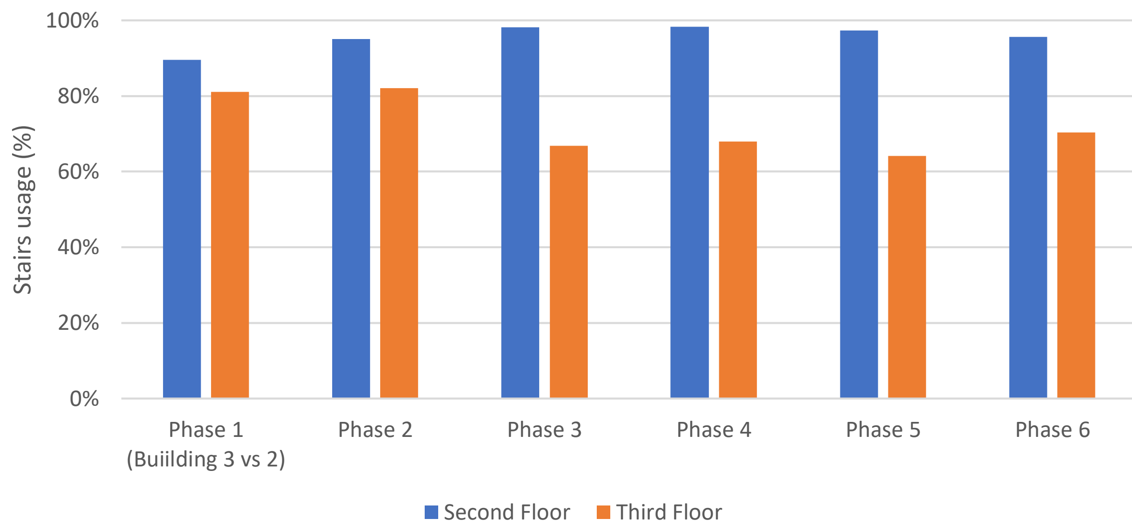

Figure 19 Average stairs usage for descending from the second and third floors, September 2018 – March 2020

Overall, both t-test and two-way ANOVA test suggest that there were significant differences between the second and the third floors for stairs usage.

4.2.3 Relationships between stairs usage and social norms

This section examines relationships between stairs usage and the level of social norms of occupants to understand how social influence affects stairs usage. Figure 20 shows the level of social norms and stairs usage for ascending on the second floor since the pre-occupancy period. In the pre-occupancy period, the level of social norms and stairs usage of occupants both in Building 2 and Building 3 are displayed. The level of social norms in Building 2 and Building 3 were 3.33 (SD = 0.46) and 2.41 (SD = 1.08) respectively (Table 13). As the graph illustrates, the levels of social norms and the percentage of stairs usage for ascending were higher in Building 2, compared to Building 3. In the post-occupancy period, the levels of social norms of Tenant C in June 2019 and June 2020 were 1.92 (SD = 0.90) and 1.89 (SD = 0.69) respectively (Table 13). The level of social norms during the post-occupancy period became lower than the pre-occupancy period while the percentage of stairs usage for ascending remained high. After the newsletter interventions in the case study building, neither stairs usage nor the level of social norms seemed to have greatly changed.

Table 13 The level of social norms of occupants on the second floor

Tenant	**Date**	**Social norms**		
		M	SD	N
Tenant B (B2)	June-2018	3.33	0.46	7
Tenant A: O1 (B3)	June-2018	2.41	1.08	4
Tenant C	June-2019	1.92	0.90	16
Tenant C	June-2020	1.89	0.69	12

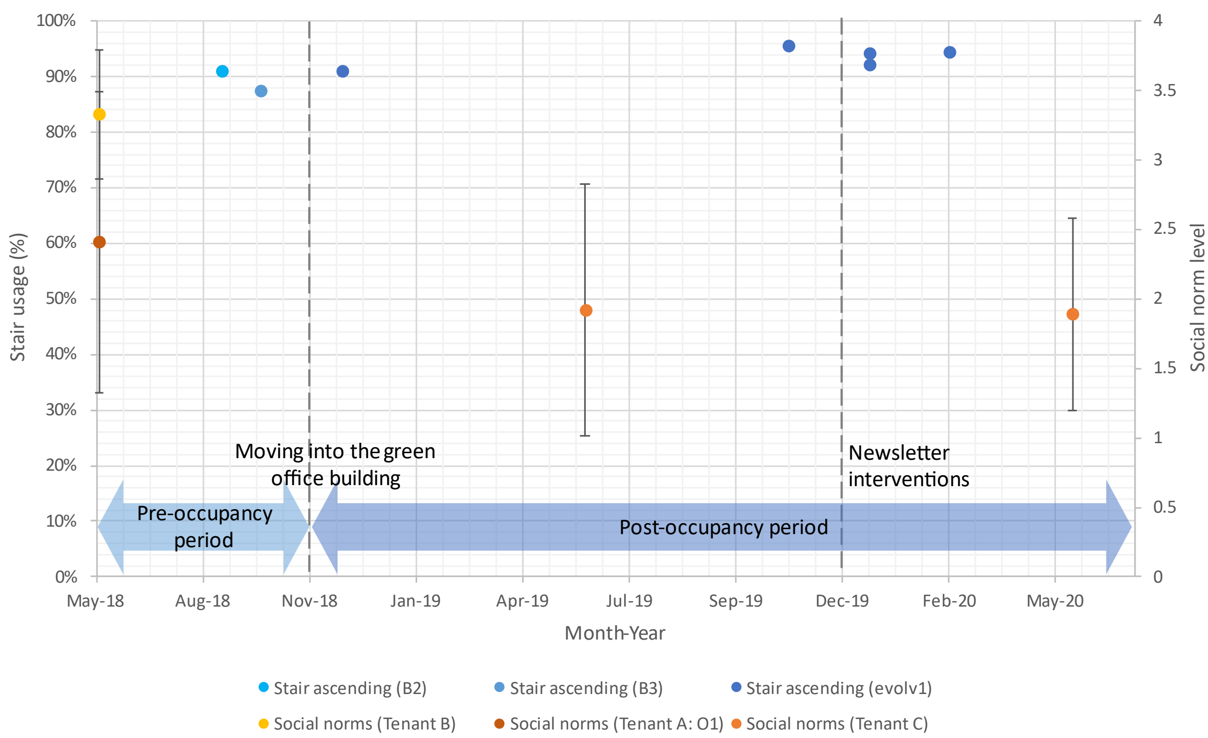

Figure 20 Comparison between social norms and stairs usage for ascending to the second floor

Figure 21 shows the level of social norms and stairs usage for descending from the second floor since the pre-occupancy period. In the pre-occupancy period, the level of social norms and the percentage of stairs usage for descending were higher in Building 2 than Building 3, which is similar to the pattern in stairs usage for ascending. In the post-occupancy period, the percentage of stairs usage for descending slightly increased while the level of social norms became lower, compared to the pre-occupancy period. In addition, there did not seem to have been significant changes in stairs usage for descending and the level of social norms after the newsletter interventions.

Based on changes in the level of social norms and the percentage of stairs usage on the second floor, positive relationships between social norms and stairs usage were not demonstrated. For both stair ascending and descending, the percentage of stairs usage tended to stay high while the level of social norms slightly reduced over time. In addition, the error bars in the graphs describes that the variance in the level of social norms was smaller in Building 2 while it was larger in Building 3 and in the case study building in June 2019. Thus, the level of social norms varied among tenants while the percentage of stairs usage was constantly high on the second floor.

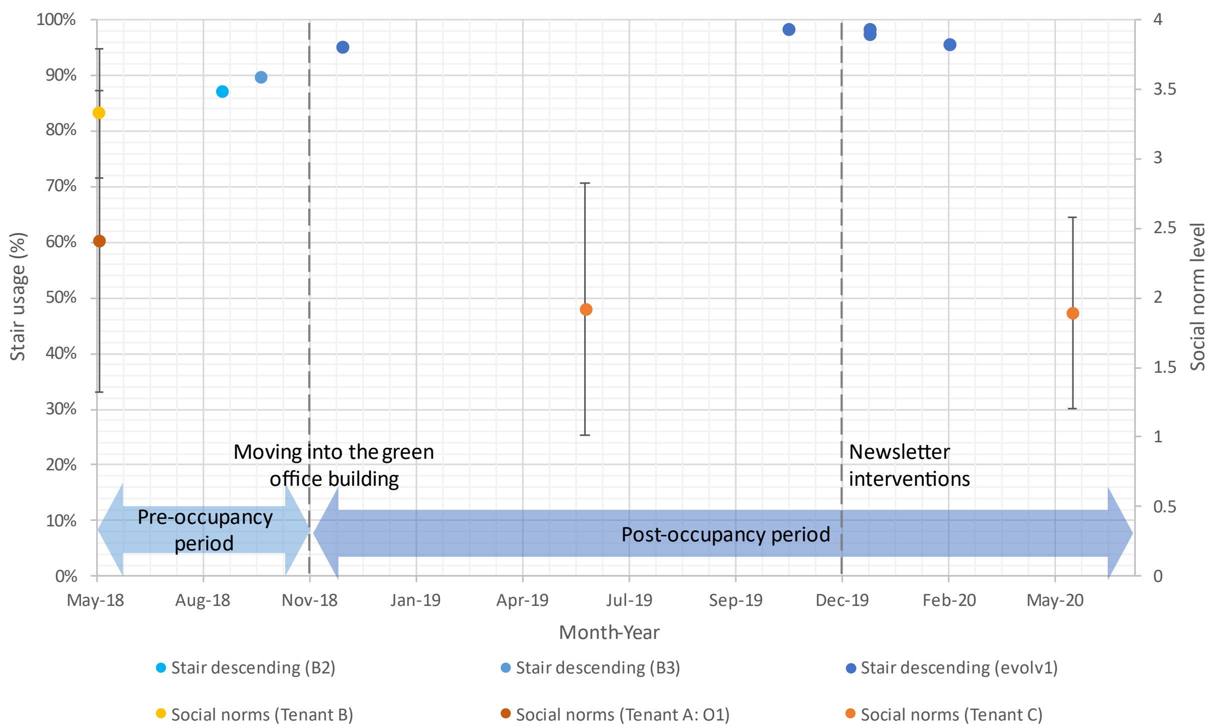

Figure 21 Comparison between social norms and stairs usage for descending from the second floor

Figure 22 shows the level of social norms and stairs usage for ascending to the third floor since the pre-occupancy period. In the pre-occupancy period, the level of social norms and the percentage of stairs usage differed greatly between Building 1 and Building 2. The levels of social norms in Building 1 and Building 2 were 1.21 (SD = 0.88) and 3.33 (SD = 0.46) respectively (Table 14). Occupants in Building 1 had the lower level of social norms and stairs usage rate than occupants in Building 2. In the post-occupancy period, the levels of social norms of Tenant D in June 2019 and June 2020 were 2.43 (SD = 0.89) and 2.62 (SD = 0.81) respectively (Table 14). Consequently, the level of social norms increased in the post-occupancy period, compared to Building 1, but it decreased compared to Building 2. Moreover, the level of social norms did not greatly change after the newsletter intervention while the stairs usage rate decreased.

Table 14 The level of social norms of occupants on the third floor

Tenant	Date	Social norms		
		M	SD	N
Tenant C (B1)	June-2018	1.21	0.88	59
Tenant B (B2)	June-2018	3.33	0.46	7
Tenant D	June-2019	2.43	0.89	76
Tenant D	June-2020	2.62	0.81	71

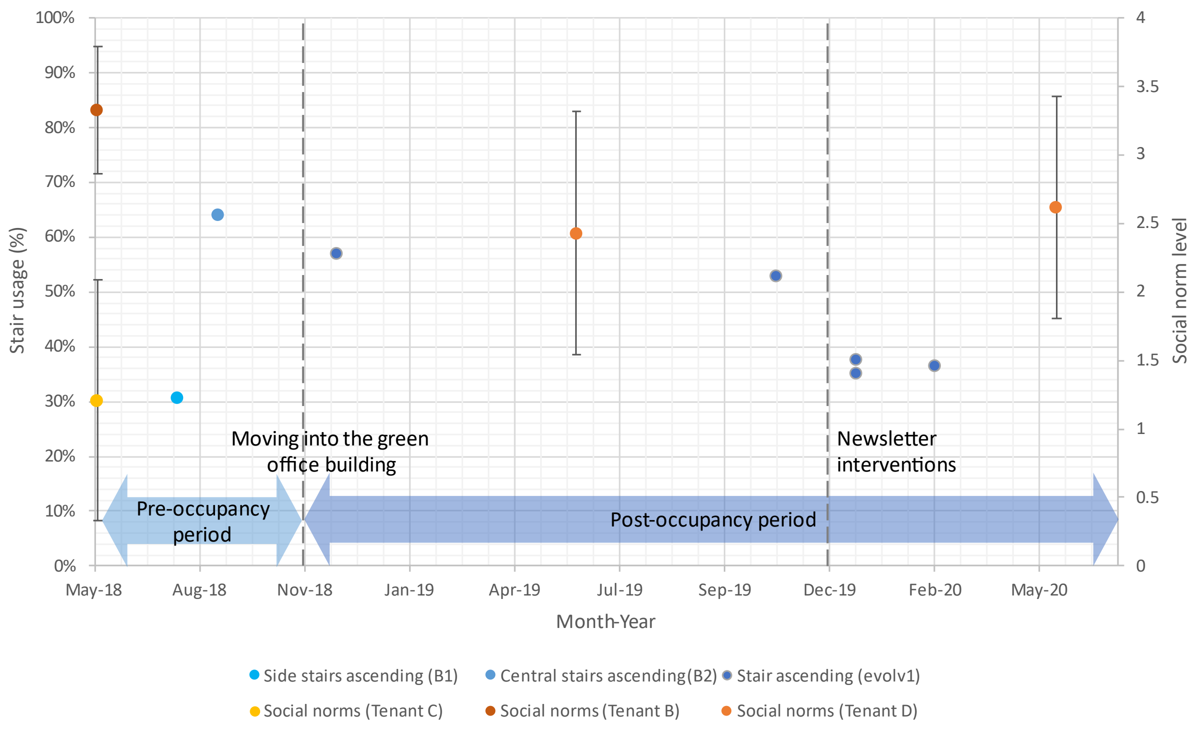

Figure 22 Comparison between social norms and stairs usage for ascending to the third floor

Figure 23 shows the level of social norms and stairs usage for descending from the third floor since the pre-occupancy period. In the pre-occupancy period, the level of social norms and the percentage of stairs usage was again higher in Building 2, compared to Building 1. In the post-occupancy period, the percentage of stairs usage was high at the beginning, but it reduced over time. On the other hand, the level of social norms did not greatly change over time in the post-occupancy period.

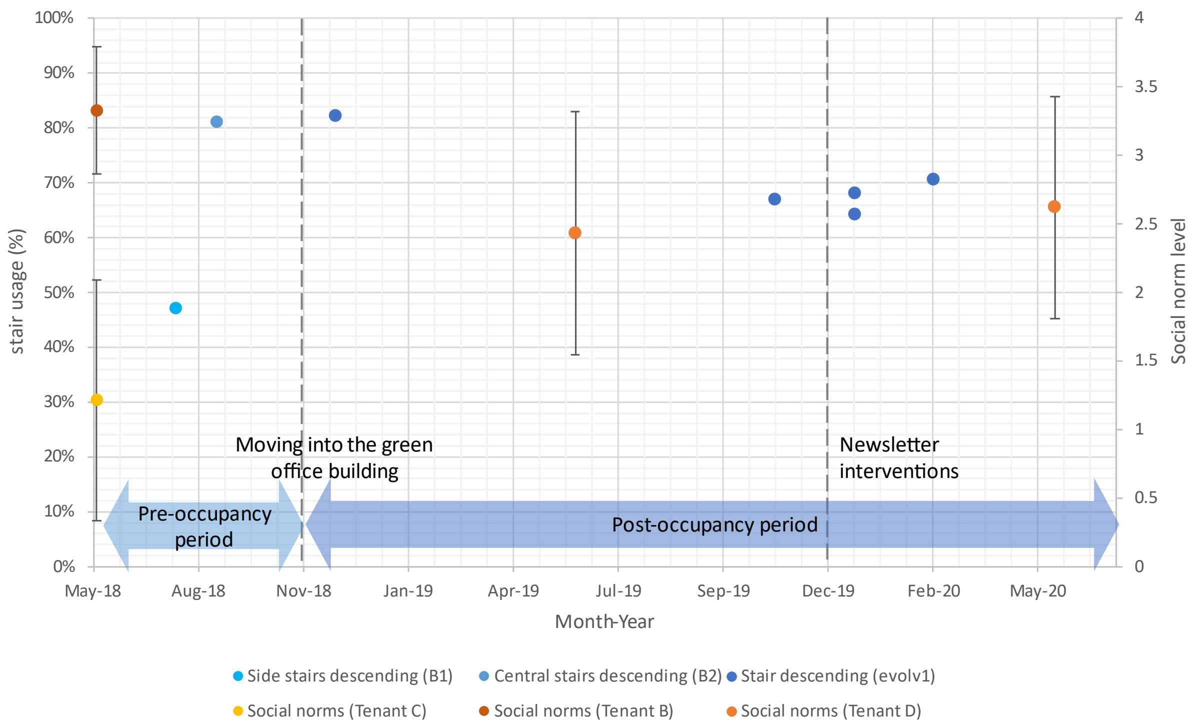

Figure 23 Comparison between social norms and stairs usage for descending from the third floor

Based on changes in the level of social norms and the percentage of stairs usage on the third floor, consistent relationships between the level of social norms and the percentage of stairs usage were not observed. Interestingly, when changes from Building 1 to the case study building were examined, the percentage of stairs usage seemed to have decreased as the level of social norms also became lower. This can be regarded as a positive relationship between social norms and stairs usage, thereby indicating the possible influence of social norms on stairs usage. However, this relationship between social norms and stairs usage was not consistently observed on the second floor. At the same time, the results did not illustrate that the newsletter interventions increased stairs usage among occupants. Instead, the percentage of stairs usage for ascending decreased on the third floor. Thus, these results do not display the hypothesized relationship between social norms and stairs usage, and do not support the idea that social norms and information provision change stairs usage by occupants.

4.3 Electricity usage for lighting and plug loads

4.3.1 Comparison of electricity usage among groups

This section compares electricity usage for lighting and plug loads among different tenants. Cronbach's alphas for lighting and plug loads were 0.78 and 0.75 respectively, which suggests satisfactory reliability of electricity data. Electricity usage in Wh per square meters and Wh per person were compared, and two-way ANOVA test was conducted to investigate differences in electricity usage for plug loads and lighting among different tenants. Since Tenant C and Tenant D have office areas and non-office areas, electricity usage of tenants was compared for only office areas, as well as for all areas including non-office areas.

<u>Lighting usage per square meter (Wh/m^2)</u>

Figure 24 shows the average weekday electricity usage for lighting (Wh/m^2) of tenants in all areas. From January 2019 and February 2020, the mean weekday lighting usage of Tenant A, Tenant B, Tenant C, and Tenant D were 49.1 Wh/m^2, 29.2 Wh/m^2, 39.8 Wh/m^2, and 69.6 Wh/m^2 respectively. As Figure 24 shows, Tenant D had the highest average weekday electricity usage for lighting in all areas over time, and Tenant A had the second highest average lighting usage. Tenant C had the third highest average lighting usage, and Tenant B had the lowest average weekday lighting usage when comparing all tenant areas.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 1112 = 2,363.252, $p < 0.05$, partial $\eta 2 = 0.864$), and months, F (13, 1112 = 8.698, $p < 0.05$, partial $\eta 2 = 0.092$). The partial eta squared suggests that the effect size of tenants was larger than months. Table 15 shows the results of the post hoc test on the weekday lighting usage of tenants, which indicates that the lighting usage was significantly different among all tenants when comparing all areas ($p < 0.05$). Therefore, tenants were a significant main effect on the weekday lighting usage in all areas.

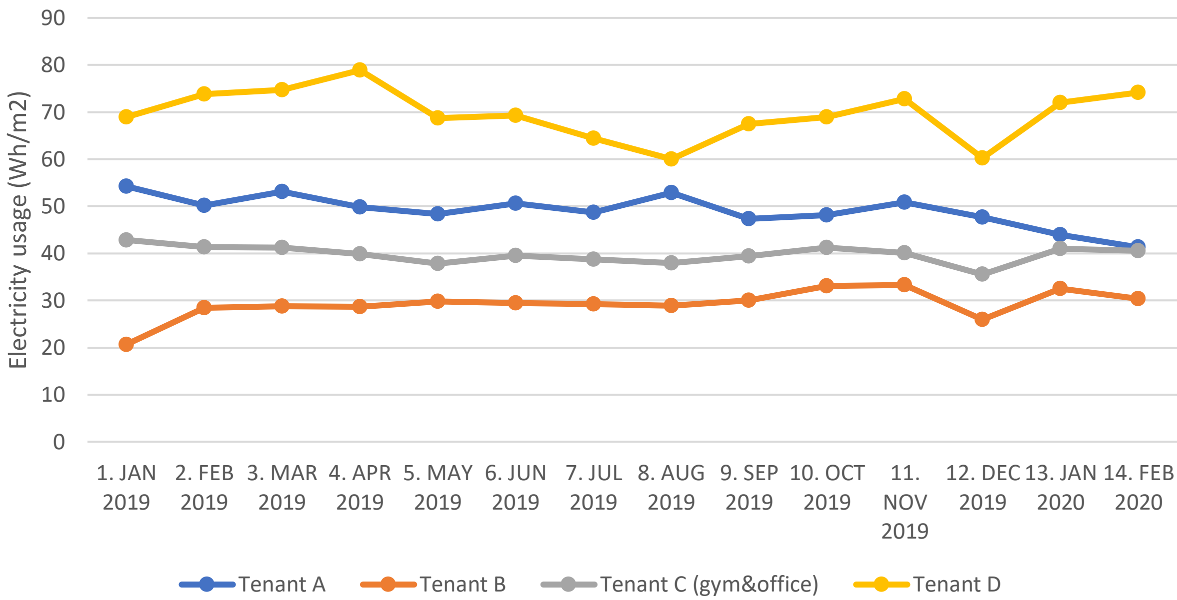

Figure 24 Average electricity usage for lighting (Wh/ m^2) per weekday in all areas, January 2019 – February 2020

Table 15 Two-way ANOVA test on the average electricity usage for lighting (Wh/m^2) per weekday (all areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				49.1	.353
Tenant B	.000	-			29.2	.353
Tenant C	.000	.000	-		39.8	.353
Tenant D	.000	.000	.000	-	69.6	.353

Figure 25 shows the average weekday electricity usage for lighting (Wh/m^2) of tenants in office areas. From January 2019 and February 2020, the mean weekday lighting usage of Tenant C in the office area was 41.1 Wh per square meters. As Figure 25 shows, the average electricity usage for lighting of Tenant D remained the highest and Tenant C remained the third highest when comparing only office areas.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 1112 = 2264.060, $p < 0.05$, partial $\eta 2 = 0.859$), and months, F (13, 1112 = 8.729, $p < 0.05$, partial $\eta 2 = 0.093$). The partial eta squared suggests that the effect size of tenants was larger than months, which is the same as the results of the weekend lighting usage in all areas. Table 16 shows the results of the post hoc test on the weekday lighting usage of tenants in office areas, which indicates that the lighting usage in office areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekday lighting usage in office areas.

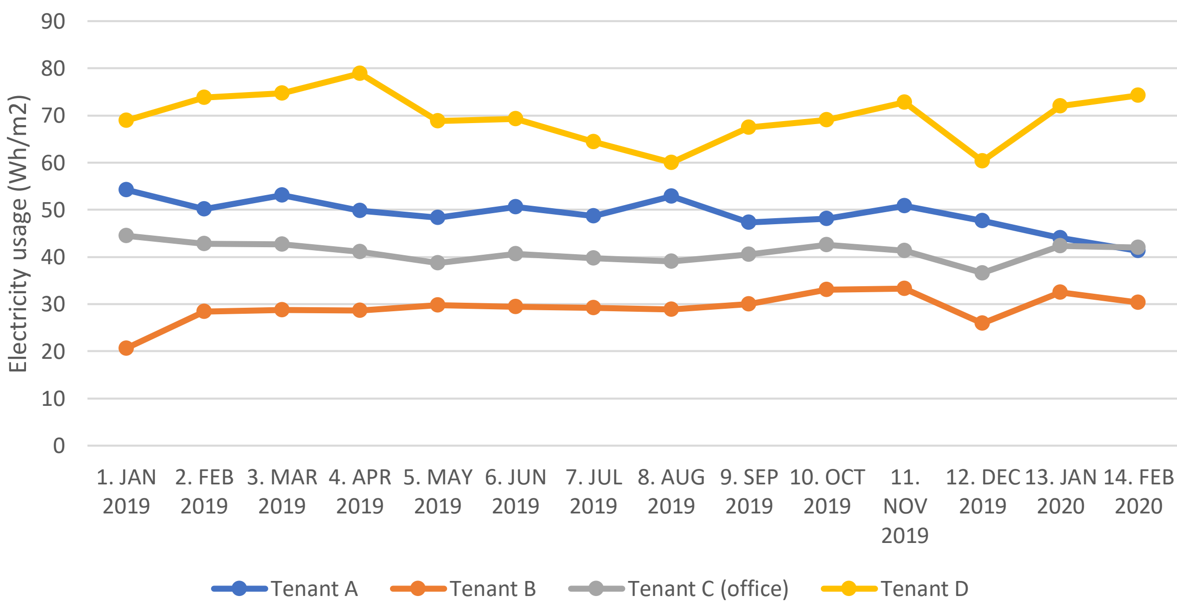

Figure 25 Average electricity usage for lighting (Wh/m^2) per weekday in office areas, January 2019 – February 2020

Table 16 Two-way ANOVA test on the average electricity usage for lighting (Wh/m^2) per weekday (only office area)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				49.1	.357
Tenant B	.000	-			29.2	.357
Tenant C (office)	.000	.000	-		41.1	.357
Tenant D	.000	.000	.000	-	69.6	.357

Figure 26 shows the average weekend electricity usage for lighting (Wh/m^2) of tenants in all areas. From January 2019 and February 2020, the mean weekend lighting usage of Tenant A, Tenant B, Tenant C, and Tenant D were 27.2 Wh/m^2, 9.21 Wh/m^2, 7.31 Wh/m^2, and 27.4 Wh/m^2. As Figure 26 shows, Tenant D had the highest lighting usage between January and April 2019, as well as between January and February 2020. On the other hand, Tenant A had the highest lighing usage between May and December 2019.

Two-way ANOVA test suggests significant effects for tenants, F (3, 428 = 428.167, $p < 0.05$, partial $\eta 2 = 0.750$), and months, F (13, 428 = 9.302, $p < 0.05$, partial $\eta 2 = 0.220$) on the weekend lighting usage in all areas. The partial eta squared suggests that the effect size of tenants was larger than months; however, the partial eta squared for months in the weekend lighting usage was larger, compared to the weekend lighting usage in office areas. Table 17 shows the results of the post hoc test on the weekend lighting usage of tenants in all areas. The weekend lighting usage in all areas were significantly different between Tenant A and Tenant B ($p > 0.05$); between Tenant A and Tenant C ($p > 0.05$); between Tenant B and Tenant D ($p > 0.05$); and between Tenant C and Tenant D ($p > 0.05$). However, the weekend lighting usage in all areas were not significantly different between Tenant A and Tenant D ($p > 0.05$); and between Tenant B and Tenant C (p >

0.05). Therefore, tenants were a significant main effect on the weekend lighting usage in all areas, but the lighting usage of some tenants was similar to one another.

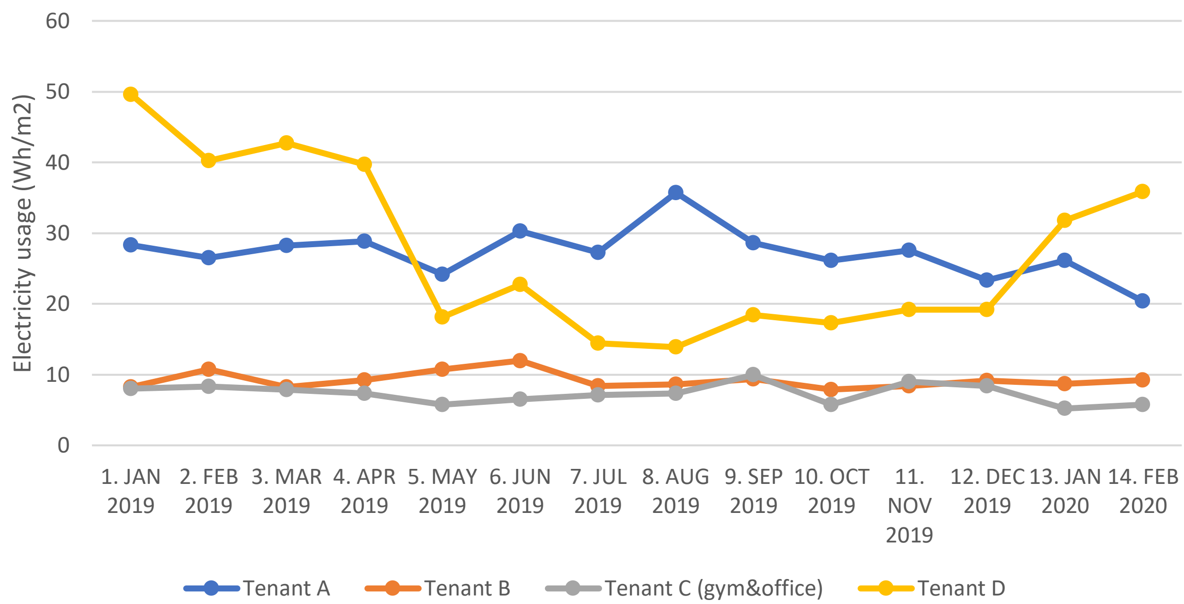

Figure 26 Average electricity usage for lighting (Wh/m^2) per weekend in all areas, January 2019 – February 2020

Table 17 Two-way ANOVA test on the average electricity usage for lighting (Wh/ m^2) per weekend (all areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				27.2	.533
Tenant B	.000	-			9.21	.533
Tenant C	.000	.073	-		7.31	.533
Tenant D	1.00	.000	.000	-	27.4	.533

Figure 32 shows the average weekend lighting usage (Wh/m^2) of tenants in office areas. From January 2019 and February 2020, the mean weekend lighting usage of Tenant C in the office area was 5.95 Wh/m^2. As Figure 27 shows, the weekend lighting usage of Tenant C in the office area was not greatly different, compared to the weekend lighting usage in all areas.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 428 = 450.730, $p < 0.05$, partial $\eta 2 = 0.760$), and months, F (13, 428 = 9.181, $p < 0.05$, partial $\eta 2 = 0.218$). The partial eta squared suggests that the effect size of tenants was larger than months. Table 18 shows the results of the post hoc test on the weekend lighting usage of tenants in office areas. The weekend lighting usage in office areas was significantly different among all tenants ($p < 0.05$), except between Tenant A and D ($p > 0.05$). As the weekend lighting usage of Tenant C in the office area was lower than the lighting usage of all areas, it became not significantly different from the lighting usage of Tenant B. Therefore, tenants were a significant main effect on the weekend lighting usage in office areas.

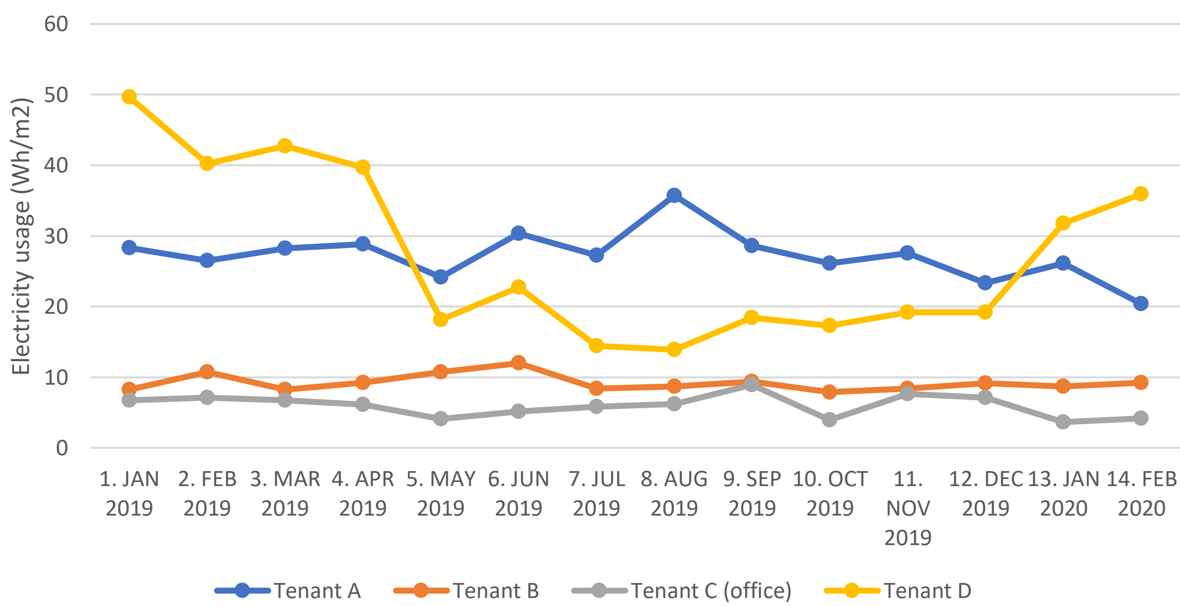

Figure 27 Average electricity usage for lighting (Wh/m^2) per weekend in office areas, January 2019 – February 2020

Table 18 Two-way ANOVA test on the average electricity usage for lighting (Wh/ m^2) per weekend (office area)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				27.2	.540
Tenant B	.000	-			9.21	.540
Tenant C (office)	.000	.000	-		5.95	.540
Tenant D	1.000	.000	.000	-	27.4	.540

Lighting usage per person (Wh/person)

Figure 28 shows the average weekday electricity usage for lighting (Wh/person) of tenants in all areas. From January 2019 and February 2020, the mean weekday lighting usage of Tenant A, Tenant B, Tenant C, and Tenant D is 1,624 Wh/person, 774 Wh/person, 727 Wh/person, and 998 Wh/person. As Figure 28 shows, Tenant A had the highest weekday lighting usage per person, and Tenant D had the second highest weekday lighting usage per person over time.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 1112 = 2981.279, $p < 0.05$, partial $\eta 2 = 0.889$), and months, F (13, 1112 = 7.122, $p < 0.05$, partial $\eta 2 = 0.077$). The partial eta squared suggests that the effect size of tenants was larger than months. Table 19 shows the results of the post hoc test on the weekday lighting usage of tenants in all areas. The weekday lighting usage in all areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekday lighting usage in all areas.

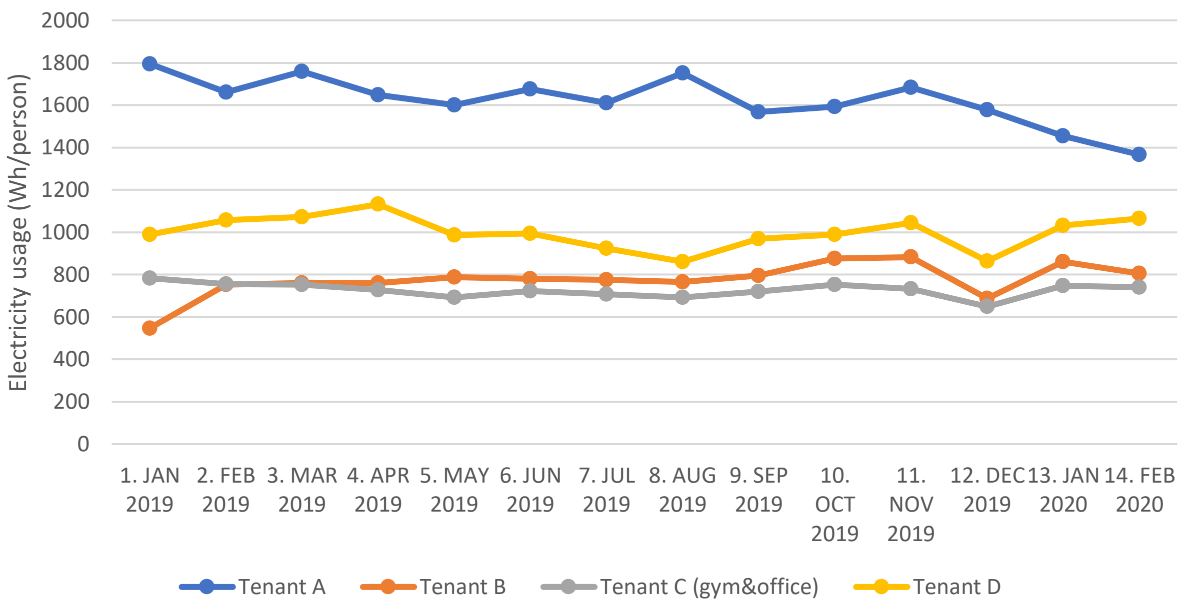

Figure 28 Average electricity usage for lighting (Wh/person) per weekday in all areas, January 2019 – February 2020

Table 19 Two-way ANOVA test on the average electricity usage for lighting (Wh/ person) per weekday (all areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				1,624	7.56
Tenant B	.000	-			774	7.56
Tenant C	.000	.000	-		727	7.56
Tenant D	.000	.000	.000	-	998	7.56

Figure 29 shows the average weekday electricity usage for lighting (Wh/person) of tenants in office areas. From January 2019 and February 2020, the mean weekday lighting usage of Tenant C became 641 Wh/person. As Figure 29 shows, the average weekday lighting usage of Tenant C in the office areas became the lowest between February and April 2019 while the lighting usage in all areas was the second lowest.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 1112 = 3337.293, $p < 0.05$, partial $\eta 2 = 0.900$), and months, F (13, 1112 = 6.999, $p < 0.05$, partial $\eta 2 = 0.076$). The partial eta squared suggests that the effect size of tenants was larger than months. Table 20 shows the results of the post hoc test on the weekday lighting usage of tenants in office areas. The weekday lighting usage in office areas was significantly different among all tenants ($p < 0.05$), which was the same result as the lighting usage in office areas. Therefore, tenants were a significant main effect on the weekday lighting usage in office areas.

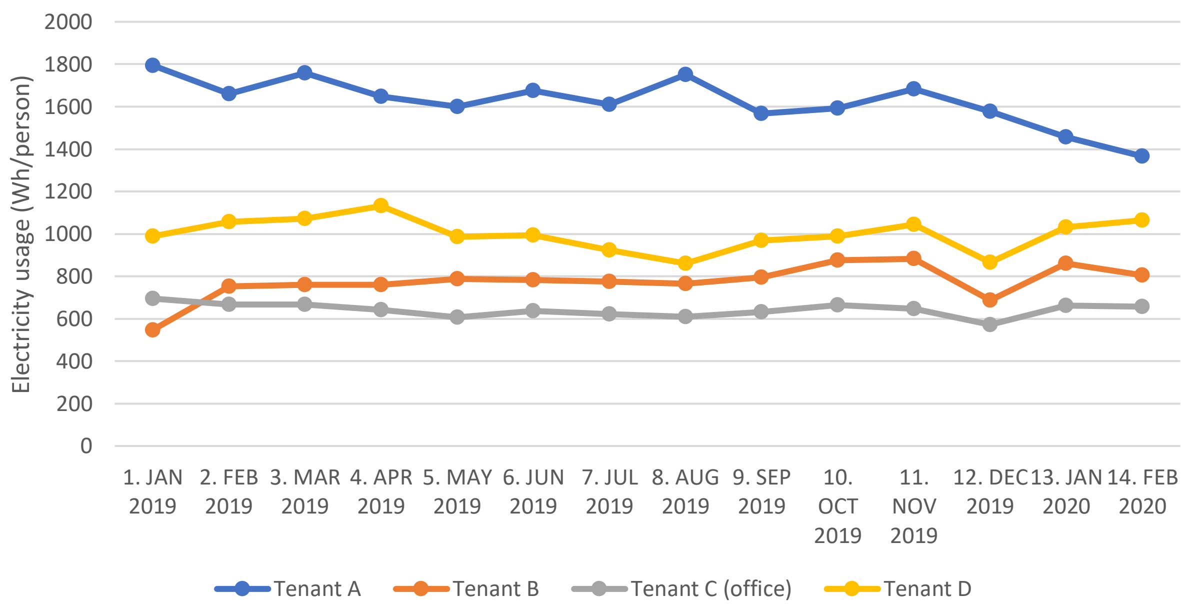

Figure 29 Average electricity usage for lighting (Wh/person) per weekday in office areas, January 2019 – February 2020

Table 20 Two-way ANOVA test on the average electricity usage for lighting (Wh/ person) per weekday (office area only)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				1,624	7.54
Tenant B	.000	-			774	7.54
Tenant C (office)	.000	.000	-		641	7.54
Tenant D	.000	.000	.000	-	998	7.54

Figure 30 shows the average weekend electricity usage for lighting (Wh/person) of tenants in all areas. From January 2019 and February 2020, the mean weekend lighting usage of Tenant A, Tenant B, Tenant C, and Tenant D is 901 Wh/person, 244 Wh/person, 134 Wh/person and 392 Wh/person. As Figure 30 shows, Tenant A had the highest average weekend lighting usage per person, and Tenant B had the second highest average lighting usage although its lighting usage per person from May 2019 and December 2019 was very close to Tenant B.

Two-way ANOVA test suggests significant main effects for tenants, $F (3, 428 = 988.177, p < 0.05$, partial $\eta 2 = 0.874$), and months, $F (13, 428 = 6.063, p < 0.05$, partial $\eta 2 = 0.156$). The partial eta squared suggests that the effect size of tenants was larger than months. Table 21 shows the results of the post hoc test on the weekend lighting usage of tenants in all areas. The weekend lighting usage in all areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekend lighting usage in all areas.

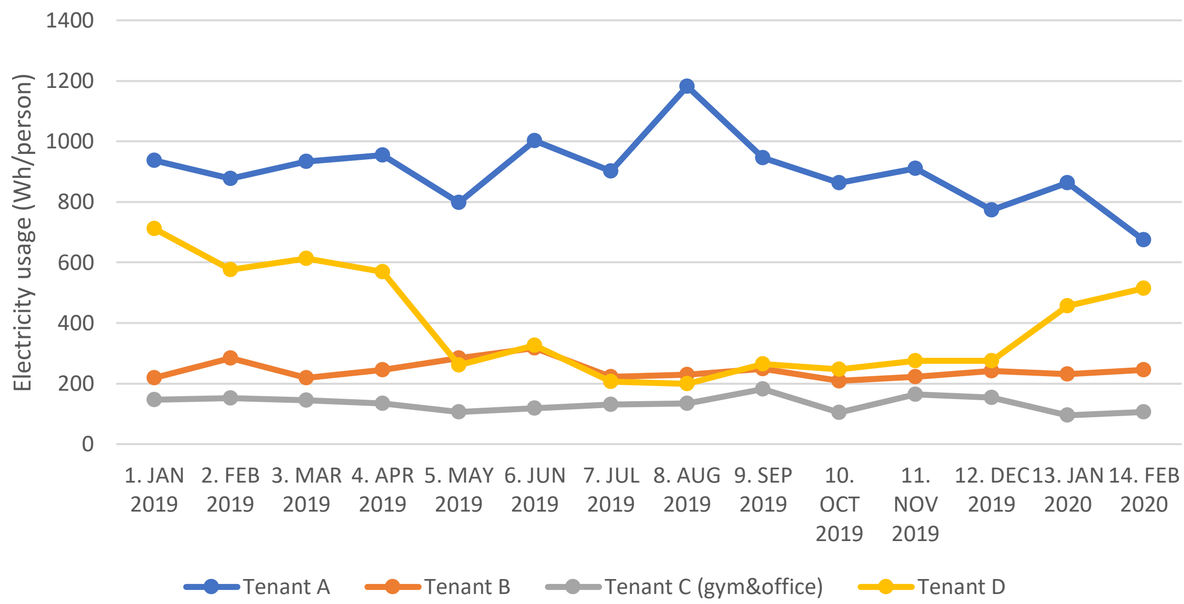

Figure 30 Average electricity usage for lighting (Wh/person) per weekend in all areas, January 2019 – February 2020

Table 21 Two-way ANOVA test on the average electricity usage for lighting (Wh/ person) per weekend (all areas)

Tenant	**A**	**B**	**C**	**D**	**M**	**Std. Error**
Tenant A	-				901	10.8
Tenant B	.000	-			244	10.8
Tenant C	.000	.000	-		134	10.8
Tenant D	.000	.000	.000	-	392	10.8

Figure 31 shows the average weekend electricity usage for lighting (Wh/person) of tenants in office areas. From January 2019 and February 2020, the mean weekend lighting usage of Tenant C dropped to 92.9 Wh/person. As Figure 31 shows, the average weekend lighting usage of Tenant C per person in the office area remained the lowest.

Two-way ANOVA test suggests significant main effects for tenants, $F(3, 428 = 1058.665, p < 0.05$, partial $\eta2 = 0.881)$, and months, $F(13, 428 = 6.120, p < 0.05$, partial $\eta2 = 0.157)$. The partial eta squared suggests that the effect size of tenants was larger than months. Table 22 shows the results of the post hoc test on the weekend lighting usage of tenants in office areas. The weekend lighting usage in office areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekend lighting usage in office areas.

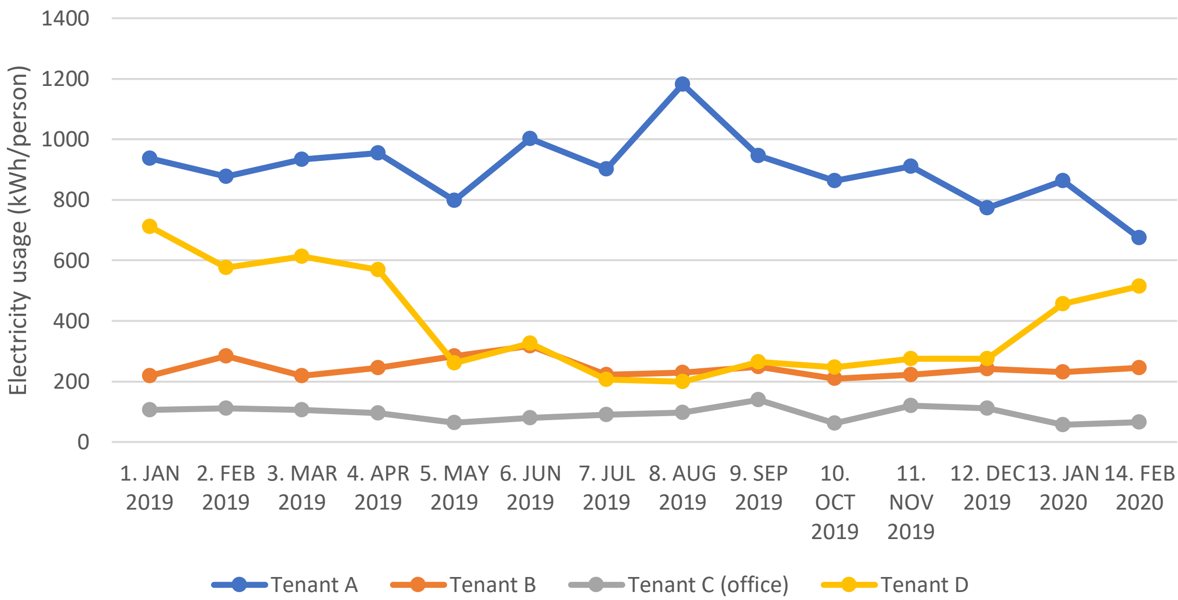

Figure 31 Average electricity usage for lighting (Wh/person) per weekend in office areas, January 2019 – February 2020

Table 22 Two-way ANOVA test on the average electricity usage for lighting (Wh/ person) per weekend (only office areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				901	10.8
Tenant B	.000	-			244	10.8
Tenant C (office)	.000	.000	-		92.9	10.8
Tenant D	.000	.000	.000	-	392	10.8

Plug loads per square meters (Wh/m^2)

Figure 32 shows the average weekday electricity usage for plug loads (Wh/m^2) of tenants in all areas. From January 2019 and February 2020, the mean weekday plug loads of Tenant A, Tenant B, Tenant C, and Tenant D were 35.1 Wh/m^2, 65.1 Wh/m^2, 97.0 Wh/m^2, and 213 Wh/m^2. As Figure 32 shows, Tenant D had the highest average weekday plug loads per square meters, and Tenant C had the second highest average weekday plug loads. Tenant B had the third highest average weekday plug loads per square meters, and Tenant A had the lowest average weekday plug loads.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 1112 = 11305.922, $p < 0.05$, partial $\eta 2 = 0.968$), and months, F (13, 1112 = 29.878, $p < 0.05$, partial $\eta 2 = 0.259$). The partial eta squared suggests that the effect size of tenants was greatly larger than months. Table 23 shows the results of the post hoc test on the weekday plug loads of tenants in all areas. The weekday usage in all areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekday plug loads in all areas.

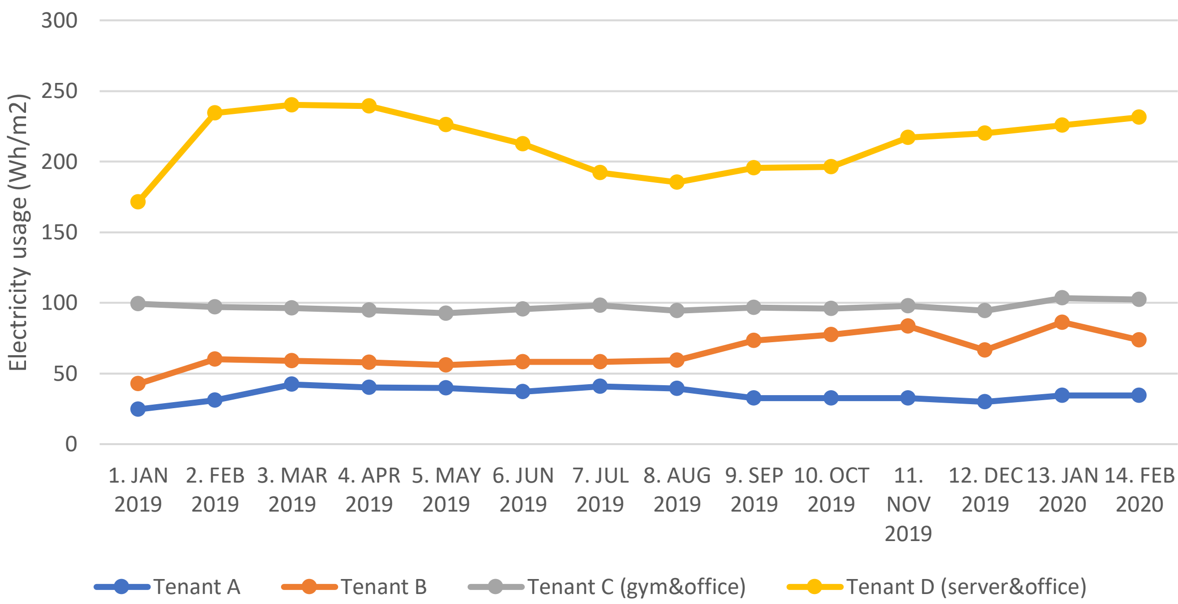

Figure 32 Average electricity usage for plug loads (Wh/m^2) per weekday in all areas, January 2019 – February 2020

Table 23 Two-way ANOVA test on the average electricity usage for plug loads (Wh/m^2) per weekday (all areas)

Tenant	**A**	**B**	**C**	**D**	**M**	**Std. Error**
Tenant A	-				35.1	.733
Tenant B	.000	-			65.1	.733
Tenant C	.000	.000	-		97.0	.733
Tenant D	.000	.000	.000	-	213	.733

Figure 33 shows the average weekday electricity usage for plug loads (Wh/m^2) of tenants in office areas. From January 2019 and February 2020, the mean weekday plug loads of Tenant C became 89.5 Wh/m^2, and the mean weekday plug loads of Tenant D became 105 Wh/m^2. As Figure 33 shows, the mean weekday plug loads of Tenant C and D become closer to each other, particularly in July and August 2019.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 1112 = 2679.780, $p < 0.05$, partial $\eta 2 = 0.878$), and months, F (13, 1112 = 21.626, $p < 0.05$, partial $\eta 2 = 0.202$). The partial eta squared suggests that the effect size of tenants was much larger than months. Table 24 shows the results of the post hoc test on the weekday plug loads of tenants in office areas. The weekday usage in office areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekday plug loads in office areas, which was the same result as the weekday plug loads in all areas.

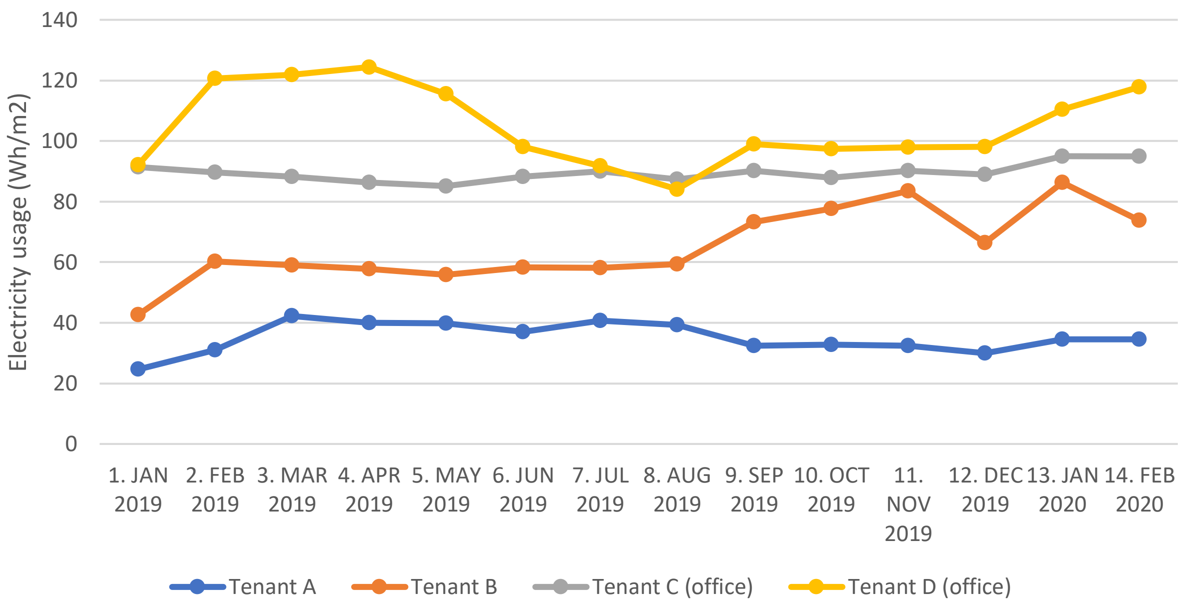

Figure 33 Average electricity usage for plug loads (Wh/m^2) per weekday in office areas, January 2019 – February 2020

Table 24 Two-way ANOVA test on the average electricity usage for plug loads (Wh/m^2) per weekday (only office area)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				35.1	.589
Tenant B	.000	-			65.1	.589
Tenant C (office)	.000	.000	-		89.5	.589
Tenant D (office)	.000	.000	.000	-	105	.589

Figure 34 shows the average weekend electricity usage for plug loads (Wh/m^2) of tenants in all areas. From January 2019 and February 2020, the mean weekend plug loads of all areas in Tenant A, Tenant B, Tenant C, and Tenant D were 24.5 Wh/m^2, 47.9 Wh/m^2, 61.9 Wh/m^2, and 186 Wh/m^2. As Figure 34 shows, Tenant D had the highest weekend plug loads in all areas, and Tenant C had the second highest weekend plug loads. Tenant B had the third highest weekend plug loads, and Tenant A had the lowest weekend plug loads in all areas.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 428 = 7062.865, $p < 0.05$, partial $\eta 2 = 0.980$), and months, F (13, 428 = 18.328, $p < 0.05$, partial $\eta 2 = 0.358$). The partial eta squared suggests that the effect size of tenants was almost three times larger than the effect size of month. Table 25 shows the results of the post hoc test on the weekend plug loads of tenants in all areas. The weekend usage in all areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekend plug loads in all areas.

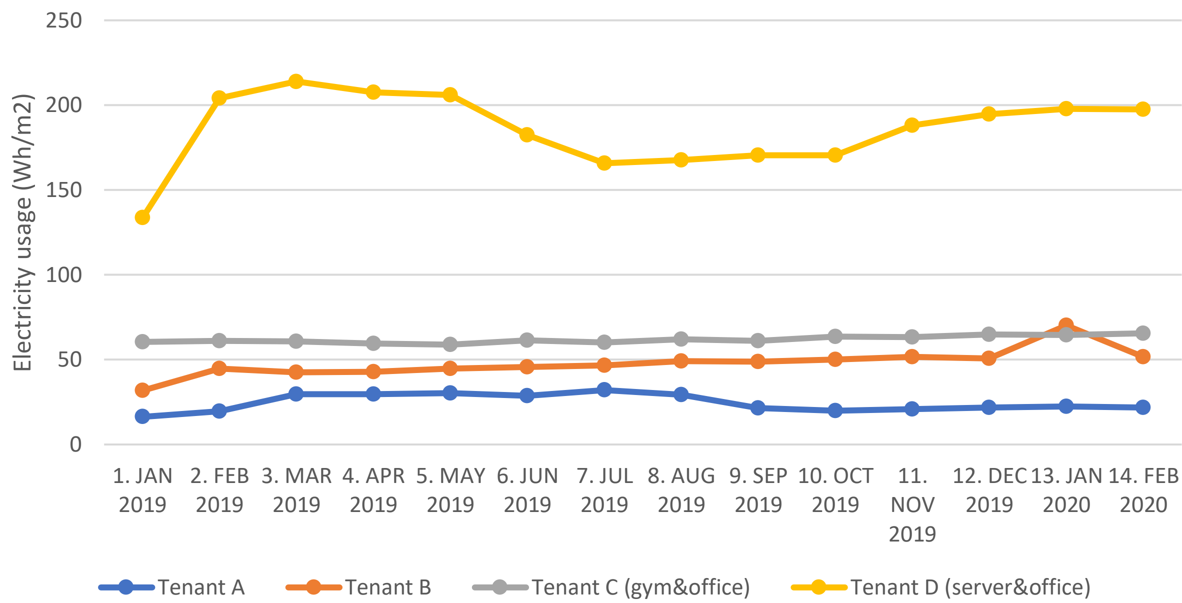

Figure 34 Average electricity usage for plug loads (Wh/ m^2) per weekend in all areas, January 2019 – February 2020

Table 25 Two-way ANOVA test on the average electricity usage for plug loads (Wh/m^2) per weekend (all areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				24.5	.858
Tenant B	.000	-			47.9	.858
Tenant C	.000	.000	-		61.9	.858
Tenant D	.000	.000	.000	-	186	.858

Figure 35 shows the average weekend electricity usage for plug loads (Wh/m^2) of tenants in office areas. From January 2019 and February 2020, the mean weekend plug loads of office areas in Tenant C and Tenant D reduced to 55.8 Wh/m^2 and 79.1 Wh/m^2 respectively. Although Tenant D maintained the highest plug loads per square meters in office areas, its plug loads became closer to other tenants.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 428 = 1441.188, $p < 0.05$, partial $\eta 2 = 0.910$), and months, F (13, 428 = 13.044, $p < 0.05$, partial $\eta 2 = 0.284$). The partial eta squared suggests that the effect size of tenants was more than three times larger than the effect size of month. Table 26 shows the results of the post hoc test on the weekend plug loads of tenants in office areas. The weekend usage in office areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekend plug loads in office areas, which was the same result as the weekend plug loads in all areas.

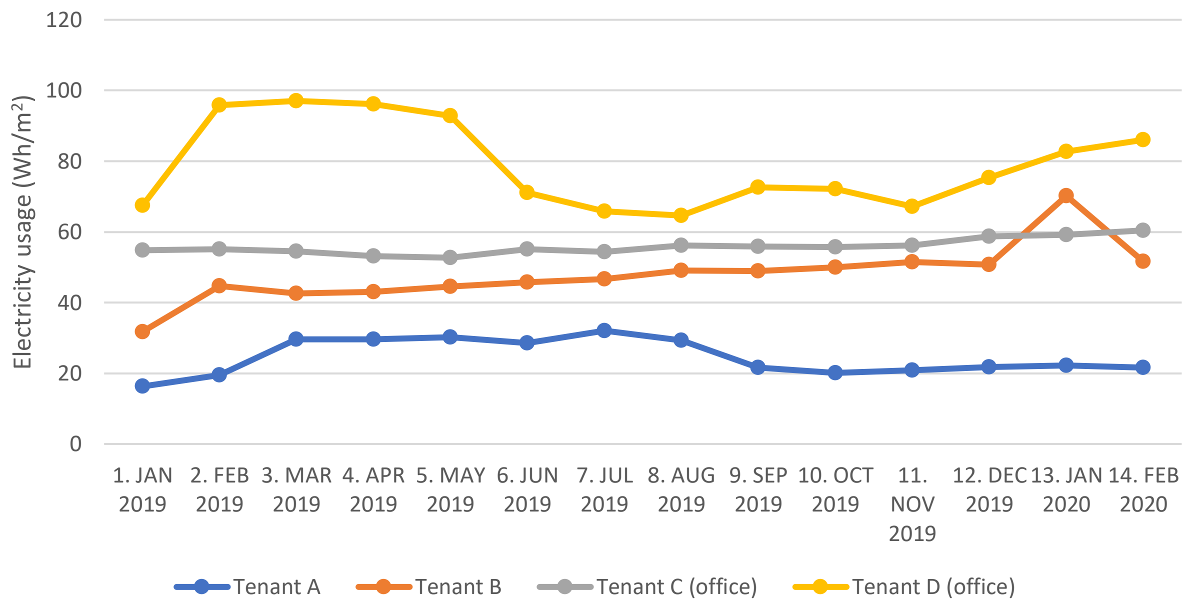

Figure 35 Average electricity usage for plug loads (Wh/m^2) per weekend in office areas, January 2019 – February 2020

Table 26 Two-way ANOVA test on the average electricity usage for plug loads (Wh/m^2) per weekends (only office areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				24.5	.593
Tenant B	.000	-			47.9	.593
Tenant C (office)	.000	.000	-		55.8	.593
Tenant D (office)	.000	.000	.000	-	79.1	.593

Plug loads per person (Wh/person)

Figure 36 shows the average weekday electricity usage for plug loads (Wh/person) of tenants in all areas. From January 2019 and February 2020, the mean weekday plug loads of Tenant A, Tenant B, Tenant C, and Tenant D were 1,162 Wh/person, 1,726 Wh/person, 1,773 Wh/person, and 3,059 Wh/person. As Figure 36 shows, Tenant D had again the highest plug loads per person in all areas. Tenant C had the second highest plug loads between January 2019 and August 2019 while Tenant B had the second highest plug loads after September 2019, which is a different result from the plug loads per square meters. Tenant A had the lowest average plug loads per person in all areas, which is the same result as plug loads per square meters.

Two-way ANOVA test suggests significant main effects for tenants, F (3, 1112 = 2884.431, $p < 0.05$, partial $\eta2 = 0.886$), and months, F (13, 1112 = 26.396, $p < 0.05$, partial $\eta2 = 0.236$). The partial eta squared suggests that the effect size of tenants was almost than four times larger than the effect size of month. Table 27 shows the results of the post hoc test on the weekday plug loads of tenants in all areas. The weekday usage in all areas was significantly different among all tenants

($p < 0.05$), except between Tenant B and Tenant C. Therefore, tenants were a significant main effect on the weekday plug loads in all areas.

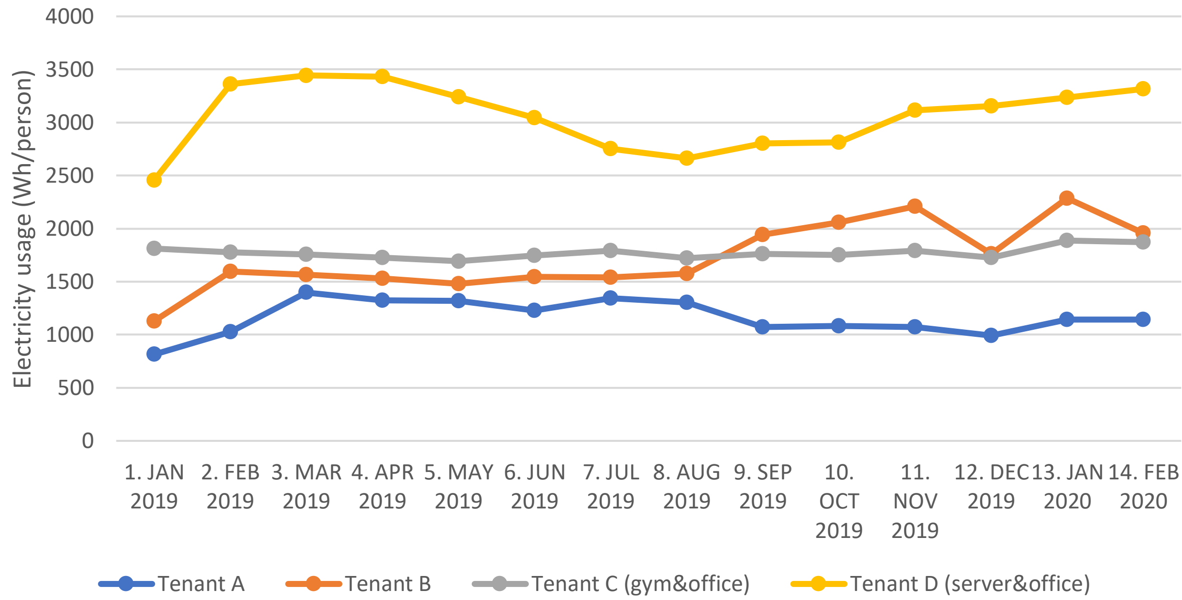

Figure 36 Average electricity usage for plug loads (Wh/person) per weekend in all areas, January 2019 – February 2020

Table 27 Two-way ANOVA test on the average electricity usage for plug loads (Wh/person) per weekday (all areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				1,162	14.9
Tenant B	.000	-			1,726	14.9
Tenant C (gym & office)	.000	.134	-		1,773	14.9
Tenant D (server & office)	.000	.000	.000	-	3,059	14.9

Figure 37 shows the average weekday electricity usage for plug loads (Wh/person) of tenants in office areas. From January 2019 and February 2020, the mean weekday plug loads of office areas in Tenant C and Tenant D reduced to 1,398 Wh/person and 1,504 Wh/person respectively. As Figure 37 shows, the weekday plug loads in office areas is different from that in all areas. Tenant B had the highest average weekday plug loads per person, and Tenant D had the second highest average weekday plug loads per person. Although Tenant A had the lowest average weekday plug loads per person, its weekday plug loads became very close to the plug loads of Tenant C. Therefore, tenants were a significant main effect on the weekday plug loads in office areas.

Two-way ANOVA test suggests significant main effects for tenants, $F (3, 1112 = 302.940$, $p < 0.05$, partial $\eta 2 = 0.450$), and months, $F (13, 1112 = 19.098$, $p < 0.05$, partial $\eta 2 = 0.183$). The partial eta squared suggests that the effect size of tenants was less than 50%, which is smaller than previous results. Nevertheless, it was more than three times larger than the effect size of month. Table 27 shows the results of the post hoc test on the weekday plug loads of tenants in office areas. The weekday usage in office areas was significantly different among all tenants ($p < 0.05$), except between Tenant B and Tenant C. Therefore, tenants were a significant main effect on the weekday plug loads in office areas, but its the main effect was not as large as in the case of the weekday plug loads in all areas.

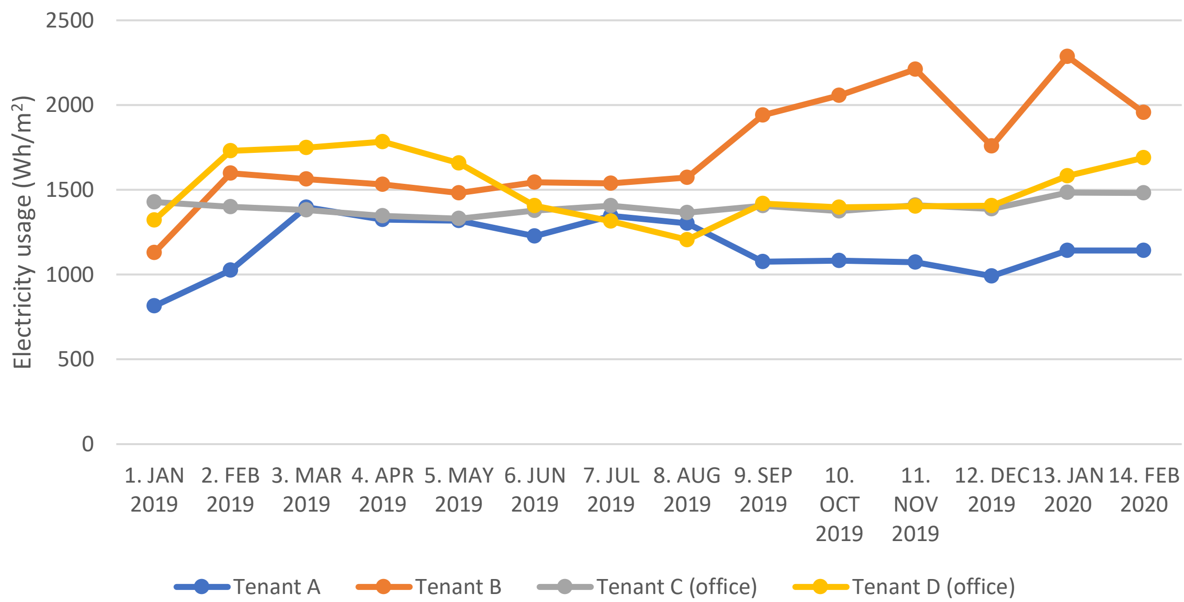

Figure 37 Average electricity usage for plug loads (Wh/person) per weekday in office areas, January 2019 – February 2020

Table 28 Two-way ANOVA test on the average electricity usage for plug loads (Wh/person) per weekday (only office areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				1,162	13.5
Tenant B	.000	-			1,726	13.5
Tenant C (office)	.000	.000	-		1,398	13.5
Tenant D (office)	.000	.000	.000	-	1,504	13.5

Figure 38 shows the average weekend electricity usage for plug loads (Wh/person) of tenants in all areas. From January 2019 and February 2020, the mean weekend plug loads of all areas in Tenant A, Tenant B, Tenant C, and Tenant C were 811 Wh/person, 1,270 Wh/person, 1,131 Wh/person, and 2,663 Wh/person. As Figure 38 shows, Tenant D had the highest plug loads per person over time while the plug loads per person of other tenants were relatively close to one another. In particular, the plug loads of Tenant A, B, and C between March 2019 and August 2019 were very similar at around 1,000 Wh/person in a month.

Two-way ANOVA test suggests significant main effects for tenants, $F(3, 428 = 2735.824$, $p < 0.05$, partial $\eta 2 = 0.950$), and months, $F(13, 428 = 17.926$, $p < 0.05$, partial $\eta 2 = 0.353$). The partial eta squared suggests that the effect size of tenants was almost three times larger than the effect size of month. Table 29 shows the results of the post hoc test on the weekend plug loads of tenants in all areas. The weekend usage in all areas was significantly different among all tenants ($p < 0.05$). Therefore, tenants were a significant main effect on the weekend plug loads in all areas.

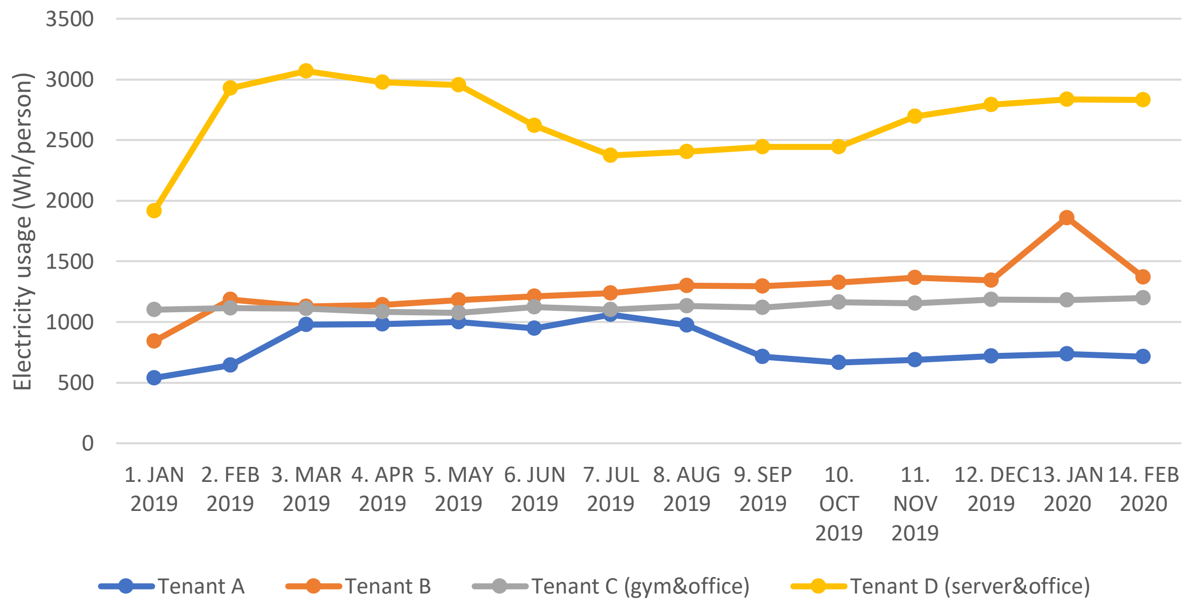

Figure 38 Average electricity usage for plug loads (Wh/person) per weekend in all areas, January 2019 – February 2020

Table 29 Two-way ANOVA test on the average electricity usage for plug loads (Wh/person) per weekend (all areas)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				811	15.7
Tenant B	.000	-			1,270	15.7
Tenant C	.000	.000	-		1,131	15.7
Tenant D	.000	.000	.000	-	2,663	15.7

Figure 39 shows the average weekend electricity usage for plug loads (Wh/person) of tenants in office areas. From January 2019 and February 2020, the mean weekend plug loads of Tenant C and Tenant D changed to 1,131 Wh/person and 2,663 Wh/person respectively. As Figure 39 shows, the plug loads per person in office areas were different from the plug loads in all areas. Tenant B had the highest average weekend plug loads although its plug loads per person were lower than Tenant D between January 2019 and May 2019. Tenant D had the second highest average weekend plug loads per person in office areas, and Tenant C had the third highest average weekend plug loads. Tenant A had the lowest average weekend plug loads per person in office areas while Tenant C had higher weekend plug loads between January and February 2019, as well as between September 2019 and February 2020.

Two-way ANOVA test suggests significant main effects for tenants, $F (3, 428 = 284.845, p < 0.05$, partial $\eta 2 = 0.666$), and months, $F (13, 428 = 11.793, p < 0.05$, partial $\eta 2 = .264$). The partial eta squared suggests that the effect size of tenants was just above 50%, which is smaller than other results. Nevertheless, it was more than two times larger than the effect size of month. Table 30 shows the results of the post hoc test on the weekend plug loads of tenants in office areas. The weekend usage in office areas was significantly different among all tenants ($p < 0.05$).

Therefore, tenants were a significant main effect on the weekend plug loads in office areas although its the main effect was not as large as other results.

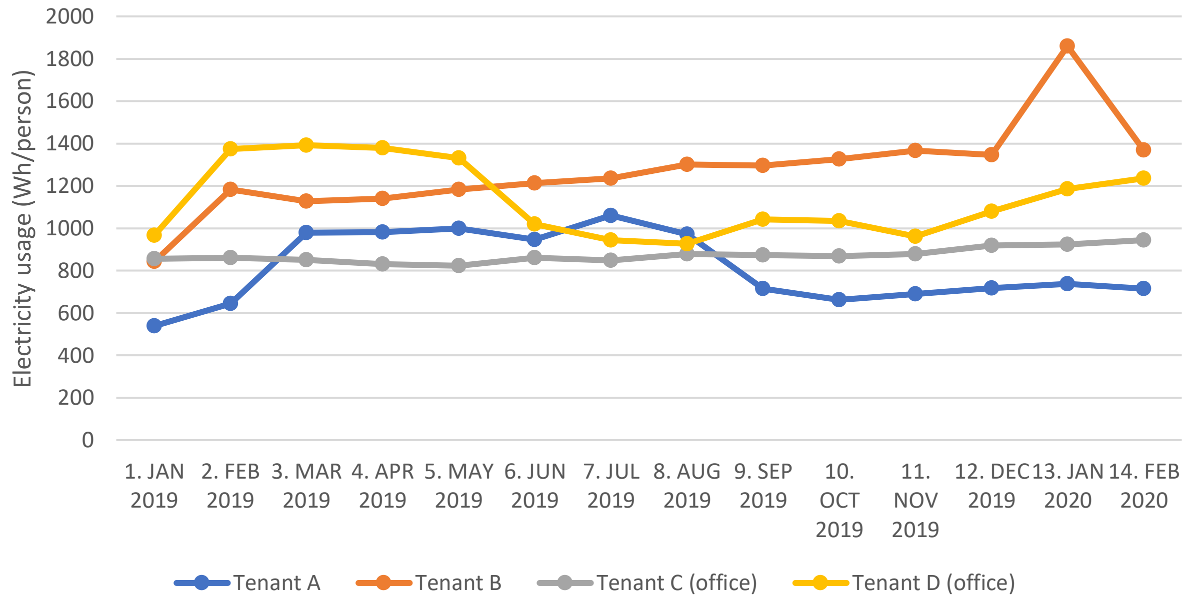

Figure 39 Average electricity usage for plug loads (Wh/person) per weekend in office areas, January 2019 – February 2020

Table 30 Two-way ANOVA test on the average electricity usage for plug loads (Wh/person) per weekend (only office area)

Tenant	A	B	C	D	M	Std. Error
Tenant A	-				811	12.8
Tenant B	.000	-			1270	12.8
Tenant C (office)	.008	.000	-		872	12.8
Tenant D (office)	.000	.000	.000	-	1134	12.8

4.3.2 Relationships among electricity usage, social norms, and social identities

This section investigates relationships among electricity usage, social norms, and social identities of occupants by examining changes in these factors over time. As it is predicted that social norms would have negative relationships with electricity usage and have positive relationships with social identities, relationships between social norms and electricity usage are separately displayed from relationships between social norms and social identities in graphs.

Figure 40 shows changes in the weekday lighting usage, the weekday plug loads, and the level of social norms in Tenant A. The levels of social norms of Tenant A in June 2018, June 2019, and June 2020 were 2.84 (SD = 1.28), 2.68 (SD = 1.28), and 2.80 (SD = 1.00) respectively constant (Table 31). As the graph illustrates, the level of social norms stayed relatively constant while lighting and plug loads decreased over time. Moreover, the levels of social identities of Tenant A in June 2018, June 2019, and June 2020 were 2.21 (SD = 0.857), 1.94 (SD = 1.05), and 1.74 (SD = 1.308) respectively (Table 31). Figure 31 displays that the level of social identities slightly reduced over time while the level of social norms did not greatly change. Consequently, neither of my predictions were observed in Tenant A; there were no negative relationships between electricity usage and social norms and no positive relationships between social norms and social identities demonstrated in this study.

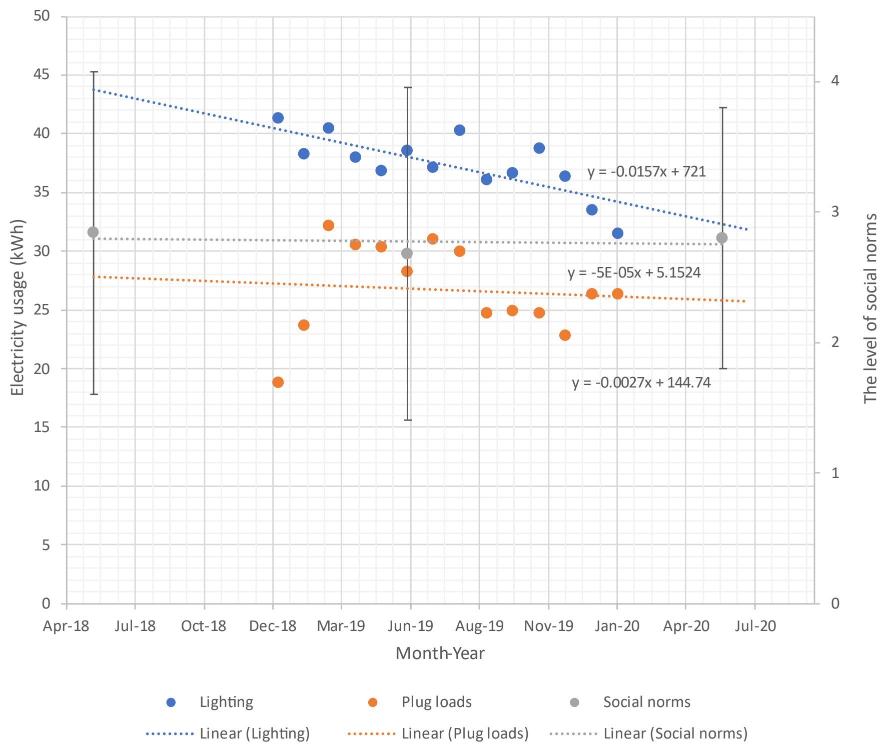

Figure 40 Comparison of electricity usage and social norms of Tenant A

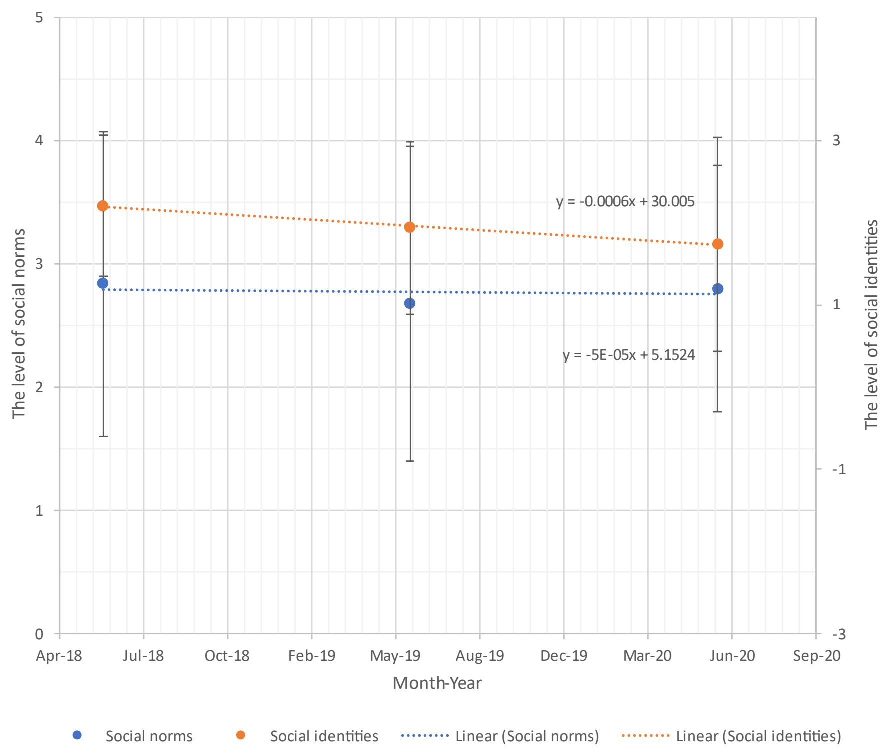

Figure 41 Comparison of social norms and social identities of Tenant A

Table 31 The levels of social norms and social identities of Tenant A

Date	Social norms			Social identities		
	M	SD	N	M	SD	N
June-2018	2.84	1.24	40	2.21	0.86	40
June-2019	2.68	1.28	17	1.94	1.05	17
June-2020	2.8	1.00	19	1.74	1.31	19

Figure 42 shows changes in the weekday lighting usage, the weekday plug loads, and the level of social norms in Tenant B. The levels of social norms of Tenant B in June 2018, June 2019, and June 2020 were 3.33 (SD = 0.46), 2.61 (SD = 0.79), and 3.07 (SD = 0.84) respectively (Table 32). As the graph illustrates, the level of social norms was more or less constant over time while lighting and plug loads increased. Moreover, the levels of social identities of Tenant B in June 2018, June 2019, and June 2020 were 2.1 (SD = 1.02), 1.48 (SD = 1.25), and 1.89 (SD = 1.16) respectively (Table 32). As Figure 43 displays, the level of social identities was also relatively constant with the level of social norms. While the level of social norms did not greatly decrease over time, it may not support the hypothesis that there are negative relationships between electricity usage and social norms. In regard to the relationship between social norms and social identities, their patterns seem similar to one another. Nevertheless, the variances in the levels of social norms and social identities are relatively large. Thus, the results did not demonstrate a clear positive relationship between social norms and social identities in Tenant B.

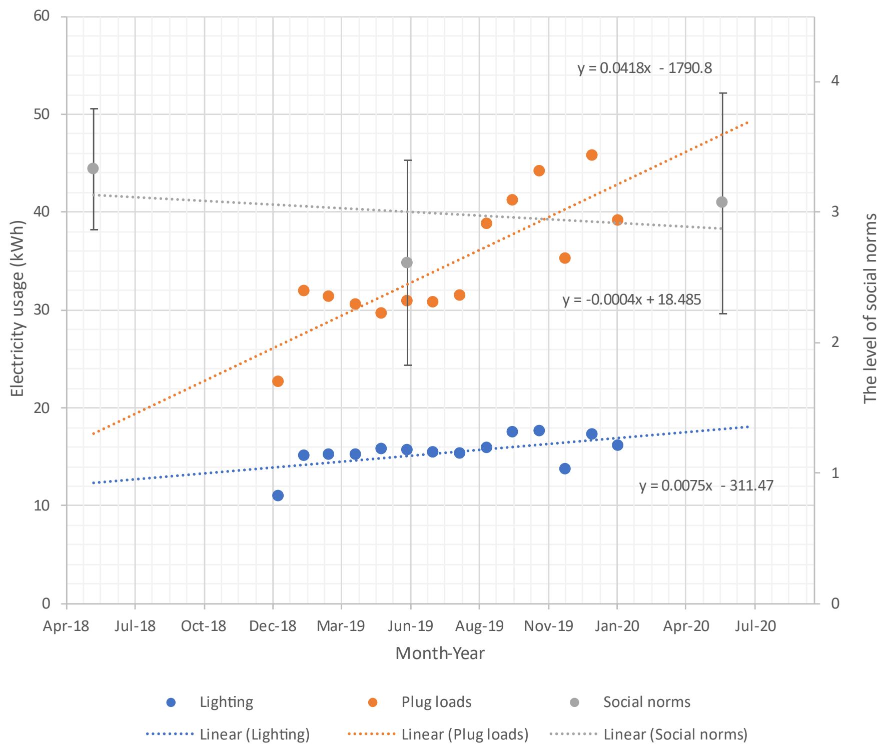

Figure 42 Comparison of electricity usage and social norms of Tenant B

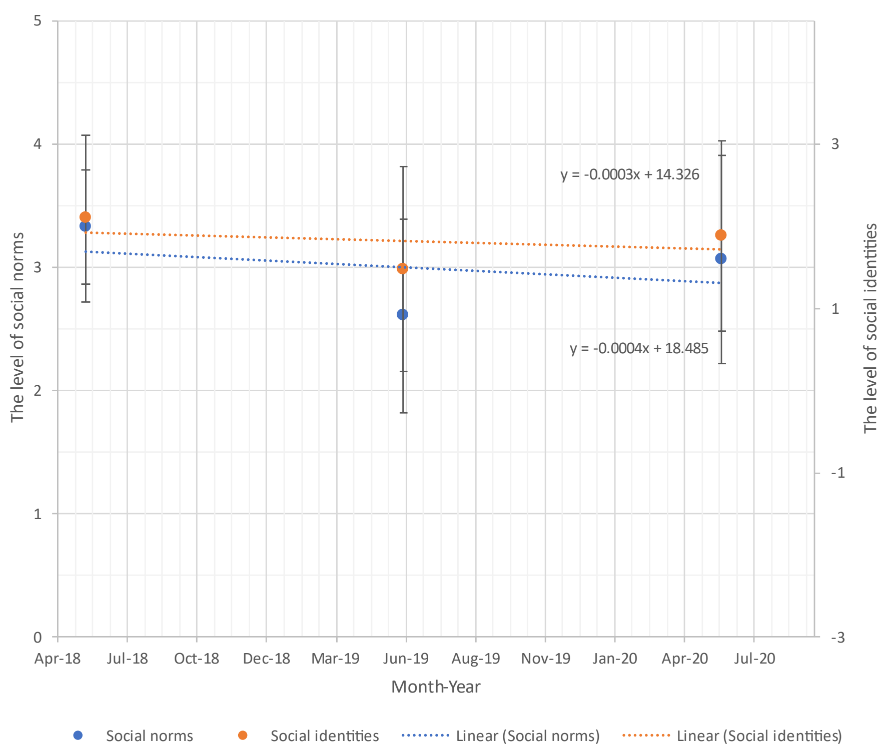

Figure 43 Comparison of social norms and social identities of Tenant B

Table 32 The levels of social norms and social identities of Tenant B

Date	Social norms			Social identities		
	M	SD	N	M	SD	N
June-2018	3.33	0.46	7	2.1	1.02	7
June-2019	2.61	0.79	8	1.48	1.25	9
June-2020	3.07	0.84	11	1.89	1.16	12

Figure 44 shows changes in the weekday lighting usage, the weekday plug loads, and the level of social norms in Tenant C. The levels of social norms of Tenant C in June 2018, July 2019, and July 2020 were 1.21 (SD = 0.88), 1.92 (SD = 0.91), and 1.89 (SD = 0.69) respectively (Table 33). As the graph displays, the level of social norms slightly increased over time while lighting usage slightly increased and plug loads more or less became lower over time. Moreover, the levels of social identities of Tenant C in June 2018, June 2019, and June 2020 were 1.74 (SD = 1.29), 2.13 (SD = 1.13), and 1.64 (SD = 0.81) respectively (Table 33). Figure 45 illustrates that the level of social identities was rather constant over time while the level of social norms became slightly higher. Thus, relationships between electricity usage and social norms were inconsistent, and positive relationships between social norms and social identities were not observed in Tenant C.

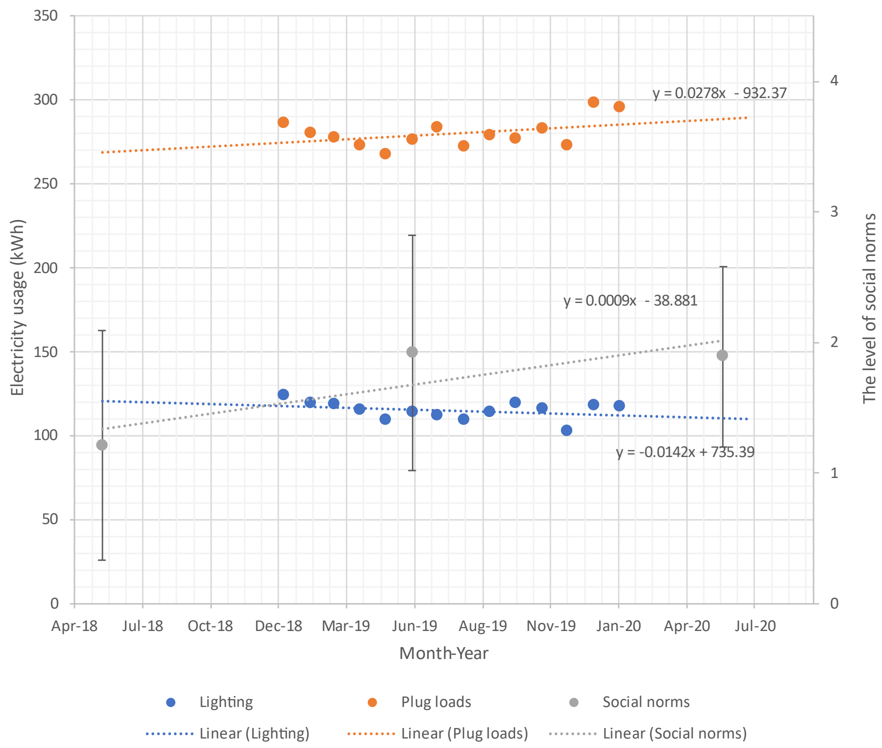

Figure 44 Comparison of electricity usage and social norms of Tenant C

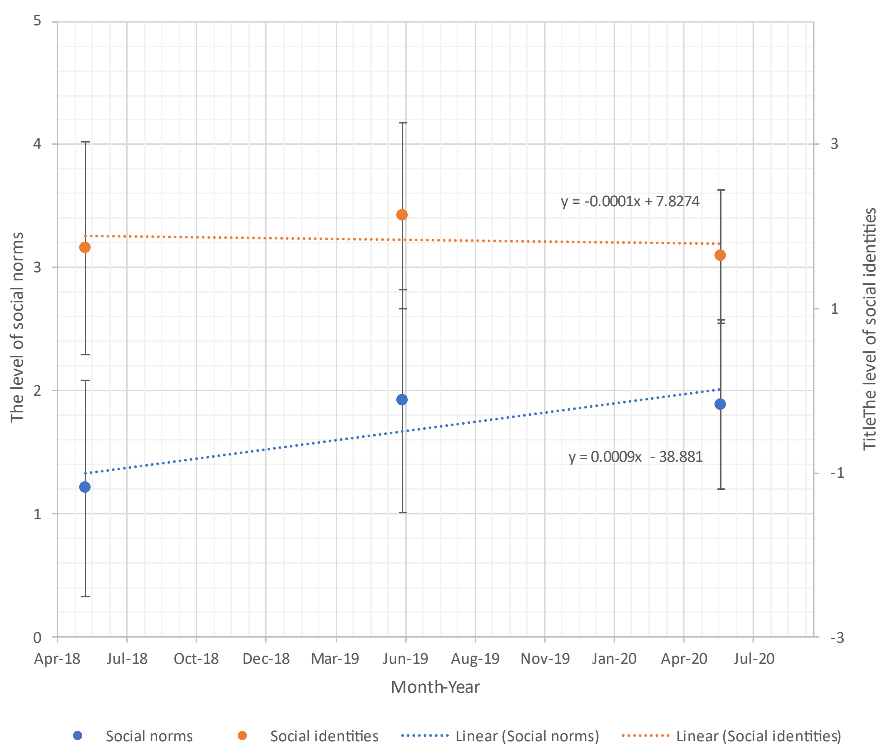

Figure 45 Comparison of social norms and social identities of Tenant C

Table 33 The levels of social norms and social identities of Tenant C

Date	Social norms			Social identities		
	M	SD	N	M	SD	N
June-2018	1.21	0.88	59	1.74	1.29	60
June-2019	1.92	0.90	16	2.13	1.13	16
June-2020	1.89	0.69	12	1.64	0.81	12

Figure 46 shows changes in the weekday lighting usage, the weekday plug loads, and the level of social norms in Tenant D. The levels of social norms of Tenant D in June 2018, June 2019, and June 2020 were 1.75 (SD = 0.83), 2.43 (SD = 0.89), and 2.62 (SD = 0.81) respectively (Table 34). As the graph displays, the level of social norms increased over time while lighting and plug loads in the office area had a tendency of declining over time. In contrast, plug loads in the server room seemed rather constant over time, which is different from electricity usage in the office area.

Furthermore, the levels of social identities of Tenant D in June 2018, June 2019, and June 2020 were 1.57 (SD = 0.96), 1.72 (SD = 1.08), and 1.76 (SD =1.03) respectively (Table 34). Figure 47 illustrates that the level of social identities was rather constant while the level of social norms increased as the time passed. The results may support the idea that there was a negative relationship between electricity usage in office areas and social norms but not between the plug loads in the server room and social norms. The graph also did not illustrate a clear positive relationship between social norms and social identities in Tenant D.

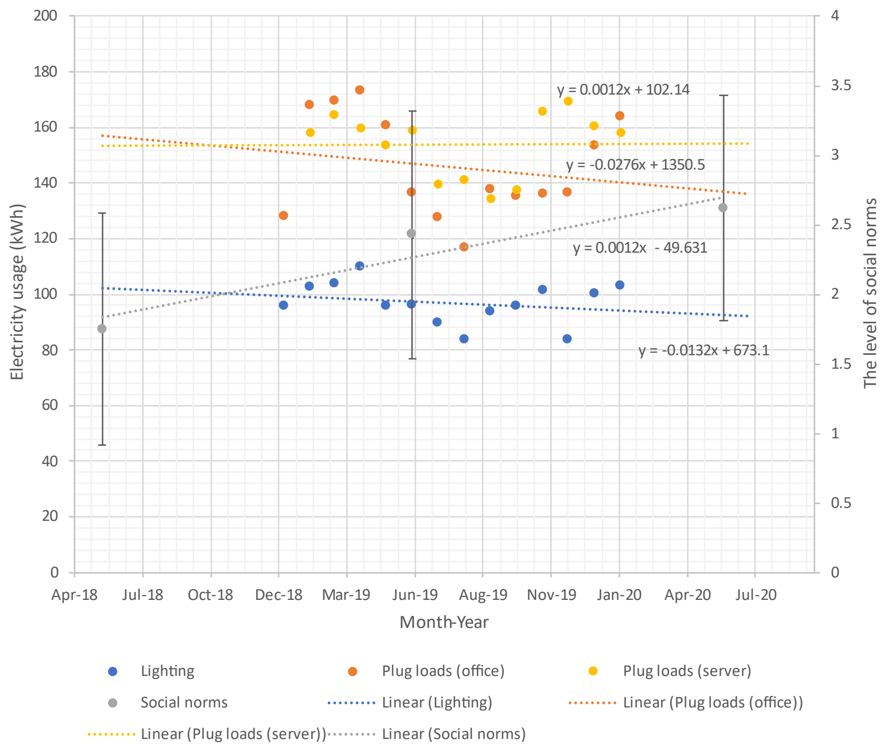

Figure 46 Comparison of electricity usage and social norms in Tenant D

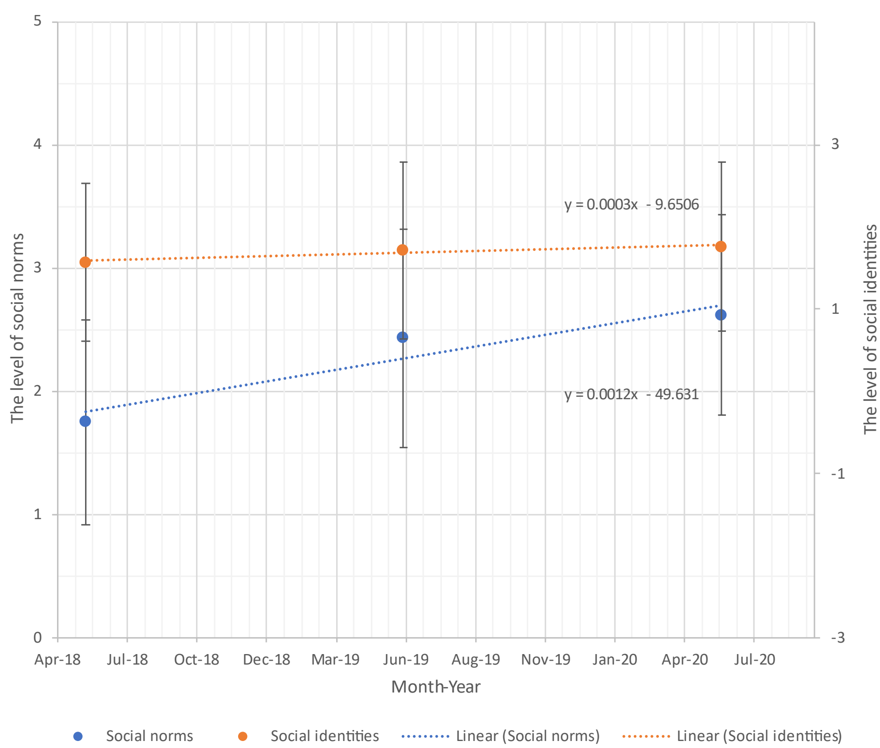

Figure 47 Comparison of social norms and social identities of Tenant D

Table 34 the levels of social norms and social identities of Tenant D

Date	Social norms			Social identities		
	M	SD	N	M	SD	N
June-2018	1.75	0.83	117	1.57	0.96	116
June-2019	2.43	0.89	76	1.72	1.08	77
June-2020	2.62	0.81	71	1.76	1.03	71

Figure 48 compares the average electricity usage for lighting on weekends and the level of social norms of Tenant A, Tenant B, Tenant C, and Tenant D. The lighting usage is displayed both in Wh per square meters and Wh per person in order to minimize the impact of differences in the floor area and the population size among tenants. As the graph shows, the relationships between lighting usage and social norms are inconsistent among tenants; the data illustrated neither positive nor negative relationships between lighting usage and the level of social norms.

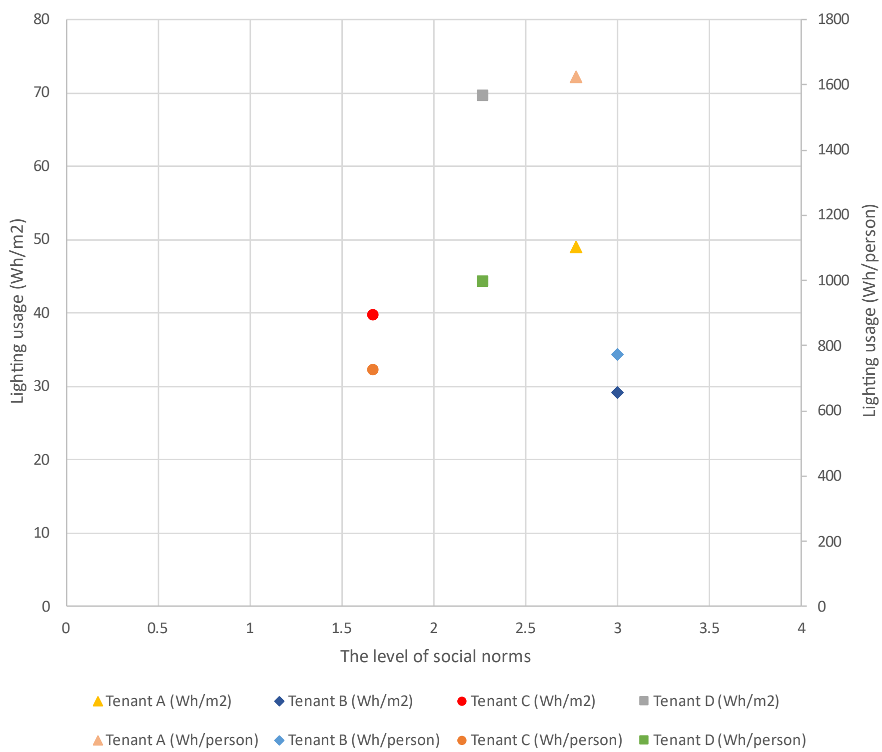

Figure 48 Comparison between lighting usage and social norms of Tenants A, B, C, and D

Figure 49 compares the average electricity usage for plug loads on weekends and the level of social norms of Tenant A, Tenant B, Tenant C, and Tenant D. The plug load usage is displayed both in Wh per square meters and Wh per person, and the server room was excluded from the plug loads data of Tenant D. While the plug load usage per person of Tenant B seems to be an outlier, the plug loads is inclined to reduce as the level of social norms increases unlike the lighting usage. This may indicate that plug loads tend to have more negative relationships with social norms than lighting usage.

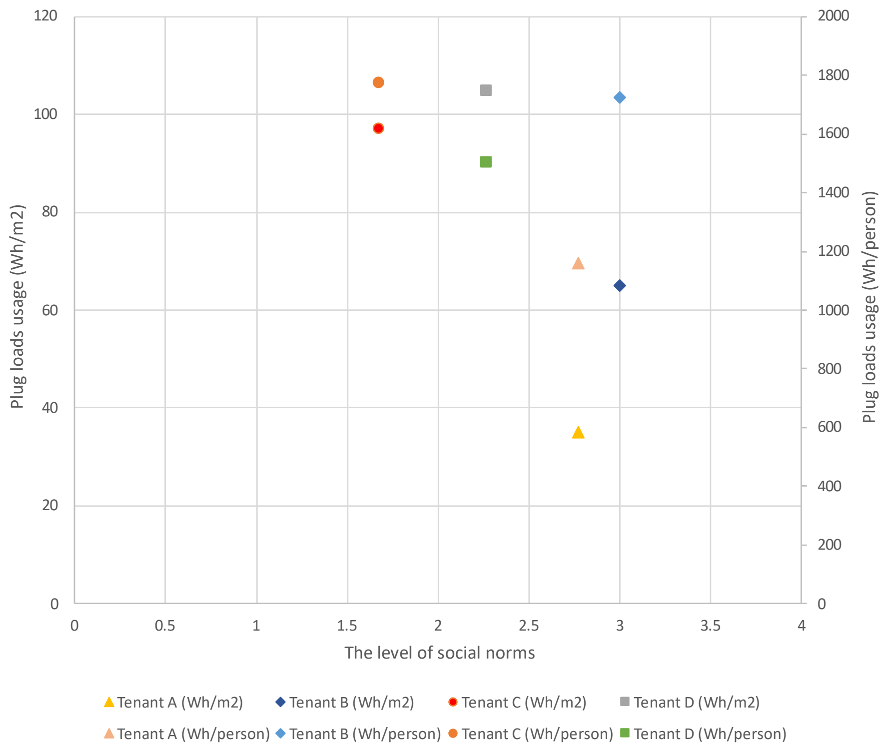

Figure 49 Comparison between plug loads and social norms of Tenant A, B, C, and D (without the server room in Tenant D)

Finally, Figure 50 compares the levels of average social norms and average social identities of Tenant A, Tenant B, Tenant C, and Tenant D. The graph indicates that social norms and social identities have neither positive relationships nor negative relationships. Although it was predicted that social norms and social identities would have positive relationships, the level of social identities of all tenants was similar to one another while the level of social norms varied. Therefore, the results did not demonstrate a positive relationship between social norms and social identities of tenants in the case study building, and the level of average social identities did not show wide variance among different tenants.

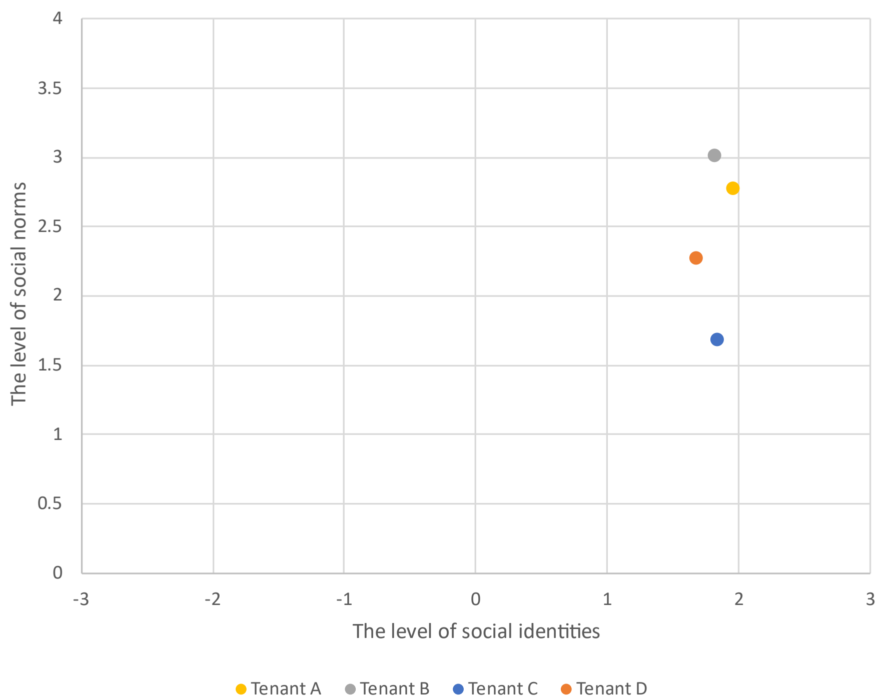

Figure 50 Comparison of social norms and social identities of Tenants A, B, C, and D

To examine the role of social identities as a moderator of relationships between social norms and pro-environmental behaviour, a study may demonstrate whether the levels of social identities are related to the degree of pro-environmental behaviour exercised in a group. Based on social influence theory, a high level of social identity was expected to increase the significance of social norms within a group, which would potentially persuade people to comply with the social norms within the group if they believe that the membership to the group is relevant for them. In this study, it was initially expected that the role of social identities as a moderator could be suggested if a higher level of social identity was observed when social norms had more negative relationships with electricity usage, thereby resulting in further reduction in electricity usage of occupants. However, there was not sufficient variance in the levels of average social identities among Tenants A, B, C and D to illustrate how different levels of social identities relate to energy saving behaviour of occupants. Thus, the effect of social identities as a moderator was not clearly observed on relationships between social norms and electricity usage in the case study building.

4.4 Occupants' impact on the building electricity usage

4.4.1 Changes in electricity usage of the building before/after the pandemic

The year of 2020 was a unique time when occupants were forced to work from home due to the pandemic. From this special opportunity, this section analyzes electricity usage of the green office building when occupants did not use the building. Figure 51 shows the total electricity usage of the case study building from January to November in 2019 and 2020. This offers an insight into differences in the building electricity usage when the building is used by occupants and when it is not. As COVID-19 infections increased in Ontario, Canada from March 2020, the usage of the building was restricted from mid-March 2020. Thus, electricity usage from April 2020 and June 2020 illustrates the building electricity usage when all occupants worked from home, while few occupants started coming back to the building from July 2020.

Moreover, Figure 51 also shows the percentage of electricity usage in 2020 compared to 2019. As the graph shows, the percentage of electricity usage in 2020 rated from 74% to 81% between January and March; however, the percentage of electricity usage reduced to 61% to 68% between April and June. In contrast, the percentage of electricity usage in 2020 rated higher around 84% to 91%. It should be noted that the total electricity usage in 2019 gradually reduced to the end of the year, which can be attributed to electricity reduction from the HVAC system. This may also partially explain the high percentage of electricity usage in 2020, compared to 2019.

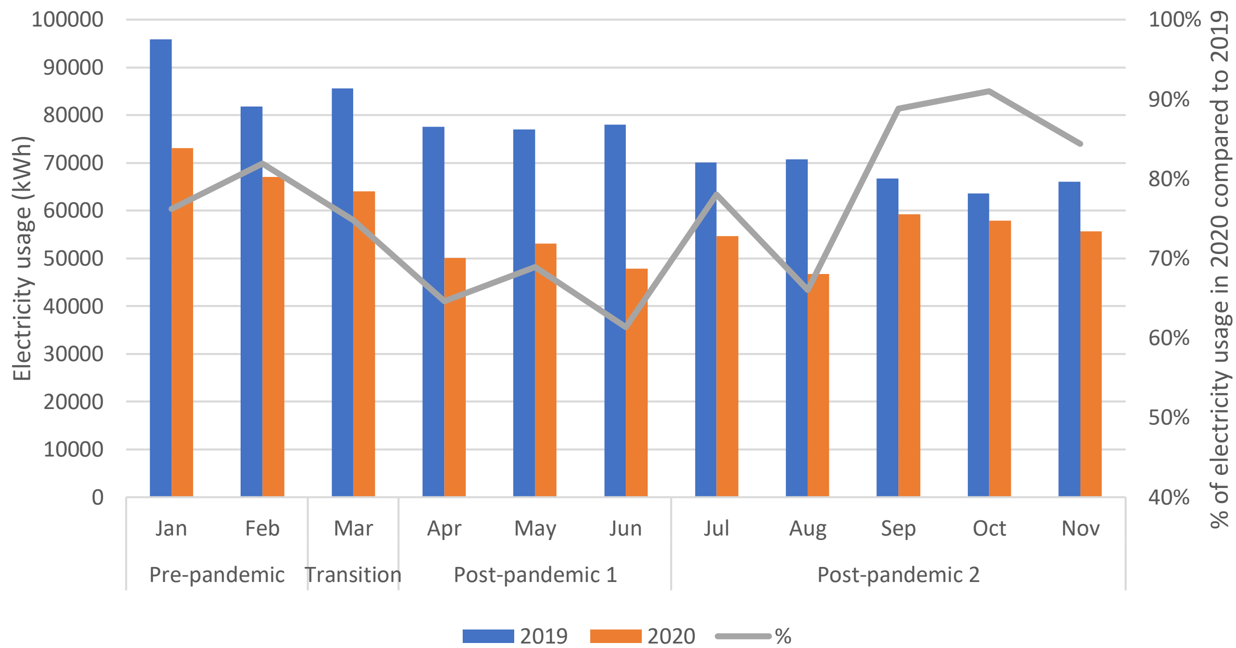

Figure 51 Comparison of the total building electricity usage of the case study building, January 2019 – November 2020

Table 35 Percentage of the total building electricity usage in 2020 relative to 2019

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
%	76.20	81.94	74.78	64.65	68.91	61.36	78.01	66.03	88.80	91.00	84.36

4.4.2 Changes in electricity usage of tenant areas before/after the pandemic

Paired samples t-test was conducted to examine differences in electricity usage of tenant areas for each month. Figure 52 shows the monthly total electricity usage of twelve meters in tenant areas. The graph displays the aggregated total electricity usage of twelve meters for each month. Table 36 shows the mean values of monthly total electricity usage of each month from April and November in 2019 and 2020. To compare the aggregated monthly electricity usage of each month between 2019 and 2020, the percentage of electricity in 2020 compared to 2019 was also added to the table. The percentage of electricity usage in 2020 compared to 2019 ranged from 58% to 71%.

Paired samples t-test shows that monthly total electricity usage of tenant areas in April, t (11 = 3.360, $p < 0.05$), May, t (11 = 3.956, $p < 0.05$), June, t (11 = 4.628, $p < 0.05$), July, t (11 = 4.982, $p < 0.05$), September, t (11 = 4.137, $p < 0.05$), October, t (11 = 4.963, $p < 0.05$), November, t (11 = 4.579, $p < 0.05$) were significantly different between 2019 and 2020.

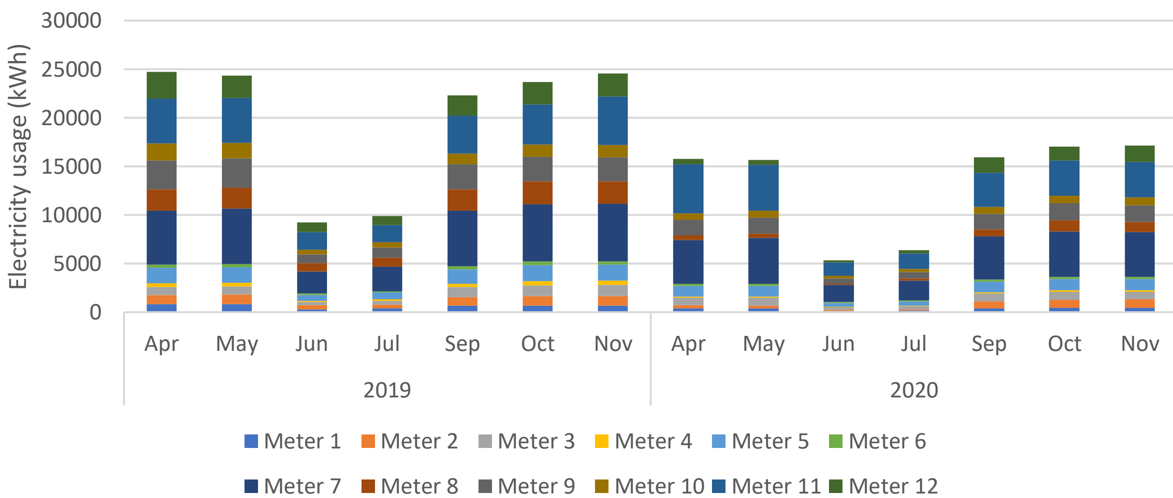

Figure 52 Monthly total electricity usage in tenant areas, April 2019 – November 2020

Table 36 Paired samples t-test on monthly total electricity usage of tenant areas, April 2019 – November 2020

Month	Mean (kWh)		% (2020/2019)	P value for paired t-test
	2019	2020		
April	2,060	1,314	63.8%	.006
May	2,028	1,306	64.4%	.002
June	769	447	58.1%	.001
July	827	531	64.2%	.000
Sep	1,859	1,327	71.4%	.002
Oct	1,973	1,421	72.0%	.000
Nov	2,046	1,427	69.8%	.001

Figure 53 shows the weekday average electricity usage of twelve meters in tenant areas. The graph illustrates the aggregated weekday average electricity usage of twelve meters in tenant areas. Table 37 shows the mean values of weekday average electricity usage of each month from April and November in 2019 and 2020. The percentage of electricity usage in 2020 compared to 2019 ranged at 41% to 69% from January to November.

Paired samples t-test shows that weekday average electricity usage of tenant areas in April, t (11 = 3.786, $p < 0.05$), May, t (11 = 3.809, $p < 0.05$), June, t (11 = 4.536, $p < 0.05$), July, t (11 = 4.602, $p < 0.05$), September, t (11 = 4.059, $p < 0.05$), October, t (11 = 4.784, $p < 0.05$), November, t (11 = 4.732, $p < 0.05$) were significantly different between 2019 and 2020.

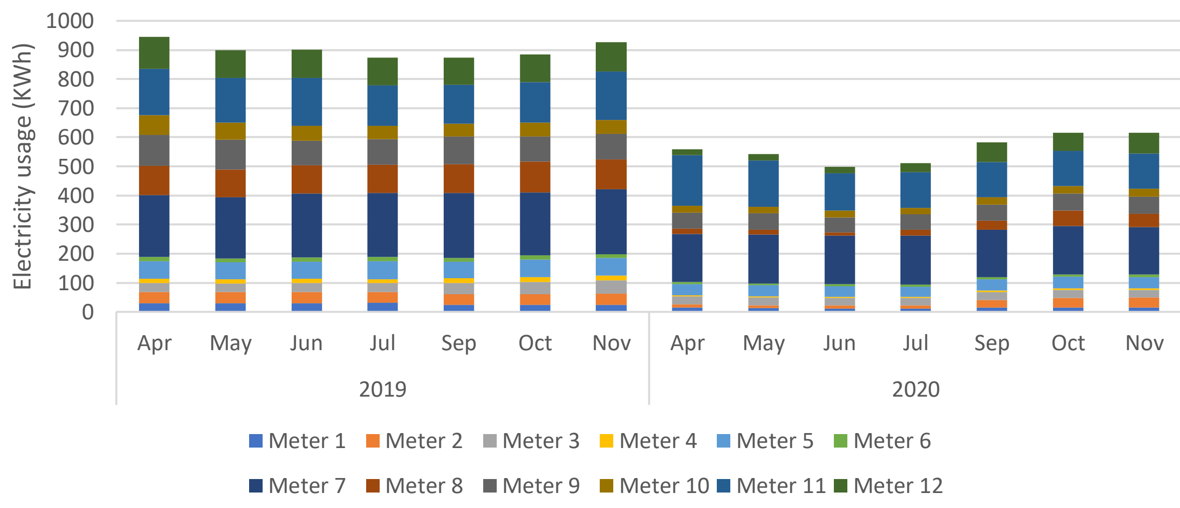

Figure 53 Weekday average electricity usage in tenant areas, April 2019 – November 2020

Table 37 Paired samples t-test on weekday average electricity usage of tenant areas, April 2019 – November 2020

Month	Mean (kWh)		%	P value for
	2019	2020	(2020/2019)	paired t-test
April	78.8	32.8	41.6%	.003
May	74.9	45.1	60.2%	.003
June	74.9	41.6	55.5%	.001
July	72.8	42.6	58.6%	.001
Sep	72.8	48.5	66.6%	.002
Oct	73.7	51.2	69.5%	.001
Nov	77.2	51.3	66.4%	.001

Figure 54 shows the weekend average electricity usage of twelve meters in tenant areas. The graph displays the aggregated weekend average electricity usage of twelve meters in tenant areas. Table 38 shows the mean values of the weekend average electricity usage of each month from April and November in both 2019 and 2020. The percentage of electricity usage in 2020 compared to 2019 ranged from 78% to 87%.

Paired samples t-test shows that weekend average electricity usage of tenant areas in April, t (11 = 1.705, $p > 0.05$) was not significantly different between 2019 and 2020. On the other hand, paired samples t-test shows that weekend average electricity usage in May, t (11 = 2.397, $p < 0.05$), June, t (11 = 3.012, $p < 0.05$), July, t (11 = 3.335, $p < 0.05$), September, t (11 = 3.002, $p < 0.05$), October, t (11 = 3.061, $p < 0.05$), November, t (11 = 2.224, $p < 0.05$) were significantly different between 2019 and 2020.

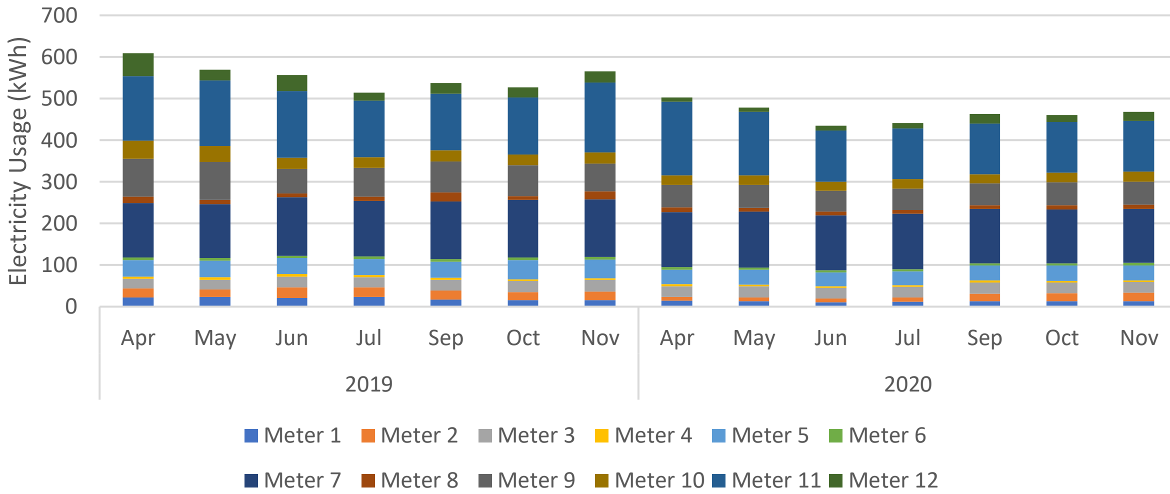

Figure 54 Weekend average electricity usage in tenant areas, April 2019 – November 2020

Table 38 Paired samples t-test on weekend average electricity usage of tenant areas, April 2019 – November 2020

Month	Mean (kWh)		% (2020/2019)	P value for paired t-test
	2019	2020		
April	50.7	41.9	82.5%	.116
May	47.4	39.9	84.2%	.035
June	46.4	36.2	78.1%	.012
July	42.9	36.7	85.7%	.007
Sep	44.8	38.6	86.2%	.012
Oct	43.9	38.4	87.4%	.011
Nov	47.1	39.0	82.7%	.048

5 Discussion

5.1 Electricity usage profile of the case study building

Examining electricity usage in the green office building identified two important trends: the total electricity usage of the building reduced over time; and the percentage of tenant electricity usage increased. As Figure 12 shows, there was a gradual reduction in the total monthly electricity usage of the building from approximately 95,000 kWh in January 2019 to 63,000 kWh in October 2019. This is partially attributed to enhanced efficiency of the HVAC operations in the building. The building owner had been working on reducing electricity usage in the building by optimizing the HVAC system, including the boiler, heat pumps, and fans. As a result, the HVAC system of the building became more energy efficient, which greatly reduced the total electricity usage of the building by October 2019. On the other hand, the percentage of tenant electricity usage relative to the total electricity usage of the building increased to 36% in February 2020. This suggests that the impact of occupant behaviour on the building electricity usage had become more significant while the baseload power decreased. Therefore, the declining electricity usage in the building demonstrates that the promotion of occupants' energy saving behaviour is essential for the reduction of the building electricity usage.

The hourly profile of electricity usage in tenant areas shows that the lighting usage corresponded to the activities of occupants in the building. As Figure 13 illustrates, the lighting usage rapidly increased after 5 a.m. when people started coming to the building, and decreased after 5 p.m. when people were leaving. The hourly profile of electricity usage for plug loads in tenant areas had a similar pattern as the lighting usage; the plug loads rapidly increased after 7 a.m. when people started coming to the building, and gradually decreased after 3 p.m. as Figure 14 illustrates. The hourly profiles of lighting and plug loads show that plug loads started reducing about for two hours earlier than lighting usage in the afternoon. This may be because devices like laptops can be used without being plugged in in the late afternoon if they were fully charged from the morning. Wang, Yan, and Ren (2016) also state that lighting usage can increase even when there is a small number of occupants, and this may be also applied to lighting usage in the case study building, which demonstrated relatively constant lighting usage in the afternoon.

Another difference between the hourly usage of lighting and plug loads was that the weekend usage was much higher in plug loads than lighting. This indicates that more devices had been plugged in during weekends while occupants were more careful about turning off lights during weekends. Gandhi and Brager (2016) also argue that there is more potential for energy conservation by switching off and unplugging unused devices, and a similar pattern was observed in the case study building. Common devices which largely contribute to phantom load include desktop servers, AV controllers, video conference cameras, and desktops (Doherty & Trenbath, 2019; Gandhi & Brager, 2016). While there is no detailed information about types and the number of devices used in tenant areas, the hourly usage profile of plug loads indicates that similar devices, as reported by the past studies, can be attributed to the higher baseload of plug loads in tenant areas. Therefore, reduction in plug loads, particularly during weekends, is a key to energy saving in tenant areas.

5.2 Stairs usage

5.2.1. Second floor

The analyses on stairs usage in the pre-occupancy and post-occupancy periods demonstrate how structural and informational interventions influence the stairs usage of occupants. Stairs usage significantly changed from the pre-occupancy period to the post-occupancy period on the second floor, which suggests a strong effect of structural factors on stairs usage. For stair ascending to the second floor, stairs usage significantly increased in Phase 3, Phase 4, and Phase 6, compared to Phase 1 of Building 3. This indicates that people on the second floor in the case study building used stairs more than those on the second floor in Building 3. Differences in structural factors, such as the design and locations of staircases and elevators, might have affected the stairs usage of occupants. Previous studies noted that more accessible and visually attractive stairs encourage people to take stairs more often (Ruff et al., 2014; Dreyer et al., in press) (Nicolle, 2007; Boutelle et al., 2020, as cited in Ruff et al., 2014). As the case study building has a central staircase with glass railing at the center of the atrium, it is likely that the staircase design and location affected the rate of stairs usage in the building. Thus, structural factors of the buildings may have affected the stairs usage of occupants.

Similarly, stairs usage for descending from the second floor significantly increased in Phase 3, Phase 4, and Phase 5, compared to Phase 1 of Building 2 while elevator usage significantly decreased. This means that people on the second floor in the case study building used more stairs than those on the second floor in Building 2. Unlike Building 3, Building 2 was a green building with a central staircase, which was similar to the case study building. One of the possible factors which influenced stairs usage is novelty effects. People have different responses to new technology as long as the technology is perceived as novel (Sung, Christensen, & Grinter, 2009). Novelty effects on technology, such as new games for energy saving, can make the technology attractive, which consequently encourages energy saving behaviour (Gamberini et al., 2011). Since the case study building was a new green office building, it is possible that the new design of the central staircase attracted occupants to use stairs more often in the post-occupancy period. Therefore, the new structural feature of the building potentially affected people’s behaviour for stairs usage

5.2.2. Third floor

Stairs usage on the third floor was also affected by structural factors although the pattern of stairs usage was different from the second floor. For stair ascending to the third floor, stairs usage significantly increased in Phase 2 and Phase 3, compared to Phase 1 of Building 1. However, stairs usage for ascending significantly decreased in Phase 4, Phase 5, and Phase 6, compared to Phase 1 of Building 2, as well as Phase 2. The increase in stairs usage in the early post-occupancy period can be attributed to novelty effects since occupants on the third floor may have perceived the visible central staircase in the case study building as novel. The reduction in stairs usage after Phase 4 can be also explained by the diminished novelty effects. As more than a year had passed in Phase 4 since occupants moved into the case study building, the central staircase may have been no longer considered to be a new building feature while occupants acclimatized to the building environment. As a result, people may have become uninspired to take stairs, which contributed to the decrease in stairs usage.

Interestingly, stairs usage on the third floor was significantly different between Building 1 and Building 2 in Phase 1. It is highly likely that this difference in stairs usage was a result of structural factors in the buildings. The major structural differences between Building 1 and Building 2 are a sustainable building design and a central staircase. Since Building 2 is a green building with a central staircase and occupants also had much higher rates of stairs usage than those in Building1, it is considered that a sustainable building design encouraged people to take the stairs in Building 2.

5.2.3. Newsletter interventions

Furthermore, the analyses on observation data did not prove that information provision had a strong influence on stairs usage. There were no significant changes in stairs usage neither on the second floor nor the third floor from Phase 4 and Phase 6. In contrast, the analyses on sensor data showed different results from the observation data; the number of occupants taking stairs on the second floor reduced both for ascending and descending in Phase 5 and Phase 6, compared to Phase 4. Therefore, the results did not clearly show that the newsletter interventions encouraged stairs usage of occupants unlike the findings of the previous study (Asensio & Delmas, 2015).

One of the possible reasons for the different results between observation and sensor data is the method of data collection. It is possible that the sensor data displays reduced stairs usage during the newsletter interventions because of the decrease in the number of occupants in the building. Since the sensor data only shows the absolute number of people taking stairs unlike the observation data showing the percentage of stairs usage, a reduction in the population may have affected the results of stairs usage rather than changes in occupant behaviour. It is possible that the number of people who came to the green office building significantly increased in Phase 4 due to the increased number of meetings at the beginning of the new year, and reduced afterwards.

The ineffectiveness of newsletter interventions on stairs usage might be attributed to the design and distribution method of newsletters. The informative messages about stairs usage were included in newsletters with other articles, and occupants may have not carefully read the messages since there were not visual images to attract the reader’s attention. At the same time, the informative messages about stairs usage were disseminated only two times between January and March 2020. Researchers state that it is important to use visual materials and combine different methods for the success of interventions, including information provision, feedback, and goal-setting (Uitdenbogerd, Egmond, Jonkers & Kok, 2007, Abrahamse et al., 2005). As there were no images used in the information provision for this research, the newsletters may not have attracted occupants' attention in the case study building. At the same time, information provision could be more effective if it was combined with feedback or goal-setting as Uitdenbogerd et al. (2007) suggested. Staats et al., 2000 also argue that information interventions need to be regularly implemented to encourage energy saving behaviour over time. This suggests that stairs usage of occupants might have been promoted further if the newsletter interventions were disseminated more often. Thus, there are multiple factors in the design and implementation of newsletter interventions which can be improved in order to effectively persuade occupants to take stairs in the long run.

5.2.4. Comparison of different floors

The comparison of stairs usage between the second and the third floors further supports the idea that structural factors are important factors affecting the stairs usage of occupants. There were significant differences between the second and the third floors in stairs usage. This suggests that floor levels affect stairs usage of occupants as a structural factor. For stairs usage, both Figure 18 and Figure 19 illustrate that the percentage of stairs usage was higher on the second floor than the third floor for ascending and descending. The results suggest that stairs usage is strongly affected by the differences in the floor levels. In fact, Ruff et al. (2014) found out that people took stairs less often as the number of floors increased. Thus, people on the third floor might have been more reluctant to take stairs since it requires more physical energy, compared to the second floor.

Two-way ANOVA tests also reveal that time was a significant main effect on stairs usage for ascending, but not for descending. This may be attributed to both physical energy required for stairs usage, as well as to novelty effects. As Figure 18 illustrates, the gap in stairs usage between the second floor and the third floor seemed larger after Phase 4. The reduction in stairs usage during the later phases may have resulted from the less impact of novelty effects since occupants may have become accustomed to the visible central staircase design. In addition, the reduction in novelty effects on the third floor might have been accelerated by physical energy required for stairs usage, which can explain the significantly lower stairs usage rate on the third floor. Therefore, differences in structural factors affected the decision of occupants on stairs usage, more than information provision in this study.

5.2.5. Stairs usage, social norms & the energy cultures framework

In this study, it was predicted that social norms would stimulate energy practices from the perspective of the energy cultures framework, which would potentially increase the stairs usage of occupants. The results did not support the idea that social norms were a strong stimulus for stairs usage of occupants in the case study building. Descriptive analyses on stairs usage and social norms of occupants on the second floor did not illustrate that there were positive relationships between stairs usage and the level of social norms. The percentage of stairs usage was relatively high both for stair ascending and descending since the pre-occupancy period. In contrast, the level of social norms was more or less low in the post-occupancy period, compared to the pre-occupancy period. As the high stairs usage rate did not correspond to the level of social norms, the results from occupants on the second floor did not demonstrate that social norms positively related with stairs usage.

Moreover, the analyses on stairs usage and social norms of occupants on the third floor demonstrate that relationships between stairs usage and social norms were inconsistent. In the pre-occupancy period, stairs usage rate and the level of social norms were higher in Building 2 for both stair ascending and descending, compared to Building 1. This may be regarded as a positive relationship between stairs usage and the level of social norms. However, there did not seem to be a such relationship between stairs usage and social norms in the post-occupancy period. While the level of social norms was relatively constant on the third floor, the percentage of stairs usage reduced both for stair ascending and descending. Thus, positive relationships between stairs usage and social norms were not observed, which is contradictory to the prediction.

At the same time, the impact of newsletter interventions on stairs usage was not observed. Although it was predicted that newsletter interventions would promote stairs usage by stimulating cognitive norms of occupants and indirectly changing energy practices of occupants, stairs usage did not increase during the interventions both on the second and the third floors. The result implies that cognitive norms, such as occupants' aspiration to increase health benefits and promote energy conservation through stairs usage, were not adequately stimulated by the newsletter interventions. The ineffectiveness of the newsletter interventions might be attributed to methodological issues since it is not certain whether occupants read newsletters or not. Moreover, there may have been a necessity of having more frequent newsletter interventions as Midden et al. (1983) argue that information provision is not effective when it is not repeated. This may indicate that cognitive norms may take a longer time to be changed unlike material culture from the perspective of the energy cultures framework. It should also be noted that this study is looking at marginal change where many occupants are already taking the pro-environment action, that is using stairs, and those who are not taking the pro-environment action may require stronger incentives or more prolonged nudge to change their behaviour. Therefore, further work is required to investigate how information provision can alter relationships between energy practices and cognitive norms of occupants.

Descriptive analyses on stairs usage and social norms suggest that structural factors are strong stimuli for stairs usage, rather than social norms and information provision. As previously discussed, the high percentage of stairs usage on the second floor can be explained by structural factors of the buildings since people tend to use more stairs when the number of steps in a staircase is low (Ruff et al., 2014). On the third floor, the high stairs usage rate in Building 2 can also be explained by structural factors; the sustainable design of Building 2 and the presence of a central staircase may have encouraged occupants to take more stairs than Building 1. In the post-occupancy period, the reduction in stairs usage rates on the third floor can be attributed to novelty effects, as well as structural factors. Occupants possibly used more stairs when they first moved into the green office building because they were attracted to the new staircase design; however, they might have become more reluctant to take stairs due to the number of steps in the staircase as novelty effects diminished. These results support the idea that structural factors, such as the design and structures of staircases and buildings influenced stairs usage of occupants.

From the perspective of the energy cultures framework, it can be considered that material culture strongly stimulated energy practices, which resulted in changes in stairs usage of occupants (Figure 55). In fact, Stephenson et al. (2010) also note that material culture has a crucial role in shaping behaviour of people since it establishes a context where interactions between human and non-human factors occur. Consequently, it can be concluded that changes in the building and the staircase design affected how occupants interacted with structural factors, which promoted pro-environment behavioural changes by occupants.

At the same time, the increase in stairs usage on the third floor lasted only in the early post-occupancy period, which suggests the necessity of further stimulation on material culture, cognitive norms, and energy practices for stairs usage. The results of this study did not demonstrate that social norms and newsletter interventions were strong external influences to affect these three factors within the energy cultures framework (Figure 55). Stephenson et al. (2010) state that “stabilisation of behaviour occurs, when norms, practices and technologies are aligned…Potential for behaviour change arises when one of these components becomes misaligned or shifts.” This suggests that stairs usage, especially on the third floor, can be promoted if these three components are adequately provoked. Therefore, structural factors seem to be more influential than social norms and newsletter interventions, but may have a reduced effect on stairs usage over time. Further stimulation on the three factors within the energy cultures framework is required to routinize stairs usage, especially on higher floors.

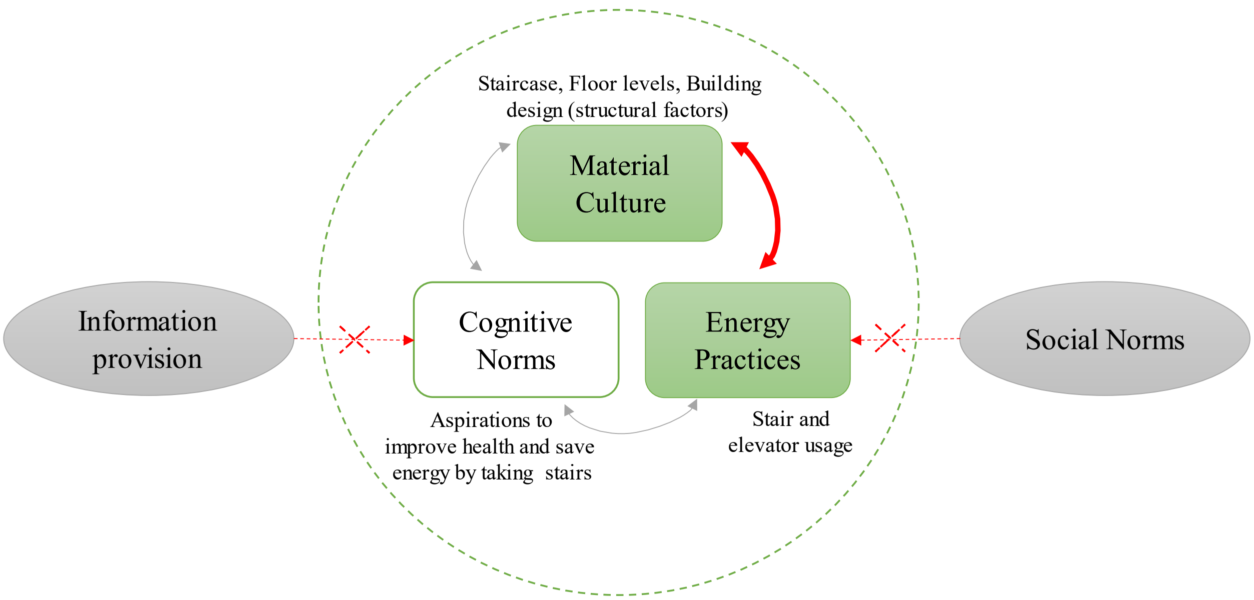

Figure 55 Energy cultures framework summarizing the results of social norms and newsletter interventions on stairs usage

It should be noted that the results of stairs usage and social norms in this study should be interpreted with caution. This is because data from different buildings and organizations were compared in various timeframes, which may have generated variance in sample groups. Differences in the circumstances of occupants, such as buildings, organizations, demography, and types of occupations, need to be carefully taken into consideration in order to analyze relationships between stairs usage and social norms. In addition, there was inconsistency in the sample profile between observation and survey data. Occupants observed for stairs usage were not necessarily included in the survey data regarding social norms since temporary occupants, such as visitors, were excluded from surveys. Therefore, the issue of inconsistency in sample groups needs to be addressed in future research to develop a more accurate picture of relationships between stairs usage and social norms.

5.3 Electricity usage for lighting and plug loads

5.3.1. Comparison of tenants

The weekday lighting usage per square meters of Tenant A, Tenant B, Tenant C, and Tenant D were significantly different from one another while the results were different when the weekend lighting usage was compared. For the weekday usage, Tenant D had the highest lighting usage and Tenant B had the lowest lighting usage per square meters both in all areas and in office areas. This difference may be due to the longer working hours of occupants in Tenant D and because students and faculty members in Tenant B normally did not stay long in the building.

In contrast, the weekend lighting usage was not significantly different between Tenant A and Tenant D, as well as between Tenant B and Tenant C in all areas. This suggests that weekend lighting usage was less affected by occupants' activities since most people left for home during weekends. The higher weekend lighting usage of Tenant A and Tenant D suggest that some people might have come to the building for work, or lighting might have been turned on over weekends.

In regard to the lighting usage per person, both the weekday and weekend lighting usage was significantly different among tenants in all areas, as well as in office areas. Tenant A had the highest lighting usage and Tenant C had the lowest lighting usage both on weekdays and weekends, which is a different result from the lighting usage per square meters. The high lighting usage per person in Tenant A might be attributed to the small population, while the lower lighting usage per person in Tenant C might be attributed to the large population.

Similarly, plug loads per square meters of Tenant A, Tenant B, Tenant C, and Tenant D significantly varied from each other both on weekdays and weekends. Since Tenant D has the server room unlike other tenants, its plug loads were much higher than other tenants when all areas were compared. However, the weekday and weekend plug loads per square meters of Tenant D reduce almost in half when only office areas were compared, which suggests a considerable amount of plug loads in the server room. Another difference from the lighting usage was that Tenant C had relatively high plug loads per square meters both on weekdays and weekends. It is highly possible that Tenant D and Tenant C had higher plug loads per square meters because there might have been more laptops, printers, and other devices necessary for businesses.

Moreover, plug loads per person of Tenant D remained the highest when all areas were compared due to the large plug loads in the server room. However, Tenant B showed higher plug loads per person both on weekdays and weekends when only office areas were compared. This suggests that the number of devices used in Tenant B is large relative to the population size, which resulted in the high plug loads per individual. In particular, Figure 39 shows that Tenant B had the highest weekday and weekend plug loads per person in office areas after June 2019, while plug loads of other tenants tended to become lower. This increase in the weekday plug loads of Tenant B can be attributed to the increase in the number of people, including students who were not counted in the population size.

At the same time, the high weekend plug loads per person of Tenant B suggests that the number of devices used in the office area was relatively high despite the small population size.

When the office area of Tenant B was observed by the author in October 2020, devices, such as monitors, printers, and refrigerators were kept plugged in. It can be considered that these devices were plugged in during weekends. Thus, the number of devices and occupant behaviour are considered to have effects on electricity usage for plug loads per person.

In sum, electricity usage for lighting and plug loads of tenants generally varied from one tenant to another, and there was a tendency that the gap in electricity usage among tenants became smaller on weekends compared to weekdays. This indicates that weekday lighting and plug loads are more affected by occupant behaviour. In addition, differences between electricity usage per square meters and per person demonstrate that electricity usage in tenant areas is affected by the area size, the population size, the number of devices, and occupant behaviour. Therefore, a balance among these four factors is necessary for the optimal electricity usage of the tenants, and this can also contribute to energy conservation in tenant areas.

5.2.6. Electricity usage, social norms, and social identities

This study predicted that social identities would act as a moderator in the relationship between social norms and electricity usage. From the perspective of social influence theory, it was hypothesized that an increased level of social identities would enhance occupants' awareness of social norms within their groups, which would then increase the likelihood of occupants complying with social norms of their groups. Consequently, it was expected that there would be positive relationships between social norms and social identities, and negative relationships between social norms and electricity usage. The results of this study did not show consistent relationships between these variables, and also suggested that the level of social norms and social identities varied among the tenants.

The descriptive analyses on electricity usage, social norms and social identities of Tenant A and Tenant C did not illustrate predicted relationships among these variables. In the case of Tenant A, the level of social norms seemed relatively constant while the level of social identities slightly reduced over time, which did not demonstrate that they positively related to one another. At the same time, the weekday lighting usage had a tendency of declining unlike the weekday plug loads. From this result, it was not proved that the change in electricity usage was affected by social norms in Tenant A. On the other hand, the level of social norms in Tenant C seemed to have an upward trend while the level of social identities was rather constant, which is also contradictory to the prediction. Lighting and plug loads of Tenant C also did not seem to have negative relationships with social norms since it did not show any significant reduction despite a slight increase in the level of social norms. These results did not support the hypothesis that social norms positively relate with social identities and negatively relate with electricity usage in Tenant A and Tenant C.

In contrast, the analyses on Tenant B and D illustrate somewhat predicted patterns in electricity usage, social norms, and social identities. In Tenant B, changes in the levels of social norms and social identities were similar to one another; both the levels of social norms and social identities became lower in the second survey, and became slightly higher in the third survey. This may imply positive relationships between social norms and social identities in Tenant B. At the same time, lighting usage and plug loads had an upward trend over time while the level of social norms showed a somewhat downward trend. This may be regarded as a negative relationship between electricity usage and social norms, which corresponds to the prediction. Nevertheless, these findings may be limited by uncertainty of students' impact since lighting and plug loads of Tenant B were influenced by university students who were not included in surveys regarding social norms.

In Tenant D, the level of social norms seemed to have increased over time while the level of social identities remained rather constant, which did not confirm a positive relationship between social norms and social identities. However, there seemed to be a negative relationship between electricity usage in the office areas and the level of social norms in Tenant D. Both the weekday lighting and plug loads reduced over time while the level of social norms showed an upward trend. This may support the idea that an increase in the level of social norms promoted energy saving behaviour in Tenant D, which means there were negative relationships between social norms and electricity usage. It is also interesting that plug loads in the server room did not show a tendency of decreasing unlike electricity usage in the office areas. As the key informant noted that occupants did not usually enter into the server room (Informant 2, personal communication, December 2, 2020), it is likely that plug loads in the server room was not subject to the social norms of occupants. Consequently, the results from Tenant B and Tenant D imply that there might be negative relationships between electricity usage and the social norms of occupants. Nevertheless, negative relationships between social norms and social identities were not observed in both tenants, which obscures the moderate effect of social identities on the relationship between social norms and electricity usage.

Overall, relationships between electricity usage and social norms were inconsistent among tenants, and their negative relationships were not clearly shown in the case study building. It is possible that types of electricity usage matter to the relationship with social norms. As Figure 48 illustrates, there does not seem to be consistent relationships between lighting usage and social norms; however, plug loads seem to be more negatively related with social norms as Figure 49 indicates. This can be explained by the different ways in which occupants use lighting and plug loads in office. Occupants may have more control over plug loads since they can change the setting and the number of their devices, such as monitors, desktop lighting, and laptops, around their desk space. On the other hand, lighting is used by multiple people in the same area, which is more difficult to be controlled by an individual occupant. In addition, the majority of lighting in the case study building is automated, which may have discouraged occupants from adjusting lighting by themselves. Consequently, plug loads are likely to be more subject to social norms since the amount of electricity for plug loads can be affected by the decision of individual occupants more than lighting electricity.

From the perspective of social influence theory, the diminished impact of social norms on lighting and plug loads can be explained by the natural tendency of small effect in social norms. As past researchers state, the effect of social norms on pro-environmental behaviour tends to be small (Smith & Louis, 2009; Abrahamse & Steg, 2013). Another possibility is the presence of other moderators. As the mechanism of energy saving behaviour is very complex (Lopes et al., 2012; Walton et al., 2019), it is highly possible that other factors, such as the circumstances of individuals, personalities, and cultural factors, can influence behaviour (Schweiker, Hawighorst, & Wagner, 2016). Although this study focused on social norms as a potential factor which promotes behavioural changes, multiple factors may also play essential roles in shaping behaviour of occupants in buildings.

Moreover, energy saving behaviour of occupants in office buildings may be relatively difficult to be encouraged. Abrahamse and Steg (2013) state that the effect of social influence may vary depending on types of behaviours; for example, behaviours which can be easily seen, such as recycling, may be effectively encouraged by social influence. Since electricity usage is rather invisible to occupants, it may have been more challenging to change electricity usage from the social influence approach. At the same time, it is also possible that occupants in the office did not feel responsible for energy saving in the workplace. As devices and appliances in the workplace are often shared by multiple occupants, electricity usage is attributed to a group of people, rather than individuals, which diminishes individual occupants' sense of responsibility for electricity usage (Carrico & Riemer, 2011). E. S. T. Wang and Lin (2017) also argue that social norms do not directly change pro-environmental behaviour, but rather "the perceived responsibility and the perceived effectiveness of environmental behaviour" act as mediators between social norms and behavioural changes. This suggests that it is necessary to increase the awareness of occupants about the impact of their behaviour on electricity usage in the building. The increased awareness and understanding of electricity usage may consequently strengthen the effect of social norms on behavioural changes. Therefore, future research may need to address other factors which influence electricity usage of occupants and the enhanced awareness of occupants regarding electricity usage in the workplace.

Another factor which may be attributed to the lack of consistent relationships between social norms and electricity usage can be critical mass. Critical mass is a point at which group behaviour is induced by a self-reinforcing mechanism (Centola, 2013; Kim and Bearman, 1997; Yin, 1998, as cited in Kim, 2015), and this concept can be applied to social influence. People within a particular group start changing their behaviour when they observe a fair number of people who have already adopted to the behaviour and showed positive attitudes (Kim, 2015). It is suggested that approximately 25% of people need to initiate actions in order to encourage behavioural changes in a workplace, and other studies also point out that the critical mass for behavioural change in the organizational level is 10 to 40% of people in the group ("Research finds tipping point for large-scale social change," 2018). It is possible that changes in electricity usage were not observed at an organizational scale because the critical mass had not been reached in the case study building. Therefore, a further study with more focus on the critical mass may offer a new insight into the relationship between social influence and behavioural changes.

It is also interesting that the levels of social norms showed a relatively larger increase after the second survey in Tenant C and Tenant D. This enhanced level of social norms might be attributed to the change to the green office building. Since pre-occupancy buildings of Tenant C and Tenant D did not have the sustainable building design and a visible central staircase, it is possible that social norms of occupants in regard to pro-environmental behaviour improved after moving into the case study building. This may correspond to the idea that the surrounding environment affects social norms of people, which is presented by past studies (Lede & Meleady, 2018; Schweiker et al., 2016).

Furthermore, it is surprising that social identities and social norms did not demonstrate clear relationships, which is contradictory to social influence theory. As Figure 50 illustrates, the level of social norms did not positively relate with the level of social identities. In addition, the average level of social identities seemed to be similar among different tenants while the average level of social norms showed more variance. One of the possible reasons for the lack of considerable changes in social identities during the third survey can be the pandemic. As occupants were forced to work from home after April 2020, they could not have in-person meetings with other occupants for several months. The reduced interaction and communications may have hindered occupants from enhancing social identities during the pandemic since interaction shapes social identity of people in a group (Hogg & Abrams, 1998). Another possible reason for the lack of clear relationships between the levels of social norms and social identities can be the process of defining social identities. As Hogg and Abrams (1998) explain that people first define their membership and then associate particular social norms to their group identity, occupants in the case study building may have been in the middle of process of defining their identities and associating social norms to their memberships. Therefore, energy saving might not have been identified as a key group norm and not have been deeply integrated into social identities of occupants because it had been only one year since occupants moved into the green office building. It also should be noted that survey questions used in this research were not specifically developed to study social norms and social identities from the perspective of social influence theory, but rather developed as indicators for COS. Thus, alteration of phrasing in survey questions may result in different responses from the occupants.

From the perspective of the energy cultures framework, social norms as an external influence did not demonstrate strong stimulation on energy practices of occupants. Like in stairs usage of occupants, material culture, such as types of equipment, devices, and appliances, seemed to have stronger influence on electricity usage of occupants. For example, the servers in Tenant D were attributed to a large amount of electricity usage, and the aggregated number of monitors and appliances in Tenant B also likely to have resulted in higher plug loads on weekends. The automated lighting system also seemed to have restricted the control of occupants over lighting usage. Thus, it is likely that material culture has a considerable impact on electricity usage by shaping the way in which occupants interact with technologies.

At the same time, ineffectiveness of social influence on the three components of the energy cultures framework might be due to the influence of cognitive norms, material cultures, and energy practices at the larger scale of the society. According to Stephenson, Barton, et al, (2015), energy cultures can be identified at different levels, such as the industrial and organizational levels, and energy cultures at a larger scale may influence energy cultures at a smaller scale as an external influence. For example, electricity usage of Tenant C and Tenant D might be affected by material cultures, cognitive norms, and energy practices within the larger energy cultures of the business sector. On the other hand, electricity usage of Tenant B might be affected by the three components within the energy cultures of the academic society.

In fact, Bell et al. (2014) found out that timber companies did not use energy efficient and cost-effective technologies even when they had the options because conventional technologies still remained as prevalent norms and major cultures of the wood industry (as cited in Walton et al., 2019). Therefore, energy cultures of particular industries or sectors may similarly influence energy cultures of tenants in the green office building, and these external influences on energy cultures of tenants may also vary depending on the type of organization and their field of expertise. Consequently, to further understand the mechanism of behavioural changes from the perspective of energy cultures framework, further research should be undertaken to identify external influences and how energy cultures at the sectoral level stimulate material cultures, cognitive norms, and energy practices of an organization.

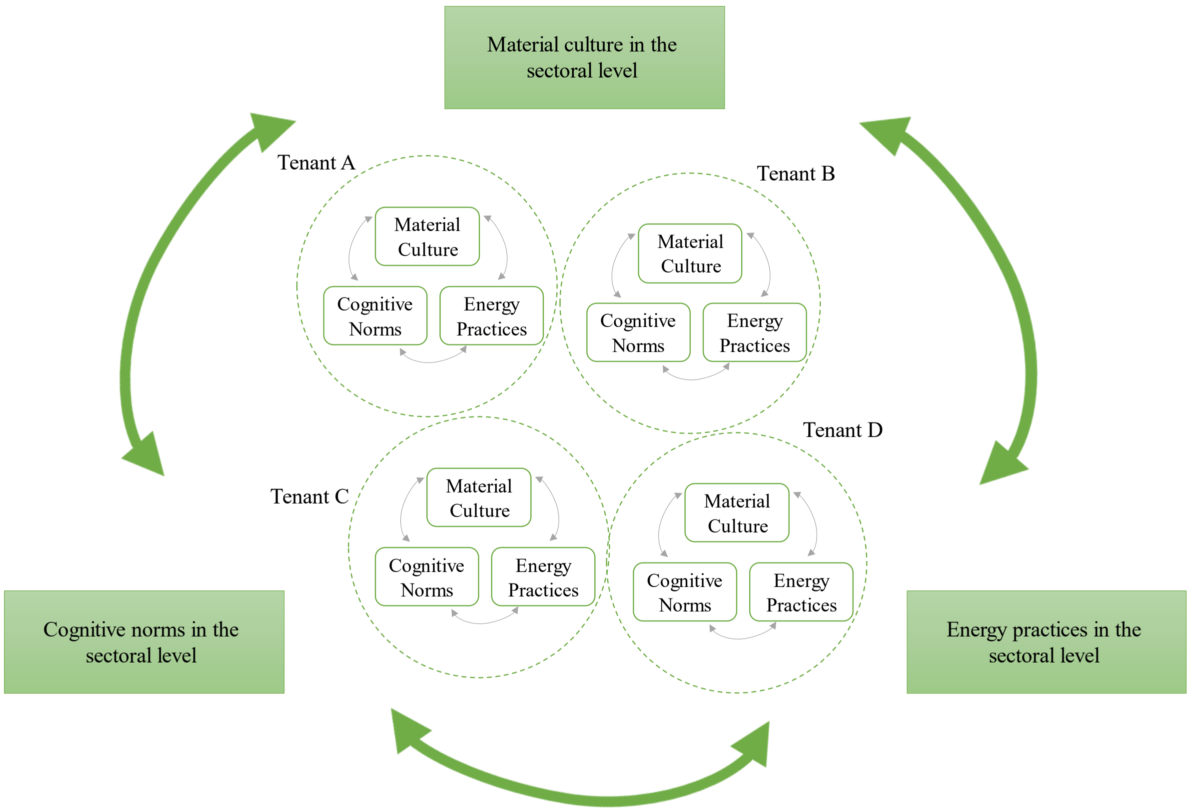

Figure 56 Energy cultures at different scales (adapted from Stephenson, Barton, et al., 2015)

5.4 The impact of occupants on the building electricity usage

5.3.1. Changes in the entire building electricity usage

Electricity usage of the entire building and tenant areas greatly changed after occupants were forced to work from home. As Figure 51 shows, the total electricity usage of the green office building was very low during the pandemic phase 1 when the building was unoccupied. The percentage of electricity usage in 2020 relative to 2019 during this time were also low. As electricity usage during the pandemic phase 1 between April 2020 and June 2020 was almost 60% of the same months in the previous year, it suggests that the presence of occupants contributes to more than 30% of electricity usage in the building.

During the pandemic phase 2 starting from July 2020, the percentage of electricity usage in 2020 gradually increased. This increase in electricity usage is attributed to some people coming back to the building as the COVID-19 restrictions were moderated (Informant 1, personal communication, December 4, 2020; Informant 2, personal communication, December 2, 2020). In particular, electricity usage between September and November 2020 was nearly 90% of electricity usage during the same months in 2019. This demonstrates that the presence of occupants can make a large impact on the total electricity usage of the building even if the number of occupants is small. It is surprising that electricity usage of the building was only different by 10% when a small percentage of occupants (approximately 10% of occupants estimated, based on vehicles counted in the carpark of the case study building) returned to the building, compared to the previous year. It should be noted that the electricity usage of the building gradually reduced over time in 2019 due to the optimization of the HVAC system as mentioned in the Section 4.1. The total electricity usage of the building was relatively high in January and February 2019 since there had not been efforts to optimize the HVAC system yet.

Since the electricity usage of the building decreased over time during 2019 due to the enhanced energy efficiency of the HVAC operations, it can be considered that the impact of occupant behaviour on electricity usage increased instead. This is implied by the high percentage of electricity usage between September and November 2020, compared to January and February 2020. Between September and November, the electricity usage of the building in 2020 was less than 15% of the previous year; however, there was about a 20% gap between 2019 and 2020 during January and February. Although the number of occupants was smaller between September and November 2020, compared to January and February 2020, the building electricity usage after September 2020 did not decrease in proportion to the number of occupants. This means that the small number of occupants contributed to a significant amount of the building electricity usage during the pandemic, thereby increasing the impact of occupants on the building. This finding also corresponds to past researchers' argument that the role of occupants becomes more crucial to energy sustainability of the building as building technologies become more energy efficient (Carpino et al., 2017; Owens & Driffill, 2008; P. Zhu et al., 2017). Thus, the presence of occupants has a large impact on the total electricity usage of the green office building, and the data shows that even a small number of occupants can greatly increase the electricity usage in the building.

5.3.2. Changes in electricity usage of tenant areas

Furthermore, electricity usage in tenant areas illustrates significant changes after occupants started working from home. The percentage of monthly total electricity usage in 2020 relative to 2019 suggests that the absence of occupants potentially reduced more than 30% of electricity usage in tenant areas. Similarly, the percentage gap between the weekday average electricity usage in 2019 and 2020 ranged from 30% to 60%, which demonstrates a considerable impact of occupant behaviour on lighting and plug loads in tenant areas. In addition, the percentage of electricity usage in 2020 relative to 2019 increased during the pandemic phase 2, compared the pandemic phase 1. This increase in electricity usage of tenant areas resulted from the small increase in the number of occupants after September 2020, which is a similar pattern with the total electricity usage of the building.

In contrast, the percentage gap between the weekend average electricity usage in 2019 and 2020 was relatively lower, compared to the monthly total and weekday average electricity usage. The weekend average electricity usage from April to November in 2020 tended to be lower by 10%, compared to 2019. This indicates that the absence of occupants did not reduce the weekend electricity usage as much as the weekday electricity usage. At the same time, paired samples t-test shows that there were no significant differences in the weekend average electricity usage between April 2019 and April 2020. This implies that weekend electricity usage did not drastically decrease after occupants left the building unlike the weekday electricity usage. Less reduction in the weekend average electricity usage during the pandemic poses the possibility of more lighting and plug loads left on during weekends even when occupants did not use the building. Consequently, the impact of occupants on electricity usage in tenant areas varied between weekdays and weekends, and the results revealed a considerable amount of phantom loads in the green building during the pandemic.

At the same time, the analyses on electricity usage in tenant areas show that the electricity usage in tenant areas during the pandemic mostly exceeded 50% of electricity usage in 2019. This is most likely to be attributed to devices and appliances, such as servers, printers, monitors, and refrigerators, which continued to consume electricity even when occupants worked from home (Informant 1, personal communication, December 4, 2020). This demonstrates that additional conservation of electricity would require the more active engagement of occupants, thereby recognizing the potential role of occupants in energy sustainability of the green building.

Overall, electricity data of the green office building during the pandemic demonstrates that occupant behaviour influences electricity usage of the building, as well as tenant areas. Electricity usage reduced after occupants left the building, but the total building electricity usage during the pandemic was still more than 50% of the total building electricity usage in the previous year. The results of this study also reveal that the impact of occupant behaviour on electricity usage has become larger as the building technologies, such as HVAC systems, became more energy efficient. Thus, there is great potential to further reduce electricity usage even when occupants do not use the building, and occupant behaviour remains essential to energy sustainability of the green office building.

5.5. Limitations and suggestions for future research

One of the limitations in this study is inconsistency in the sample. This study used the longitudinal data of stairs usage, as well as electricity data in the green office building. While the data had been collected, it is possible that the profile of occupants in the building changed over time. Since most occupants were employed by corporations or organizations in the building, some occupants may have left or been recruited during the data collection. Therefore, changes in the overall stairs usage, as well as changes in electricity usage may be influenced by changes in the occupants.

The observation method used in this study may also have bias in data collection. Observation was conducted since the pre-occupancy period, and students were recruited as observers to count the number of people using stairs. There may have been inconsistencies in the way each observer recorded the number of stairs usage, and human errors in data collection are also possible since it could be confusing when groups of people use stairs and elevators at the same time.

Another obvious limitation is the sample size of data sets. There have been only three surveys conducted in the case study building, and the total number of tenant organizations was not sufficient to conduct quantitative analyses on survey data. As a result, statistical analyses, such as multilevel modeling, could not be used to analyze relationships between social norms and energy saving behaviour of occupants. The descriptive analyses on relationships between survey results and energy saving behaviour in this study, therefore, may not offer a complete understanding of the relationships between social influence and occupant behaviour in the building. If more surveys are conducted to collect data regarding social norms and social identities of occupants, future studies would be able to offer insights into how social influence affects and promotes energy saving behaviour of occupants based on more data points.

At the same time, this study initially planned to conduct comparative feedback interventions on electricity usage of occupants in the case study building. The feedback messages which suggest descriptive and injunctive norms and compare energy usage of groups were considered to play a role in promoting energy saving behaviour of occupants. Comparison of energy usage of different groups would make people more conscious of their own group by emphasizing perceived membership (Siero et al., 1996; Abrahamse et al., 2005). Since people tend to aspire for a "positive self-image," they would likely to cooperate with each other to save energy usage after having comparative feedback (Siero et al., 1996). At the same time, people would be inspired to save energy by descriptive norms when energy usage of a group is compared with the average energy usage of different groups as it suggests how much energy other people generally consume (Schultz et al., 2007; Allcott, 2011). People would also be encouraged to reduce energy usage if they see injunctive norms suggesting whether their energy usage is acceptable (Schultz et al., 2007; Allcott, 2011). Thus, it was predicted that comparative feedback with descriptive and injunctive norms would be an effective intervention which may potentially motivate occupants in the case study building to save electricity in the workplace. However, the feedback interventions could not be carried out due to the outbreak of the COVID-19 as occupants were forced to work from home. Thus, there is abundant room for further progress in studying the relationships between social influence and energy saving behaviour of occupants in the building. Future studies should consider using interventions to promote further energy saving in the green office building.

A further study with more focus on the profiles of electricity usage in the green office building is suggested. While this study was unable to examine types and number of devices in tenant areas in detail due to the privacy purpose and the limited time frame, future researchers may collect such data to understand the patterns of individual occupant behaviour, as well as to identify key factors which contribute to phantom loads. There is also more room to explore electricity usage in tenant areas; future research may investigate the detailed patterns of electricity usage and the difference in the impact of occupant behaviour depending on times and days. This would allow researchers to develop a more complete picture of the role that occupants play in shaping energy cultures of the green office building.

6 Conclusions

This study explored energy saving behaviour of occupants in a green office building in Canada. The integration of social influence theory and the energy cultures framework allows researchers to understand how human and technological factors affect energy saving behaviour of occupants in the building. The electricity usage profile of the green office building reveals that occupant behaviour became an increasingly important component of the total electricity usage of the building. The percentage of monthly electricity usage in tenant areas relative to the entire building increased from 24% to 36% as the building system became more energy efficient through operational adjustments. The increased percentage of electricity usage in tenant areas illustrates the essential role which occupants play in the energy conservation of green buildings.

The results also show that electricity usage for lighting and plug loads have distinct patterns. Electricity usage for lighting can easily be increased with a small number of occupants coming to the workplace, which means that the amount of lighting electricity does not equally correspond to the number of occupants. On the other hand, electricity usage for plug loads changes relative to the number of occupants and their activity levels. As a result, plug loads tend to be more subject to behaviour of individual occupants in the building. Moreover, the weekend plug loads were more than three times higher than the weekend lighting. This suggests that a lot of devices, including monitors, printers, and appliances, contributed to a considerable phantom load in the workplace. Thus, the necessity of reducing the weekend plug loads was identified as a large opportunity to contribute to energy conservation in the green office building.

This study also applied social influence theory and the energy cultures framework to energy saving behaviour of occupants in the green office building. Stairs usage of occupants was examined to identify factors which motivate people to take stairs. The analyses suggest that material culture, such as the building design, a presence of a central staircase, and the floor level, had strong effects on stairs usage of occupants in the buildings. The stair usage rate was higher when the building had sustainable design, a central staircase, and occupants were located on the lower floor level. In contrast, this study could not demonstrate that social norms and information provision significantly encouraged stairs usage of occupants in the green office building. The results also suggest that material culture alone may have short-term effects on stairs usage as the reduced stairs usage rate of occupants on the third floor was observed in the later post-occupancy period. Therefore, further stimulation of cognitive norms and energy practices within the energy cultures framework is needed to promote stairs usage of occupants in the long run.

Furthermore, this study predicted negative relationships between social norms and electricity usage of occupants, as well as positive relationships between social norms and social identities of occupants. The descriptive analyses showed inconsistent patterns across different tenants in the green office building. The predicted relationships among electricity usage, social norms, and social identities were not observed in two tenants in the building. However, the results indicate the possibility of negative relationships between social norms and electricity usage in the two other tenants though the positive relationships between social norms and social identities were not observed. The analyses also implies that plug loads tended to be more subject to social norms than lighting usage since individual occupants had more control over electricity usage of devices near their desk space. Consequently, the predicted relationships among social norms, electricity usage, and social identities could not be demonstrated in this study; however, the potential impact of social norms on plug loads and possible influence of other factors, such as the occupants' sense of responsibility for electricity usage and energy cultures at the sectoral level, were suggested.

At the same time, this study investigated the impact of occupant behaviour on electricity usage of the green office building by comparing electricity usage before and after the outbreak of COVID-19. When all occupants were forced to work from home during the early stage of the pandemic, the total electricity usage of the green office building in 2020 relative to 2019 ranged from 61% to 68% of the building electricity usage in the previous year. Nevertheless, the percentage of electricity usage increased to maximum of 91% when a few occupants (approximately 10%) returned to the building. These results demonstrate that even a small number of occupants can increase the total electricity usage of the building, and the impact of occupants became more considerable as the building technology became more energy efficient. The analyses on electricity usage in tenant areas similarly suggest that the absence of occupants significantly reduced electricity usage in tenant areas, but a fair amount of lighting and plug loads was still consumed in the workplace even when occupants did not use the building.

Ultimately, this study revealed that occupants had a considerable impact on electricity usage of the green office building, and their role in energy saving becomes larger as building technologies become more energy efficient. Although social influence was not proven to significantly promote energy saving behaviour in the building, this study suggests the need of further investigation on the role of social influence in encouraging energy saving behaviour of occupants with the combination of other factors. From the perspective of the energy cultures framework, material culture alone seemed to have larger, but in some cases short-term effects on energy practices, both stairs usage and electricity usage. Further stimulation of the factors within the energy cultures framework is necessary to encourage energy saving behaviour of occupants in the long run. The potential impact of the energy cultures at the sectoral level was indicated as a possible complication requiring further investigation at multiple scales.

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Appendix

Appendix A – Holidays excluded from lighting and plug loads data from tenant areas

Year	Date	Name
2019	January 1	New Year's Day
	February 18	Family Day
	April 19	Good Friday
	May 20	Victoria Day
	July 01	Canada Day
	August 05	Civic Day
	September 02	Labour Day
	October 14	Thanksgiving
	December 25	Christmas Day
	December 26	Boxing Day
2020	January 1	New Year's Day
	February 17	Family Day
	April 10	Good Friday
	May 18	Victoria Day
	July 1	Canada Day
	August 3	Civic Day
	September 7	Labour Day
	October 12	Thanksgiving

Appendix B – Timeline of observation for stairs and elevator usage

Period	Phase	Building	Observation Dates	Observation time	Floor level
Pre-occupancy	1	Building 1	Aug. 28, 2018 Aug. 30, 2018 Sep. 04, 2018 Sep. 06, 2018	8:45 a.m. ~ 10:00 a.m. 11:55 a.m. ~ 1:00 p.m. 4:55 p.m.~ 6:00 p.m.	Third floor
		Building 2	Sep. 19, 2018 Sep. 20, 2018 Sep. 26, 2018	8:00 a.m~9:00 a.m. 12:00 p.m. ~ 1:00 p.m. 3:30 p.m. ~ 4:30 p.m.	Second and third floor
		Building 3	Sep. 24, 2018 Sep. 28, 2018 Oct. 02, 2018	8:00 a.m~9:00 a.m. 12:00 p.m. ~ 1:00 p.m. 3:30 p.m. ~ 4:30 p.m.	Second floor
Post-occupancy	2	The case study building	Dec. 04, 2018 Dec. 05, 2018 Dec. 06, 2018	8:00 a.m~9:30 a.m. 12:00 p.m. ~ 1:00 p.m. 4:00 p.m.~5:00p.m.	Second and third floor
	3	The case study building	Nov. 04, 2019 Nov. 05, 2019 Nov. 08, 2019	8:00 a.m. ~ 6:00 p.m.	Second and third floor
	4	The case study building	Jan. 22, 2020 Jan. 23, 2020 Jan. 24, 2020	8:00 a.m. ~ 10:00 a.m. 11:35 a.m. ~1:30 p.m. 4:00 p.m. ~ 6:00 p.m.	Second and third floor
	5	The case study building	Jan. 29, 2020 Jan. 30, 2020 Jan. 31, 2020	8:00 a.m. ~ 10:00 a.m. 11:35 a.m. ~1:30 p.m. 4:00 p.m. ~ 6:00 p.m.	Second and third floor
	6	The case study building	Mar. 02, 2020 Mar. 03, 2020 Mar. 04, 2020	8:00 a.m. ~ 10:00 a.m. 11:35 a.m. ~1:30 p.m. 4:00 p.m. ~ 6:00 p.m.	Second and third floor

Appendix C – Copy of survey questions

ECS **Please rate the extent to which each of the following items accurately describes <u>your organization</u>:**

	Does not describe my organization 0 (0)	1 (1)	2 (2)	3 (3)	Describes my organization very well 4 (4)
Environmental considerations play a role in day-to-day decision-making. (ECS1)	○	○	○	○	○
In comparison to other issues, reducing environmental impact is considered a priority. (ECS2)	○	○	○	○	○
People in management positions lead or support environmental initiatives. (ECS4)	○	○	○	○	○
Taking care of the environment is central to who we are. (ECS5)	○	○	○	○	○
There is prominent signage that promotes environmental awareness and	○	○	○	○	○

practices. (ECS6)					
There are numerous symbols that reflect environmental engagement (e.g. composting bins, solar panels). (ECS7)	○	○	○	○	○
People commonly use environmental terminology (e.g. carbon, environmental footprint). (ECS8)	○	○	○	○	○
There are regular programs and activities focused on environmental impact. (ECS9)	○	○	○	○	○
People fulfill job tasks in environmentally-friendly ways. (ECS10)	○	○	○	○	○
Environmental achievements are recognized and celebrated. (ECS11)	○	○	○	○	○
Environmental objectives and performance are regularly communicated	○	○	○	○	○

to employees. (ECS12)

Please rate your agreement or disagreement with the following items:

	Strongly disagree -3 (-3)	Moderately disagree -2 (-2)	Slightly disagree -1 (-1)	Neither agree nor disagree 0 (0)	Slightly agree 1 (1)	Moderately agree 2 (2)	Strongly agree 3 (3)
Membership in this organization is meaningful and valuable to me. (BELONG_1)	○	○	○	○	○	○	○
I feel loyal to the people in this organization. (BELONG_2)	○	○	○	○	○	○	○
This organization feels like a community. (BELONG_4)	○	○	○	○	○	○	○

Appendix D – Baseline of electricity usage for lighting and plug loads in tenant areas

The average electricity usage by day of the week were computed for Tenant A, Tenant B, Tenant C, and Tenant D. Electricity usage both for lighting and plug were loads examined. The patterns of electricity usage from Monday to Sunday (excluding holidays) were shown. Electricity data from January 2019 to February 2020 was used to calculate the average electricity usage by day of the week in each month. Electricity data on holidays were excluded from the analysis due to the inconsistent pattern of energy usage on holidays. For each month, the average electricity usage by day of the week was calculated as follow:

$$Average\ electricity\ usage\ by\ day\ of\ the\ week\ = \frac{Total\ electricity\ usage\ by\ day\ of\ the\ week}{Number\ of\ days\ in\ a\ month}$$

Lighting

Figure 57 shows the lighting usage of Tenant A by day of the week. The average monthly lighting usage of Tenant A was 978 kWh (SD = 90, COV = 11) from January 2019 and February 2020. The average lighting usage of Tenant A on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 36.4 kWh, 37.3 kWh, 38.3 kWh, 38.1 kWh, 36.8 kWh, 21.5 kWh, and 19.9 kWh respectively. The Sunday lighting usage was almost half of the lighting usage on Wednesday and Thursday. Figure 57 also shows that the weekend lighting usage is almost half of the weekday lighting usage.

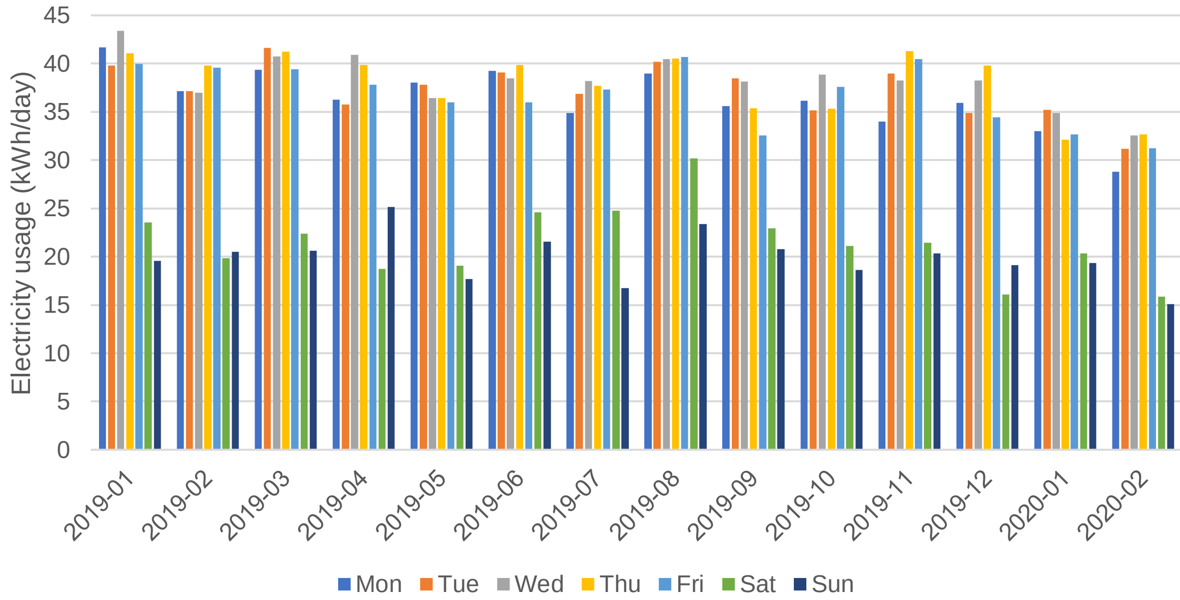

Figure 57 Average electricity usage for lighting of Tenant A by day of the week,

January 2019 – February 2020

Figure 58 shows the lighting usage of Tenant B by day of the week. The average monthly lighting usage of Tenant B was 370 kWh (SD = 38, COV = 10) from January 2019 and February 2020. The average lighting usage of Tenant B on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 15.5 kWh, 16.5 kWh, 16.0 kWh, 16.1 kWh, 13.6 kWh, 4.96 kWh, and 4.82 kWh respectively. As Figure 58 shows, the weekday lighting usage of Tenant B increased from October 2019 although it temporarily reduced in December 2019. The weekend lighting usage of Tenant B was also very low, at one-third of the weekday lighting usage.

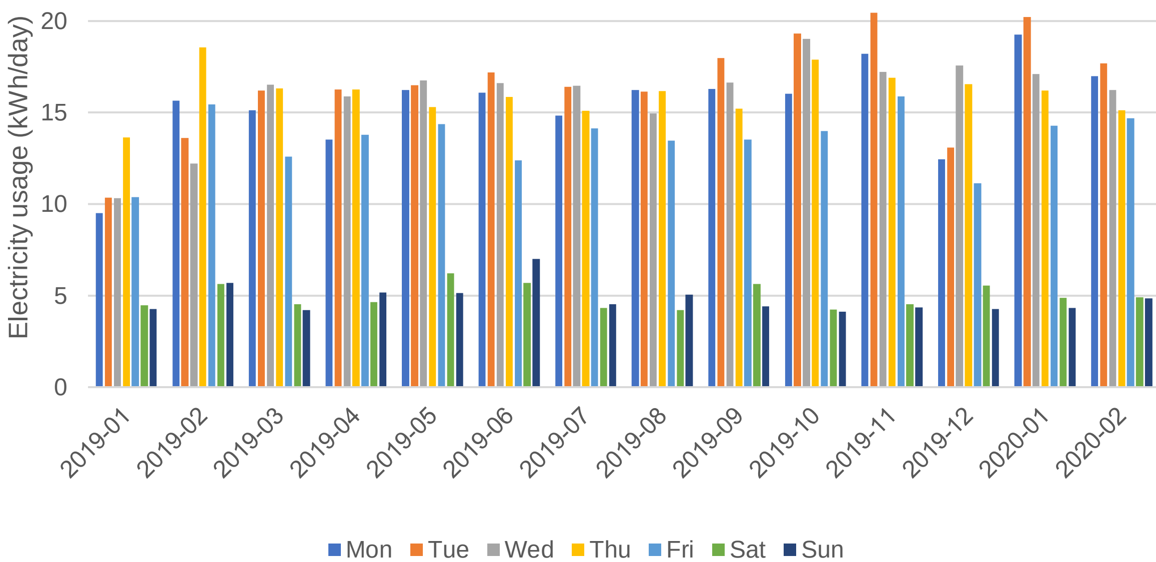

Figure 58 Average electricity usage for lighting of Tenant B by day of the week, January 2019 – February 2020

Figure 59 shows the lighting usage of Tenant C in the non-office area by day of the week. The average monthly lighting usage of Tenant C in the non-office area was 344 kWh (SD =17, COV=20) from January 2019 and February 2020. The average lighting usage of Tenant C in the non-office area on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 13.1kWh, 12.8 kWh, 14.7 kWh, 13.3 kWh, 14.0 kWh, 6.38 kWh, and 6.45 kWh respectively. As Figure 59 also shows, the weekend lighting usage of Tenant C in the non-office areas was one-half of the weekday lighting usage.

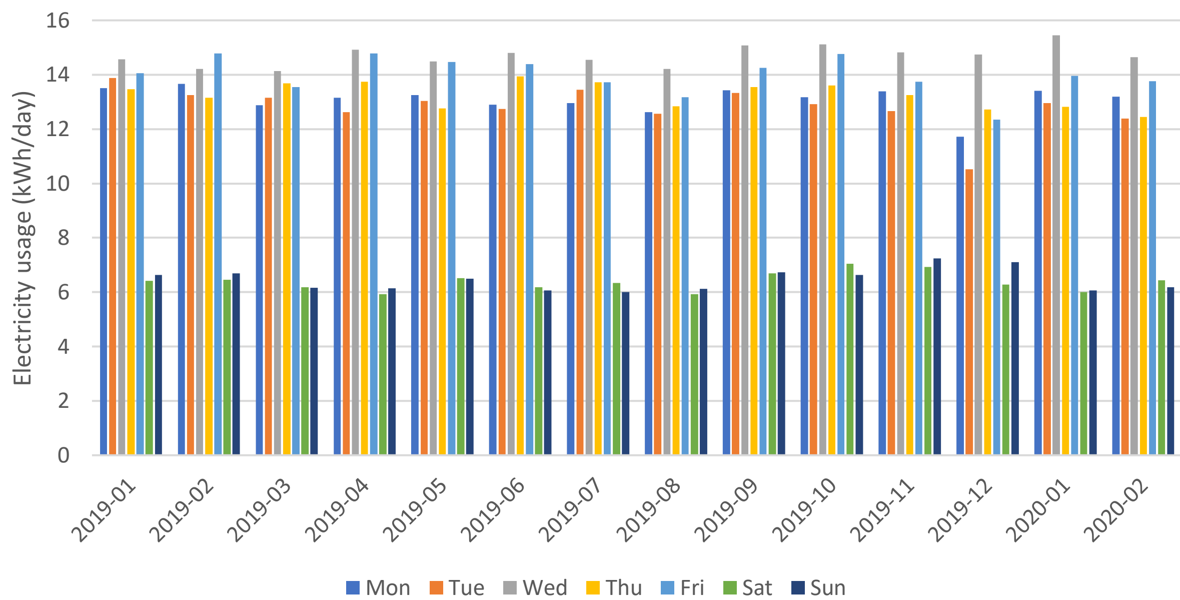

Figure 59 Average electricity usage for lighting of Tenant C (non-office area), January 2019 – February 2020

Figure 60 shows the lighting usage of Tenant C in the office area by day of the week. The average monthly lighting usage of Tenant C in the office area was 2,250 kWh (SD = 149, COV =15) from January 2019 and February 2020. The average lighting usage of Tenant C in the office area on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 99.0 kWh, 103 kWh, 102 kWh, 103 kWh, 98.7 kWh, 15.4 kWh, and 13.9 kWh respectively from January 2019 and February 2020. As Figure 60 shows, the weekend lighting usage of Tenant C in the office area was just 13% to 15% of the weekday lighting usage.

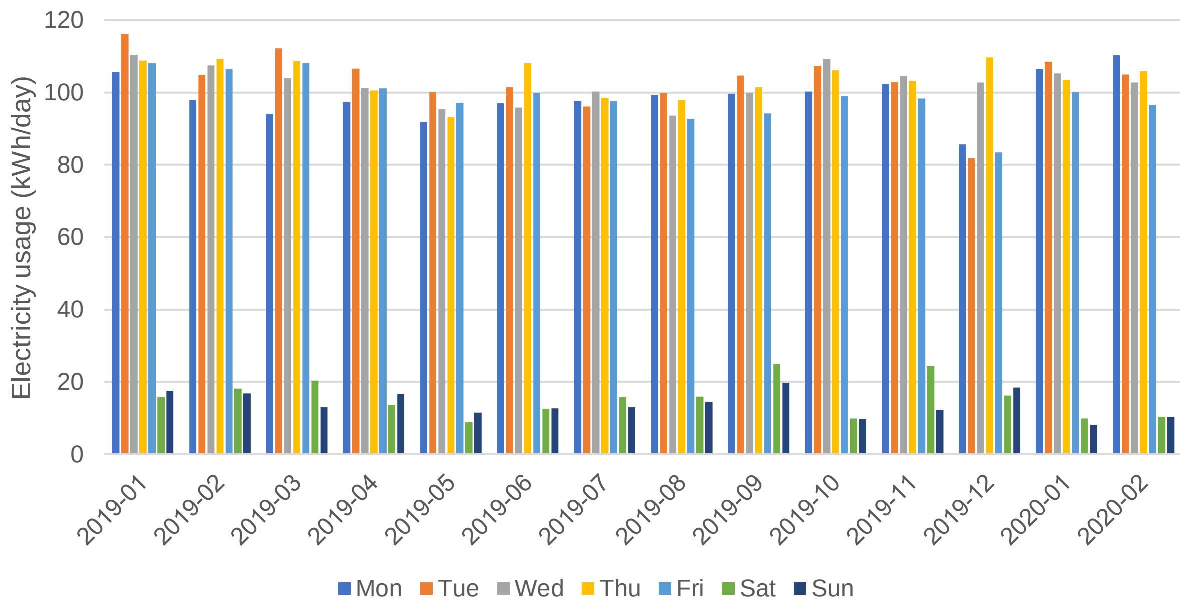

Figure 60 Average electricity usage for lighting of Tenant C (office area), January 2019 – February 2020

Figure 61 shows the lighting usage of Tenant D by day of the week. The average monthly lighting usage of Tenant D was 2,385 kWh (SD= 279, COV=9) from January 2019 and February 2020. The average lighting usage of Tenant D on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 97.2 kwh, 97.7 kWh, 99.4 kWh, 99.8 kWh, 91.5 kWh, 43.4 kWh, and 32.7 kWh respectively. As Figure 61 shows, the weekend lighting usage of Tenant D greatly changed over time, and the weekday and weekend lighting usage of Tenant D decreased from May 2019 and October 2019. In addition, the average weekend lighting usage of Tenant D was less than half of the weekday lighting usage.

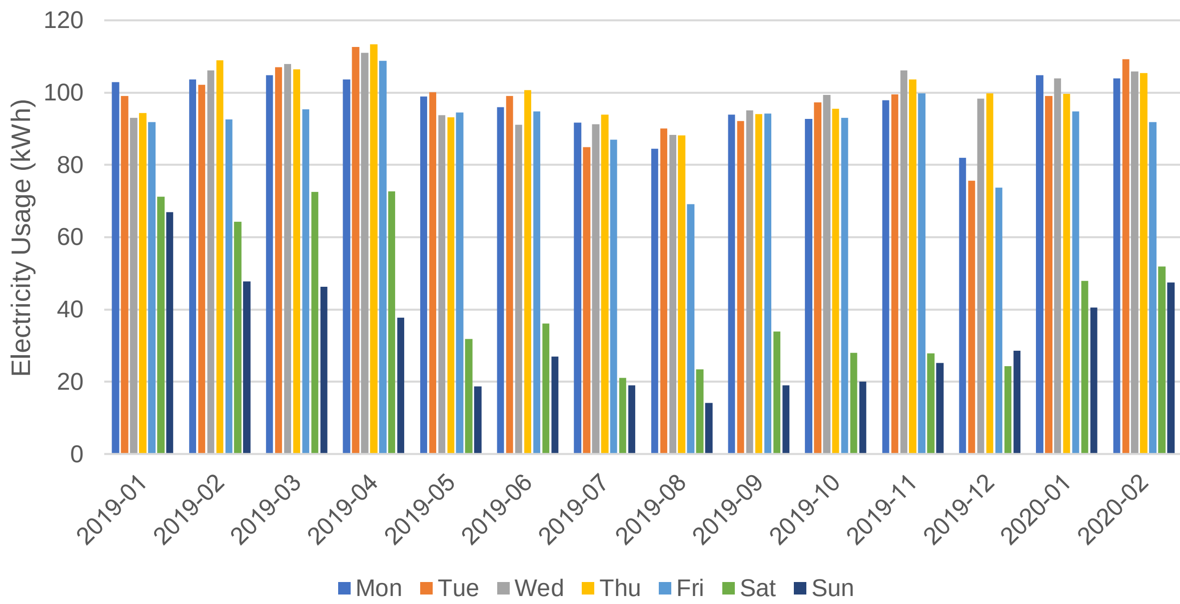

Figure 61 Average electricity usage for lighting of Tenant D,

January 2019 – February 2020

Plug loads

The average electricity usage for the plug loads of Tenant A, Tenant B, Tenant C, and Tenant D is displayed by day of the week. Figure 62 shows the plug loads of Tenant A. The monthly average electricity usage for plug loads of Tenant A was 735 kWh (SD=122, COV=6), and the plug loads changed over time. The average electricity usage for plug loads on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday is 27.9 kWh, 27.2 kWh, 26.1 kWh, 27.3 kWh, 25.4 kWh, 18.9 kWh, and 18.4 kWh respectively. As Figure 62 shows, the weekend plug loads were relatively very high compared to the weekday plug loads because it is more than two-thirds of the weekday usage.

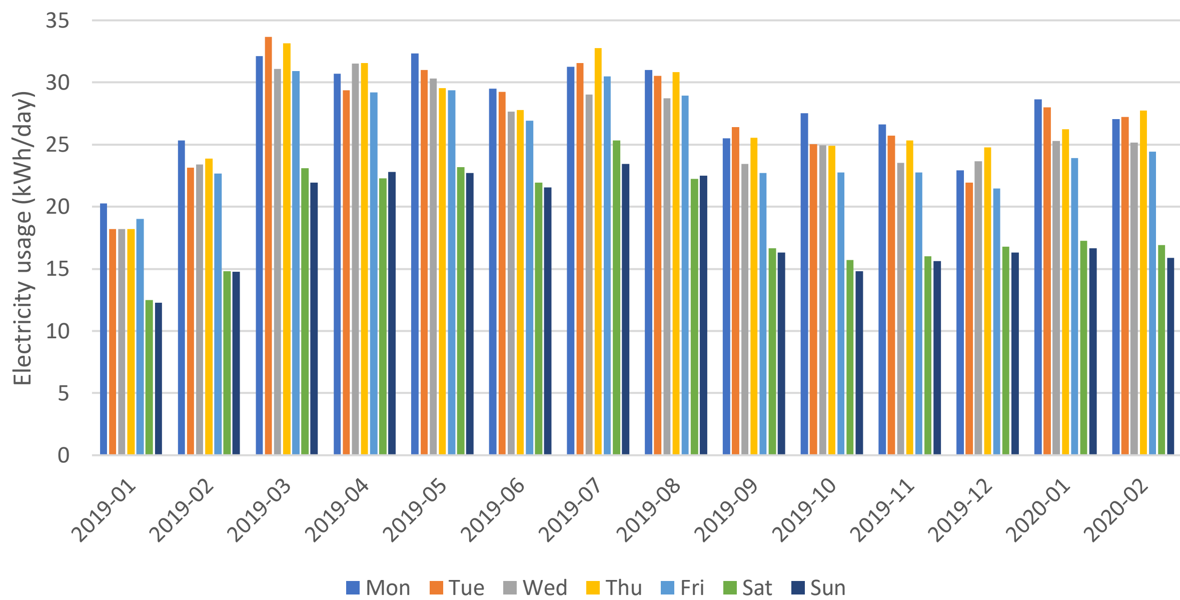

Figure 62 Average electricity usage for plug loads of Tenant A, January 2019 – February 2020

Figure 63 shows the plug loads of Tenant B by day of the week. The average monthly electricity usage for plug loads of Tenant B was 960 kWh (SD = 173, COV =6) from January 2019 and February 2020. The average electricity usage for plug loads of Tenant B on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 34.8 kWh, 37.0 kWh, 34.7 kWh, 34.6 kWh, 31.2 kWh, 25.7 kWh, and 25.1 kWh. As Figure 63 shows, the weekday plug loads of Tenant B increased from September 2019 and once decreased in December 2019. The weekend plug loads of Tenant B is also relatively high, compared to the weekday plug loads, since it is more than 70% of the weekday plug loads.

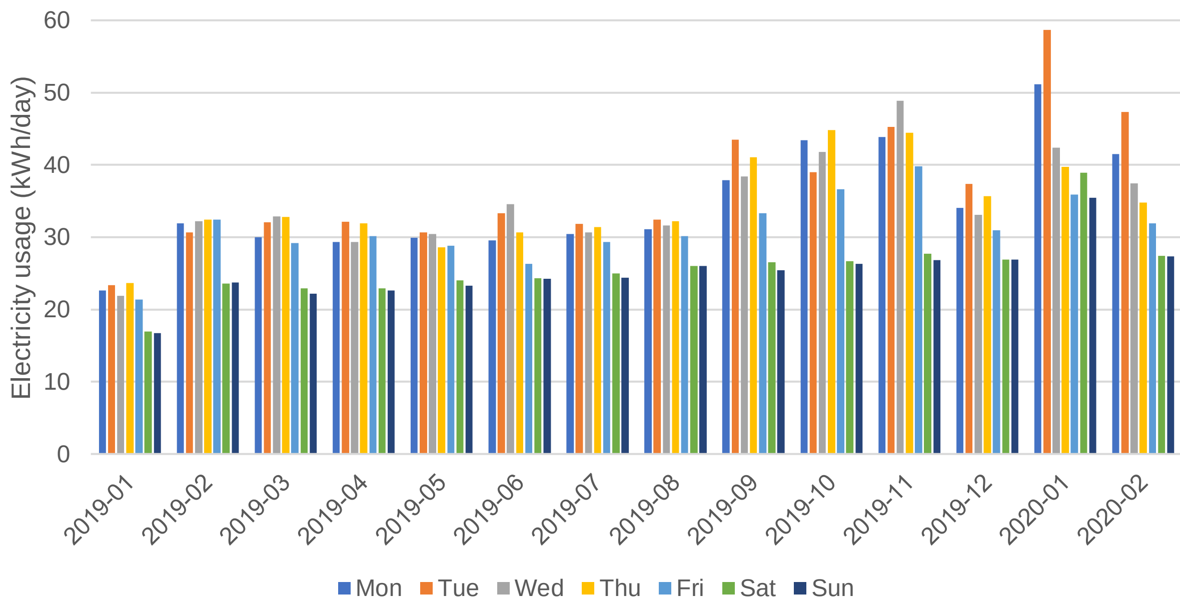

Figure 63 Average electricity usage for plug loads of Tenant B, January 2019 – February 2020

Figure 64 shows the plug loads of Tenant C in the non-office area by day of the week. The average monthly electricity usage for plug loads of Tenant C in the non-office area was 1,623 kWh (SD = 83, CIV=19) from January 2019 and February 2020. The average electricity usage for plug loads of Tenant C in the non-office area on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 56.5 kWh, 61.1 kWh, 59.2 kWh, 60.0 kWh, 59.6 kWh, 40.9 kWh, and 40.9 kWh respectively. As Figure 64 shows, the weekday and weekend plug loads of Tenant C in the non-office area was almost constant over time. Compared to the weekday plug loads, the weekend plug loads of Tenant C in the non-office area is relatively higher, and it is two-thirds of the weekday plug loads.

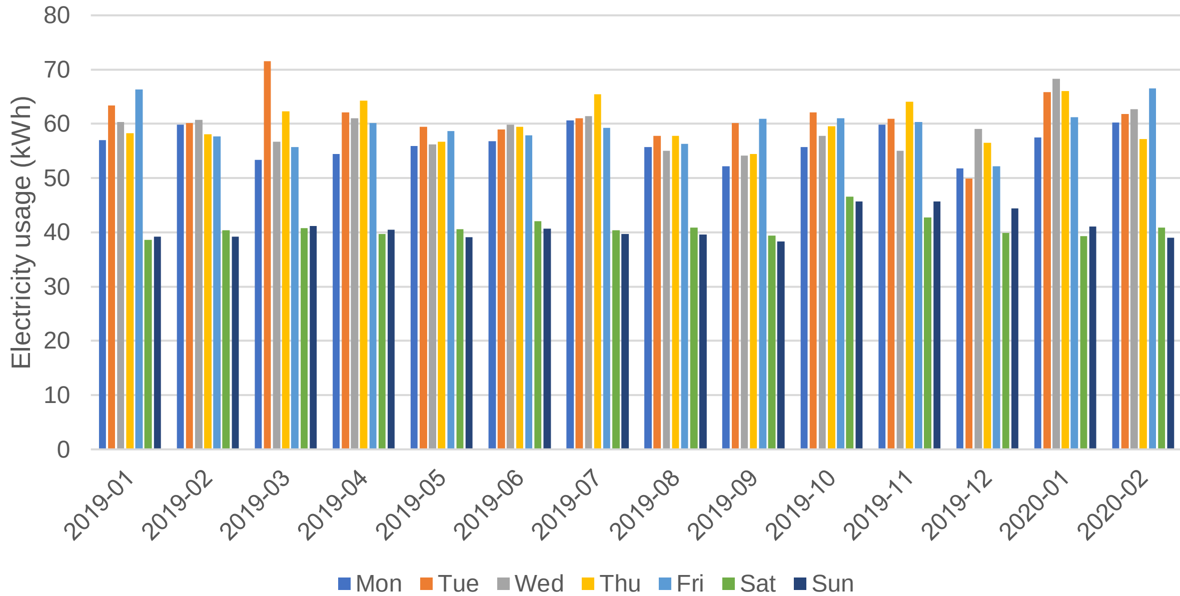

Figure 64 Average electricity usage for plug loads of Tenant C (non-office area), January 2019 – February 2020

Figure 65 shows the plug loads of Tenant C in the office area by day of the week. The average monthly electricity usage for plug loads of Tenant C in the office area was 5,946 kWh (SD=255, COV=23) from January 2019 and February 2020. The average electricity usage for plug loads of Tenant C in the office area on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 220 kWh, 222 kWh, 224 kWh, 222 kWh, 217 kWh, 139 kWh, and 137 kWh respectively. As Figure 65 shows, the weekday and weekend plug loads of Tenant C in the office area did not greatly change over time as the same as the plug loads in the non-office area. Compared to the weekday plug loads of Tenant C in the office area, the weekend plug loads were relatively high as they were more than half of the weekday plug loads.

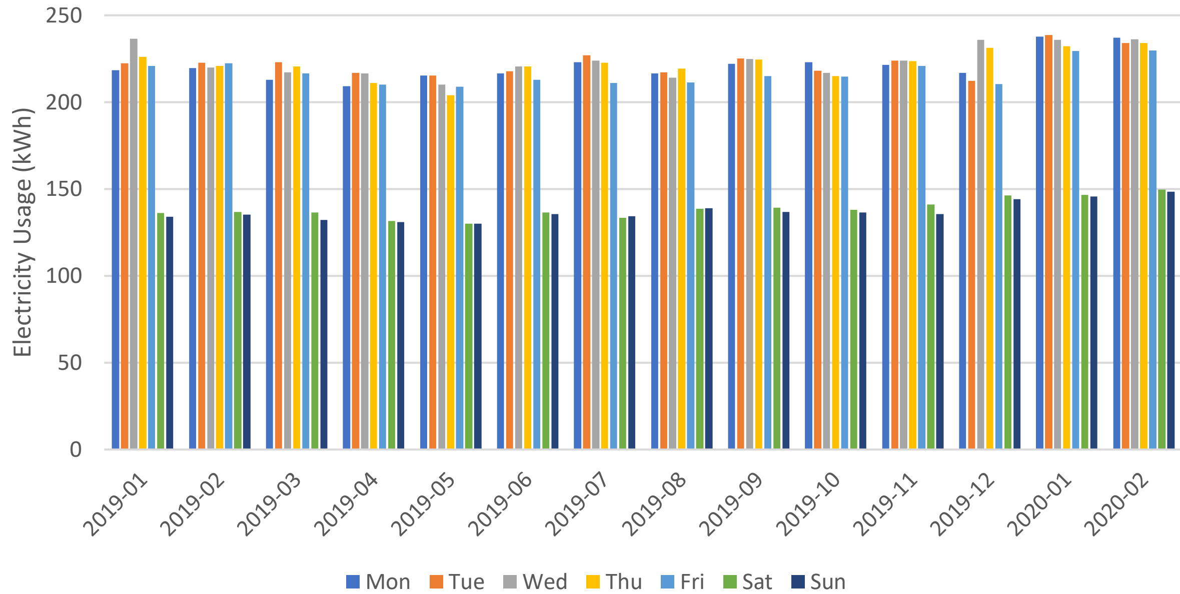

Figure 65 Average electricity usage for plug loads of Tenant C (office area),

January 2019 – February 2020

Figure 66 shows the plug loads of Tenant D in the server room by day of the week. The average monthly electricity usage for plug loads of Tenant D in the server room was 4,549 kWh (SD=511, COV=9) from January 2019 and February 2020. The average electricity usage for plug loads of Tenant D in the server room on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 152 kWh, 151 kWh, 151 kWh, 151 kWh, 149 kWh, 149 kWh, and 148 kWh respectively. As Figure 66 also shows, the weekend plug loads of Tenant D in the server room were almost the same as the weekday plug loads, which is different from other circuits. In addition, the plug loads of Tenant D in the server room were lower in January 2019 and between August and October 2019.

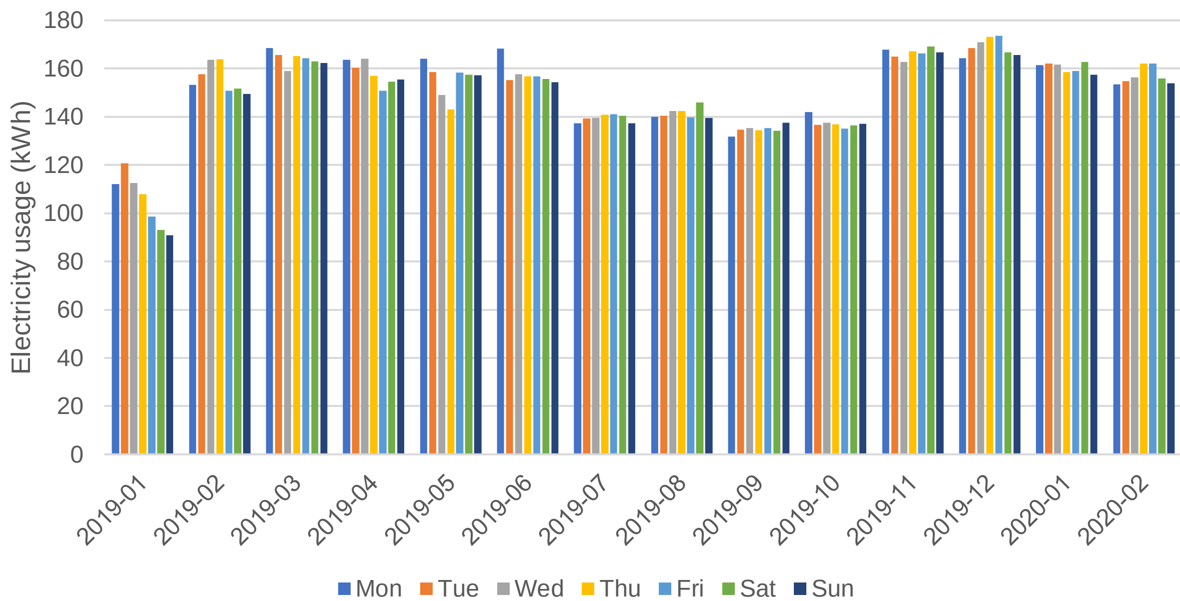

Figure 66 Average electricity usage for plug loads of Tenant D (the server room), January 2019 – February 2020

Figure 67 shows the plug loads of Tenant D on the east side by day of the week. The average monthly electricity usage for plug loads of Tenant D on the east side was 2,703 kWh (SD=296, COV=9) from January 2019 and February 2. The average electricity usage for plug loads of Tenant D on the east side on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 95.4 kWh, 94.7 kWh, 94.7 kWh, 94.9 kWh, 92.5 kWh, 78.7 kWh, and 76.9 kWh respectively. Compared to the weekday plug loads, the weekend plug loads of Tenant D were relatively high as they were more than 80% of the weekday plug loads. As Figure 67 shows, both the weekday and weekend plug loads of Tenant D on the east side reduced between June and August 2019, and started increasing again from September 2019.

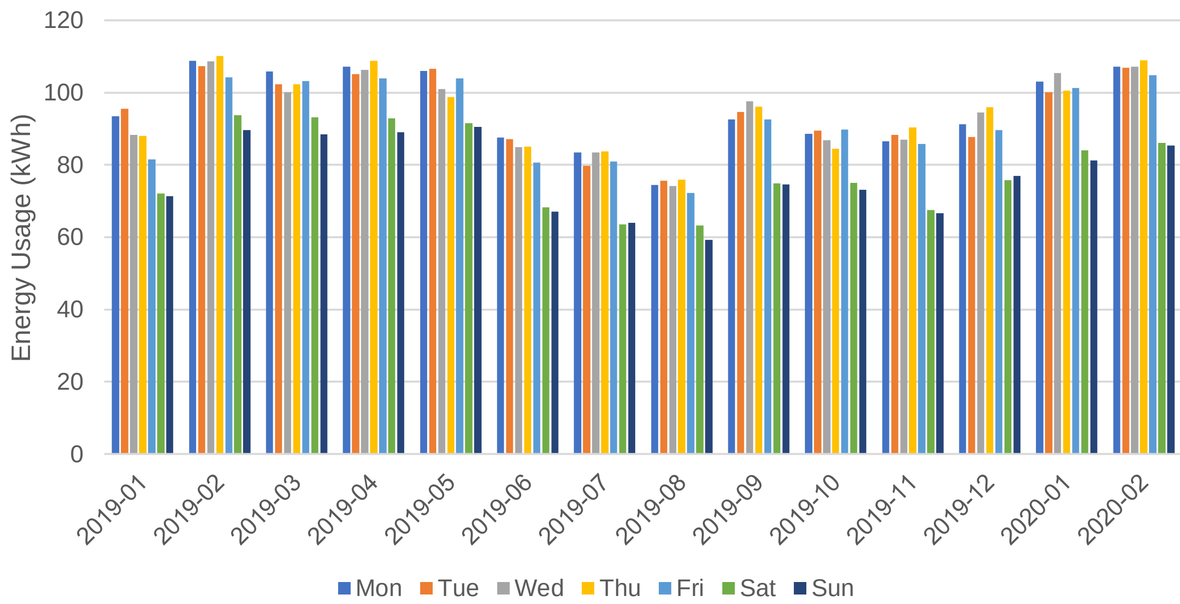

Figure 67 Average electricity usage for plug loads of Tenant D (the east side), January 2019 – February 2020

Finally, Figure 68 shows the plug loads of Tenant D on the west side by day of the week. The average monthly electricity usage for plug loads of Tenant D on the west side was 1,380 kWh (SD=243, COV=6) from January 2019 and February 2. The average electricity usage for plug loads of Tenant D on the west side on Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday was 53.8 kWh, 52.3 kWh, 52.1 kWh, 51.9 kWh, 48.5 kWh, 33.1 kWh, and 31.2 kWh respectively. Compared to the weekday plug loads, the weekend plug loads of Tenant D on the west side were relatively high; the percentage of the weekend plug loads, compared to the weekday plug loads, ranged from 60% to 80%. As Figure 68 shows, the plug loads of Tenant D on the west side greatly changed over time; in addition, it reduced from May 2019 and slightly increased from October 2019.

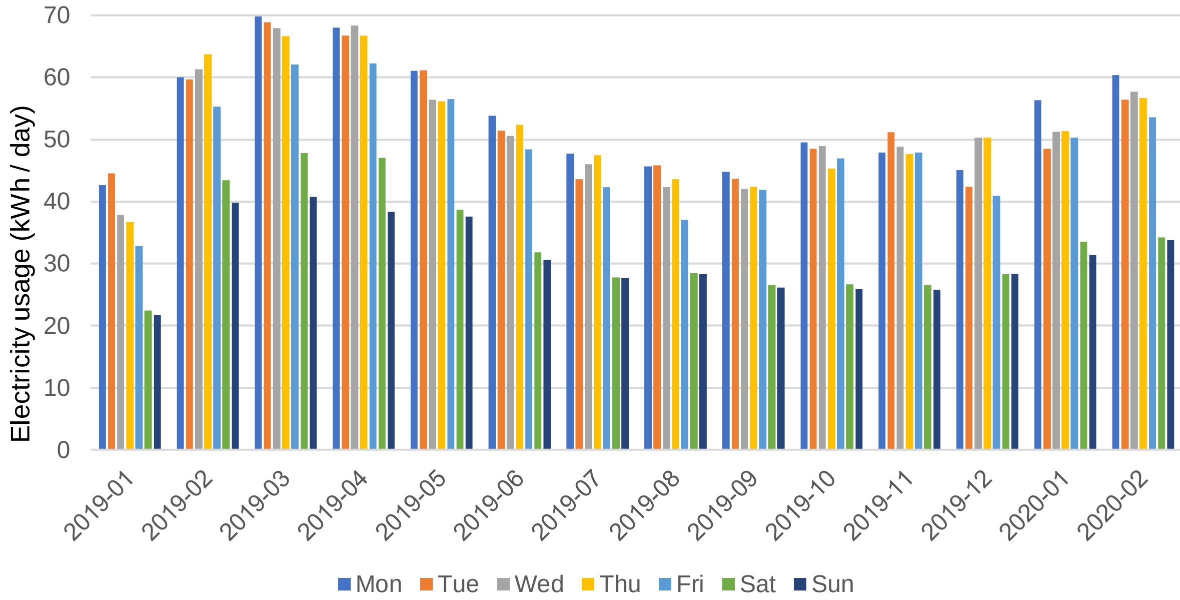

Figure 68 Average electricity usage for plug loads of Tenant D (the west side), January 2019 – February 2020

In sum, the average electricity usage for lighting by day of the week demonstrates that lighting usage in tenant areas tended to be very different between weekdays and weekends. The weekend lighting usage of tenants was generally less than half of the weekday lighting usage though there were some variations in the patterns of lighting usage among tenants. For instance, the weekend lighting usage of Tenant A was relatively high, compared to the weekday lighting usage. This may be because Tenant A had a shared kitchen space where lighting could be used when a few people came on weekends. The weekend lighting usage of Tenant B is also low, but Figure 58 also illustrates that the lighting usage on Thursday and Friday was lower than other weekdays since September 2019 when university classes started. This change in the weekday lighting usage may be attributed to the schedules of classes which were normally held on the same day each week.

In contrast, the pattern of lighting usage of Tenant C was relatively constant throughout the week in the office area while the pattern was slightly different in the non-office area. The lighting usage on Wednesday was slightly higher than other weekdays in the non-office area of Tenant C. This may be because the non-office area of Tenant C was used for the fulfilment of orders (Informant 1, personal communication, December 4, 2020), and shipping schedules may have affected the pattern of lighting usage. The lighting usage of Tenant C from Monday to Friday was more constant in the office area, which suggests that the way in which the office area was used did not greatly change on weekdays.

The lighting usage of Tenant D also did not dramatically change from Monday to Friday; however, the lighting usage was lower during July and August 2019. This reduction in the lighting usage may be due to people taking vacations as a key informant suggested during the feedback sessions (Informant 2, personal communication, December 2, 2020). At the same time, the gap between the weekday and weekend lighting usage seemed smaller between January 2019 and April 2019. This may be because it was a busy time for employees due to tax accounting (Informant 2, personal communication, December 2, 2020), and there might have been more people working longer than usual. Therefore, the lighting usage was affected by the amount of work employees had, which resulted in the increased lighting usage on weekends.

When compared to lighting usage, the average electricity usage for plug loads of tenants had different patterns. The weekend plug loads were mostly lower than the weekday plug loads for most tenants. Nevertheless, the weekend plug loads were higher than 50% of the weekday plug loads in all tenant areas, which is very different from the lighting usage. This also corresponds to the large amount of plug loads used on weekends, which was revealed by the hourly profile. As the tendency of the high weekend plug loads was found in Tenants A, B, C, and D, phantom loads from plug loads are a common issue for energy saving across all tenant areas.

At the same time, this study reveals that servers consume a large amount of plug loads both on weekdays and weekends. As Figure 66 illustrates, the plug loads of Tenant D in the server room were almost the same on weekdays and weekends. This means that servers constantly used a large amount of electricity even when people are not working. Devices were often kept plugged in when they were unused, and some equipment such as servers constantly operated even outside of business hours. Thus, there are more opportunities to look for energy savings in the weekend plug loads rather than lighting.

Appendix E – Analyses on changes in elevator usage

Elevator usage was analyzed according to the direction of movement (descending or ascending), as well as the floor level (the second floor or the third floor). The percentages of elevator usage in each phase were calculated as follow:

$$Elevator\ Usage\ (\%) = \frac{Total\ number\ of\ people\ using\ elevators}{Total\ number\ of\ people\ using\ stairs\ and\ elevators}$$

Figure 70 shows the percentage of elevator usage on the second floor from the pre-occupancy period until the post-occupancy period in March 2020. For elevator ascending, the mean percentage of elevator usage in Phase 1 of the Building 2 was 8.94%, and the mean percentage of elevator usage in Phase1 of the Building 3 was 12.8%. During the post-occupancy period, the mean percentage of elevator usage in Phase 2, Phase 3, Phase 4, Phase 5, and Phase 6 was 8.98%, 4.40%, 5.68%, 7.79%, and 5.58% respectively.

For elevator descending, the mean percentage elevator usage in Phase 1 of the Building 2 was 12.8%, and the mean elevator usage in Phase 1 of the Building 3 was 10.4%. During the post-occupancy period, the mean percentage of elevator usage in Phase 2, Phase 3, Phase 4, Phase 5, and Phase 6 was 4.88%, 1.88%, 1.75%, 2.73%, and 4.43% respectively.

Figure 69 shows the percentage of elevator usage on the third floor from the pre-occupancy period until the post-occupancy period in March 2020. For elevator ascending, the mean elevator usage in Phase 1 of Building 1 was 69.4%, and the mean elevator usage in Phase 1 of Building 2 was 35.75%. During the post-occupancy period, the mean elevator usage in Phase 2, Phase 3, Phase 4, Phase 5, and Phase 6 was 42.9%, 47.0%, 64.8%, 62.4%, and 63.6%.

For elevator descending, the mean elevator usage in Phase 1 of Building 1 was 52.9%, and the mean elevator usage in Phase 1 of Building 2 was 18.9%. During the post-occupancy period, the mean elevator usage in Phase 2, Phase 3, Phase 4, Phase 5, and Phase 6 was17.9%, 33.2%, 32.1%, 35.9%, and 29.6% respectively.

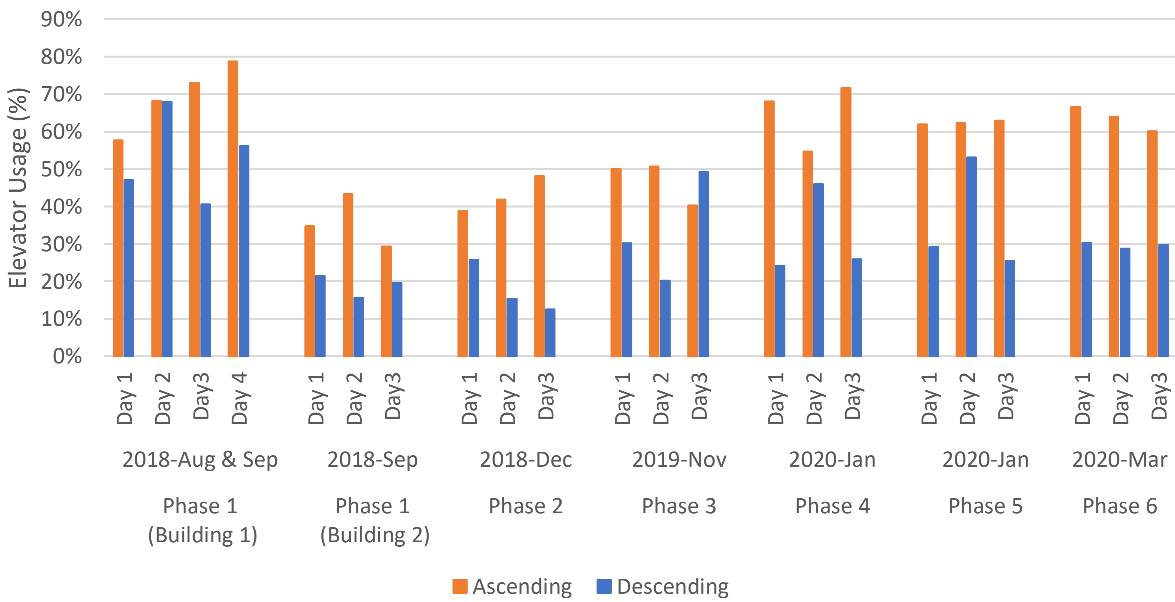

Figure 69 Elevator usage of the third floor, September 2018 – March 2020

Table 39 shows the results of one-way ANOVA test on elevator-ascending data of the third floor. There were significant changes between Phase 1of Building 1 and Phase 1 of Building 2 ($p < 0.05$); Phase 1 of Building 1and Phase 2 ($p < 0.05$); and Phase 2 of Building 1 and Phase 3 ($p < 0.05$). Between the pre-occupancy and the newsletter intervention period, there were significant differences between Phase 1 of Building 2 and Phase 4 ($p < 0.05$); Phase 1 and Phase 5 ($p < 0.05$); and Phase 1 of Building 2 and Phase 6 ($p < 0.05$).

During the post-occupancy period, there were significant differences between Phase 2 and Phase 4 ($p < 0.05$); Phase 2 and Phase 5 ($p < 0.05$); and Phase 2 and Phase 6 ($p < 0.05$). The results show that the elevator usage for ascending was almost twice higher in Building 1 than Building 2 during Phase 1. Elevator usage then reduced in Phase 2, compared to Phase 1 of Building 1. Although there were no significant differences in elevator usage for ascending during the newsletter interventions on the third floor, elevator usage increased between Phase 4 and 6, compared to Phase 1 of Building 2

Table 39 One-way ANOVA test on elevator usage for ascending to the third floor, September 2018 – March 2020 (observation data)

Phase	1 (B1)	1 (B2)	2	3	4	5	6	M	SD
Phase 1 (Building 1)	-							69.4%	0.09
Phase 1 (Building 2)	0.00*	-						35.8%	0.07
Phase 2	0.00*	0.82	-					42.9%	0.05
Phase 3	0.01*	0.39	0.99	-				47.0%	0.06
Phase 4	0.96	0.00*	0.01*	0.05	-			64.8%	0.09
Phase 5	0.79	0.00*	0.03*	0.12	1.00	-		62.4%	0.00
Phase 6	0.89	0.00*	0.02*	0.08	1.00	1.00	-	63.6%	0.03

*The mean difference is significant at the 0.05 level.

Table 40 shows the results of one-way ANOVA test on elevator-descending data of the third floor. There were significant differences only during the pre-occupancy period and the early post-occupancy period: between Phase 1 of Building 1 and Phase 1 of Building 2 ($p < 0.05$); and Phase 1 of Building 1 and Phase 2 ($p < 0.05$). This indicates that elevator usage for descending was significantly higher in Phase 1 of Building 1, compared to Phase 1 of Building 2 and Phase 2. On the other hand, there was no significant difference after Phase 3, which suggests that the newsletter interventions did not significantly affect elevator usage for descending on the third floor.

Table 40 One-way ANOVA test on elevator usage for descending from the third floor, September 2018 – March 2020 (observation data)

Phase	1 (B1)	1 (B2)	2	3	4	5	6	M	SD
Phase 1 (Building 1)	-							52.9%	0.12
Phase 1 (Building 2)	0.01*	-						18.9%	0.03
Phase 2	0.01*	1.00	-					17.9%	0.07
Phase 3	0.26	0.67	0.60	-				33.2%	0.15
Phase 4	0.21	0.74	0.67	1.00	-			32.1%	0.12
Phase 5	0.42	0.48	0.42	1.00	1.00	-		35.9%	0.15
Phase 6	0.13	0.88	0.82	1.00	1.00	0.99	-	29.6%	0.01

*The mean difference is significant at the 0.05 level.

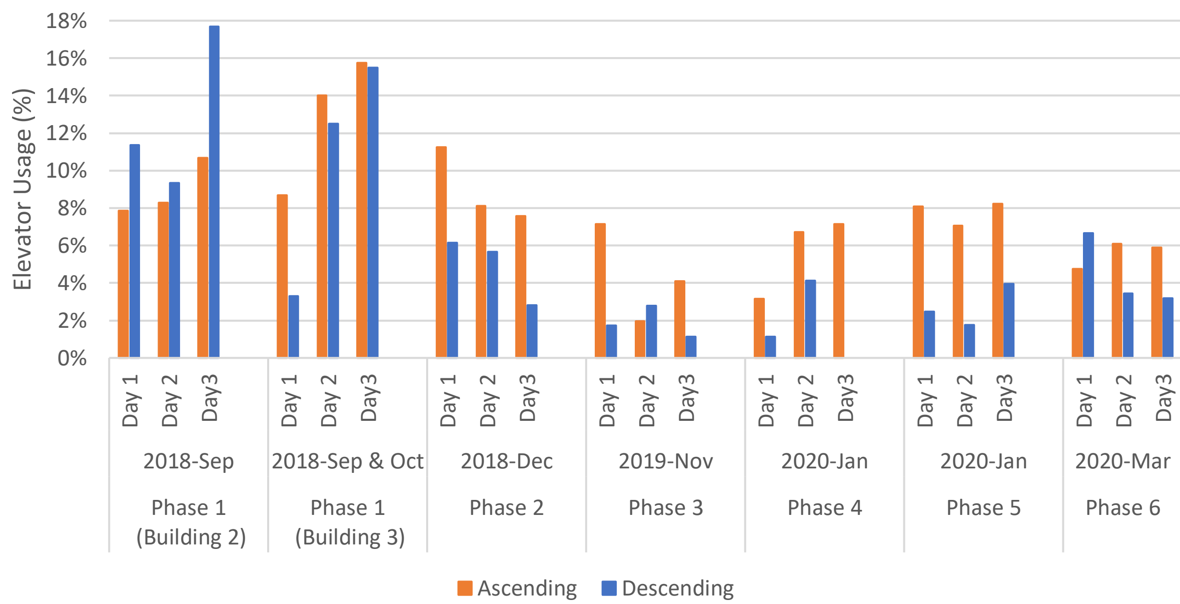

Figure 70 Elevator usage of the second floor, September 2018 – March 2020

Table 41 shows the results of one-way ANOVA test on elevator-ascending data of the second floor. There were significant changes between Phase 1 of the Building 3 and Phase 3 ($p < 0.05$); Phase 1 of the Building 3 and Phase 4 ($p < 0.05$); and Phase 1 of the Building 3 and Phase 6 ($p < 0.05$). This suggests that elevator usage for ascending reduced from Phase 1 of Building 3 to Phases 3, 4, and 6. Like stair ascending on the second floor, there were no significant differences during the newsletter interventions from Phase 4 to Phase 6. Thus, newsletters did not seem to affect elevator usage for ascending on the second floor.

Table 41 One-way ANOVA test on elevator usage for ascending to the second floor, September 2018 – March 2020 (observation data)

Phase	1 (B2)	1 (B3)	2	3	4	5	6	M	SD
Phase 1 (Building 2)	-							8.94%	0.02
Phase 1 (Building 3)	0.35	-						12.8%	0.04
Phase 2	1.00	0.36	-					8.98%	0.02
Phase 3	0.20	0.00*	0.19	-				4.40%	0.03
Phase 4	0.54	0.02*	0.52	0.99	-			5.68%	0.02
Phase 5	0.99	0.13	0.99	0.49	0.88	-		7.79%	0.01
Phase 6	0.50	0.01*	0.49	0.99	1.00	0.86	-	5.58%	0.01

*The mean difference is significant at the 0.05 level.

Table 42 shows the results of one-way ANOVA test on elevator-descending data of the second floor. There were significant changes between Phase 1 of Building 2 and Phase 3 ($p < 0.05$); Phase 1 of Building 2 and Phase 4 ($p < 0.05$); and Phase 1 of Building 2 and Phase 5 ($p < 0.05$). This indicates that elevator usage for descending decreased from Phase 1 of Building 2 to Phases 3, 4, and 5. There were no significant differences during the newsletter intervention for elevator descending on the second floor.

Table 42 One-way ANOVA test on elevator usage for descending from the second floor, September 2018 – March 2020 (observation data)

Phase	1 (B2)	1 (B3)	2	3	4	5	6	M	SD
Phase 1 (Building 2)	-							12.8%	0.04
Phase 1 (Building 3)	0.97	-						10.4%	0.06
Phase 2	0.10	0.40	-					4.88%	0.02
Phase 3	0.01*	0.07	0.91	-				1.88%	0.01
Phase 4	0.01*	0.06	0.89	1.00	-			1.75%	0.02
Phase 5	0.02*	0.12	0.98	1.00	1.00	-		2.73%	0.01
Phase 6	0.08	0.32	1.00	0.95	0.94	0.99	-	4.43%	0.02

*The mean difference is significant at the 0.05 level.

Appendix F – Comparison of elevator usage between the second and third floors

Elevator usage between the second and the third floors was examined. Figure 71 displays elevator usage for ascending between the second and the third floors from Phase 1 to Phase 6. T-test shows there was a significant difference between the second and the third floor for elevator ascending from Phase 1 to Phase 6, t (34 = -14.644, $p < 0.05$). Two-way ANOVA test also showed that the floor, F (1,24 = 977.320, $p < 0.05$), and Phase, F (5,24 = 9.051, $p < 0.05$), were significant main effects on elevator usage for ascending. As Figure 71 illustrates, elevator usage for ascending was also higher on the third floor than on the second floor. In particular, the gap between the second and the third floors seemed larger from Phase 3 to Phase 6, compared to Phases 1 and 2.

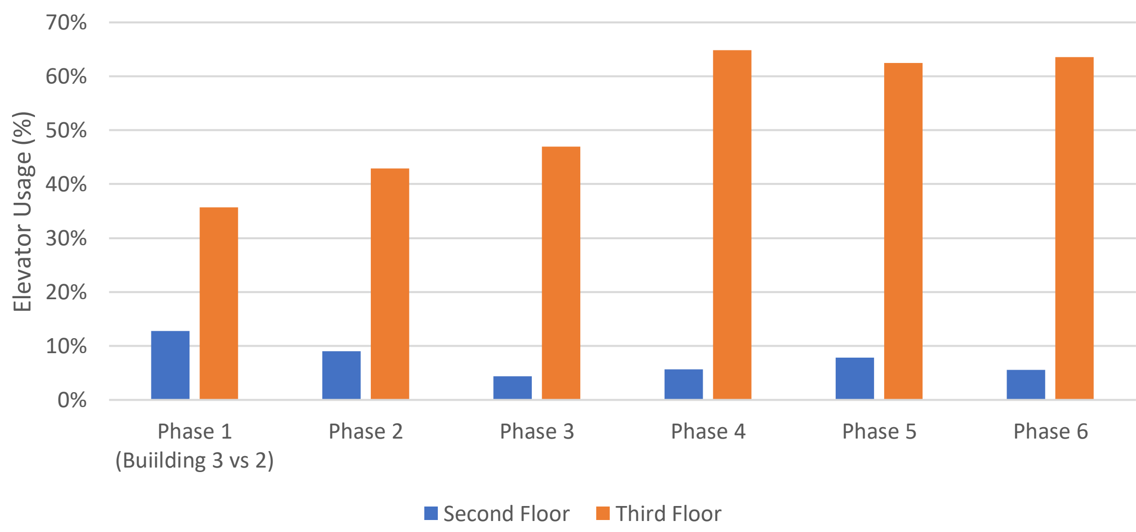

Figure 71 Average elevator usage for ascending to the second and third floors, September 2018 – March 2020

Finally, Figure 72 shows elevator usage for descending between the second and the third floors. T-test shows that there was a significant difference between the second and the third floors for elevator descending, t (34 = -8.343, $p < 0.05$). Two-way ANOVA test also suggests that the floor was a significant main effect on stairs usage for descending, F (1,24 = 85.357, $p < 0.05$). However, the test shows that Phase was not a significant main effect on stairs usage for descending, F (5,24 = 0.781, $p > 0.05$).

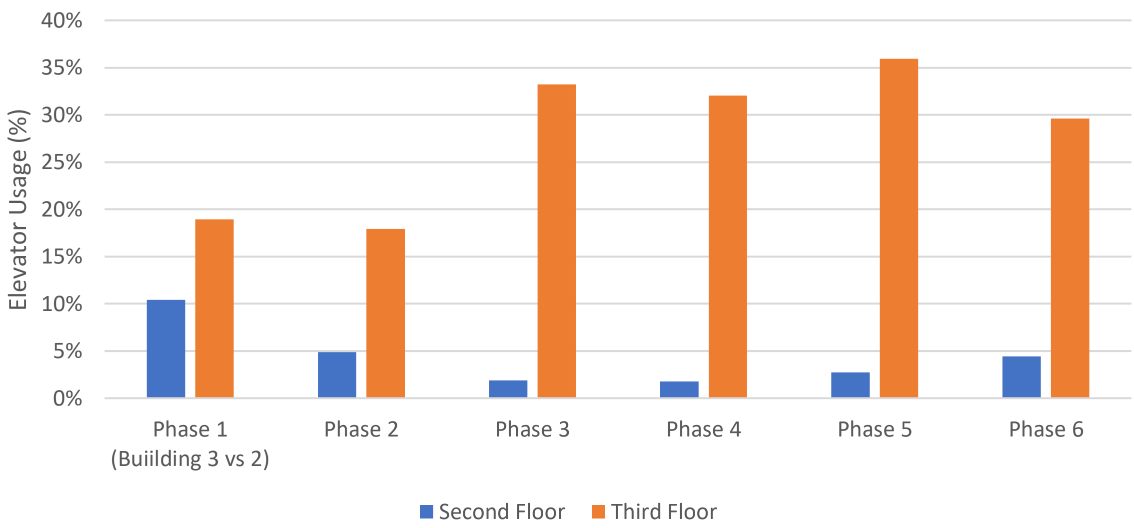

Figure 72 Average elevator usage for descending from the second and third floors, September 2018 – March 2020

Appendix G – Analyses on changes in electricity usage of Tenant A

Changes in electricity usage of Tenant A for lighting and plug loads were analyzed by using linear regression and one-way ANOVA. Figure 73 shows the average electricity usage for lighting of Tenant A on weekdays and weekends. Linear regression on the weekday lighting usage was significantly different, F (1,290 = 68.385, $p < 0.05$). Linear regression on the weekend lighting usage was significantly different F (1, 119 = 6.587 and $p < 0.05$). One-way ANOVA test on the weekday lighting usage also indicates that electricity usage reduced after January 2020 ($p < 0.05$) when comparing January 2019 and January 2020. On the other hand, one-way ANOVA test on the weekend lighting usage indicates that electricity usage tended to be more constant except August 2019, and the p value was less than 0.05 when comparing August 2019 and February 2020.

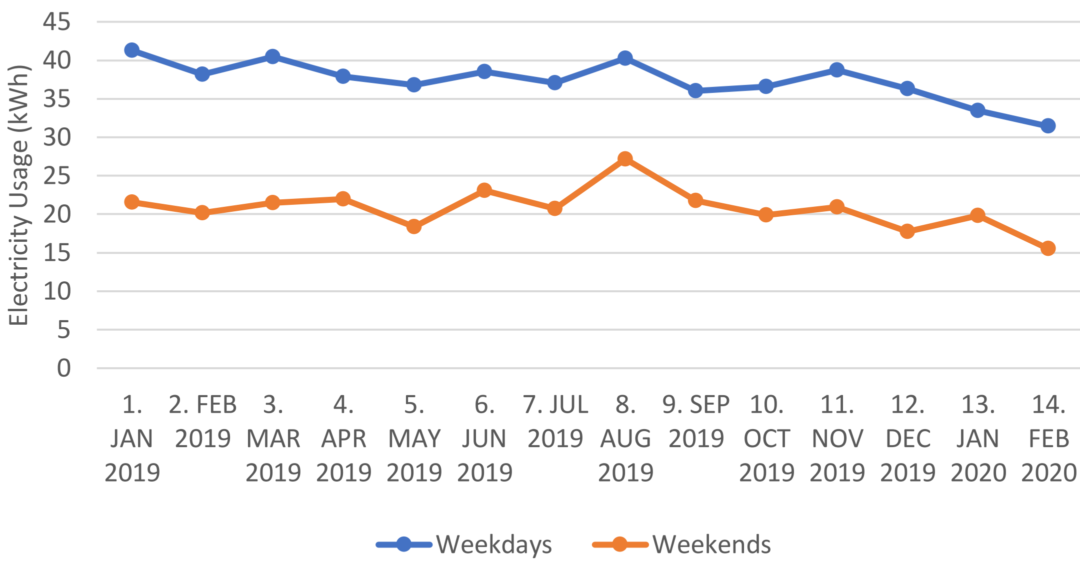

Figure 73 Average electricity usage for lighting of Tenant A, January 2019 – February 2020

Figure 74 shows the average electricity usage for plug loads of Tenant A on weekdays and weekends. Linear regression on the weekday plug loads was not significantly different, F (1,290 = 1.070, $p > 0.05$). On the other hand, one-way ANOVA test on the weekday plug loads suggests that electricity usage was significantly different in January and February 2019 ($p < 0.05$), compared to the electricity usage from March to August 2019. As Figure 74 shows, plug loads for weekdays were higher between March and August 2019, compared to plug loads after September 2019.

Moreover, One-way ANOVA also indicates that the weekday plug loads were significantly different between March and August 2019 ($p < 0.05$), compared to plug loads after September 2019. As Figure 74 also displays, the weekday plug loads were higher between March and August 2019, compared to plug loads after September 2019. Thus, one-way ANOVA test shows that the weekday plug loads changed among different months but linear regression suggests that there was no linear trend over time.

Linear regression on the weekend plug loads of Tenant A was significantly different, F (1,119 = 4.262, $p < 0.05$). One-way ANOVA test suggests that the weekend plug loads in January and February 2019 were significantly different from March to August 2019 ($p < 0.05$), and Figure 74 also shows electricity usage for plug loads was relatively low in January and February 2019. In addition, one-way ANOVA test on the weekend plug loads also indicates that plug loads from September 2019 to February 2020 were significantly different from July and August. As Figure 74 indicates, plug loads significantly reduced after September 2019.

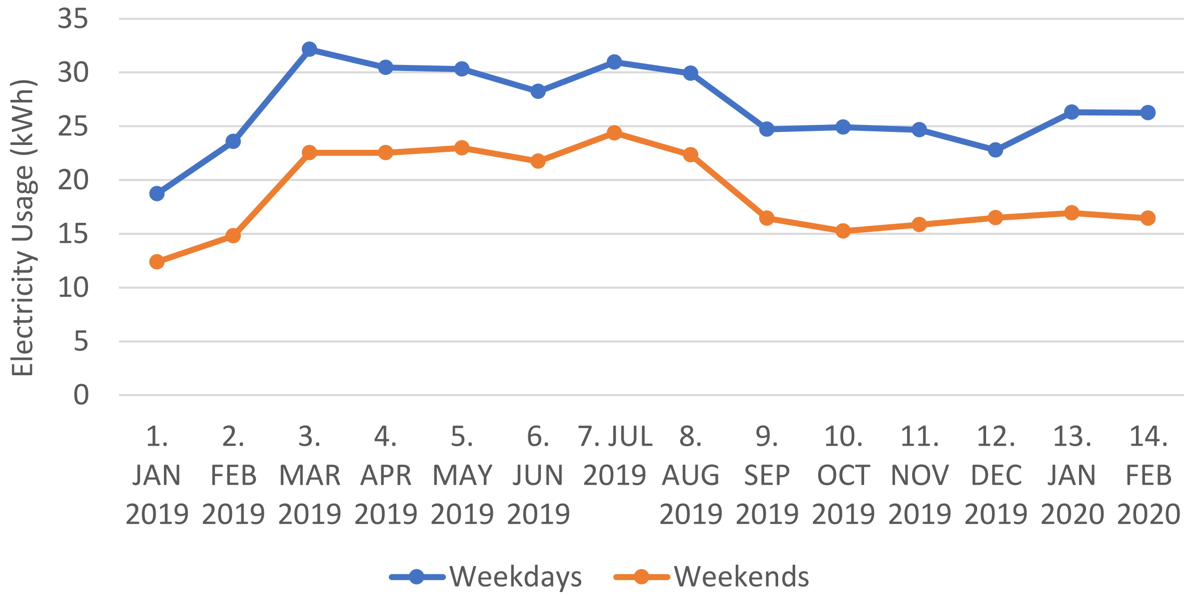

Figure 74 Average electricity usage for plug loads of Tenant A, January 2019 – February 2020

Linear regression suggests that both the weekday and weekend lighting usage of Tenant A significantly changed over time. As Figure 73 shows, the weekday and weekend lighting usage gradually reduced in January and February 2020. While the reasons for the reduction in lighting usage are not clearly understood, the number of occupants could possibly affect this, or occupants may have turned off lighting more frequently.

On the other hand, changes in plug loads of Tenant A were very different from lighting usage. Linear regression suggests that the weekday plug loads of Tenant A did not significantly change over time, but the weekend plug loads showed a significant change. Unlike lighting usage, the weekday and weekend plug loads of Tenant A significantly increased from January 2019 to March 2019. The lower plug loads in the early 2019 may be attributed to the smaller number of occupants since the number of staff increased during the year.

The weekday and weekend plug loads of Tenant A between March 2019 and August 2019 were relatively high, and this may be due to the increased number of occupants. It is also possible that Tenant A installed more devices and equipment in March 2019 as staff settled into the case study building. From September 2019, the weekday and weekend plug loads significantly reduced. Although the cause for this change is not clear, it might be due to changes in the dish washer setting as Tenant A reduced the frequency of dish washer usage for water conservation.

The weekend plug loads of Tenant A were likely to be attributed to devices and appliances, including monitors, printers, refrigerators, dishwashers, microwaves, and coffee makers, which were kept plugged in. An electricity energy meters was used to examine electricity usage of refrigerators and coffee makers (Appendix C). A refrigerator consumed approximately 0.62 kWh per day and a coffee maker consumed approximately 1.17 kWh per day. This shows that an individual device or appliance does not use a large amount of electricity, which is similar to the findings of Doherty and Trenbath (2019) that devices, such as printers, microwaves, and coffee makers, do not have significant contributions to the total plug loads. Nevertheless, the weekend plug loads of Tenant A suggests that the aggregate plug loads from multiple devices and appliances resulted in total electricity usage of 15-25 kWh per day on weekends.

As the analyses demonstrate, electricity usage for lighting and plug loads of Tenant A changed in different ways. Lighting usage did not show dynamic changes, but rather a gradual reduction while plug loads greatly changed over time. One of the reasons for less reduction in lighting usage might be automation of lighting in the building. Researchers argue that automated building systems may hinder energy saving behaviour of occupants; such systems can make occupants feel uncomfortable, which diminishes occupants' motivation to engage themselves in energy conservation (Brown & Cole, 2009; Day, 2014; Day & O'Brien, 2017; Frederiks, Stenner, & Hobman, 2015). It is, therefore, important to teach occupants how to use the building system, including automated lighting systems, and this will not only satisfy occupants, but also promote their energy saving behaviour as they understand how to control lighting in tenant areas (Brown & Cole, 2009; Day, 2014; Day & Gunderson, 2015; Day & O'Brien, 2017; Heerwagen & Richard C Diamond, 1992).

Since lighting in tenant areas of the case study building is semi-automated and occupants have not been taught how to fully use the system, it is highly possible that the lack of knowledge about the lighting system discouraged occupants from practicing energy saving behaviour. In contrast, occupants tended to have more control over plug loads since there were plug loads besides each desk. Thus, lighting and plug loads of Tenant A suggests that electricity usage can vary depending on the type of usage and the level of control that occupants have over the energy system.

It also should be noted that linear regression on the weekend plug loads suggests insignificant changes probably due to inconsistent changes over time. It seems that linear regression did not detect changes over time in the weekday plug loads because the increase and decrease in plug loads were repeated over time. In fact, the weekday and weekend plug loads of Tenant A had similar patterns except between January and February 2020 when only the weekday plug loads increased. As a result, the weekend plug loads of Tenant A did not show significant linear increase or decrease although there were some changes across months. Thus, linear regression may not be suitable when changes in electricity usage are influenced by multiple factors that vary over time.

Appendix H – Analyses on changes in electricity usage of Tenant B

Changes in electricity usage of Tenant C for lighting and plug loads were analyzed by using linear regression and one-way ANOVA. Figure 75 shows the average electricity usage for lighting of Tenant B on weekdays and weekends. Linear regression on the weekday lighting usage was significantly different, F (1,290 = 27.969, $p < 0.05$). One-way ANOVA test on the weekday lighting usage in January 2019 was significantly different than other months; in addition, lighting usage in December 2019 was significantly different from that of between October and November 2019. As Figure 75 shows, lighting usage was low in January 2019 and December 2019. At the same time, one-way ANOVA test indicates that lighting usage did not significantly change between February to November 2019, and between January and February 2020.

Linear regression on the weekend lighting usage was not significantly different, F (1,119 = 1.214 and $p > 0.05$). One-way ANOVA test also suggests that weekend lighting usage was significantly different in June 2019, compared to January, March, October, and November in 2019. Figure 75 also illustrates that the weekend lighting usage in June 2019 slightly increased.

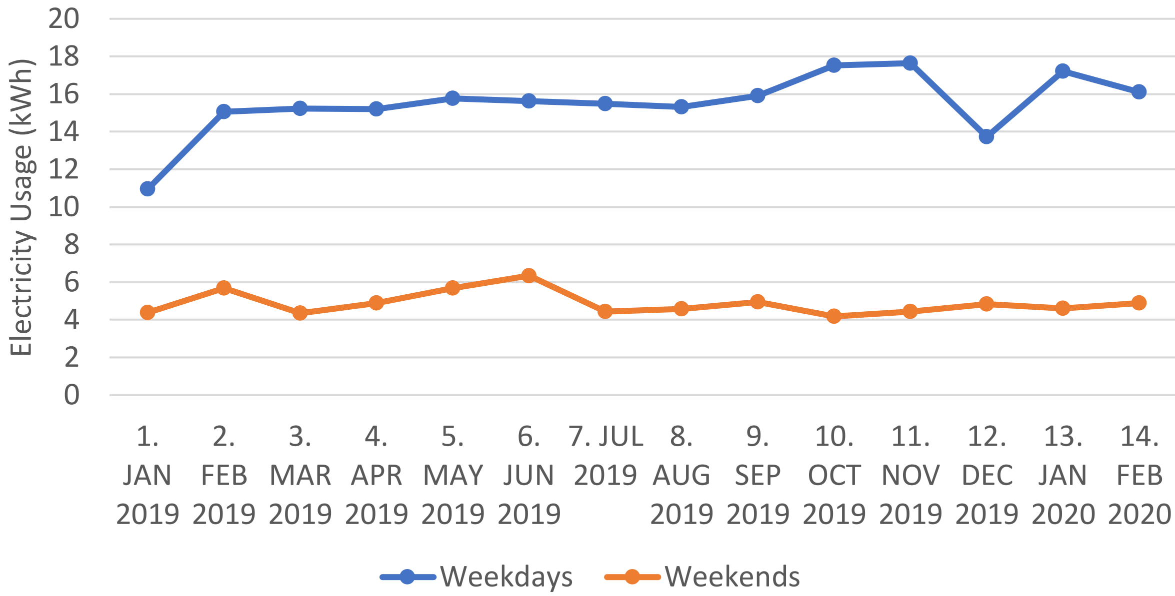

Figure 75 Average electricity usage for lighting of Tenant B, January 2019 – February 2020

Figure 76 shows the average electricity usage for plug loads of Tenant B on weekdays and weekends. Linear regression on the weekday plug loads was significantly different, F (1,290 = 110.548, $p < 0.05$). One-way ANOVA test suggests that the weekday plug loads in January 2019 were significantly different from other months, except May 2019. The weekday plug loads from September to November 2019 were also significantly different from the plug loads between April and May 2019. As Figure 76 also shows, the weekday plug loads were very low in January 2019, and increased after September 2019 although they dropped during December 2019.

Linear regression on the weekend plug loads was significantly different, F (1,119 = 54.503, $p < 0.05$). One-way ANOVA test suggests that the weekend plug loads in January 2019 were significantly different, compared to plug loads between July 2019 and February 2020. Moreover, one-way ANOVA test also indicates that plug loads in January 2020 were significantly different from other months. As Figure 76 shows, the weekend plug loads were very low in January 2019, and they were greatly high in January 2020. Therefore, linear regression and one-way ANOVA test indicate that plug loads both on weekdays and weekends increased in January 2020.

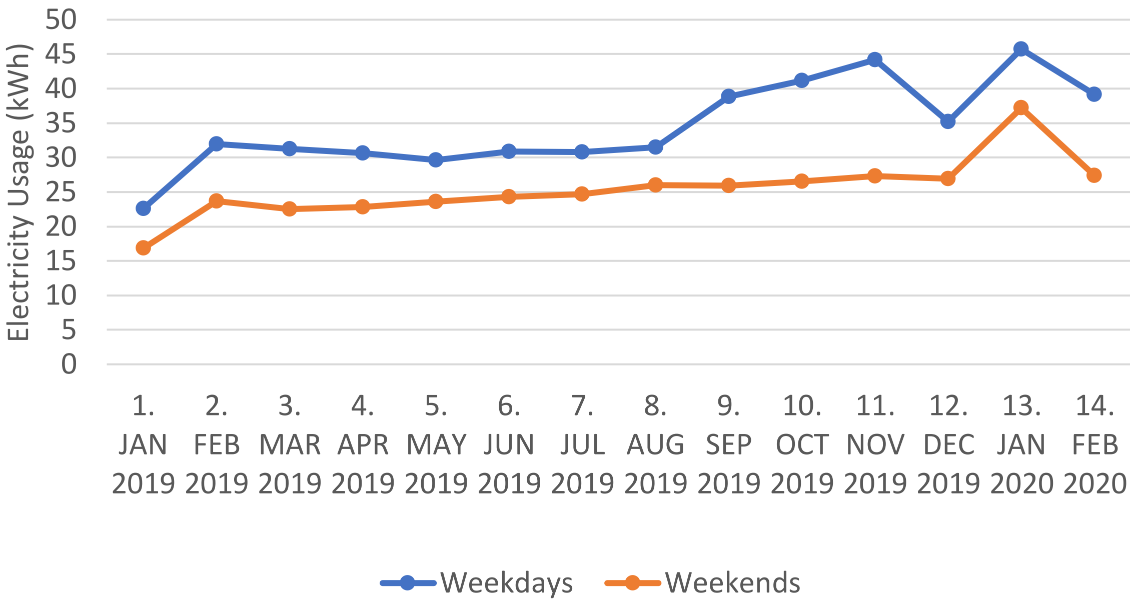

Figure 76 Average electricity usage for plug loads of Tenant B, January 2019 – February 2020

Tenant B had similar patterns of changes in electricity usage for lighting and plug loads over time. As linear regression suggests, the weekday lighting usage of Tenant B gradually increased over time while the weekend lighting usage was relatively constant. There was a slight increase in the weekday lighting usage from September 2019, which might be due to the start of university classes. The drop in the weekday lighting usage during December 2019 was due to the end of classes and a holiday season.

The weekend plug loads of Tenant B, on the other hand, showed more increases after September 2019, which is largely caused by increased activities of students and faculty members in the new school term. As students and faculty members started using their laptops and devices, the weekday plug loads rapidly increased from September 2019. The influence of campus activities on plug loads was also shown during December 2019 and January 2020; the weekday plug loads dropped in December 2019 due to the end of classes and a holiday season and increased again in January 2020 as classes started again. In addition, there was a small refrigerator which was kept plugged in all the times in the office area of Tenant B, and its plug loads were also examined by using an electricity energy meter (Appendix C). We found that the refrigerator only consumed approximately 0.5 kWh per day, which suggests that this is not a major contributor of plug loads, but rather multiple devices, including printers and monitors, contributed to the weekend plug loads. Thus, both lighting and plug loads of Tenant B were greatly affected by campus activities, and plug loads were more susceptible to changes in the number of people and the level of activities.

Appendix I – Analyses on changes in electricity usage of Tenant C

Changes in electricity usage of Tenant C for lighting and plug loads were analyzed by using linear regression and one-way ANOVA. Figure 77 shows the average electricity usage for lighting of Tenant C in the non-office area on weekdays and weekends. Linear regression for the weekday lighting usage shows $F(1,290) = 5.684$ and $p < 0.05$, and therefore the regression is statistically different. One-way ANOVA suggests that the weekday lighting usage in December 2019 was significantly lower than September and October 2019.

Linear regression on the weekends lighting usage shows $F(1,119) = 2.491$ and $p > 0.05$, and therefore the regression is not statistically different. One-way ANOVA suggests that the weekend lighting usage between September and December 2019 was significantly higher than April and August 2019. In addition, one-way ANOVA test also indicates that the weekend lighting usage in January and February 2020 was lower compared to November 2019. Consequently, linear regression suggests that the weekend lighting usage did not significantly change overall, but one-way ANOVA test indicates that there were some differences in plug loads among different months.

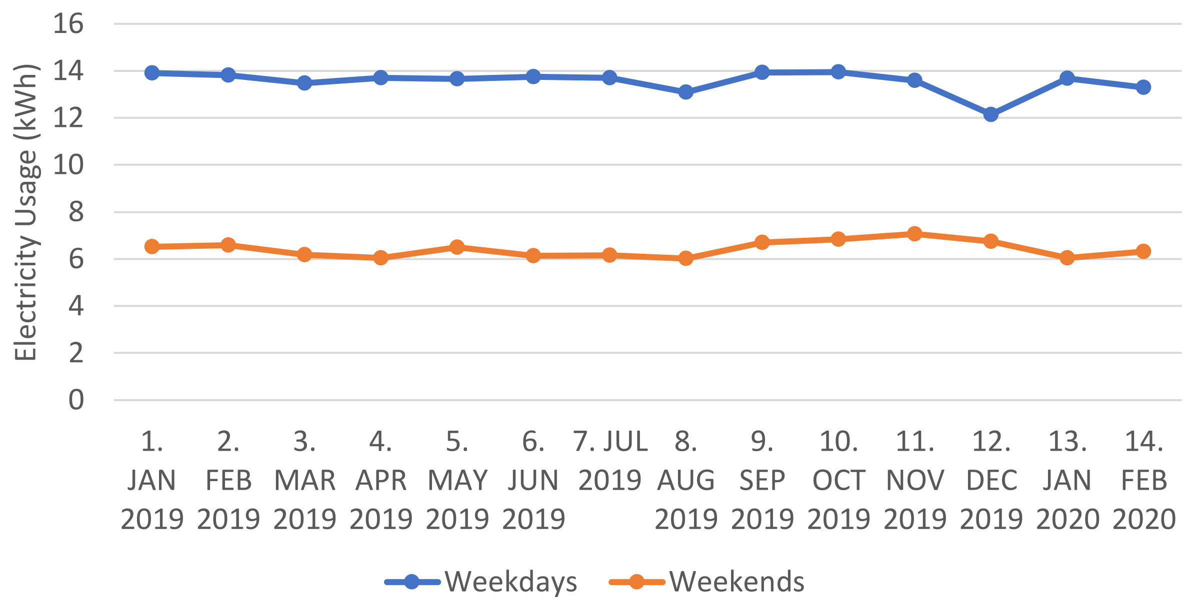

Figure 77 Average electricity usage for lighting of Tenant C (non-office area),

January 2019 – February 2020

Figure 78 shows the average electricity usage for plug loads of Tenant C in the non-office area on weekdays and weekends. Linear regression on the weekday plug loads was not significantly different, F (1,290 = 0.001, $p > 0.05$). One-way ANOVA test also shows that the weekday plug loads did not significantly change until November 2019. The test suggests that the weekday plug loads in December 2019 were significantly different from plug loads between January and July 2019. As Figure 78 shows, the weekday plug loads reduced in December 2019; thus, the weekday plug loads of Tenant C did not significantly change over time in the non-office area.

Linear regression on the weekend plug loads was significantly different, F (1,119 = 5.049, $p < 0.05$). One-way ANOVA test shows that the weekend plug loads in October and November 2019 were significantly different from plug loads in January 2019 and September 2019. However, the weekend plug loads did not significantly change between January to September 2019. As

Figure 78 shows, the weekend plug loads were relatively constant from January 2019 and September 2019, and increased from October 2019. Therefore, as the graph and analyses demonstrate, the weekend plug loads increased significantly in October 2019.

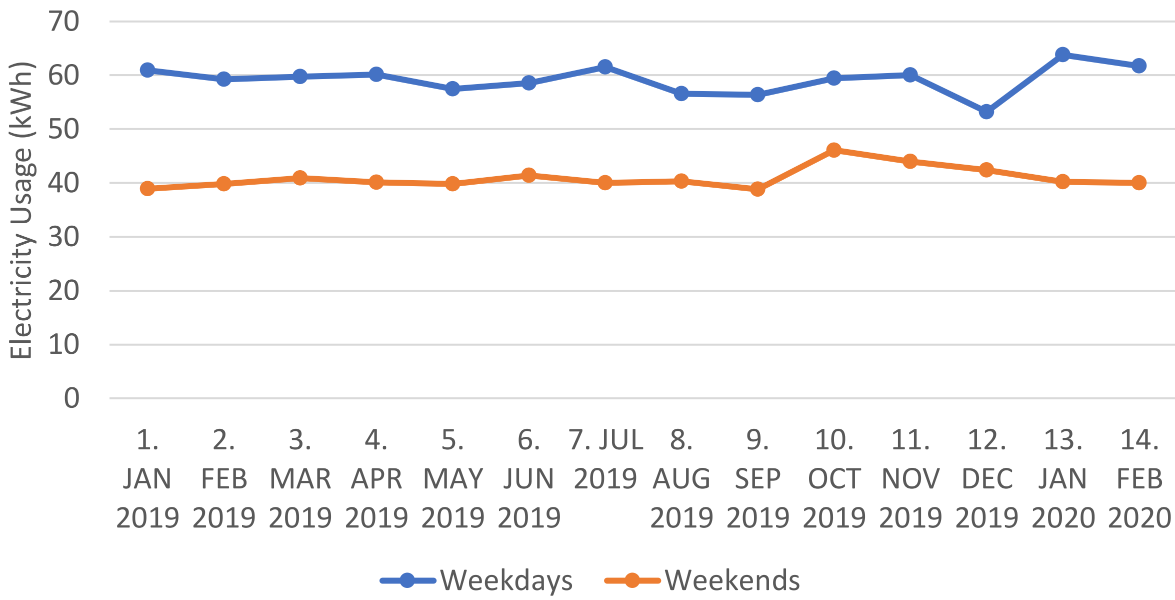

Figure 78 Average electricity usage for plug loads of Tenant C (non-office area), January 2019 – February 2020

Figure 79 shows the average electricity usage for lighting of Tenant C in the office area on weekdays and weekends. Linear regression on the weekday lighting usage was significantly different, F (1,290) = 5.741, $p < 0.05$). One-way ANOVA test suggests that the weekday lighting usage in December 2019 was significantly different from January 2019. However, one-way ANOVA test also indicates that there were no significant changes in the weekday lighting usage except December 2019. As Figure 79 shows, the weekday lighting usage was relatively constant, but reduced in December 2019.

Linear regression on the weekend lighting usage was not significantly different, F (1,119 = 1.153, $p > 0.05$). One-way ANOVA test suggests also that there were no significant differences in the weekend lighting usage among different months. Thus, both linear regression and one-way ANOVA test indicate that the weekend lighting usage of Tenant C in the office area did not significantly change over time.

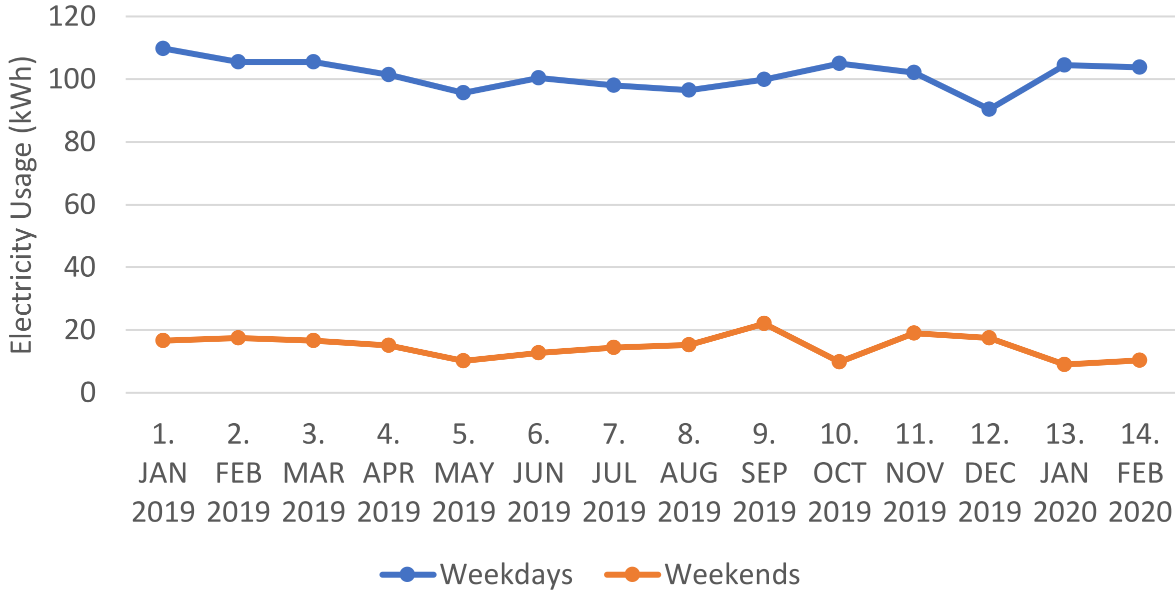

Figure 79 Average electricity usage for lighting of Tenant C (office area), January 2019 – February 2020

Figure 80 shows the average electricity usage for plug loads of Tenant C in the office area on weekdays and weekends. Linear regression on the weekday plug loads was significantly different, F (1,290 = 21.479, $p < 0.05$). One-way ANOVA test suggests that the weekday plug loads in May 2019 were significantly different from January 2020. In addition, one-way ANOVA test suggests that the weekday plug loads in January and February 2020 were different from the plug loads in March and June 2019. Figure 80 also shows that the weekday plug loads gradually increased from May 2019 to February 2020. Thus, the plug loads increased in 2020 compared to the previous year.

Linear regression on the weekend plug loads of Tenant C in the office area was significantly different, F (1,119 = 55.449, $p < 0.05$). One-way ANOVA test suggests that the weekend plug loads between December 2019 and February 2020 were significantly different from January 2019, between March and May 2019, and July 2019. As Figure 80 shows, the weekend plug loads gradually increased until February 2020. Thus, the weekend plug loads of Tenant in the office area increased in the early 2020, compared to 2019.

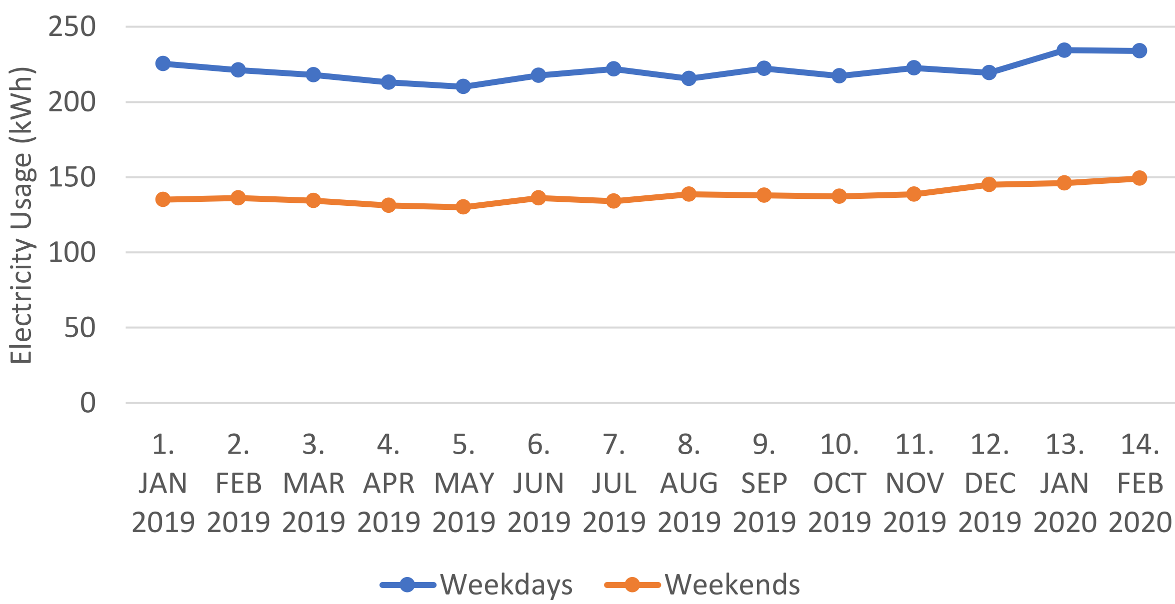

Figure 80 Average electricity usage for plug loads of Tenant C (office area),

January 2019 – February 2020

Tenant C did not have major changes in electricity usage for lighting and electricity usage for plug loads unlike Tenant B. In the non-office area, the weekday lighting usage moderately decreased over time while the weekend lighting usage did not significantly change. Linear regression on the weekday lighting usage data suggested changes as lighting usage in December 2019 dropped, which is due to a holiday season. On the other hand, the weekend plug loads of Tenant C in the non-office area had changes over time according to linear regression. As Figure

78 illustrates, the weekend plug loads of Tenant C in the non-office area increased after October 2019. Although the cause of this increase in plug loads is not clearly revealed, it is possible that the area was used more on weekends due to an increased number of fulfilment orders. Thus, data indicates that there were no changes in energy saving behaviour of occupants in the non-office area of Tenant C. Similarly, lighting and plug loads of Tenant C in the office area did not show major changes over time. As Figure 79 shows, the weekday lighting usage in the office area slightly reduced over time, and it reduced in December 2019 like the lighting usage in the non-office area. This sudden drop in the weekday lighting usage is again due to a holiday season. Overall, changes in occupant behaviour for lighting usage were not observed from the data.

On the other hand, the weekday and the weekend plug loads of Tenant C in the office area gradually increased over time. As Figure 80 illustrates, both the weekday and weekend plug loads seem to have slightly decreased from March 2019 and became more or less higher after January 2020. Although the factor for these patterns in plug loads of Tenant C remains unknown, it is possible that the differences in plug loads are attributed to seasonal changes. Occupants may have used less desktop light or fewer personal heaters during the spring compared to the winter, which may have resulted in an increased plug loads during winter. Overall, lighting and plug loads of Tenant C in both the non-office area and office area show relatively constant electricity usage, compared to other tenants. This implies that there have not been major changes in energy practices nor the number of employees in Tenant C throughout the year. Consequently, it is likely that seasonal changes affected electricity usage of Tenant C more than changes in occupant behaviour.

Appendix J – Analyses on changes in electricity usage of Tenant D

Changes in electricity usage of Tenant D for lighting and plug loads were analyzed by using linear regression and one-way ANOVA. Figure 81 shows the average electricity usage for lighting of Tenant D on weekdays and weekends. Linear regression on the weekday lighting usage was not significantly different, F (1,290 = 3.767, $p > 0.05$). One-way ANOVA test shows that the weekday lighting usage in December 2019 was significantly different from the lighting usage between February and April 2019, and between January and February 2020. As Figure 81 shows, the weekday lighting usage in December 2019 was lower than between February and April 2019, as well as between January and February 2020. While the weekday lighting usage significantly reduced in August and December 2019, the changes in lighting usage were not statistically significant over time according to the linear regression.

Linear regression on the weekend lighting usage of Tenant D was significantly different, F (1,119 = 20.375, $p < 0.05$). One-way ANOVA test indicates that the weekend lighting usage between January and April 2019 was significantly different from the lighting usage between May and December 2019. In addition, one-way ANOVA test also suggests that the weekend lighting usage between January and February 2020 was significantly different from the lighting usage between July and August 2019. Figure 81 also illustrates that the weekend lighting usage of Tenant D reduced in the summer and fall (May 2019 – December 2019), and increased again in January – February 2020. Overall, the weekend lighting usage significantly reduced between May and December 2019, and the overall change in the lighting usage was also statistically different.

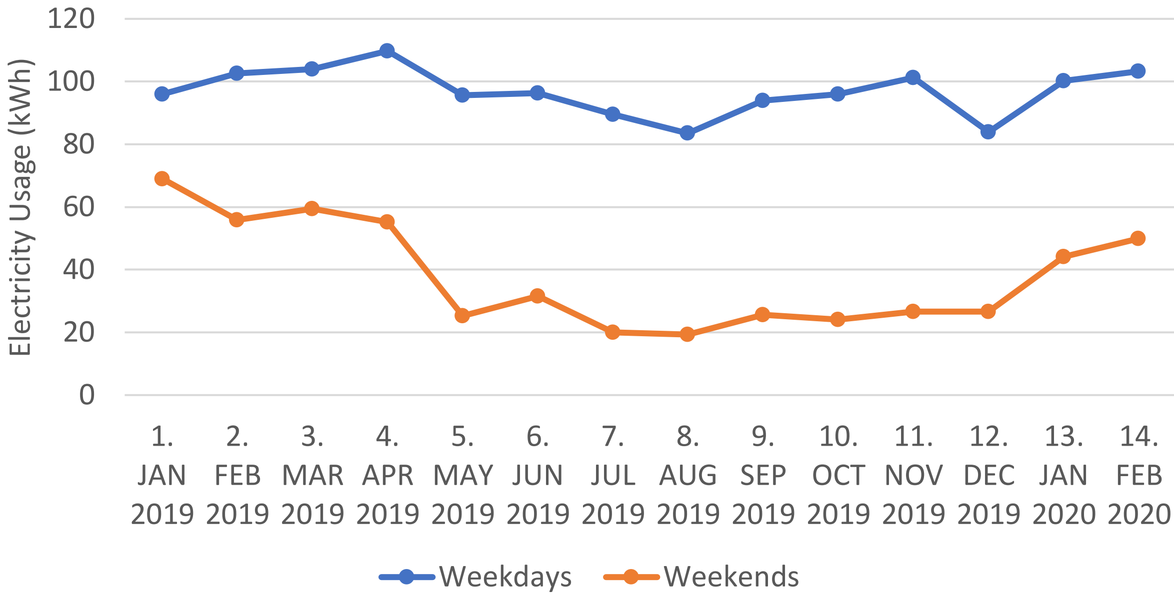

Figure 81 Average electricity usage for lighting of Tenant D, January 2019 – February 2020

Figure 82 shows the average electricity usage for plug loads of Tenant D in the server room on weekdays and weekends. Linear regression on the weekday plug loads was significantly different, F (1,290 = 22.532, $p < 0.05$). One-way ANOVA test suggests that January 2019 was significantly different from other months. The test also indicates that the weekday plug loads in the server room between February and April 2019 were significantly different from the plug loads between July and October 2019.

At the same time, the weekday plug loads in the server room between July and October 2019 were significantly different from the plug loads between November 2019 and February 2020. Figure 82 also shows that the weekday plug loads in the server room was low in January 2019, and increased between February and May 2019. In addition, the weekday plug loads reduced from July to October, but increased again from November 2019. Thus, the weekday plug loads in the server room reduced during the summer in 2019 but increased from the winter 2019.

Linear regression on the weekend plug loads of Tenant D in the server room was significantly different, F (1,119 = 15.584, $p < 0.05$). One-way ANOVA test suggests that the weekend plug loads in the server room in January 2019 was statistically different from other months, which is the same as the weekday plug loads. The test also indicates that the weekend plug loads in March 2019 were significantly different from the plug loads between July and October in 2019. Figure 82 also shows that the weekend plug loads in the server room were low in January 2019, and reduced again between July and October 2019.

Moreover, the weekend plug loads in the server room between November 2019 and January 2020 were significantly different from the plug loads between July and October 2019. Figure 82 also illustrates that the weekday plug loads increased from November 2019. Therefore, likewise with weekdays, both linear regression and one-way ANOVA test suggest that the weekend plug loads in the server room significantly changed over time, as well as among different months.

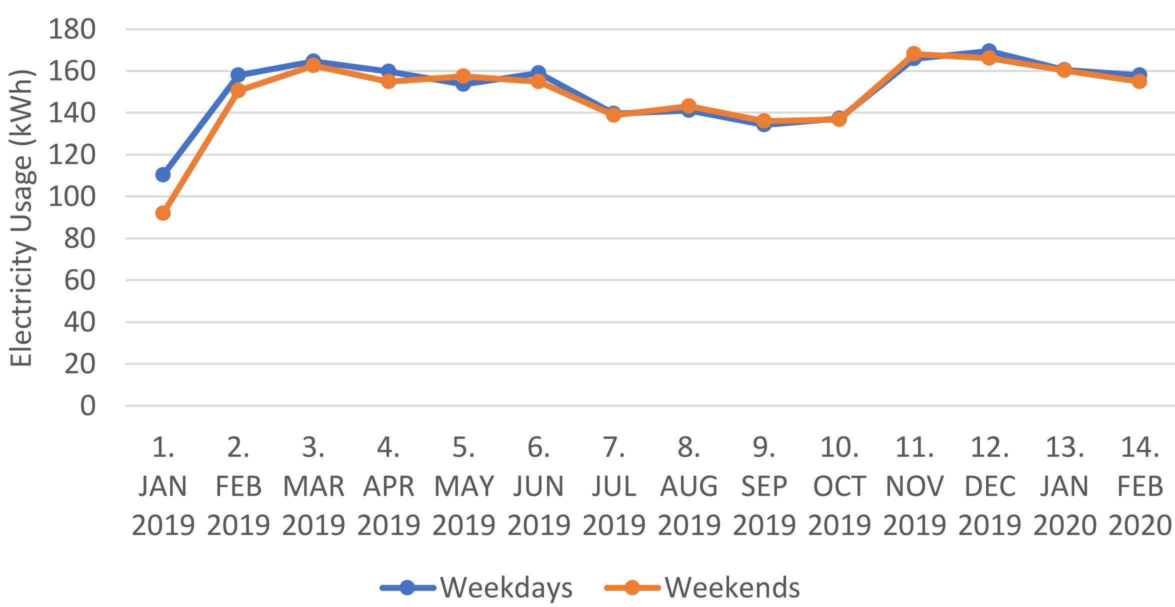

Figure 82 Average electricity usage for plug loads of Tenant D (the server room),

January 2019 – February 2020

Figure 83 shows the average electricity usage for plug loads of Tenant D on the east side on weekdays and weekends. Linear regression on the weekday plug loads on the east side was not significantly different, $F (1,290 = 1.804, p > 0.05)$. One-way ANOVA test shows that the weekday plug loads on the east side between February and May 2019 was significantly different from the plug loads in January 2019, between June and August 2019, and October and December 2019. At the same time, the one-way ANOVA test shows that the weekday plug loads in February 2020 was significantly different from the plug loads between July and December 2019. Figure 83 also shows that the plug loads between February and May 2019 were higher than January 2019, and reduced between June and August 2019. The plug loads again slightly increased after September 2019. Thus, the weekday plug loads on the east side reduced in the summer 2019 but the overall changes in the plug loads were not statistically different.

Linear regression on the weekend plug loads of Tenant D on the east side was significantly different, $F (1,119 = 4.578, p < 0.05)$. One-way ANOVA test suggests that the weekend plug loads between February and May 2019 were significantly different from the plug loads between June and December 2019, as well as January 2019. At the same time, the weekend plug loads in January and February 2020 were significantly different from June and August 2019, and November 2019. Figure 83 also illustrates that changes in the weekend plug loads on the east side were similar to the weekday plug loads on the east side. The weekend plug loads reduced between June and August 2019, and gradually increased again from November 2019. Therefore, the weekend plug loads on the east side significantly reduced in the 2019 summer and increased from the winter 2019.

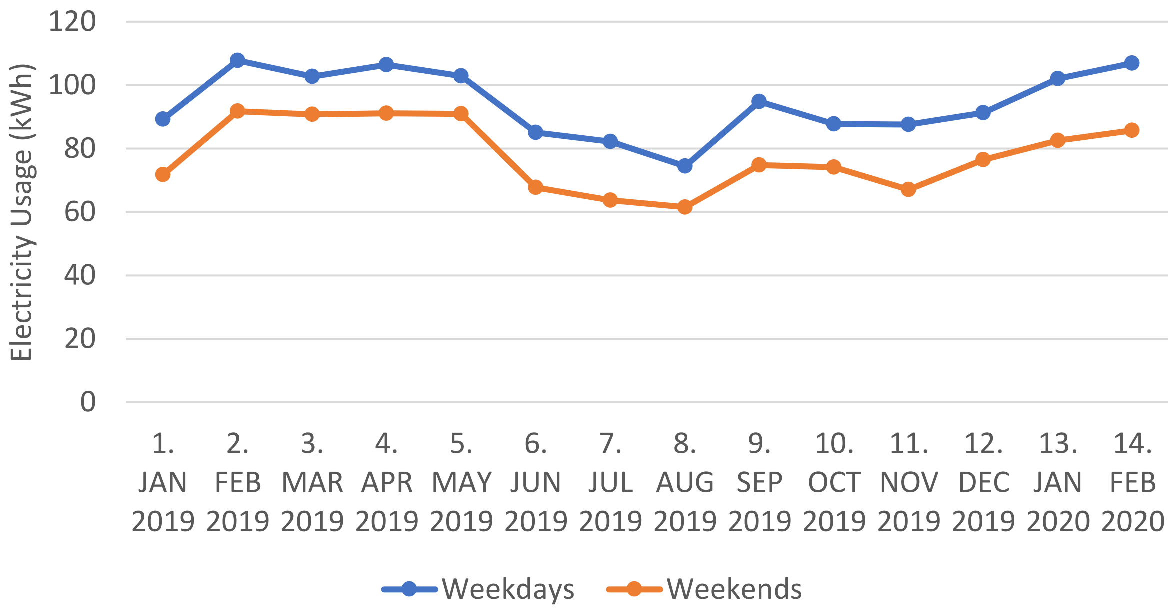

Figure 83 Average electricity usage for plug loads of Tenant D (the east side), January 2019 – February 2020

Figure 84 shows the average electricity usage for plug loads of Tenant D on the west side on weekdays and weekends. Linear regression on the weekday plug loads on the west side was significantly different, F (1,290 = 11.416, $p < 0.05$). One-way ANOVA test suggests that the weekday plug loads on the west side between February and May 2019 were significantly different from the plug loads between July and December 2020. At the same time, the weekday plug loads on the west side in February 2020 were significantly different from the plug loads in January 2019, between March and April 2019, July and October 2019, and December 2019. Figure 84 also shows that the plug loads between February and May 2019 were high, and reduced between July and December 2020. The weekday plug loads increased again in the early 2020. Thus, the weekday plug loads on the west side significantly reduced from July to December 2019, but increased in February 2020.

Linear regression on the weekend plug loads of Tenant D on the west side was significantly different, F (1,119 = 11.991, $p < 0.05$). One-way ANOVA test also suggests that the weekend plug loads on the west side between February and May 2019 were significantly different from the plug loads between July and December 2019 while the plug loads in January 2019 were significantly different from the plug loads between February and June 2019. The test also indicates that the weekend plug loads on the west side in February 2020 were significantly different from January and March 2019. Figure 84 also shows that the weekend plug loads increased between February and May 2019 and reduced between July and December 2019, which is similar to the weekday plug loads. Therefore, the weekend plug loads of Tenant D on the west side significantly reduced from July to December 2019, and therefore the plug loads over time as the linear regression and one-way ANOVA test suggest.

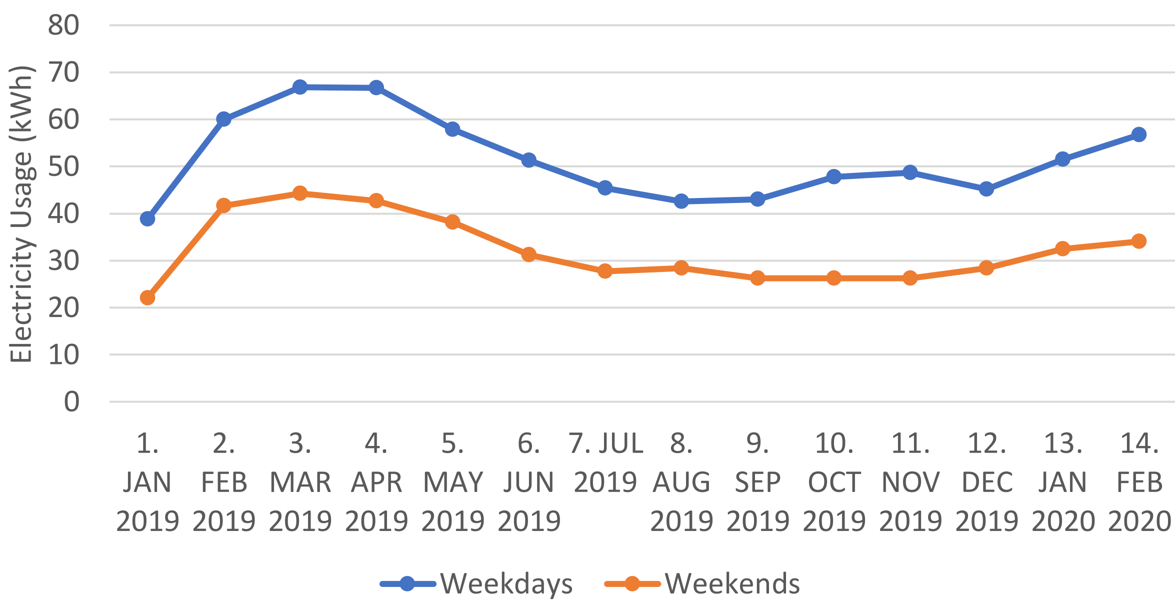

Figure 84 Average electricity usage for plug loads of Tenant D (the west side), January 2019 – February 2020

Tenant D had some variations in lighting and plug loads depending on the type of usage and the type of areas. For lighting usage, linear regression suggests significant changes in the weekend lighting usage, but not in the weekday lighting usage although Figure 81 illustrates that both the weekday and weekend lighting usage changed over time. This is possibility the same reason as Tenant A whose weekday plug loads did not show significant changes by linear regression due to the repeated increase and decrease in the plug loads.

From the results of one-way ANOVA test and Figure 81, it was revealed that the weekday lighting usage of Tenant D was relatively high between January 2019 and April 2019, but reduced from May 2019 until August 2019. The high lighting usage before April 2019 can be attributed to longer working hours of occupants due to tax accounting (Informant 2, personal communication, December 2, 2020). The weekday lighting usage reduced during the summer probably because some occupants left for vacations (Informant 2, personal communication, December 2, 2020). The similar pattern was observed in the weekend lighting usage of Tenant D, and the same reasons can be found as for the weekday lighting pattern. In addition, both the weekday and weekend lighting usage of Tenant D increased again from January 2020, and this might be also because occupants were becoming busier for tax accounting.

On the other hand, the plug loads of Tenant D in the server room were different from lighting usage. Linear regression shows that there were significant changes over time both on weekdays and weekends since the plug loads increased after November 2019 as Figure 82 illustrates. The plug loads in the server room were lower between July and October 2019, and this may be because of a reduced number of occupants during vacations (Informant 2, personal communication, December 2, 2020).

It also should be noted that the plug loads in the server room were the lowest in January 2019, while the lighting usage in the same month was relatively high. This may be because the installation of servers may have taken longer time, which resulted in lower plug loads in the server room at the beginning of the year. The plug loads in the server room increased again from November 2019. Although the reason is still not clarified, it is possible that there might have been new devices installed in the server room from November 2019. Or it might have been affected by an increase in working hours of occupants. Another unique pattern in the server room of Tenant D was that the weekday and weekend plug loads were almost the same throughout the year. This pattern was not observed in other tenants, and the data demonstrates that servers constantly consume a large amount of electricity. Since employees of Tenant D did not frequently access the server room (Informant 2, personal communication, December 2, 2020), occupants were probably not aware of the amount of plug loads used by the servers. Thus, the data revealed the great potential to save plug loads in the server room of Tenant D.

Furthermore, electricity usage for plug loads of Tenant D in the office areas is divided into the east side and west side, and the pattern of plug loads slightly varied depending on the location. On the east side, linear regression suggests insignificant changes in the weekday plug loads but suggests significant changes in the weekend plug loads. This difference in linear regression is somewhat surprising because the patterns of the weekday and weekend plug loads on the east side were similar, which is illustrated by Figure 83. This result of linear regression can be due to the repeated increase and decrease in plug loads, which is similar to the pattern of Tenant A. Since the weekend plug loads of Tenant D on the east side decreased during the summer and increased again after the fall in 2019, this change may have contributed to more fluctuated changes in plug loads, rather than a linear change. The reduction in the plug loads during the summer is possibly attributed to the reduced number of occupants leaving for vacations. It can also be explained that the plug loads increased again after September 2019 as more people started coming back to work. Therefore, the plug loads on the east side tended to be affected by the seasonal change.

In contrast, the plug loads of Tenant D on the west side showed more dynamic changes unlike the east side. As linear regression suggests, both the weekday and weekend plug loads significantly changed over time. In particular, the weekday and weekend plug loads during February and April 2019 was much higher than the rest of the months. The key informant mentioned that the higher plug loads on the west side in the early 2019 might be because employees worked longer for tax accounting (Informant 2, personal communication, December 2, 2020). Since the office area on the west side was used as a workplace for occupants while the east side was used more for meetings (Informant 2, personal communication, December 2, 2020), the plug loads on the west side might have been more susceptible to occupants' work schedules and practices.

At the same time, it is unknown whether the reduction in plug loads after April 2019 is attributed to energy saving behaviour of occupants in Tenant D. While there is a possibility of energy saving behaviour, such as increased usage of daylight and reduced usage of personal heaters, another factor for the reduced plug loads might be the lower number of occupants during seasonal vacations. Therefore, plug loads of Tenant D in the office areas varied between the east side and the west side since these areas were used for different purposes. The plug loads on the west side were more subject to occupant behaviour as the area was constantly used by employees as an active workplace. Consequently, the plug loads in the office area were influenced by the type of usage and the level of occupants' activities.

Overall, analyses on electricity usage for lighting and plug loads of tenants demonstrate that electricity usage varies according to the type of energy source and occupants' activities which are largely affected by seasonality. It should be also noted that plug loads tended to have larger changes over time, compared to lighting usage, since individual occupants' behaviour can affect plug loads more than lighting. As the amount of lighting usage becomes high when the number of occupants reaches a fair number (C. Wang et al., 2016), it is more difficult for an individual occupant to control the lighting usage. On the other hand, individual occupants can more easily affect the plug loads at the device level as they can change the number and the power setting of their own devices. Hence, plug loads showed a greater tendency to change in accordance with occupant behaviour.

Appendix K – Image of electricity meter for selected plug loads